

**THE CITY OF EDMONTON**  
**PROJECT AGREEMENT**  
**VALLEY LINE LRT – STAGE 1**

*Schedule 5 – D&C Performance Requirements*

*Part 4: Transportation and Building Structures*

**VALLEY LINE PROJECT**  
**SCHEDULE 5**  
**D&C PERFORMANCE REQUIREMENTS**

**PART 4: TRANSPORTATION AND BUILDING STRUCTURES**

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## PART 4: TRANSPORTATION AND BUILDING STRUCTURES

### SECTION 4-1 GENERAL DESIGN REQUIREMENTS

#### 4-1.1 SCOPE

- A. Part 4 [*Transportation and Building Structures*] sets out structural design and construction requirements for all Building Structures and Transportation Structures unless otherwise specified.

#### 4-1.2 TRANSPORTATION STRUCTURES DESIGN OVERSIGHT

- A. Project Co shall engage and retain an individual to oversee the Design of all Transportation Structures (the “**Transportation Structures Lead Engineer**”). The Transportation Structures Lead Engineer shall have a minimum of 10 years of experience in the design of bridges and other Transportation Structures.
- B. Project Co shall engage and retain an individual to oversee the Design of the Tawatinâ Bridge (the “**Lead Structures Engineer**”). The Lead Structures Engineer shall have previous experience in leading the design of extradosed or cable stayed bridges.

#### 4-1.3 GENERAL STRUCTURAL PERFORMANCE REQUIREMENTS

##### 4-1.3.1 Safety

- A. Building Structures shall be designed to have a minimum reliability index consistent with that achieved by designs complying with the ABC.
- B. Transportation Structures shall be designed to have a minimum reliability index that complies with Section 3.5.1 of CAN/CSA S6. This requirement is deemed to be complied with for Transportation Structures designed in accordance with Schedule 5 [D & C Performance Requirements] provided additional design requirements as noted in Section 4-1.4D [*Codes and Standards*] are not required in the design of the Transportation Structure.
- C. Structures shall be operationally safe in terms of the accommodation of all intended uses, including all Operations and Maintenance activities throughout their Design Service Life.
  - 1. Elevated Guideways, Quarters Tunnel, Davies Station, Churchill Connector and Stops shall meet the life safety requirements of NFPA 130 and ABC, as applicable.
- D. The Construction, Operations and Maintenance of Structures shall not adversely impact the structural integrity or safety of other structures.
- E. Single load path structures may be used for Transportation Structures provided their critical components fail in a ductile manner and provide warning of failure prior to failure, e.g. critical concrete components fail in bending rather than in shear.

##### 4-1.3.2 Functionality

- A. The geometry and details of the Structures shall permit the safe Operation, inspection and Maintenance of the System, including requirements during emergencies.

##### 4-1.3.3 Serviceability / Durability

- A. There shall be no noticeable or measurable deterioration of the performance or ability of a Structure to carry load over its Design Service Life. There shall be no deterioration detrimental to the appearance of a Structure over its Design Service Life.

1. Transportation Structure components, such as bearings and deck joints, for which it may not be practical to achieve the Design Service Life specific for the Structure may be designed for a shorter Design Service Life provided Project Co can demonstrate during the Operating Period that the component can be replaced without adversely impacting Operations.
- B. The performance of a Structure shall not result in discomfort to users of the Structure.

#### **4-1.4 CODES AND STANDARDS**

- A. Without limiting Section 1-1.7 [*Reference Documents*] of this Schedule and except as otherwise specified herein, the Building Structures shall comply with the ABC.
- B. Without limiting Section 1-1.7 [*Reference Documents*] of this Schedule and except as otherwise specified herein, the Transportation Structures shall comply with CAN/CSA S6.
  1. In CAN/CSA S6 references to the Regulatory Authority shall be taken to be references to the City.
- C. ABC and CAN/CSA S6 shall be supplemented by other codes where required in this Part 4 [*Transportation and Building Structures*]
- D. The design requirements in this Part 4 [*Transportation and Building Structures*] may also be supplemented with additional design requirements from other codes and standards provided it is demonstrated that the reliability index criteria of Section 4-1.3.1 [*Safety*] of this Schedule are met when the supplemental design requirements are used.
- E. Other codes and standards referenced in Section 4-1 [*General Design Requirements*], Section 4-2 [*Structural Component Requirements*] and Section 4-3 [*Structure Specific Requirements*] of this Schedule are:
  1. Canadian Foundation Engineering Manual (CFEM);
  2. Floor Vibrations Due to Human Activity, AISC Steel Design Guide 11 (AISC 11);
  3. CEB-FIP Model Code, Chapter 2, 1990 Edition (CEB-FIP);
  4. AASHTO, LRFD Bridge Design Specifications (AASHTO LRFD);
  5. PTI DC35.1, Recommendations for Prestressed Rock and Soil Anchors (PTI DC35.1);
  6. PTI DC45.1, Recommendations for Stay-Cable Design, Testing, and Installation (PTI DC45.1);
  7. EN 1991 - Part 2, Eurocode 1: Actions on Structures - Traffic Loads on Bridges (EC1);
  8. EN 1993 - Part 2, Eurocode 3: Design of Steel Structures - Steel Bridges (EC3);
  9. Guidelines for the Design of Footbridges, International Federation for Structural Concrete (fib), Bulletin 32, Lausanne, Switzerland, Published in 2005 (FIB Guidelines);
  10. Technical Guide Footbridges - Assessment of Vibrational Behaviour of Footbridges under Pedestrian Loading, Paris, France, Published in 2006 (Sétra);
  11. AASHTO, LRFD Bridge Construction Specifications (AASHTO LRFD BCS);
  12. AASHTO, Standard Specifications for Highway Bridges (AASHTO SSHB);



13. AWS D1.5 Bridge Welding Code (AWS D1.5); and
14. PTI/ABSI M50.3 Guide Specification for Grouted Post-Tensioning (PTI/ABSI M50.3)

#### 4-1.5 DESIGN LOADS

- A. This Section 4-1.5 [Design Loads] sets out loads to be accounted for in the design of Structures, which are additional to those in CAN/CSA S6 or the ABC, as applicable.
- B. The loads given in this Section 4-1.5 [Design Loads] are listed as minimum loads. Actual On-track Vehicle loads or other loads exceeding these minimum loads shall be used if these result in more unfavourable effects.

##### 4-1.5.1 On-track Vehicle Vertical Live Load

###### A. Load Model

1. On-Track Vehicle vertical live loads shall be used as live loads, "L", in CAN/CSA S6 and ABC.
2. The minimum On-track Vehicle vertical live load shall be the load presented in Figure 4-1.5.1-1 [On-track Vehicle Vertical Live Load];

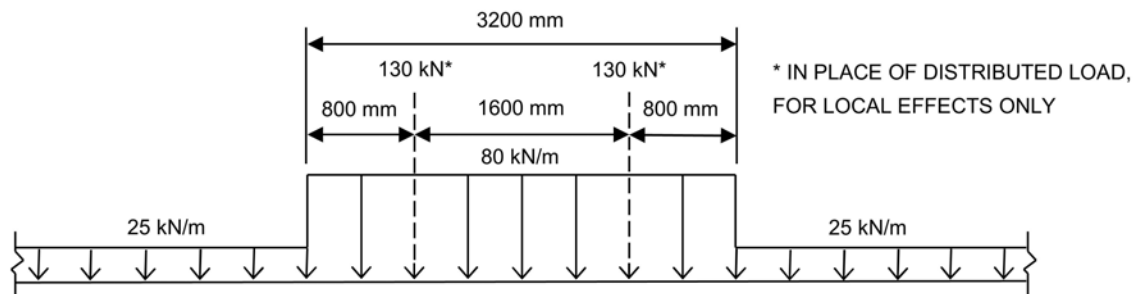


Figure 4-1.5.1-1: On-track Vehicle Vertical Live Load

3. The load shown in Figure 4-1.5.1-1 [On-track Vehicle Vertical Live Load] is the load applied to one Track. The length of the 25 kN/m portion of the load shall be varied so as to maximize the load effects in the Transportation Structure.

###### B. Dynamic Load Allowance (DLA)

1. The On-track Vehicle vertical live load shall include a dynamic load allowance. The dynamic load allowance shall be used as DLA for the purpose of CAN/CSA S6, and shall have at least the following magnitudes:
  - a. For global effects  $DLA = \frac{2.16}{\sqrt{L_\phi - 0.2}} - 0.27$ , but  $0 \leq DLA \leq 1$ , where  $L_\phi$  is according to Table 6.2 in EC1 (in metres). If  $L_\phi$  is not specified in Table 6.2 in EC1,  $L_\phi$  shall be taken equal to the length of the influence line for deflection of the component being considered;
  - b. For local effects due to loading from one bogie -  $DLA = 1.00$ ; and
  - c. For slabs on grade supporting direct fixation or embedded track -  $DLA = 1.00$ .
2. DLA does not need to be included for the On-track Vehicle horizontal live loads.

C. Tracks to Be Loaded

1. Each Track on a Transportation Structure shall be loaded simultaneously with the On-track Vehicle vertical live load, using the full live load on each Track unless the loading of fewer Tracks results in more unfavourable load effects in the Transportation Structure.

D. Rolling or Lurching Load

1. The lateral shifting of the On-track Vehicle vertical live load from one rail to another shall be referred to as "rolling" or "lurching".
2. The design rolling or lurching load applied to the Transportation Structure shall be equal to the torque associated with an unbalanced wheel condition where 45% of the On-track Vehicle vertical live load is on one wheel of an axle and 55% of the On-track Vehicle vertical live load is on the other wheel of the axle.
3. Only one On-track Vehicle rolling or lurching load shall be considered at one time.

4-1.5.2 **On-track Vehicle Horizontal Live Loads**

- A. On-track Vehicle horizontal live loads shall be used as live loads, "L", in CAN/CSA S6. On-track Vehicle vertical live load, On-track Vehicle horizontal live loads acting perpendicular to the Track centerline and On-Track Vehicle horizontal live loads acting parallel to the Track centerline shall act concurrently. All loads that act favourably shall be neglected.

- B. For horizontal live loads acting perpendicular to the Track centreline:

1. the hunting (nosing) load shall be a minimum of 50 kN applied at the top of the rails over the length of one bogie, but not over a length of more than 1.5 metres, at the location on the Transportation Structure resulting in the most unfavourable load effect; and
2. Transportation Structures supporting non-tangent Track shall be designed for centrifugal loads according to CAN/CSA S6 with "v" being at least the Maximum Design Speed of the On-track Vehicle.

- C. For horizontal live loads acting parallel to the Track centreline:

1. the load due to On-track Vehicle acceleration shall be applied uniformly at the top of the rails over a length of 6 m and be the greater of:
  - a. 180 kN; or
  - b. the actual acceleration load of the On-track Vehicle; and
2. the load due to On-track Vehicle deceleration shall be applied uniformly at the top of the rails over a length of "ℓ", where "ℓ" is the length of the Transportation Structure in metres, and be the greater of:
  - a.  $10\ell$  kN, where "ℓ" is not more than 90m; or
  - b. the actual deceleration load of the On-track Vehicle.

4-1.5.3 **On-track Vehicle Wind Loads**

- A. The wind load on On-track Vehicles shall be used as a wind load "V" in CAN/CSA S6.
- B. The horizontal drag coefficient on the On-track Vehicles shall be a minimum of  $C_h = 2.0$ .

#### 4-1.5.4 **On-track Vehicle Derailment Load**

- A. The On-track Vehicle derailment load, including both vertical and horizontal loads, shall be used as a collision load, "H", in CAN/CSA S6.
- B. The On-track Vehicle derailment load shall be considered at the Ultimate Limit State (ULS) only. The load need not be applied to barriers.
- C. In the absence of a more detailed method, the minimum On-track Vehicle derailment loads, applied concurrently to the supporting Transportation Structure, shall be as follows:
  - 1. The vertical load shall be:
    - a. the On-track Vehicle vertical live load with DLA = 1.0, positioned between the rail and the barrier so as to cause the maximum load effects in the Transportation Structure; and
    - b. a second On-track Vehicle vertical live load with DLA = 0.0, applied on the adjacent Track, if it increases the load effects in the Transportation Structure.
  - 2. The horizontal load (perpendicular to the Track centreline) shall be 10% of the On-track Vehicle vertical live load with DLA = 0.0 acting at an elevation of 1.05 m above the top of the rail.
- D. For local effects, the wheels shall bear directly on the Transportation Structure. A rational method shall be used to determine the wheel load distribution.

#### 4-1.5.5 **Roadway Traffic Live Load**

- A. The minimum CL-W load on a Transportation Structure supporting a Roadway shall be CL-800, as defined in CAN/CSA S6.

#### 4-1.5.6 **Stops and Stations Live Load**

- A. Publicly accessible areas of Davies Station and Churchill Connector and all Platforms shall be designed for a minimum live load of 4.8 kPa.

#### 4-1.5.7 **Rail-Structure Interaction**

- A. Loads created by rail-structure interaction shall be taken into account and used as thermal loads, "K", in CAN/CSA S6.
- B. Submit a rail-structure interaction report with the applicable Final Design of each Transportation Structure supporting the Trackway summarizing the methodology used to determine the rail-structure interaction load. A rational analysis model that includes the stiffness of the Transportation Structure, rails, and rail fastenings, the rail fastenings load response and accurate boundary conditions shall be used to account for the rail-structure interaction.
- C. The relative temperature difference between the rail and the Transportation Structure used to determine the design forces shall be:
  - 1. at least 30 degrees Celsius for a temperature rise with the rail being warmer; and
  - 2. at least 40 degrees Celsius for a temperature fall with the rail being colder.

These temperature differences shall be relative to the average Transportation Structure temperature and shall be accounted for in combination with the thermal gradient effects specified in Section

3.9.4.4 of CAN/CSA S6 except that for segmental concrete girders they shall be accounted for in combination with the thermal gradient effects specified in Section 4-2.6.2.1B.1 [*Thermal Loads*] of this Schedule.

- D. Broken rail forces shall be accounted for. No more than one rail shall be considered broken on a given Transportation Structure. The broken rail forces shall be based on the rail break gap as described in Section 3-1.1.5.1 [*General*] of this Schedule but no greater than 50mm.

#### 4-1.5.8 **Snow Loads on Transportation Structures**

- A. Minimum snow loads on Transportation Structures shall be determined according to the ABC and shall be used as a live load "L" in CAN/CSA S6 except that a load factor of 1.3 shall be used for snow load in all load combinations.
- B. Snow loads shall be accounted for in locations on a Transportation Structure where snow does not require removal for Operation of the On-track Vehicles.
- C. Snow load shall be increased above that determined according to the ABC if snow clearing Operations will increase the height of snow above that due to natural accumulation.

#### 4-1.5.9 **Collision Loads**

- A. The collision loads set out in this Section 4-1.5.9 [*Collision Loads*] shall be used as collision loads, "H", in CAN/CSA S6.
- B. Transportation Structure substructures located less than 10 m horizontally from the centreline of any Track shall be designed for a minimum collision load of 50% of the On-track Vehicle vertical live load, where the length of the load shall be at least 90 m. The load shall be applied in a horizontal plane at an angle of up to 10° to the direction of the Tracks and at a height of 600 mm above the top of rail at the collision location. The DLA shall be assumed to be equal to 0.0.
  - 1. The collision load need not be applied to Protection Railings, barriers or to components that are protected from being struck by an On-track Vehicle.
- C. Transportation Structure substructures located less than 10 m horizontally from the edge of a Roadway shall be designed for the collision load specified in CAN/CSA S6, except that for Roadways with a design speed  $\geq 80$  km/h, the collision load shall be increased to 1800 kN. The load shall be applied in a horizontal plane at an angle of up to 10° to the direction of the Roadway and at a height of 1.2 m above ground.
- D. Except for Transportation Structures with a vertical clearance above the underpassing Roadway of 6.0 m or more, Transportation Structure superstructures over Roadways shall be designed for a minimum collision load of 1000 kN applied to the superstructure. The connections between the superstructure and the substructure shall be designed to transfer the load to the substructure.
- E. Transportation Structures located less than 8 m horizontally from the centreline of any Heavy Rail track shall be designed for a minimum collision load of 2000 kN, applied in a horizontal plane at an angle of up to 10° to the direction of the Heavy Rail track and at a height of 1.8 m above top of rail of the nearest Heavy Rail track, unless more unfavourable loads are specified by the Railway Company owning the nearest Heavy Rail track, in which case the loads specified by the Railway Company owning the nearest Heavy Rail track govern.
- F. Transportation Structures spanning over the North Saskatchewan River shall be designed for vessel collisions in accordance with Annex A3.3 of CAN/CSA S6.

#### 4-1.5.10 Seismic Loads

- A. Transportation Structures shall have a CAN/CSA S6 seismic importance category of “Other Bridges”.
- B. Building Structures shall have an ABC seismic importance category of “Normal”.

### 4-1.6 LIMIT STATES DESIGN

#### 4-1.6.1 Introduction

- A. Unless stated otherwise in this Part 4 [*Transportation and Building Structures*], limit state design shall be used for the design of all Building Structures and Transportation Structures.
- B. Where the design of the structural elements of a Structure is affected by a combination of live loads for Building Structures and for Transportation Structures, limit states design shall be in accordance with the requirements for Transportation Structures.

#### 4-1.6.2 Ultimate Limit State (ULS)

- A. In addition to the load combinations defined in CAN/CSA S6, the following ULS load combinations shall be accounted for in all Transportation Structures:

- 1.  $\alpha_D D + \alpha_E E + \alpha_P P + 1.0L + 1.25K + 1.5(W+V)$  ULS Combination 4a
- 2.  $\alpha_D D + \alpha_E E + \alpha_P P + 0.5W + 1.0F$  ULS Combination 10
- 3.  $\alpha_D D + \alpha_E E + \alpha_P P + 1.0L + 1.0F$  ULS Combination 11

- B. In addition to the load combinations defined in Section 4-1.6.2A [*Ultimate Limit State (ULS)*] of this Schedule the following ULS load combinations shall be accounted for on all Transportation Structure components supporting or supported by stay cables or hangers:

- 1.  $\alpha_D D + \alpha_E E + \alpha_P P + 1.5L^* + CEF$  ULS Combination 12

\* Only far Track is loaded

- 2.  $\alpha_D D + \alpha_E E + \alpha_P P + 0.75L^{**} + 1.1CLDF$  ULS Combination 13

\*\* Both Tracks are loaded

where CEF: cable exchange force for the replacement of one stay cable or hanger.

CLDF: cable loss dynamic force for the sudden loss of one stay cable or hanger as defined by PTI DC45.1 for stay cables.

- C. In addition to the load combinations defined in Sections 4-1.6.2A [*Ultimate Limit State (ULS)*] of this Schedule, the following ULS load combinations shall be accounted for on all Transportation Structure components supporting or supported on hangers:

- 1.  $\alpha_D D + \alpha_E E + \alpha_P P + 0.7L + CEF$  ULS Combination 14
- 2.  $\alpha_D D + \alpha_E E + \alpha_P P + 1.0L + 1.1CLDF$  ULS Combination 15

- D. In addition to the load combinations defined in Sections 4-1.6.2A [*Ultimate Limit State (ULS)*] to 4-1.6.2C [*Ultimate Limit State (ULS)*], Transportation Structures erected using segmental concrete construction shall satisfy the load combination requirements in Section 5.14.2.3.4 [*Construction Load Combinations at Strength Limit States*] of AASHTO LRFD.

#### 4-1.6.3 Serviceability Limit State (SLS)

##### 4-1.6.3.1 General

- A. In addition to the load combinations defined in CAN/CSA S6, Transportation Structures erected using segmental concrete construction shall satisfy the load combination requirements in Section 5.14.2.3.3 [*Construction Load Combinations at the Service Limit State*] of AASHTO LRFD.

##### 4-1.6.3.2 Live Load Deflections of Structures Carrying On-track Vehicles

- A. The live load deflections of Transportation Structures carrying On-track vehicles shall be determined based on SLS Combination 2 in CAN/CSA S6.
- B. The live load deflections of Transportation Structures carrying On-track Vehicles shall not exceed  $L/1000$ , with “L” being the distance between adjacent vertical supports, such as piers or abutments. For cantilever structures the live load deflections shall not exceed  $1/400$  of the length of the cantilever.

##### 4-1.6.3.3 Vibrations

- A. For Transportation Structures carrying On-track Vehicles and/or pedestrians and having a fundamental vertical flexural frequency of less than 3.5 Hz, submit a vibration analysis report with the Final Design of each Transportation Structure providing a summary of the methodology used to determine Transportation Structure accelerations, accounting for the interaction between the On-track Vehicle and the Transportation Structure, where applicable, and identifying the maximum accelerations expected to be experienced by:
  1. Passengers in a Train; and
  2. pedestrians on an SUP
- B. In addition to the provisions of Section C3.4.4 of the Commentary to CAN/CSA S6 regarding serviceability limit states for pedestrian bridges, vibrational analyses shall be carried out for all Transportation Structures carrying pedestrians using forcing functions specified by the FIB Guidelines and Sétra. The accelerations experienced by pedestrians shall not exceed:
  1. the vertical accelerations specified in Figure C3.3 in the Commentary to CAN/CSA S6, except that all accelerations below  $0.50 \text{ m/s}^2$  shall be acceptable, irrespective of the first flexural frequency; and
  2.  $0.10 \text{ m/s}^2$  for horizontal accelerations.
- C. The vertical acceleration limits of components in Building Structures occupied by Persons shall not exceed those specified in AISC 11. Publicly accessible areas of Davies Station and the Churchill Connector and all Platforms shall be considered as “indoor footbridges” as defined in AISC 11.

#### 4-1.6.4 Fatigue Limit State (FLS)

- A. For Transportation Structures carrying On-track Vehicles:
  1. the FLS shall be satisfied according to CAN/CSA S6 using the following design criterion:

$$\lambda_1 \cdot f_{sr} < F_{sr}$$

where  $f_{sr}$  is the calculated fatigue stress range at the considered detail due to the passage of the On-track Vehicle vertical live load and  $\lambda_1$  is a correction factor accounting

for the difference in fatigue damage caused by the On-track Vehicle vertical live load and the actual On-track Vehicles that pass over a Structure;

2. a rational analysis shall be performed to determine  $\lambda_1$  accounting for the anticipated actual On-track Vehicle loads and their frequency and the Design Service Life of the Transportation Structure. The anticipated frequency of the On-track Vehicle loads shall be based on the System operating at the Maximum Service Level; and
3. a fatigue report providing a summary of the methodology used to determine  $\lambda_1$  and the recommended value of  $\lambda_1$  shall be submitted to the City with the Final Design of each Transportation Structure supporting the Trackway. Values for  $\lambda_1$  shall not be smaller than those obtained with the following equations:
  - a.  $\lambda_1 = 2.0$  for local effects and  $L \leq 5$  m
  - b.  $\lambda_1 = 2.0 - 0.11(L - 5)$  for  $5 \text{ m} < L \leq 15$  m
  - c.  $\lambda_1 = 0.9$  for  $L > 15$  m

where  $L$  is the length (m) of the influence line as defined in Section 9.5 of EC3.

#### 4-1.7 MATERIALS

- A. This Section 4-1.7 [Materials] sets out minimum requirements for the following materials used in Structures.

##### 4-1.7.1 Concrete

- A. Concrete classes shall conform to Table 4-1.7.1-1 [Concrete Classes].
- B. All concrete shall be normal weight concrete.
- C. Unless otherwise specified, concrete in Transportation Structures, shall as a minimum, meet the requirements for Class C concrete, except that piles shall as a minimum meet the requirements for Pile Concrete.
- D. Unless otherwise specified, concrete in Building Structures shall, as a minimum, meet the requirements for Class B Concrete.

Table 4-1.7.1-1 – Concrete Classes

Class of Concrete <sup>[6]</sup>	Minimum Specified Compressive Strength at 28 Days (MPa)	Size of Coarse Aggregate <sup>[2]</sup> (mm)	Range of Slump <sup>[7,8]</sup> (mm)	Total Air Content <sup>[4]</sup> (%)	Max. Water/Cementing Materials Ratio
B	25	28 to 5	100 ± 30	4 – 7 <sup>[5]</sup>	0.45
C	35	20 to 5 <sup>[1]</sup>	100 ± 30	5 - 8	0.40
HPC <sup>[3]</sup>	45	20 to 5	120 ± 30	5 - 8	0.38
Pile	30	28 to 5	130 ± 30	4 - 7	0.42

Notes:

1. *The size of coarse aggregate shall be 28 to 5 mm for Class C concrete when used in mass pours such as piers and abutments.*
2. *For thin concrete members the nominal maximum size of aggregate may be reduced to 14 mm.*
3. *Class HPC concrete shall contain silica fume. Additional requirements for concrete containing silica fume are set out in Section 4-1.7.2 [Additional Requirements for Concrete Containing Silica Fume] of this Schedule.*
4. *Ranges in air contents shall be in compliance with maximum aggregate size as per CAN/CSA A23.1 Table 4.*
5. *For Building Structures, where the concrete is not exposed to freeze-thaw, sulfates or chlorides, air entrainment is not required.*
6. *The fly ash content for concrete not containing silica fume shall not exceed 30% by mass of cementing materials unless otherwise specified in Section 4-1.8 [Durability] of this Schedule.*
7. *For MSE wall panels, the range of slump may be determined by Project Co.*
8. *Slumps higher than 100 mm shall be obtained using superplasticizers.*

#### 4-1.7.2 **Additional Requirements for Concrete Containing Silica Fume**

- A. The concrete mix shall include silica fume and fly ash as supplementary cementing materials in combination with compatible air entraining, water reducing and/or superplasticizing admixtures, as required, by the mix design.
- B. The gradation limits for the fine aggregate shall conform to CAN/CSA A23.1, except that the amount of material finer than 160 µm shall not exceed 5%.
- C. Coarse aggregate shall conform to CAN/CSA A23.1 and the maximum combination of flat and elongated particles (4:1 ratio), as determined by CAN/CSA A23.2-13A, shall not exceed 10% of the mass of coarse aggregate.
- D. Minimum cement content (excluding supplementary cementing materials) shall be 335 kg/m<sup>3</sup>.
- E. Sum of silica fume and fly ash by mass of cementing materials shall be 17% to 20%.
- F. Silica fume by mass of cementing materials shall be 6% to 8%.
- G. Fly ash by mass of cementing materials shall be 11% to 15%.
- H. Resistance to chloride ion penetration shall be determined in accordance with ASTM C1202 on duplicate laboratory moist cured samples at 28 days. The average of all tests shall not exceed 1000 coulombs, with no single test greater than 1250 coulombs. When only two test values are used to calculate the average coulomb rating, no test shall exceed 1000 coulombs. For Class HPC concrete with steel fibres, testing shall be done without the presence of the steel fibres.
- I. An air-void spacing factor shall be determined in accordance with ASTM C457 modified point-count method at 100 times magnification. The average of all tests shall not exceed 230 µm with no single test greater than 260 µm. When only two test values are used to calculate the average air void spacing, no test shall exceed 230 µm.

#### 4-1.7.3 **Reinforcing Steel and Deformed Welded Wire Mesh**

- A. Reinforcing steel shall be carbon steel, stainless steel or low carbon/chromium steel unless specified otherwise:



1. Carbon steel reinforcing steel shall conform to CAN/CSA G30.18M, with a minimum yield strength of 400 MPa;
  2. Stainless steel reinforcing steel shall conform to ASTM A276 and ASTM A955M (including Annex 1.2 or 1.3) with a minimum yield strength of 420 MPa. The UNS designations shall be UNS S31653, S31603, S31803, S30400, or S32304; and
  3. Low carbon/chromium reinforcing steel shall conform to ASTM A1035, with a minimum yield strength of 690 MPa, based on the 0.2% offset method.
- B. Deformed welded wire mesh shall conform to ASTM A615, with a minimum yield strength of 480 MPa.

#### 4-1.7.4 **Prestressing Steel**

- A. Prestressing steel strand shall conform to ASTM A416 for low relaxation strand.
- B. Prestressing steel bars shall conform to CAN/CSA G279.

#### 4-1.7.5 **Stay Cables**

- A. Materials for stay cables, including anchorages and saddles, shall conform to the requirements of PTI DC45.1.
1. Stay cable strands shall conform to ASTM A416 for weldless low relaxation strand.
  2. Epoxy coated stay cable strands shall not be used.

#### 4-1.7.6 **Ground Anchors**

- A. Ground anchors shall be prestressed steel bars and shall conform to the requirements of PTI DC35.1.
1. The use of prestressed steel strands is not permitted.
- B. Ground anchor anchorages shall conform to the requirements of PTI DC35.1.

#### 4-1.7.7 **Structural Steel**

##### 4-1.7.7.1 **Transportation Structures**

- A. The structural steel for Transportation Structures shall conform to CAN/CSA G40.20/G40.21 and the following requirements:
1. Girders, girder splice plates, and all materials welded to steel girders: Grade 350AT CAT 3;
  2. Ungalvanized bearing and bracing materials bolted to girders: Grade 350A; and
  3. Hangers: Grade 350WT CAT 2.

##### 4-1.7.7.2 **Building Structures**

- A. Structural steel for Building Structures shall conform to CAN/CSA G40.20/G40.21 and the following requirements:
1. Steel roof and floor decks shall conform to CSSBI 10M and 12M, respectively, and shall be designed to act as diaphragms; and

2. Cold-formed structural steel shall conform to the material standards in CAN/CSA S136.

#### 4-1.7.7.3 **Structural Bolts**

- A. Structural bolts shall conform to ASTM A325 except that bolts in contact with CAN/CSA G40.20/G40.21 Grade 350 AT or 350A steel shall conform to ASTM A325, Type 3.

#### 4-1.7.8 **Structural Wood**

- A. The use of structural wood in Structures shall only be permitted in Building Structures, and as a wearing surface on Transportation Structure SUPs.
- B. Structural wood shall conform to the material standards in CAN/CSA O86.
- C. Structural wood used as a wearing surface on Transportation Structures shall be sawn lumber with a minimum dynamic coefficient of friction as specified in Section 5-1.3.6 [*Slip Resistance of Flooring*] of this Schedule.
- D. Structural wood shall be installed in such a manner that moisture is not trapped within the wood.
- E. Structural wood shall have the appropriate preservatives and treatments to provide protection from exposure.

#### 4-1.7.9 **Masonry**

- A. The use of masonry material in Structures shall only be permitted in Building Structures, and for Transportation Structure veneers.
- B. Masonry materials shall conform to CAN/CSA A371.
- C. Veneers used in Transportation Structures shall not be considered a protection system against chloride attack.

### 4-1.8 **DURABILITY**

- A. This Section 4-1.8 [*Durability*] sets out minimum durability requirements for structural components of Transportation Structures unless otherwise specified.
  - 1. The minimum durability requirements for Building Structures are specified in CAN/CSA S478, *Guideline on Durability in Buildings*.
- B. Structures shall have sufficient durability to meet the Design Service Life requirements of Section 1-2.8 [*Design Service Life*] of this Schedule.
- C. The Stray Current levels allowed by the Stray Current Sub-Plan shall be taken into consideration when determining the Design Service Life of a Structure.

#### 4-1.8.1 **Splash Zone Surfaces**

- A. Prepare and submit a report to the City justifying the selection of materials to be used in all concrete within 300 mm of any Splash Zone Surface, so as to achieve the minimum Design Service Life of the Structure.
- B. CAN/CSA G40.20/G40.21, Grade 350A and 350AT steel shall not be used as a Splash Zone Surface.
- C. The fly ash content in concrete used as a Splash Zone Surface shall not exceed 15%.

#### 4-1.8.2 **Clear Concrete Cover**

- A. The nominal concrete covers for Transportation Structures specified in Table 8.5 of CAN/CSA S6 shall be considered to be minimum concrete covers with no negative tolerance on the nominal cover.

#### 4-1.8.3 **Steel Surfaces**

- A. All steel surfaces, except CAN/CSA G40.20/G40.21, Grade 350A and 350AT steel surfaces and pier nose plate steel surfaces, shall be protected by hot-dip galvanizing or by metallizing.
  - 1. Galvanizing shall conform to ASTM A123 and A385.
  - 2. Metallizing shall be a minimum of 180 microns thick and shall conform to CAN/CSA G189.
- B. Galvanized or metallized surfaces shall be isolated from unprotected steel by painting with an organic zinc epoxy primer meeting the requirements of Section 4-4.9.8.4 [*Prime Coating*] of this Schedule.

#### 4-1.8.4 **Voids**

- A. All voids shall be inaccessible to birds and other wildlife, with gaps and holes no larger than 20 mm.

#### 4-1.8.5 **Ground Anchor Corrosion Protection**

- A. All ground anchors, including anchorages and couplers, shall be provided with a Class 1 or “double corrosion” protection system in accordance with the requirements of PTI DC35.1.

#### 4-1.8.6 **Stay Cable Corrosion Protection**

- A. All stay cables shall be provided with a qualified nested corrosion protection system continuous over the entire length of the stay cables, including anchorages, transition zones and saddles. The corrosion protection system shall meet the requirements of PTI DC45.1.
- B. Each stay cable strand shall be individually protected against corrosion with an internal barrier meeting the requirements of PTI DC45.1 and consisting of a HDPE sheath and a corrosion inhibitor filling the intermediate spaces between the strand wires.
- C. Each stay cable strand shall also be protected against corrosion with an external barrier meeting the requirements of PTI DC45.1 and consisting of a HDPE stay pipe.
- D. The corrosion protection system shall accommodate and provide corrosion protection under the full design range of thermal expansion and contraction.
- E. The gap between the stay cables strands and external barrier shall not be filled with grout.
- F. At the anchorages the anchor plate, wedges and ends of the stay cable strands shall be protected with an enclosure that is watertight under all anticipated service conditions and that has a removable cap for inspection. The enclosure shall be filled with a material that does not permit hydrogen embrittlement in the strands.
- G. The stay cable corrosion protection system shall accommodate monitoring, removal and replacement of individual stay cable strands.

- H. Prepare and submit a report describing how the stay cable corrosion protection requirements of this Section 4-1.8.6 [*Stay Cable Corrosion Protection*] and PTI DC45.1 have been met as part of the Final Design of the Tawatinâ Bridge, (the “**Stay Cable Corrosion Protection Report**”).

#### 4-1.8.7 **Post-Tensioning Tendon Corrosion Protection**

- A. All post-tensioning tendons shall be provided with a “Protection Level 2” protection system in accordance with the requirements of PTI/ABSI M50.3.

#### 4-1.9 **GEOMETRICS**

- A. This Section, 4-1.9 [*Geometrics*] sets out minimum geometric requirements for Transportation Structures.

##### 4-1.9.1 **Structure Headslopes**

- A. If head slopes are used at the end of a Transportation Structure, the top of headslope widths shall be the out-to-out Structure end width plus at least 2 m. The top of headslope width shall be transitioned at 30:1 or flatter back to the top of approach fill width away from the Transportation Structure. Headslopes shall be no steeper than 2H:1V.
- B. The minimum horizontal distance from the toe of a Transportation Structure headslope to the face of curb of the underpassing Roadway shall be a minimum of 3.0 m unless otherwise specified in Section 4-3 [*Structure Specific Requirements*] of this Schedule.

##### 4-1.9.2 **Horizontal Clearances**

- A. Transportation Structures carrying On-track Vehicles shall have adequate deck widths to accommodate the Dynamic Envelopes of the vehicles on two side by side Tracks, emergency egress requirements in accordance with NFPA 130 and all required inspection and Maintenance activities.
- B. The minimum distance from the face of a substructure element, e.g. abutment, pier, retaining wall, etc., to the adjacent Roadway shall be equal to, or greater than:
  - 1. The clear zone specified in the TAC Geometric Design Guide for Canadian Roads; and
  - 2. The offset distance required to meet the upper limit sight distance requirements as specified in the TAC Geometric Design Guide for Canadian Roads.
- C. The use of barriers to reduce clear zone dimensions is not permitted unless otherwise specified in Section 4-3 [*Structure Specific Requirements*] of this Schedule.
- D. The minimum horizontal clearance between the centreline of a Heavy Rail track and any substructure component of a Transportation Structure shall meet the minimum requirements specified in the applicable Railway Agreement.

##### 4-1.9.3 **Vertical Clearances**

- A. Transportation Structures carrying On-track Vehicles shall have adequate vertical clearances over the Tracks to accommodate the Dynamic Envelopes of the vehicles.
- B. The minimum vertical clearance between a Roadway and the underside of any Transportation Structure shall be 5.4 m unless otherwise specified in Section 4-3 [*Structure Specific Requirements*].

- C. The minimum vertical clearance between a sidewalk or SUP and the underside of any Transportation Structure shall be 3.5 m unless otherwise specified in Section 4-3 [*Structure Specific Requirements*].
- D. The minimum vertical clearance between the top of rail of a Heavy Rail line and the underside of any Transportation Structure shall be the greater of 7.01 m and the requirements specified in the applicable Railway Agreement.
- E. Vertical clearance signs shall be provided on all Transportation Structures at the locations of underpassing Roadways and shall be mounted on the lower half of the upstream fascia girder. Shop drilled holes for steel girders or cast-in inserts for concrete girders shall be incorporated during girder fabrication.

#### **4-1.10 GEOTECHNICAL**

##### **4-1.10.1 General**

- A. This Section 4-1.10 [*Geotechnical*] sets out general geotechnical requirements for Building Structures and Transportation Structures other than for the Mined Tunnel. Geotechnical requirements for the Mined Tunnel are set out in Section 4-5 [*Mined Tunnel Design and Construction Requirements*] of this Schedule.
- B. The geotechnical designs required for Transportation Structures and Building Structures, including slope stability assessments and stabilization, shall be undertaken with due consideration for the geotechnical conditions encountered at the relevant Site. Site specific geotechnical investigations shall be carried out in sufficient detail to allow for the identification, consideration and advance treatment of all geotechnical issues.
- C. The design and construction of all Structures shall ensure the short and long term stability of all slopes, including the NSRV and ravine slopes. All measures required to prevent erosion of embankment slopes and any altered natural slopes shall be implemented.
- D. The geotechnical investigations and the geotechnical engineering evaluations for Transportation Structures shall be completed in accordance with the requirements of CAN/CSA S6 and the CFEM. For Building Structures, the geotechnical investigations and evaluations shall be completed in accordance with the requirements of the ABC and the CFEM.
- E. Detailed geotechnical reports documenting the geotechnical conditions and engineering recommendations to address the Design and Construction Requirements shall be submitted to the City as part of the Final Design of each Transportation Structure. The submission date of each Transportation Structure geotechnical report shall allow adequate time prior to construction of the applicable Transportation Structure for review of the Submittal by the City and for Project Co to make changes to the Submittal as may be required to account for any comments received from the City.

##### **4-1.10.2 Foundations**

- A. Transportation Structure foundations shall be designed in accordance with CAN/CSA S6 and the CFEM. Building Structure foundations shall be designed in accordance with the ABC and the CFEM.
- B. Geotechnical boreholes shall be drilled at all Transportation Structure foundation locations and shall extend a minimum of 3 m below the estimated pile tip elevation.
- C. Geotechnical boreholes shall be drilled at Building Structure foundation locations except that where available, existing borehole information may be used in lieu of drilling new boreholes.

The depth of the boreholes shall be consistent with the data requirements for the foundation designs.

- D. The selection of representative or “characteristic” geotechnical parameters used to determine foundation capacity shall be based on the results of field and laboratory investigations appropriate to the nature of the Structure and ground conditions and shall represent a cautious “best estimate” of the likely values of each parameter, taking into account all the factors that may have influence on the soil properties, in accordance with the CFEM, Section 8.5, and CAN/CSA S6.

#### 4-1.10.3 **Fills**

- A. Silt material specified as “ML” or “MH” material (in accordance with the “Modified Unified Soil Classification System” as described in the document “Prairie Farm Rehabilitation Administration, 1992, Small Dam Design and Construction Manual, Agriculture Canada, Prairie Resources Service”) shall not be used in the construction of any Transportation Structure headslopes or approach fills, or in the construction of any embankments supporting the Trackway.

#### 4-1.10.4 **Slopes and Retaining Walls**

- A. Unless noted otherwise in Section 4-3 [*Structure Specific Requirements*] of this Schedule the global stability of Transportation Structure headslopes, embankment side slopes, cut slopes, and retaining walls, shall be designed for a minimum factor of safety of 1.3 at the end of slope construction and 1.5 in the long term upon dissipation of construction induced excess pore water pressures.
- B. The design of retaining walls and Transportation Structure headslopes shall account for global stability, bearing capacity (where applicable), long-term settlements, and wall deformations. Stability analyses to confirm that all headslopes and retaining walls have short term and long term stability sufficient to prevent failure or excessive deformation shall be carried out. Deformations of the headslopes or retaining walls (including settlements and lateral movements) shall be determined using appropriate deformation analyses, with representative soil parameters derived from site specific geotechnical investigations and local experience. The estimated range of embankment and wall displacements including settlements and lateral movements shall be taken into account in the design of the Transportation Structure and shall provide for acceptable structural performance and aesthetics of the embankments and walls.

#### 4-1.11 **DRAINAGE**

- A. Drainage of Transportation Structures shall be in accordance with Section 3-4 [*Stormwater Management*] of this Schedule as well as the minimum requirements set out in this Section 4-1.11 [*Drainage*]
- B. Drainage on Transportation Structures shall channel all water off of, and away from, the Transportation Structures and into the overall Stormwater Management System in a controlled manner without creating erosion, flooding, icing of Roadways, sidewalks or SUPs or other detrimental effects.

#### 4-1.11.1 **Wash Slopes/Drip Grooves**

- A. The tops of sidewalks, SUPs and medians adjacent to a Transportation Structure deck shall have a minimum slope of 2% towards the deck. The tops of abutment seats, pier caps and barriers shall have a minimum wash slope of 3%.
- B. Drip grooves shall be provided near the outsides edges of all deck soffits so as to prevent water running down the exposed girder faces.

- C. Water from the Tawatinâ Bridge shall be prevented from dripping onto the underslung SUP.

#### 4-1.11.2 **Drainage Collection on Decks**

- A. Drainage shall be collected at the low corners of Transportation Structure decks, and at other locations along the length of the decks as necessary, to channel water off of the decks. Differential settlements and other movements between Transportation Structures and approach fills shall not compromise the collection of drainage.
- B. Transportation Structure drainage shall not splash onto any river bank slopes, discharge above ground within 8 m of piers, abutments or other structure elements, nor be directed onto any Roadways, sidewalks or SUPs.
- C. All Transportation Structure decks shall be watertight.
  - 1. Leakage through decks shall not be permitted, including at construction joints.

#### 4-1.11.3 **Drainage Collection in Box Girders**

- A. Box girders shall have 50 mm minimum diameter ventilation/drain holes provided on each side of the bottom flange at a maximum spacing of 15 m to drain water from the box girder. Additional drains shall be provided wherever water can be trapped within the girder, including against internal barriers such as diaphragms, post-tensioning anchorage blisters or ribs.

#### 4-1.11.4 **Drainage Collection at Abutments/Retaining Walls**

- A. Joints around abutments, abutment approach slabs and retaining walls shall be sealed at the surface to prevent water infiltration. A secondary system shall be provided to collect, channel and remove any seepage that penetrates the seals.
- B. Drainage shall be provided behind abutments and retaining walls to prevent the buildup of water pressures.
  - 1. If the fill behind the abutment/retaining wall is backfill, the drainage system shall include clean granular backfill with a maximum aggregate size of 25 mm, complete with perforated weeping drains, day lighted or connected for Positive Drainage.
  - 2. If the material retained behind the abutment/retaining wall is in-situ soil, the drainage system shall include a sheet drain that is placed directly against the excavation face and is continuous from the top to the bottom of the wall. At the bottom of the wall the sheet drain shall be connected to a perforated weeping drain located below grade and daylighted or connected for Positive Drainage.
- C. Any buried structural element surface, other than a Splash Zone Surface, that may be exposed to leakage of salt contaminated moisture shall be protected by an impervious waterproofing membrane.
- D. Swales shall be provided behind the tops of all retaining walls to collect and discharge surface water away from the walls in a manner that prevents erosion. Swales and top of walls shall slope away from abutments.

#### 4-1.11.4.1 **Drainage Collection at MSE Retaining Walls**

- A. Surface drainage shall be controlled and channeled away from the back of MSE wall panels and the mechanically stabilized earth mass.
- B. Weeping drains shall be provided near the front and back bottom corners of all mechanically stabilized earth masses. The weeping drains shall be day lighted or connected for Positive

Drainage. The water level within the mechanically stabilized earth mass shall be assumed to be at the invert level of the weep drains or higher should the design warrant it.

- C. All steel soil reinforcement shall be protected from exposure to de-icing salts by an impermeable membrane which shall be:
  - 1. placed below the surface receiving de-icing salts and above the top layer of soil reinforcement to collect and discharge all runoff;
  - 2. sealed to prevent leakage;
  - 3. sloped to drain away from the MSE wall into an intercepting weeping drain leading away from and outletted beyond the MSE mass and the weeping tile shall not be located over the steel soil reinforcement or within the reinforced soil zone;
  - 4. provided with a non-woven geotextile filter fabric layer that shall be placed below and above the membrane to prevent puncture; and
  - 5. extended for the full width of the surface receiving de-icing salts and not less than 2 m beyond it on either side, and not less than 500 mm beyond the ends of the reinforced soil zone.
- D. For MSE wall abutments, the concrete walkway provided in front of the abutment for inspection purposes shall be underlain by the impermeable membrane.

#### **4-1.12 DUCT BANKS**

- A. Duct bank accommodation requirements for Transportation Structures shall be in accordance with Section 6-1.7 [*Systems Duct Bank and Associated Infrastructure*] and Section 6-2.10 [*Traction Power Duct Bank*] of this Schedule.

#### **4-1.13 INSPECTION ACCESS**

- A. This Section 4-1.13 [*Inspection Access*] sets out general inspection access requirements for Transportation Structures in addition to the requirements of CAN/CSA S6.
- B. Transportation Structure components that are not completely accessible using conventional and readily available inspection equipment, such as manlifts and bridge inspection vehicles, shall be provided with permanent access suitable for safe inspection activities.
- C. For abutments on headslopes a minimum 0.6 m wide bench shall be provided in front of the abutment seat suitable for bearing inspection access. The abutment height shall be such that the bearings can be viewed by an inspector standing directly on the bench, with a maximum abutment seat height of 1.5 m above the bench.
- D. For abutments behind retaining walls a minimum 1.0 m wide concrete inspection walkway with a 1.2 m minimum vertical clearance suitable for inspection access shall be provided in front of the abutment seat. The inspection walkway shall be accessible from the side without the need of any equipment.
- E. A suitably flat area shall be provided at the base of all retaining walls over 2 m in exposed height and all abutment seats over 1.5 m in exposed height, to enable ladder access to the wall or abutment at any location along the wall or abutment to be done in a safe manner.
- F. Voids inside abutments shall be accessible for inspections via access hatches in the abutment backwall.
- G. All box girders having internal voids deeper than 1200 mm shall:



1. have internal voids that are continuous along the length of the girder with a minimum of 2 access openings;
2. be provided with access openings with minimum dimensions of 820 mm by 1100 mm if rectangular and a minimum diameter of 920 mm if circular:
  - a. near each girder end;
  - b. spaced so that the maximum distance from any opening to any location within the box girder is 100 m or less; and
  - c. provided with access hatches that shall be lockable and operable by one person.

## SECTION 4-2 STRUCTURAL COMPONENT REQUIREMENTS

- A. This Section 4-2 [*Structural Component Requirements*] sets out requirements for specific components forming part of a Transportation Structure unless otherwise specified.

### 4-2.1 FOUNDATIONS

- A. Foundation requirements shall apply to Building Structures as well as to Transportation Structures.
- B. Driven piles shall not be permitted anywhere except between Coronet Road and the south abutments of the Whitemud Drive bridges unless specified otherwise in Section 4-3 [*Structure Specific Requirements*] of this Schedule.
- C. The pile bearing capacities shall be determined based on the geotechnical parameters and method of installation.
  - 1. The pile driving criteria for driven piles shall be determined using wave equation analysis and may be verified using pile driving analyzer testing.
- D. All welded pile splices whose tensile or flexural capacity is required for the structural stability of a Structure shall be identified on the applicable Final Design and tested for Deficiencies or Early Handover Deficiencies using non-destructive ultrasonic testing techniques as specified in Section 4-4.1.5.4 [*Steel Pile Splices*] of this Schedule.
  - 1. Deficiencies or Early Handover Deficiencies which are discovered shall be repaired and the suspect area re-inspected.
- E. Dynamically compacted, cast-in place concrete piles are not permitted.
- F. Timber piles are not permitted for Transportation Structures.
- G. Foundations, including footings and pile caps, shall be buried a minimum of 600 mm below ground.

### 4-2.2 ABUTMENTS

#### 4-2.2.1 General

- A. Abutments shall be supported on piles.
- B. Wingwalls generally parallel to the approach fill shall extend a minimum distance of 0.6 m beyond the top of approach fill headslope.
- C. Any abutments with wingwalls over 8 m in length shall include roof slabs spanning between the end of the main superstructure members and the top of the approach fill headslope.
- D. Expanded polystyrene foam and MSE walls shall not be used behind abutment seats to reduce earth pressures on the abutments or abutment wingwalls or to support the abutment roof slab.
- E. Abutment seats and wingwalls shall be embedded a minimum of 0.5 m below finished grade.
- F. Transportation Structure headslopes for Transportation Structures spanning over Roadways shall be covered with concrete slope protection unless other specified within this Schedule. The concrete slope protection shall extend from the abutment seat to the bottom of the headslope and 0.5 m past the edges of the Transportation Structure on each side of the Transportation Structure.

#### 4-2.2.2 Integral Abutments

- A. Integral abutments, including both fully integral and semi-integral abutments, shall not be used for bridge thermal spans greater than 45 m for steel girder bridges, or greater than 60 m for concrete girder bridges, where the thermal span is the distance between the thermal fixity point and the centreline of the integral abutment piles.
- B. In addition to the requirements of Section 4-2.2.1 *[General]* of this Schedule, integral abutments shall be designed to meet the following requirements:
1. The effects of skew and potential for twisting of the superstructure in plan and bi-axial bending of the piles shall be analyzed and accounted for.
  2. The amount of Transportation Structure and earth that have to move with the abutment during thermal movement of the superstructure shall be minimized by limiting the abutment seat height above grade to not more than 1.5 m. Turned back wingwalls shall be parallel to the approach fill and cantilevered off the back of the abutment. They shall not exceed 8 m in length measured from the back of the abutment seat/abutment diaphragm to the end of the wingwall.
  3. Deck reinforcement shall be provided at the abutments to resist negative bending moments due to torsional restraints provided by the stiff abutment diaphragms and adjacent girders.
  4. For fully integral abutments (monolithic connection between abutments and superstructure) the abutment foundation shall be a single row of steel H-piles. For thermal spans exceeding 22.5 m for steel girder bridges and 30 m for concrete girder bridges or when surrounding soils will restrict pile movement the piles shall be installed in permanent steel casings. The casings shall be filled with expanded polystyrene beads having a nominal diameter of 5 mm or an equivalent material and shall be designed to allow free movement of the piles within the casings and to last for the Design Service Life of the supported Transportation Structure. A sacrificial corrosion thickness or galvanizing shall be provided for the casings. The H-piles shall be embedded a minimum of 2 pile widths into the abutment seat.
  5. Cycle control joints at the ends of the approach slabs shall be located at least 1 m beyond the ends of the wing walls by extending the length of the approach slab. A sleeper slab shall be provided under the approach fill end of the approach slab. Drainage shall be provided beneath the joint between the approach slab and sleeper slab to drain water away from the abutment.
  6. Approach slabs shall not move longitudinally in and out between stationary and parallel non-integral wingwalls.
  7. Two layers of polyethylene sheet shall be provided under the approach slab to minimize frictional forces due to longitudinal movement. The connection between the approach slab and the superstructure shall be designed to resist all friction forces due to horizontal movement.
  8. Barriers constructed on approach slabs shall be designed such that:
    - a. Loss of barrier height due to settlement does not exceed 50 mm;
    - b. The differential settlement between adjacent barrier segments does not exceed 25 mm; and
    - c. The joints between barrier segments remain sealed.

9. Provision shall be made to accommodate thermal movement between integral abutments, slope protection, inspection walkways, etc. Gaps shall be protected against moisture ingress.

#### **4-2.3 PIERS**

- A. Piers in water courses shall be founded on piles with a minimum penetration of 5 m into competent material.
- B. Land piers, outside the zone of any potential water course erosion, may be founded on piles or spread footings, but spread footings shall not be used unless founded directly on competent bedrock.
- C. The ends of pier cap cantilevers shall have cast-in stainless steel drip sheets across the full underside width of the pier cap or equivalent to prevent staining of substructure concrete.
- D. The upstream face of piers in water courses shall be protected from ice loads by a steel nose plate with a minimum thickness of 10 mm.

#### **4-2.4 RETAINING WALLS**

##### **4-2.4.1 General**

- A. Retaining walls generally parallel to a Roadway located adjacent to the base of the wall shall have their ends on the approaching traffic side flared away from traffic at a 20:1 taper. A 20:1 taper shall also be used for both ends of walls generally parallel to a Trackway or Heavy Rail located adjacent to the base of the wall.
- B. Long term lateral displacements of the tops of retaining walls shall not adversely affect the safety, serviceability and durability of:
  1. the Infrastructure, including the retaining wall; and
  2. any buildings, surface facilities and Utility Infrastructure.
- C. Notwithstanding Section 4-2.4.1.B [*General*] above, long term lateral displacements of the tops of retaining walls shall in no case exceed 20 mm.
- D. The exterior faces of retaining walls shall be sloped at a minimum of 1H:50V towards the retained fill and shall be designed to discourage attempts to climb the wall.
- E. Any Transportation Structure components located immediately behind retaining walls, including abutment seats, abutment wingwalls, abutment deck joints, abutment bearings and barriers, shall be designed to accommodate any movements resulting from retaining wall displacements.
- F. Dry cast concrete block walls are not permitted for retaining walls.

##### **4-2.4.2 Mechanically Stabilized Earth (MSE) Walls**

- A. All MSE walls shall comply with the requirements of CAN/CSA S6 except that the capacity of the MSE wall shall be determined in accordance with AASHTO LRFD.
- B. MSE walls shall not be used for Transportation Structures crossing watercourses.
- C. Maximum reinforcement loads shall be calculated using the "Simplified Method" as presented in AASHTO LRFD.

- D. MSE wall embedment depths below finished grade shall not be less than the minimum depth provided in Table C11.10.2.2.1 “Guide for Minimum Front Face Embedment Depth” in the AASHTO LRFD Commentary, but shall not be less than 1 m.
- E. MSE wall backfill shall extend a minimum of 0.5 m beyond the end of the soil reinforcement.

#### 4-2.4.2.1 Utilities

- A. Mechanically stabilized earth shall not be placed over or in the vicinity of any Utility Infrastructure, unless the following conditions are met:
  - 1. All applicable Utility Infrastructure can be removed and repaired without disturbing the mechanically stabilized earth;
  - 2. Utility Infrastructure carrying potentially eroding materials, including water carrying appurtenances, such as catch basins, drainage inlets/outlets, and culverts, shall not be permitted within 10 m of any MSE wall backfill unless the Utility Infrastructure are appropriately sheathed to protect the MSE wall system from any leakage, and the extent of the sheathing is sufficient to protect the MSE wall system against discharges from the ends of the sheathing; and
  - 3. No change of direction of Utility lines, and no valves, valve chambers or other discontinuity shall be permitted within the mechanically stabilized earth.

#### 4-2.4.2.2 Facing

- A. All MSE walls shall be faced with precast concrete wall panels. The minimum precast concrete panel thickness shall be 140 mm, excluding any additional thickness required for aesthetic surface treatment. Minimum cover to reinforcing steel shall be 50 mm (excluding any additional thickness required for aesthetic surface treatment) on both front and back faces of the panels, and reinforcing steel shall be electrically isolated from soil reinforcement attachment hardware.
- B. The precast concrete panel system shall not be subjected to a differential settlement of more than 100 mm in 10 m of length along the wall.
- C. Joints between panels shall prevent the loss of fill through the joints.
- D. Corner units shall be provided and designed to prevent joint gaps from opening up between adjacent panels orientated in different directions. Acute wall corners less than 70° (measured between backfill sides of panels) shall not be used.
- E. The non-exposed side of MSE wall panels shall be in full contact with compacted backfill.
- F. Installed MSE wall panels shall be repairable/replaceable without adverse impact to the Transportation Structure and a repair/replacement procedure shall be included with the applicable Final Design.

#### 4-2.4.2.3 Coping Cap

- A. A cast-in-place concrete coping cap shall be placed on the top of all MSE walls not covered by a concrete barrier, and shall have full depth joints lining up with panel joints.
- B. The top of the cast-in-place concrete wall coping shall be smooth and have no steps or abrupt changes in height. The top of the coping shall have a consistent negative slope from its high point to the ends of the wall.

#### 4-2.4.2.4 Barriers

- A. MSE walls with traffic running adjacent to the top of the wall shall have rigid traffic barriers. Such barriers shall be supported on moment slabs to resist sliding and overturning, and shall be located on top of the MSE walls. Flexible guardrail systems shall not be used. The MSE wall shall be designed to resist the loads applied to the barrier.
- B. MSE walls with a sidewalk or SUP adjacent to the top of the wall shall be provided with a pedestrian or bicycle rail as required by CAN/CSA S6. The rail shall be mounted on the top surface of the concrete coping of the MSE wall.

#### 4-2.4.2.5 Obstructions within the Backfill

- A. Soil reinforcing shall accommodate any obstruction within the mechanically stabilized earth, including foundation piles and associated casings, and casing for future pile installations. For MSE wall systems that lend themselves to splaying of the soil reinforcement, the splay angle shall not exceed 20° perpendicular to the facing panel. For MSE wall systems that do not lend themselves to splaying, additional soil reinforcement shall be provided to compensate for the loss of soil reinforcement at obstruction locations.

#### 4-2.4.2.6 Inspection Wires

- A. Galvanized steel inspection wires shall be provided in all MSE wall systems in addition to the soil reinforcement design requirements. One inspection wire shall be provided for each 25 m<sup>2</sup> of wall area. Inspection wires shall be placed in vertically distributed sets of 2 or 3 depending on the wall height. Two locations shall be provided where the wall height is less than 6 m and 3 locations provided where the wall height is greater than 6 m. Vertical distribution shall be such that a single inspection wire is placed within the center of the bottom wall panel, center of the top wall panel, and in the center wall panel where 3 locations are required. Sets of inspection wires shall be evenly distributed along the length of the wall.
- B. Inspection access ports and wire removal and centering devices shall be detailed in accordance with the California Department of Transportation standard bridge detail sheet XS13-020-3. Inspection access ports shall be cast as voids in the panels at the panel manufacturing facility and the remaining cavity placed and filled with an OH-V patching product from the Alberta Transportation Approved Product List and in accordance with the manufacturer's recommendations. All inspection access ports shall be marked with a 25 mm diameter galvanized survey target anchored into the patching material and flush with the wall surface.

#### 4-2.4.3 Retaining Walls with Ground Anchors

- A. Ground anchors shall not extend laterally beyond the boundary of the City Lands unless otherwise specified, and:
  - 1. along the west boundary of the City Lands, adjacent to the Trackway between Muttart Stop and 100 m south of Muttart Stop, ground anchors may extend up to 10 m beyond the boundary of the City Lands provided the ground anchors do not extend laterally beyond land owned by the City or result in any surface disturbance beyond the boundary of the City Lands; and
  - 2. along the north boundary of the City Lands, adjacent to the North River Bank Tunnel Approach Access Road, ground anchors may extend up to 8 m beyond the boundary of the City Lands provided the ground anchors do not extend laterally beyond land owned by the City or result in any surface disturbance beyond the boundary of the City Lands.

- B. Ground anchors shall be designed in accordance with the most stringent requirements of the following standards:
  - 1. CAN/CSA S6; and
  - 2. PTI DC35.1.
- C. The load-carrying capacity of ground anchors shall be verified by verification tests on sacrificial pre-production anchors and performance and proof tests on production anchors, in accordance with the recommendations of PTI DC35.1. For permanent anchors, a minimum of one verification test in each significantly different soil condition (in terms of geologic origin, composition and strength) at each Transportation Structure shall be performed. Performance tests shall be conducted on a minimum of 5 percent of production anchors, and proof tests shall be carried out on all production anchors not subjected to performance tests.
- D. The minimum bond length of a ground anchor shall be 4.5 m.
- E. The factored design load, service design load, lock-off load, and test load of the ground anchors shall be stated on the applicable Final Design.
- F. The free stressing length (unbonded length) of a ground anchor shall extend at least 1.5 m or 20 % of the height of the wall, whichever is greater, behind the critical failure surface. The critical failure surface shall be determined using slope stability analyses.
- G. A ground anchor design report containing all design parameters required for load resistance calculations, installation procedures, procedures required for installation verification and details on how the corrosion-protection system provides the necessary corrosion protection over the Design Service Life shall be submitted with the applicable Final Design.

#### **4-2.5 BEARINGS**

##### **4-2.5.1 General**

- A. Expansion bearings shall provide an excess travel capacity in each direction of at least 25% of the theoretical thermal movement, but not less than 25 mm. An allowance shall be made for additional movement including movements due to concrete creep and shrinkage and foundation conditions.
- B. Steel sole plates and base plates shall be provided. All steel components except those welded to steel girders shall be galvanized, metallized, or stainless steel.
- C. The beneficial effect of friction shall be neglected in proportioning fasteners and anchors to resist horizontal loads at the ULS.
- D. An 80 mm nominal thickness grout pad shall be provided under all bearing base plates. The grout shall sit in a grout pocket recessed 40 mm nominally into the top of the substructure. The grout pocket shall be at least 75 mm larger than the base plate around the perimeter.
- E. Shim plates used for shim stacks shall be hot-dip galvanized.
- F. Attachment of bearing sole plates to steel girders by welding shall be in the longitudinal direction along the edge of the girder. Overhead welding shall not be permitted. Transverse sole plate ends not welded shall be sealed against moisture.
- G. Bearings shall be designed and detailed to allow for bearing replacement without damage to the Transportation Structure and without removal of any concrete, welds, or anchorages permanently attached to the Transportation Structure. Bearing replacement shall be designed based on simultaneously jacking all girder lines, and supporting them in the raised position

while bearings are replaced one at a time. Bearings shall be replaceable with a maximum jacking height of 3 mm. Locations for future jacking shall be shown on the applicable Final Design and shall be based on estimated jack and distribution plate sizes. Details of the bearing replacement procedure shall be noted on the applicable Final Design, together with the unfactored dead load and live load jacking forces that will be required for bearing replacement.

H. Disk bearings shall not be used.

#### 4-2.5.2 **Elastomeric Bearings**

A. Elastomeric bearings shall incorporate the following standard features:

1. Elastomeric bearing pads shall be designed at SLS for all rotations that take place after the bearings are grouted, plus a tolerance of 0.005 radians. Rotations taking place prior to grouting need not be considered if the bearing base plate is supported on a self-rocking pintle that ensures uniform contact between the elastomeric bearing pad and the bearing sole plate/girder bottom flange at erection.
2. Notwithstanding Section 11.6.6.2.2 of CAN/CSA S6, elastomeric bearings shall conform to Section 18 “Bearings” Division II of the AASHTO SSHB. Elastomeric material shall meet the requirements of AASHTO Grade 5 for cold temperature performance.
3. Sliding surfaces shall allow for translation by sliding of a stainless steel surface against a mating PTFE element. PTFE shall be unlubricated, unfilled 100% virgin polymer conforming to Section 18.8.2.5 (Unfilled PTFE Sheet) of the AASHTO LRFD BCS. PTFE sheets shall be recessed and bonded into a 2.5 mm deep recess in the top of a minimum 10 mm thick galvanized steel plate vulcanized to the top of the elastomeric pad.
4. Elastomeric pads shall be restrained from walking out by means of keeper bars attached to the top of the base plate.

#### 4-2.5.3 **Pot Bearings**

A. Pot bearings shall incorporate the following standard features:

1. Bearings shall be designed to prevent moisture and dirt from entering internal surfaces.
2. Expansion bearings shall allow for translation by sliding of a stainless steel surface against a mating PTFE element. Except for lateral restraints, the stainless steel surface shall be positioned above the PTFE element.
3. Except when used as a mating surface for guides for lateral restraints, PTFE shall be unfilled, 100% virgin polymer conforming to Section 18.8.2.5 (Unfilled PTFE Sheet) of the AASHTO LRFD BCS. When used as a mating surface for guides for lateral restraints PTFE may be unfilled or filled with up to 15% by mass glass fibres.
4. Notwithstanding Section 11.6.3.6 of CAN/CSA S6, the average contact pressure for unfilled PTFE elements, based on the recessed area of the PTFE, shall not exceed the following:

Table 4-2.5.3-1 Average Contact Pressure for Unfilled PTFE Elements

Limit State	Permanent Load (MPa)	All Loads (MPa)
SLS	25	35



ULS	40	55
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5. The maximum contact pressures at the extreme edges of flat and curved PTFE elements shall not exceed 1.2 times the values specified in Table 4-2.5.3-1 [*Average Contact Pressure for Unfilled Elements*].
6. Notwithstanding Section 11.6.3.6 of CAN/CSA S6, the average contact pressure for all loads at the ULS for PTFE elements filled with up to 15% by mass of glass fibres and used to face mating surfaces of guides for lateral restraint shall not exceed 45 MPa.
7. Notwithstanding Section 11.6.5.4 of CAN/CSA S6, the average stress in the elastomer at SLS loads shall not exceed 30 MPa. The elastomer shall conform to Section 18 "Bearing", Division II of AASHTO SSHB and shall meet the requirements of AASHTO Grade 5 for cold temperature performance.
8. The elastomer shall be a single disc of confined elastomer. The effective thickness of the elastomeric disk to evaluate the rotational capacity of the bearing shall be limited to the thickness of the disk excluding the brass rings.
9. Pot bearings shall be installed on a level base plate on galvanized steel shim stacks. The bearings shall be designed for all rotations that take place at the ULS, plus a fabrication and construction tolerance allowance of 0.02 radians. The total rotational capacity shall not be less than  $\pm 1^\circ$ .
10. The depth of the pot wall shall be such that a vertical distance of at least 2.5 mm remains between the top of the pot wall and the closest point of contact of the brass sealing rings with the pot wall upon rotating the piston an amount equal to the maximum design rotation at the ULS.
11. The pot and piston surfaces in contact with the confined elastomer shall be lubricated with silicone grease. The bearing shall be sealed by a one piece continuous preformed closed cell compressible ring against entry of dirt, dust and moisture between the elastomer and the pot and piston contact surfaces. Any joint in the ring shall be bonded and the strength shall be at least equal to the strength of the ring.
12. Bearings shall be set level by using tapered sole plates except at cover plated joints, where the sliding plane of the abutment expansion bearings shall be set parallel to the grade slope for proper functioning of the joints. In this case, the effects on the Transportation Structure of longitudinal forces generated by the inclined sliding bearings shall be designed for.

#### **4-2.6 GIRDERS**

##### **4-2.6.1 General**

- A. Continuous span Transportation Structures shall have the same number of girder lines in adjacent spans or adjacent segments, such that each individual girder line is fully continuous from end to end of the Transportation Structure.

##### **4-2.6.2 Concrete Girders**

- A. Concrete girders shall meet the following requirements:
  1. Stirrup projections from the top of the girder into the deck shall meet CAN/CSA S6 requirements for developing full composite action between the girder and the deck. All stirrups shall be hooked around longitudinal bars. When the projection of the underside of the stirrup tops is less than 25 mm above the top of the bottom mat of deck bars,

additional extension bars shall be provided to tie the girder and the deck together to provide composite action.

2. The horizontal interface shear design for composite action between the girder and the deck shall satisfy the requirements of CAN/CSA S6 or AASHTO LRFD, whichever is more stringent. The longitudinal distribution of shear forces shall be taken to be the same as the ULS applied shear envelope.
3. The area of stirrups required for end crack control in pretensioning anchor zones shall be calculated in accordance with CAN/CSA S6, Section 8.16.3.2. Fifty percent of this amount of stirrups shall be distributed over a distance equal to  $0.125h$  from the end of the girder where "h" is the depth of the girder. The end stirrup shall be located as close to the end of the girder as cover permits.
4. For post-tensioning ducts in concrete girders with a 28 day concrete strength greater than or equal to 65 MPa, the inside duct diameter shall not exceed 50% of the web thickness and the inside duct area shall be  $> 250\%$  of the strand area.

#### 4-2.6.2.1 Segmental Concrete Girders

##### A. General

1. Segmental concrete girders shall meet the following requirements, in addition to those of Section 4-2.6.2 [*Concrete Girders*] of this Schedule. The method of construction shall be shown on the applicable Final Design.

##### B. Loads

###### 1. Thermal Loads

- a. In lieu of the requirements of CAN/CSA S6, Section 3.9.4.4 (Thermal gradient effects) segmental concrete girders shall be designed for the temperature gradient specified for Zone 1 in AASHTO LRFD, Section 3.12.3 (Temperature Gradient).

###### 2. Creep and Shrinkage

- a. Creep and shrinkage strains shall be based on the provisions of the CEB-FIP rather than on the requirements of CAN/CSA S6, Sections 8.4.1.5 (Shrinkage) and 8.4.1.6 (Creep).
- b. The creep and shrinkage strains predicted by CEB-FIP shall be adjusted as required based on tests carried out on the actual concrete mix used for the girders, including on tests measuring concrete creep and shrinkage.

###### 3. Closure Force Loads

- a. Closure forces for segmental concrete cantilever construction due to vertical girder misalignment shall be based on a minimum girder misalignment of  $L/1000$  (where L is the cantilever length from centre of pier to the cantilever tip) and assuming uncracked sections.
- b. Closure forces shall be used as load "K" in CAN/CSA S6.

##### C. Analysis

###### 1. Transverse Analysis

- a. The transverse design of segmental concrete box girder segments for flexure shall consider the segment as a rigid box frame. Flanges shall be analyzed as variable depth sections considering the fillets between the flanges and the webs. Wheel loads shall be positioned to provide maximum moments, and elastic analysis shall be used to determine the effective longitudinal distribution of wheel loads for each load location. Increase in web shear and other effects on the cross-section resulting from eccentric loading or unsymmetrical structure geometry shall be accounted for.
  - b. Transverse elastic and creep shortening due to prestressing and shrinkage shall be accounted for in the transverse analysis.
  - c. The effects of secondary moments due to prestressing shall be included in stress calculations at the SLS and during Construction. Secondary moments shall also be accounted for at the ULS.
  - d. At stay cable locations the loads applied by the stay cable anchors shall be accounted for.
2. Longitudinal Analysis
- a. Longitudinal analysis of segmental concrete girders shall account for the actual Construction method and Construction schedule as well as the time-related effects of concrete creep, shrinkage and prestress losses.
  - b. The effects of secondary moments due to prestressing shall be included in stress calculations at the SLS and during Construction. Secondary moments shall also be accounted for at the ULS.
  - c. At stay cable locations, the loads applied by the stay cables on the girders shall be accounted for.
  - d. All Construction loads and conditions, temporary supports or restraints, closure forces due to misalignment corrections and changes in the structural static system occurring during Construction shall be accounted for.
  - e. At stay cable locations, the loads applied by the stay cables shall be accounted for.
3. Analysis of Final Structural System
- a. The final structural system shall be analyzed and designed for redistribution of Construction stage force effects due to internal deformations and changes in support and restraint conditions, including accumulated locked-in force effects from the Construction process.
4. Analysis of Girder Segment Joints
- a. Joints in segmental girders made continuous by unbonded post-tensioning steel shall be designed at the ULS for the simultaneous effect of axial force, moment and shear that may occur at a joint. These force effects, the opening of the joint, and the remaining contact surface between the components shall be determined by global consideration of strain and deformation. Shear shall be assumed to be transmitted through the contact area only.

D. Serviceability Limit State Stresses

1. Stresses at SLS shall be in accordance with CAN/CSA S6, Section 8.8.4.6, such that:

- a. the principle tensile stress at the neutral axis of the girder shall not exceed  $0.288\sqrt{f'c}$  for SLS Load Combination 1; and
  - b. the maximum concrete compression stress at SLS under permanent loads shall not exceed  $0.4f'c$ .
2. The principal tensile stress shall be determined using classical beam theory and Mohr's Circle. The width of the web for these calculations shall be measured perpendicular to the plane of the web. The vertical force component of draped longitudinal tendons may be considered to reduce the shear force due to the applied loads provided the tendons are anchored or fully developed in the top or bottom 1/3 of the webs. Local tensions produced in the webs due to the anchorage of tendons shall be included in the principal tension stress check.

#### E. Resistance Factors

1. Resistance factors for the ULS shall be in accordance with CAN/CSA S6 if the post-tensioning tendons are fully bonded. If the post-tensioning tendons are partially bonded or unbonded the resistance factors shall be reduced by 0.05 from those given in CAN/CSA S6. In order for a post-tensioning tendon to be considered to be fully bonded the tendons must be fully developed at the section being considered. If a bonded tendon is not fully developed at the section under consideration, it shall be considered to be partially bonded.
2. Where the post-tensioning is a combination of fully bonded tendons, partially bonded tendons and unbonded tendons, the resistance factor at any section shall be based on fully bonded tendons, if the tendons providing the majority of the prestressing force at the section are fully bonded and on unbonded tendons if the tendons providing the majority of the prestressing force at the section are partially bonded or unbonded.

#### F. Girder Detailing

##### 1. Minimum Top Flange Thickness

- a. Girders shall have a minimum top flange thickness of 200 mm except that the minimum thickness shall be increased to 230 mm in anchorage zones where transverse post-tensioning is used.

##### 2. Minimum Web Thickness

- a. Girders shall have a minimum web thickness of:
  - i. 200 mm if there are no longitudinal post-tensioning tendons in the webs; and
  - ii. 300 mm if there are longitudinal post-tensioning tendons in the webs.

##### 3. Closure Segment

- a. Cast-in-place concrete closure joints wider than 225 mm shall be reinforced with reinforcing steel.

##### 4. Post-Tensioning Tendons

- a. All Transportation Structures erected using the balanced cantilever method shall have a minimum of two draped external or internal continuity post-tensioning tendons per girder web that extend to the adjacent pier or abutment diaphragms.

- b. Vertical post-tensioning tendons shall not be used.
  - c. The unsupported length of external post-tensioning tendons shall not exceed 8.0 m.
5. External Post-Tensioning Tendon Deviators
- a. External post-tensioning tendon deviators shall fully extend from the bottom flange to the top flange of the girder.
  - b. External post-tensioning tendons passing through deviators shall be contained in grouted steel pipes cast into the deviators.
6. Internal Post-Tensioning Ducts
- a. Internal post-tensioning ducts shall be positively sealed with segmental duct couplers or o-rings at all segment joints. Duct couplers shall have a maximum deflection angle of 6° at the segment joints. The duct couplers shall be mounted perpendicular to the bulkheads at the segment joints.
  - b. The minimum centre-to-centre post-tensioning duct spacing shall be the greater of 200 mm, 2 times the outer duct diameter and the outer duct diameter plus 115 mm.

#### 4-2.6.3 **Steel Girders**

- A. Steel girders shall meet the following requirements:
1. All bearing stiffeners shall be “fit to bear” bottom and “fit only” top, and then fillet welded to both top and bottom flanges and to the web. As defined in AWS D1.5, Bridge Welding Code, “fit to bear” requires minimum 75% contact and “fit only” allows a maximum gap of 1 mm.
  2. Jacking stiffeners shall be provided for future bearing replacement. Locations of jacking stiffeners shall be based on the estimated jack sizes required for bearing replacement, plus sufficient clearance to the edge of the abutment seat or pier cap.
  3. Diaphragm connector plates as well as intermediate stiffeners at stress reversal locations shall be welded to both top and bottom flanges. Intermediate stiffeners, other than at stress reversal locations, shall be welded to the compression flange only, and cut short of the tension flange with a web gap meeting the requirement of Section 10.10.6.4 of CAN/CSA S6.
  4. No intersecting welds are allowed. The ends of stiffeners shall be corner coped a minimum of 25 mm x 25 mm.
  5. All weld ends for stiffeners, gussets, and other attachments to girders shall terminate at least 10 mm from the edge or end of the plates.
  6. Gusset plates for attachment of horizontal bracing shall be bolted and not welded to girders.
  7. Staining of the sub-structure concrete or any other Structure components beneath the girders shall be prevented. Measures taken to prevent staining shall include:
    - a. at pier locations, as a minimum, the exterior edge of the bottom flange of exterior steel girders shall have a 19 x 19 x 8000 mm long rubber strip centred over the pier; and

- b. at abutments, as a minimum, exterior steel girders shall have the same rubber strip attached around the bottom flange at 2000 mm from the face of the abutment walls. Where steel girders are cast into fully integral abutments, a second rubber strip shall be applied all around the bottom flange of all girders immediately in front of the concrete abutment face.
8. Shear stud projections from the top of girder flanges into the deck shall meet all CAN/CSA S6 requirements for stud development and anchorage and ensure full composite action between the girder and the deck. When the shear stud projection, measured from the underside of the head of the stud to the top of the bottom transverse deck reinforcement, is less than 25 mm, additional reinforcement shall be provided and designed as shear friction reinforcement for a horizontal shear plane at the deck/girder haunch interface.

#### **4-2.7 STAY CABLES**

##### **4-2.7.1 Design**

- A. Stay cables shall comply with the requirements of PTI DC45.1 with the following modifications:
  1. In Sections 5.1.1 to 5.1.4 of PTI DC45.1, the dead loads, live loads, fatigue loads and dynamic load allowance shall be based on CAN/CSA S6, and Section 4-1 [*General Design Requirements*] of this Schedule rather than AASHTO LRFD;
  2. in Sections 5.3.1 and 5.3.2 of PTI DC45.1, the design limit states, load factors and load combinations shall be based on CAN/CSA S6, and Section 4-1 [*General Design Requirements*] of this Schedule rather than AASHTO LRFD . However, the construction limit states of Section 5.3.2.1 of PTI DC45.1 shall apply;
  3. in Section 5.3.5 of PTI DC45.1, the FLS load factor ( $\gamma$ ) and stress range ( $\Delta F$ ) shall be based on CAN/CSA S6, and Section 4-1 [*General Design Requirements*] of this Schedule rather than AASHTO LRFD. However, the nominal fatigue resistance ( $\Delta F$ )<sub>n</sub> shall be determined in accordance with PTI DC45.1, Section 5.3.5. AADT<sub>SL</sub> shall be the average daily number of On-track Vehicles on one Track based on the System operating at the Maximum Service Level; and
  4. in Section 5.7.2.4 of PTI DC45.1 the structural design of saddle components shall be based on CAN/CSA S6 and Section 4-1 [*General Design Requirements*] of this Schedule rather than on AASHTO LRFD.

##### **4-2.7.2 Stay Cables**

- A. The stay cables shall be designed and detailed so that each stay cable strand can be installed, tensioned, removed and replaced individually.
- B. Stay cables shall be designed and detailed to prevent ice build-up on the cables from falling on the Transportation Structure.
- C. For each Transportation Structure with stay cables, a minimum of 8 additional reference strands shall be distributed throughout the stay cables for corrosion and Design Service Life monitoring purposes.
  1. The reference strands shall be installed, stressed and protected under identical conditions to the other stay cable strands.
  2. The stay cables shall be designed such that any reference strands that are removed do not have to be replaced.

#### 4-2.7.3 **Anchorage**

- A. Anchorages shall be capable of anchoring the full ultimate tensile force of the stay cables.
- B. Anchorages shall include cable guide systems that prevent significant bending stresses due to angular deviations of the strands from extending to the anchorages. Cable guide systems shall not impose transverse forces on the Transportation Structure ahead of the anchorages.
- C. Anchorages shall be designed and detailed so that each stay cable strand can be installed, tensioned, removed and replaced individually.
- D. Anchorages shall be designed and detailed so that a force adjustment of 2.5% can be made simultaneously in all of the stay cable strands without the use of shims.
- E. Anchorages shall provide for a minimum of five percent additional strands for contingency. The holes provided for the additional strands shall be positively sealed to protect the stay cable interior from corrosion.

#### 4-2.7.4 **Saddles**

- A. Saddles shall provide for continuity of the stay cable strands across the saddle and shall individually anchor each strand by a means that allows for the removal of the strand.
- B. The load transfer capacity between the strands and the saddle shall be sufficient to prevent the strands from slipping under any load case.
- C. Steel to steel contact shall not be allowed between the stay cable strands and any part of the saddle.
- D. Saddles shall include a cable guide system at each end that prevents significant bending stresses due to angular deviations of the strands from extending to the saddle entry and exit points.
- E. Saddles shall provide for a minimum of five percent additional strands for contingency. The slots provided for the additional strands shall be positively sealed to protect the stay cable interior from corrosion.

### **4-2.8 DECKS**

#### 4-2.8.1 **General**

- A. The design of Transportation Structure barriers and decks for load effects due to barrier loading may be based on the AASHTO LRFD, Appendix A13.

#### 4-2.8.2 **Deck Systems Using Cast in Place Concrete**

- A. Cast in place concrete decks shall meet the following requirements:
  - 1. deck slabs shall have a minimum thickness of 225mm, unless otherwise specified, and shall have two mats of reinforcing steel;
  - 2. deck slabs, supporting sidewalks or SUPs, shall have a minimum thickness of 175mm; and
  - 3. stay in place deck soffit formwork is not allowed.

### 4-2.8.3 Deck Systems Using Precast Concrete Partial Depth Deck Panels

#### 4-2.8.3.1 Design

- A. Deck slabs using precast concrete partial depth deck panels shall meet the following requirements:
1. Deck slabs using precast concrete partial depth deck panels shall consist of a cast-in-place concrete deck slab on partial depth precast concrete panels (precast panels).
  2. The cast-in-place concrete deck slab shall be fully composite with the precast panels.
  3. The minimum composite deck slab system thickness shall be the greater of the deck slab span divided by 15.0 or 225 mm. In addition, the following shall be satisfied:
    - a. the precast panels shall have a minimum thickness of 90 mm; and
    - b. the cast-in-place concrete portion of the composite deck slab system shall have a minimum thickness of 115 mm.
  4. The precast panels shall be fully prestressed and the stresses in the precast panels shall not exceed the following at SLS:
    - a. from transfer until the 28 day strength is attained:
      - i. compression:  $0.6 f_{ci}$ ;
      - ii. tension:  $0.5 f_{cr}$ ;
    - b. after the 28 day strength is attained:
      - i. tension:  $f_{cr}$ ; and
    - c. the average compressive stress in the precast panels at prestress strand release shall be  $\leq 7.0$  MPa and the minimum concrete strength at release shall be 30 MPa.
  5. The empirical method of Section 8.18.4 of CAN/CSA S6 shall not be permitted for design of the composite deck slab system using precast panels.
  6. The composite deck slab system using precast panels shall be designed using flexural design methods based on elastic moments:
    - a. the maximum positive moments shall be used to design the transverse positive moment reinforcing requirements in the precast panels and the composite slab and the maximum negative moments shall be used to design the negative moment reinforcing requirements in the cast-in-place portion of the deck slab. In addition, reinforcement development and cut-off locations shall be determined using moment envelopes based on elastic analysis;
    - b. the following minimum transverse positive moment reinforcing shall be provided over supporting girder lines:
      - i. in addition to the prestressing strands required by CAN/CSA S6, transverse reinforcing steel bars, with a minimum reinforcement ratio,  $\rho$ , of 0.003, shall be provided throughout the precast panels and shall project over the girder lines and into the cast-in-place concrete portion of the composite deck slab system. The reinforcement ratio,  $\rho$ , shall be calculated for "d" equal to the effective depth of the



- composite deck slab system. The spacing of the transverse reinforcing steel bars shall not exceed 300 mm;
- ii. at interior girder lines, the transverse reinforcing steel bars shall project out of the precast panel edges and over the girder flanges as required to provide a lap splice with the bars projecting from the opposing precast panels supported on the same girder; and
  - iii. at exterior girder lines, the transverse reinforcing steel bars shall be extended at least one full development length beyond the exterior girder centreline.
7. The composite deck slab system shall conform to the following:
    - a. the precast panels shall have a minimum age of 45 days and a maximum age of 120 days when the cast-in-place portion of the deck is cast; and
    - b. the cast-in-place concrete portion of the deck shall have a minimum of 15M continuous bottom longitudinal reinforcing steel bars (parallel to girder lines) spaced at 300 mm on centre and placed directly on top of the precast panels. Where conflict with the transverse positive moment reinforcing steel bars exists, the longitudinal reinforcing steel bars shall be placed directly on top of the transverse reinforcing steel bars.
  8. Transverse precast panel joints shall have a 55 x 55 mm chamfer along their top edges.
  9. Prestressing strands shall not project beyond the edges of the precast panels.
  10. The precast panel lengths shall be set to provide a minimum 75 mm width of bearing (as measured perpendicular to the girder line) on the haunch concrete. The haunch concrete shall have a minimum thickness of 50 mm beneath the underside of each precast panel.
  11. Stirrups or shear studs projecting above the top girder flange shall provide a minimum of 25 mm clearance between the underside of the stirrup tops or shear stud heads and the top of the transverse reinforcing steel bars projecting out of the precast panels.
  12. Vertical bleed holes shall be provided through the precast panels along the two supported panel edges at a maximum spacing of 200 mm on centre. The holes shall be not less than 25 mm in diameter, and shall be located adjacent to the formed edge of the haunch to allow the escape of entrapped air.

#### **4-2.9 DECK JOINTS**

##### **4-2.9.1 General**

- A. The deck joint expansion gaps shall close before the barrier expansion gaps at deck joints.
- B. All deck joints shall be sealed deck joints.
- C. Deck joints shall run continuously across the full width of the deck and shall be turned up at their ends as required to prevent water from draining out of their ends.
- D. Exterior barriers shall have removable cover plates on both the inside and outside faces and across the top.
- E. Interior barriers and medians shall have removable cover plates on both sides and across the top.

- F. Deck joints across the width of sidewalks, SUPs and emergency egress routes shall have non-slip surface cover plates.
- G. The free ends of any deck joint cover plates at abutments shall be fixed to the deck side to allow for jacking of the superstructure.
- H. Deck joint cover plates at piers shall be removable to allow for jacking of the superstructure.

#### 4-2.9.2 Strip Seal Deck Joints

- A. The design shear movement (joint movement parallel to the joint) from joint installation to the maximum or minimum design gap shall not exceed 13 mm for cellular strip seals.
- B. Deck joints shall incorporate stop movement bars to maintain a minimum joint gap sufficient for seal replacement. The joint gap shall be maintained at a minimum of 60 mm notwithstanding any narrower gap width recommended by the manufacturer.

### 4-2.10 BARRIERS

#### 4-2.10.1 Traffic Barriers

- A. Transportation Structures carrying On-track Vehicles and with an elevation difference of 600 mm or more between grade and top of deck shall be provided with barriers. The barriers combined with restraint rails, emergency rails or other means shall be sufficient to prevent On-track Vehicles from falling off of the Structure, including due to tipping.
- B. A barrier may be considered to be sufficient to prevent an On-track Vehicle from falling off of a Structure provided it meets the following requirements:
  1. the barrier has sufficient strength to resist a horizontal load of 115 kN combined with a vertical load of 100 kN. The loads shall be distributed over a barrier length of 6 m. The vertical load shall be neglected if it reduces the load effects due to the horizontal load. The barrier loads shall be used as live loads, "L", in CAN/CSA S6; and
  2. the barrier has sufficient height to prevent an On-Track Vehicle from tipping over it. The height of the centre of gravity of the On-track Vehicle above the top of rail shall be based on the actual On-track Vehicle centre of gravity except that the centre of gravity shall not be taken as being less than 1.8 m above the top of rail.
- C. Unless otherwise specified Transportation Structure components located behind barriers shall be set-back a minimum of 600 mm from the traffic face of the barrier.
- D. Concrete barriers shall have crack control joints at a maximum spacing of 3 m. The crack control joints shall be sealed against moisture ingress. Barrier posts, if required, shall be centered between crack control joints.
- E. Base plates and anchors for barrier posts shall be grouted. A minimum 40 mm nominal thickness grout pad shall be provided under base plates. The grout shall sit in a grout pocket recessed 20 mm nominal into the surface of the Transportation Structure. The grout pocket shall be at least 40 mm larger than the base plate around the perimeter.

#### 4-2.10.2 Attachments behind Traffic Barriers

- A. Unless otherwise specified, attachments such as sign supports, OCS pole supports, lamp post supports and sign structure supports mounted on top of or behind traffic barriers shall be set-back a minimum of 600 mm from the traffic face of the barrier.

- B. Base plates and anchors for attachments shall be grouted. A minimum 40 mm nominal thickness grout pad shall be provided under base plates. The grout shall sit in a grout pocket recessed 20 mm nominal into the surface of the Transportation Structure. The grout pocket shall be at least 40 mm larger than the base plate around the perimeter.

#### **4-2.11 CURBS**

- A. Sidewalks or SUPs on Transportation Structures shall have curbs along their outside edges which project at least 100 mm above the finished top of sidewalk or SUP and are a minimum of 150 mm wide.

#### **4-2.12 TRACK SLABS**

- A. Joints between at-grade Track slab segments shall allow for expansion and contraction to occur across the joint while preventing differential settlement across the joint.

#### **4-2.13 POLE FOUNDATIONS**

- A. OCS and other poles supported on Transportation Structures shall fail before their foundations and anchorages. The factored resistances of the foundations and anchorages as determined in accordance with CAN/CSA S6 shall be a minimum of 120% of the factored resistances of the poles they support as determined in accordance with CAN/CSA S6.
  - 1. The factored resistance of an OCS or other pole may be assumed to be limited to the factored resistance of a weaker link placed between the pole and pole anchorage/foundation which limits the amount of force that can be transferred between the pole and pole foundation/anchorage to the factored resistance of the link.

#### **4-2.14 PLINTHS**

- A. The Design Service Life of plinths shall be the same as the Design Service Life of the Transportation Structure supporting the plinth.
- B. For plinths that are not monolithically poured with the deck, the deck shall have a recess to accommodate the plinth. The depth of the recess shall be a minimum of 40 mm and its plan area shall be equal to the plan area of the plinth.

#### **4-2.15 TEMPORARY GROUND ANCHORS**

- A. Temporary ground anchors are ground anchors with a Design Service Life that is less than the Design Service Life of the Transportation Structure or Building Structure of which the ground anchors are part of.
- B. Temporary ground anchors shall be de-stressed no later than by Completion of the applicable Work Package.
- C. Temporary ground anchors shall not extend beyond the boundary of the City Lands unless otherwise specified, and:
  - 1. at Sir Winston Churchill Square, temporary ground anchors may extent up to 10m beyond the boundary of the City Lands within the limits of Sir Winston Churchill Square and the adjacent Roadways.

## SECTION 4-3 STRUCTURE SPECIFIC REQUIREMENTS

- A. This Section 4-3 [*Structure Specific Requirements*] sets out requirements for specific Transportation Structures.

### 4-3.1 102 AVENUE TUNNEL APPROACH AND 102 AVENUE CUT AND COVER TUNNEL

#### 4-3.1.1 Loads

- A. The portion of the 102 Avenue Tunnel Approach and 102 Avenue Cut and Cover Tunnel located beneath or adjacent to any roadway shall be designed for at least CL-800 loading as defined by CAN/CSA S6.
- B. Regardless of surcharge loading from adjacent building foundations or surface loads, a minimum surcharge load of 20 kPa shall be applied to surfaces where no surcharge load or less than a 20 kPa surcharge load is applied, except that the minimum 20 kPa surcharge load shall not be applied in locations where it acts favourably.
1. The minimum surcharge load shall be used as a live load, "L", in CAN/CSA S6.
- C. The most unfavourable combination of the maximum and minimum earth pressure load factors given in CAN/CSA S6, Table 3.3 shall be used in determining the load effects in the 102 Avenue Tunnel Approach and 102 Avenue Cut and Cover Tunnel.

#### 4-3.1.2 Geotechnical

- A. Construction of the 102 Avenue Tunnel Approach and 102 Avenue Cut and Cover Tunnel shall not result in relaxation of the adjacent soil to detrimentally affect the foundations of nearby buildings, including yet to be constructed buildings. The requirements for pre-construction and post-construction condition surveys of adjacent buildings in Section 4-5.7 [*Protection of Existing Lands and Infrastructure*] of this Schedule shall apply to the 102 Avenue Tunnel Approach and 102 Avenue Cut and Cover Tunnel, except that the Zone of Influence shall be the depth of the excavations required for the 102 Avenue Tunnel Approach and 102 Avenue Cut and Cover Tunnel Construction.
- B. Instrumentation and monitoring of vertical and lateral displacements of the ground surrounding the 102 Avenue Tunnel Approach and 102 Avenue Cut and Cover Tunnel and the vertical and lateral displacements of adjacent buildings and Utility Infrastructure shall be carried out in accordance with the requirements of Section 4-5.8 [*Instrumentation and Monitoring*] of this Schedule except that in Section 4-5.8 [*Instrumentation and Monitoring*] of this Schedule the only surface based instrumentation required is Building Monitoring Points, Utility Monitoring Points and slope inclinometers. Slope inclinometers required by Section 4-5.8M [*Instrumentation and Monitoring*] of this Schedule shall be placed along the outside of the 102 Avenue Tunnel Approach and 102 Avenue Cut and Cover Tunnel excavations.

#### 4-3.1.3 Durability

- A. The requirement of Section 4-5.12.2 [*Fire Resistance*] of this Schedule shall apply to the 102 Avenue Tunnel Approach and 102 Avenue Cut and Cover Tunnel.

#### 4-3.1.4 Drainage

- A. The 102 Avenue Tunnel Approach and 102 Avenue Cut and Cover Tunnel and its interface with the Mined Tunnel shall meet the requirements of Section 4-5.12.3 [*Infiltration*] of this Schedule.
- B. Ice, from surface drainage or from leaks in the Transportation Structures, shall not be allowed to form on the Track bed.

#### 4-3.1.5 **System Requirements**

- A. The requirements of Section 4-5.14 [*Tunnel Systems*], Section 4-5.15 [*Design Fire Specification*] and Section 4-5.19 [*Firefighting System Requirements*] of this Schedule shall apply to the 102 Avenue Tunnel Approach and 102 Avenue Cut and Cover Tunnel.

#### 4-3.2 **MINED TUNNEL**

- A. See Section 4-5 [*Mined Tunnel Design and Construction Requirements*] of this Schedule for Mined Tunnel requirements.

#### 4-3.3 **NORTH RIVER BANK CUT AND COVER TUNNEL AND NORTH RIVER BANK TUNNEL APPROACH**

##### 4-3.3.1 **Load**

- A. The most unfavourable combination of the maximum and minimum earth pressure load factors given in CAN/CSA S6, Table 3.3 shall be used in determining the load effects in the North River Bank Cut and Cover Tunnel and North River Bank Tunnel Approach.
- B. Regardless of surcharge loading from adjacent building foundations or surface loads, a minimum surcharge load of 20 kPa shall be applied to surfaces where no surcharge load or less than a 20 kPa surcharge load is applied, except that the minimum 20 kPa surcharge load shall not be applied in locations where it acts favourably.
  - 1. The minimum surcharge load shall be used as a live load, “L”, in CAN/CSA S6.

##### 4-3.3.2 **Geotechnical**

- A. The stability of the north bank of the NSRV at the location of the North River Bank Cut and Cover Tunnel and North River Bank Tunnel Approach shall be evaluated and appropriate stabilization measures implemented to ensure the integrity and serviceability of the completed Infrastructure over their respective Design Service Life (specified in Section 1-2.8 [*Design Service Life*] of this Schedule) and that the System operates in full compliance with the Project Requirements. The minimum bank area requiring evaluation and stabilization shall extend from the crest of the slope to the toe of the slope in the north-south direction and for 10 m beyond either side of the North River Bank Cut and Cover Tunnel and North River Bank Tunnel Approach in the east-west direction. The scope and extent of the slope stabilization measures shall meet the minimum requirements described in this Section 4-3.3.2 [*Geotechnical*].
- B. The North River Bank Cut and Cover Tunnel and North River Bank Tunnel Approach shall be of monolithic construction as well as monolithic with the Tawatinâ Bridge north abutment.
- C. The North River Bank Cut and Cover Tunnel and North River Bank Tunnel Approach shall be founded on piles and anchored into stable bedrock beyond the limits/base of the historical Grierson Hill slide.
  - 1. The North River Bank Cut and Cover Tunnel and North River Bank Tunnel Approach shall not depend on support from landfill material.
- D. The North River Bank Cut and Cover Tunnel and North River Bank Tunnel Approach shall be designed to tolerate lateral movements of at least 80 mm in any direction over their respective Design Service Life (specified in Section 1-2.8 [*Design Service Life*] of this Schedule).
- E. The global slope stability of the north bank of the NSR shall be evaluated using limit equilibrium and stress-strain analyses. The analyses shall account for all possible failure mechanisms, including sliding along all identified bentonite seams and weak layers. Slope stabilization measures shall be implemented to increase the critical factor of safety of the north river bank

by a minimum of 30%. The improved factor of safety shall become the target factor of safety for sliding along other less critical bentonite seams or weak layers.

- F. Horizontal drains and drainage wells shall not be relied upon, as part of the permanent slope stabilization system, to achieve the required improvement in the long term slope factor of safety.
- G. Shallow and surficial modes of slope instability shall also be evaluated and addressed. Stabilization measures shall be installed as required to maintain a minimum long term factor of safety (following the dissipation of construction induced pore water pressures) of 1.5.
- H. Slope stabilization measures shall extend a minimum of 10 m beyond either side (east and west) of the North River Bank Cut and Cover Tunnel and North River Bank Tunnel Approach.
- I. Construction of slope stabilization measures necessary to attain the required improvement in the north river bank factor of safety shall be completed prior to the commencement of any other Construction activities on the north bank of the NSR other than those required for access.
- J. The placement of additional loading onto the north bank of the NSR during Construction shall be kept to a minimum and shall have no adverse effect on slope stability. Temporary Construction measures, Construction sequence, the installation of temporary and permanent access roads and the erection of any components of the permanent Infrastructure shall not result in any deterioration in the stability condition of the slope.
- K. A geotechnical report demonstrating the slope stabilization measures needed to attain the required improvement in the slope factor of safety shall be submitted to the City as part of the Final Design of the slope stabilization measures prior to the start of any Construction on the north bank of the NSR. The geotechnical report shall account for among others the following issues:
  - 1. the potential for altered river hydraulics resulting from instream Construction works to erode the toe of the north bank of the NSR and the potential for flood events and upstream dam releases to alter slope stability;
  - 2. the potential for grading and excavation works to alter the stability of the north bank of the NSR during Construction; and
  - 3. the potential for removal of vegetation and changes to natural drainage patterns due to Construction to alter the stability of the north bank of the NSR.
- L. The requirements of pre-construction and post-construction condition surveys of adjacent buildings of Section 4-5.7 [*Protection of Existing Lands and Infrastructure*] of this Schedule shall apply to the North River Bank Cut and Cover Tunnel and North River Bank Tunnel Approach.
- M. The instrumentation and monitoring of vertical and lateral displacements of adjacent buildings, Structures, Infrastructure and Utility Infrastructure during Construction shall be carried out in accordance with the requirements of Section 4-5.8 [*Instrumentation and Monitoring*].
- N. In relation to the monitoring requirements in Section 4-3.3.2M [*Geotechnical*] of this Schedule the extent of the Zone of Influence on either side of any excavations or embankments required for the North River Bank Cut and Cover Tunnel, North River Bank Tunnel Approach, slope stabilization measures, or any temporary or permanent access roads on the north bank of the NSR shall extend 25 m north of/beyond the crest of the north bank of the NSR above the excavation or embankment and 20 m downslope of the excavation or embankment.

- O. An instrumentation program to monitor the vertical and lateral displacements of the north bank of the NSR during the Construction Period shall be implemented. The instrumentation program shall be extensive enough to detect ground movements occurring at locations within 30 m east and west of the centrelines of the northbound and southbound Trackways respectively. As a minimum, the instrumentation shall include slope inclinometers, settlement points and survey markers. The monitoring results shall be used to provide early information regarding the impact of Construction on the ground and nearby structures and to adjust, in a timely manner, the Construction methodology to prevent damage to adjacent buildings, structures, Infrastructure and Utility Infrastructure.
- P. The results of monitoring of the north bank of the NSR during the Construction Period shall be submitted to the City within one week of the date of measurements.
- Q. The global stability of the north bank of the NSR shall not be adversely affected by construction of the North River Bank Tunnel Approach Access Road. Cuts and fills necessary for the construction of the North River Bank Tunnel Approach Access Road shall be kept to a minimum. The volumes of cut and fill shall be balanced such that the net additional loading exerted on the valley slope is minimized. Cuts deeper than 0.5 m shall be supported using an appropriate retaining wall system. Slope stabilization measures shall be implemented, as required, such that the long term factors of safety of roadway fill slopes, backslopes and retained cuts are at least 1.5. Retaining walls along the North River Bank Tunnel Approach Access Road shall have a maximum height of 5 m.

#### 4-3.3.3 Durability

- A. The requirements of Section 4-5.12.2 [*Fire Resistance*] of this Schedule shall apply to the North River Bank Cut and Cover Tunnel and North River Bank Tunnel Approach.

#### 4-3.3.4 Drainage

- A. The North River Bank Cut and Cover Tunnel, North River Bank Tunnel Approach and its interface with the Mined Tunnel shall meet the requirements of Section 4-5.12.3 [*Infiltration*] of this Schedule.
- B. Ice, from surface drainage or from leaks in the Transportation Structures, shall not be allowed to form on the Track bed.

#### 4-3.3.5 System Requirements

- A. The requirements of Section 4-5.14 [*Tunnel Systems*], Section 4-5.15 [*Design Fire Specification*] and Section 4-5.19 [*Firefighting System Requirements*] of this Schedule shall apply to the North River Bank Cut and Cover Tunnel and North River Bank Tunnel Approach.

### 4-3.4 TAWATINÂ BRIDGE

#### 4-3.4.1 Loads

##### 4-3.4.1.1 Live Load

- A. The Tawatinâ Bridge SUP shall be designed to support the maintenance vehicle load specified in CAN/CSA S6, Section 3.8.11 as well as pedestrian loads.

##### 4-3.4.2 Vessel Collision Load

- A. The vessel collision load on the Tawatinâ Bridge shall be based on the Edmonton Queen with a DWT of 212 tonnes. The navigation water level shall be taken to be not less than EL 615.9 and the collision load shall be based on a vessel design collision speed of not less than 4.2 m/sec. The collision load applied to the substructure shall be applied 1.5 m above water level.

The collision load applied to the superstructure shall be applied to the SUP and shall be based on 50% of the deck house collision force specified in CAN/CSA S6, Section A3.3.7.2.

#### 4-3.4.3 **Geotechnical**

- A. The north abutment of the Tawatinâ Bridge shall be of monolithic construction and monolithic with the North River Bank Cut and Cover Tunnel and North River Bank Tunnel Approach. It shall meet the requirements of Section 4-3.3.2 [*Geotechnical*] of this Schedule.
- B. Excavation for the foundation of the north river pier shall not result in any deterioration in the stability condition of the north bank of the NSR. Pre-drilling to facilitate the installation of sheet piles shall not be permitted.
- C. Temporary sheet piles may be driven at the river piers to limit the extents of the river pier excavations.
- D. The foundations of the river piers shall be supported on piles and the pile caps keyed into bedrock so that the sides of the pile caps bear against bedrock and the tops of the pile caps are not higher than 0.5 metres below the top of bedrock.
- E. No piers may be placed between the north river pier and the north abutment.

#### 4-3.4.4 **Geometrics**

##### 4-3.4.4.1 **North Abutment Location**

- A. The Tawatinâ Bridge north abutment shall be located a minimum of 100 m north of the north river pier.

##### 4-3.4.4.2 **Pier Locations**

- A. A maximum of two piers may be placed in the North Saskatchewan River. The centre of the north river pier shall be in line east-west with the centerline of the north pier of the Existing Cloverdale Footbridge. A second river pier may be placed in the river 110 m from the north river pier and nominally in line east-west with the centerline of the south pier of the Existing Cloverdale Footbridge.
- B. The first pier on the south river bank shall be a minimum of 160 m from the north river pier.

##### 4-3.4.4.3 **Vertical Clearances**

- A. Unless noted otherwise, the Tawatinâ Bridge, including the Tawatinâ Bridge SUP, shall as a minimum provide the same vertical clearance over the river as the Existing Cloverdale Footbridge along the entire length of the Tawatinâ Bridge SUP.
  - 1. The piers, including haunched sections supporting the pier lookouts, need not meet the vertical clearance requirement of this section subject to acceptance by Transport Canada under the Navigation Protection Act.

##### 4-3.4.5 **System Requirements**

- A. A dry fire standpipe system shall be provided for the Tawatinâ Bridge. This system shall:
  - 1. be a single standpipe loop spanning the bridge from an FDC located at the North River Bank Tunnel Approach Access Road to an FDC located on 98A Avenue;
  - 2. consist of a DN150 (6 inch) galvanized carbon steel standpipe routed across the Structure, containing a series of at least seven FHV's at a maximum spacing of 70 m;



3. contain a series of ARVs spaced equally along the standpipe to allow for the release of air from the pipe when it is being filled from either FDC;
4. incorporate check valves on each end of the standpipe to enable water to be filled from either of the FDCs located at grade; and
5. include drain valves at all low points to permit draining of the standpipe.

#### 4-3.4.6 **Hydrotechnical**

- A. A detailed hydrotechnical report addressing the hydrology and hydraulics of the North Saskatchewan River at the Tawatinâ Bridge site shall be submitted to the City as part of the Final Design for the Tawatinâ Bridge. The study area shall include all potentially affected downstream areas. The report shall as a minimum provide recommendations and the rationale for the recommendations for the following:
  1. design discharge and high water level;
  2. design ice loads, including elevations;
  3. design water velocities and pier scour; and
  4. river bank protection from erosion.
- B. The normal design flood shall have a minimum return period of 100 years.
- C. Riprap erosion protection shall be provided along the banks of the NSR as required to prevent toe erosion of the banks. This erosion protection shall also meet the requirements found in Section 1.20.2.3(4) c) and d) [*Permanent Accommodation of Wildlife Movement*] of Schedule 10 [*Environmental Performance Requirements*].

#### 4-3.4.7 **Wind Effects**

- A. A wind study shall be carried out on the Tawatinâ Bridge. The study shall generate site specific wind climate data obtained from an analysis of long-term wind data available from reliable data sources in the area. As a minimum, the following shall apply:
  1. design wind speed shall be the 100 year mean hourly speed at the deck level;
  2. design flutter speed shall be the 10,000 year 10 minute mean speed;
  3. design wind speed for the Construction phase shall as a minimum be the 20 year mean hourly speed at the deck level; and
  4. design flutter speed for the Construction phase shall as a minimum be the 1,000 year 10 minute mean speed.
- B. The wind study shall assess the aerodynamic stability of the deck and pier of both the completed Structure and the Structure during Construction. Critical Construction stages shall be determined, and at a minimum, shall include two Construction stage conditions consisting of a stand-alone pier and fully extended cantilever conditions just prior to closure.
- C. The wind study shall also include an assessment of the stay cables for vibration stability with and without the effects of rain and/or ice build-up on the cables.
  1. Stay cable vibrations shall not cause deflections exceeding  $L/1200$ , where L is the stay cable length in millimetres, under normal operating conditions and a wind speed of 55

km/hr and shall not cause damage to or fatigue failure of any stay cable or Structure component.

2. A stay cable damping system shall be provided if required.
- D. Stability of the deck, pier and stay cables may be based on an analytical “desktop” study approach and sectional or aeroelastic model testing is not required.
- E. A theoretical buffeting analysis to determine equivalent static wind loads for the completed Structure and during critical Construction stages for use in structural design shall be completed. The equivalent static wind loads shall not be less than those specified in CAN/CSA S6, Section 3.10.
- F. A final wind study report documenting the study and its recommendations shall be submitted to the City as part of the Final Design of the Tawatinâ Bridge.

#### 4-3.4.8 Dynamic Behaviour

- A. The Tawatinâ Bridge SUP shall be designed as a Class I bridge according to Sétra.
- B. In addition to the requirements specified in Section 4-1 [*General Design Requirements*], the dynamic performance of the Tawatinâ Bridge SUP shall be tested at Commissioning. The testing shall include the following excitations:
  1. passage over the Structure of a single Train consisting of one or more LRVs up to a maximum Train length of 90 m. The LRVs shall be loaded or unloaded and shall travel at speeds up to the Maximum Design Speed as required to produce the highest acceleration amplitudes on the Transportation Structure;
  2. rhythmic jumping of a single person on the Tawatinâ Bridge SUP at the fundamental vertical frequency of the Transportation Structure at the location with the highest acceleration amplitude;
  3. continuous jogging by five persons over the Tawatinâ Bridge SUP, separated by approximately 2-3 m, and synchronized at the vertical frequency between 1.5 Hz and 4.0 Hz that produces the highest vertical acceleration amplitude on the Transportation Structure; and
  4. continuous jogging by five persons over the Tawatinâ Bridge SUP, separated by approximately 2-3 m, and synchronized at the horizontal frequency between 1.5 Hz and 4.0 Hz that produces the highest horizontal acceleration amplitude on the Transportation Structure.
- C. The testing parameters above shall be completed with a prevalent wind speed of 15 km/hr or lower.
- D. The vertical and horizontal accelerations under each of the above excitations shall not exceed the limits specified in Section 4-1.6.3.3 [*Vibrations*] of this Schedule.
  1. Meeting the vertical and horizontal acceleration limits specified in Section 4-1.6.3.3 [*Vibrations*] during testing shall not void the requirement to meet these limits under all LRV and pedestrian/bicyclist loading conditions over the Design Service Life of the Structure.

#### 4-3.4.9 Stay Cable Inspection Access

- A. Access shall be provided for the safe inspection of the stay cables, including anchorages and saddles.

#### 4-3.4.10 River Piers

- A. The Tawatinâ Bridge river piers shall have solid cross-sections, with no voids, below high water level.

### 4-3.5 SOUTH RIVER VALLEY ELEVATED GUIDEWAY/98 AVENUE BRIDGE

#### 4-3.5.1 Geometrics

##### 4-3.5.1.1 Horizontal Clearances

- A. Piers adjacent to 98 Avenue shall be placed to conform to the horizontal clearance requirements of Section 4-1.9.2 [*Horizontal Clearances*] of this Schedule.

##### 4-3.5.1.2 Vertical Clearances

- A. During Construction the minimum vertical clearance of the 98 Avenue Bridge over 98 Avenue may temporarily be reduced to 4.0 m.

### 4-3.6 CONNORS ROAD TRACKWAY

#### 4-3.6.1 Loads

- A. The SUP adjacent to the LRT Tracks on the Connors Road Trackway shall be designed to support the maintenance vehicle load specified in CAN/CSA S6, Section 3.8.11 as well as pedestrian loads.

#### 4-3.6.2 Geotechnical

- A. The stability of the south bank of the NSRV along Connors Road Trackway shall be evaluated and appropriate stabilization measures implemented as necessary to ensure the integrity and serviceability of the completed Trackway and associated structures over their respective Design Service Life (specified in Section 1-2.8 [*Design Service Life*] of this Schedule) and that the System operates in full compliance with the Project Requirements. The minimum bank area requiring evaluation and stabilization shall extend from 95<sup>th</sup> Avenue at the crest of the slope to 70 m north of the northbound Trackway centerline. The scope and extent of the slope stabilization measures shall satisfy the minimum criteria described in this Section 4-3.6.2 [*Geotechnical*].
- B. The minimum separation distance between the north edge of the Track slab foundation and the crest of the valley slope before Construction north of Connors Road (Gallagher Park slope) shall be established such that the long term factor of safety of slip surfaces daylighting north of the Track slab foundation is greater than 1.5. The factor of safety shall be determined based on limit equilibrium analyses, using representative soil and pore water pressure parameters derived from site specific geotechnical investigations and local experience.
- C. Where the separation distance between the northern edge of the Track slab foundation and the crest of the Gallagher Park slope before Construction is such that the target factor of safety cannot be achieved, slope stabilization measures shall be implemented. The slope stabilization measures shall be installed within the City Lands and shall be designed such that the minimum long term factor of safety of slip surfaces that originate south of the northern limit of the City Lands and daylight on the downhill valley slope within 70 m north of the northbound Trackway centerline is greater than 1.5.
- D. Where the northern edge of the Track slab foundation is situated less than 3 m south of the crest of the Gallagher Park slope before Construction (defined as the break line associated with a distinct topographic change between the flat area at Connors Road and the downhill sloping ground), the Track slab shall be supported on piles. Slope stabilization measures shall

also be implemented within the City Lands such that the minimum long term factor of safety of slip surfaces that originate south of the northern limit of the City Lands and daylight on the downhill valley slope within 70 m north of the northbound Trackway centerline is greater than 1.5.

- E. Any piles required to support the Track slab shall be founded in competent bedrock and shall be designed to withstand lateral forces exerted by any slope movement without detrimental impact on the performance of the LRT System.
- F. Cuts along the valley slope south of Connors Road shall be supported using a piled retaining wall system. The retaining wall system shall be designed such that the long term global factor of safety of the overall valley slope south of Connors Road to 95<sup>th</sup> Avenue is greater than 1.5, or a minimum of 10% greater than the factor of safety of the slope prior to Construction, whichever is larger. The factor of safety against local instabilities at the cut face shall also be greater than 1.5. The lateral displacements of the retaining wall system and the retained slope shall not adversely affect the integrity or performance of buildings, Utility Infrastructure or Infrastructure.
- G. Horizontal drains and drainage wells shall not be relied upon, as part of the permanent slope stabilization system, to achieve the required improvement in the long term slope factor of safety.
- H. The final configuration and layout of the Infrastructure shall not result in any reduction in the global factor of safety of the overall NSRV slope from 95 Avenue at the crest to the river terrace at the toe, or any part thereof.
- I. The placement of additional fill onto the valley slopes for temporary or permanent purposes shall be kept to a minimum and shall have no adverse effect on slope stability. Temporary Construction measures, Construction sequence and the erection of any components of the permanent Infrastructure shall not adversely affect the slope condition and shall not result in any reduction in the slope factors of safety from the initial values prior to the commencement of Construction.
- J. A geotechnical report demonstrating the slope stabilization measures needed to attain the required improvements in the slope factor of safety shall be submitted to the City as part of the Final Design of the stabilization measures prior to the start of Construction of the Connors Road Trackway. The geotechnical report shall account for among others the following issues:
  - 1. the potential for grading and excavation works to alter the stability of the valley slope during Construction; and
  - 2. the potential for removal of vegetation cover and changes to natural drainage patterns due to Construction to alter the stability of the valley slope.
- K. The requirements of the pre-construction condition survey of adjacent buildings of Section 1-6 [*Pre-Construction Asset Condition Survey*] in this Schedule shall apply to the Connors Road Trackway and Connors Road Construction as well as to the Construction of any retaining walls required along Connors Road.
- L. An instrumentation program shall be implemented to monitor the vertical and lateral displacements of the valley slopes during the Construction Period. The instrumentation program shall be extensive enough to detect ground movements within 50 m downslope and 50 m upslope of the centrelines of the northbound and southbound Trackways respectively. As a minimum, the instrumentation shall include slope inclinometers, settlement points and survey markers. During Construction, the monitoring results shall be used to provide early information regarding the impact of Construction on the ground and nearby structures and to adjust, in a

timely manner, the Construction methodology to prevent damage to adjacent buildings, Structures, Infrastructure, and Utility Infrastructure.

- M. The results of slope monitoring during the Construction Period shall be submitted to the City within one week of the date of measurements.

#### **4-3.7 KÂHASINĪSKĀK BRIDGE**

##### **4-3.7.1 Loads**

- A. The Kâhasinîskâk Pedestrian Bridge shall be designed to support the maintenance vehicle load specified in CAN/CSA S6, Section 3.8.11 as well as pedestrian loads.

##### **4-3.7.2 Geometrics**

###### **4-3.7.2.1 Pier Placement**

- A. A pier may be placed between the Tracks and the north curb of Connors Road. No other piers are permitted.
- B. The pier shall be placed to meet the horizontal clearance requirements of Section 4-1.9.2 [*Horizontal Clearances*] of this Schedule except that if clear zone requirements cannot be met the pier shall be protected by a barrier and as required by the Road Safety Audit. If a barrier is required, the pier shall be setback a minimum of 600 mm from the traffic face of the barrier.

###### **4-3.7.2.2 Vertical Clearance**

- A. The minimum vertical clearance of the Kâhasinîskâk Bridge over Connors Road shall be 6.0 m.

##### **4-3.7.3 Drainage**

- A. Water shall be collected on the Transportation Structure and discharged at its ends. Water shall not be discharged onto Connors Road, the Tracks or the Transportation Structure head slopes.

##### **4-3.7.4 Dynamic Behaviour**

- A. The Kâhasinîskâk Bridge shall be designed as a Class II bridge according to Sétra.
- B. In addition to the requirements specified in Section 4-1 [*General Design Requirements*] of this Schedule, the dynamic performance of the Kâhasinîskâk Bridge shall be tested at Commissioning. The testing shall include the following excitations:
  1. rhythmic jumping of a single person at the fundamental vertical frequency of the Transportation Structure at the location with the highest acceleration amplitude;
  2. continuous jogging by five persons over the Transportation Structure, separated by approximately 2-3 m, and synchronized at the vertical frequency between 1.5 Hz and 4.0 Hz that produces the highest vertical acceleration amplitude on the Transportation Structure; and
  3. continuous jogging by five persons over the Transportation Structure, separated by approximately 2-3 m, and synchronized at the horizontal frequency between 1.5 Hz and 4.0 Hz that produces the highest horizontal acceleration amplitude on the Transportation Structure.
- C. The testing parameters above shall be completed with a prevalent wind speed of 15 km/hr or lower.

- D. The vertical and horizontal accelerations under each of the above excitations shall not exceed the limits specified in Section 4-1.6.3.3 [*Vibrations*] of this Schedule.
1. Meeting the vertical and horizontal acceleration limits specified in Section 4-1.6.3.3 [*Vibrations*] of this Schedule during testing shall not void the requirement to meet these limits under all pedestrian/bicyclist loading conditions over the Design Service Life of the Transportation Structure.

#### **4-3.8 WILDLIFE UNDERPASS STRUCTURE**

##### **4-3.8.1 Loads**

- A. Wildlife Underpass Structures crossing underneath Roadways shall be designed for CL-800 loading as defined by CAN/CSA S6.
- B. Wildlife Underpass Structures crossing underneath Trackways shall be designed for the On-track Vehicle loading specified in Section 4-1 [*General Design Requirements*] of this Schedule.

##### **4-3.8.2 Geometrics**

- A. For the Wildlife Underpass Structure crossing underneath Connors Road and the adjacent Trackway:
  1. the opening shall be nominally 1.5 m high and a minimum of 2.2 m wide;
  2. the access to the south side of the Structure shall:
    - a. have a minimum width of 2.2 m;
    - b. have a maximum slope of 10H:1V; and
    - c. have a side slope no steeper than a slope of 2H:1V on the north side of the access;
  3. the access to the north side of the Structure shall be in accordance with Section 1.20.2.3 5 [*Permanent Accommodation of Wildlife Movement*] of Schedule 10 [*Environmental Performance Requirements*], and
  4. retaining walls shall only be permitted along the south side of the access to the south side of this structure and shall meet the requirements of Section 4-3.6.2 [*Geotechnical*] of this Schedule.

##### **4-3.8.3 Durability**

- A. The top surface of a Wildlife Underpass Structure crossing underneath Roadways shall be considered to be a Splash Zone Surface.

##### **4-3.8.4 Drainage**

- A. Grading at the accesses to a Wildlife Underpass Structure shall be graded to minimize drainage into and through the structure.

#### **4-3.9 DAVIES ELEVATED GUIDEWAY**

##### **4-3.9.1 Geometrics**

##### **4-3.9.1.1 Substructure Placement**

- A. Piers and abutments shall be placed to meet the horizontal clearance requirements of Section 4-1.9.2 [*Horizontal Clearances*] of this Schedule except that if clear zone requirements cannot

be met the pier or abutment shall be protected by a barrier and as required by the Road Safety Audit. If a barrier is required the pier or abutment shall be setback a minimum of 600 mm from the traffic face of the barrier.

- B. A pier shall not be placed within 7.5 m of each side of the thalweg of Mill Creek in Wagner Park.

#### 4-3.9.1.2 **Vertical Clearances**

- A. The minimum vertical clearance of the Davies Elevated Guideway over 75<sup>th</sup> Street shall be 6.5 m.

#### 4-3.9.2 **Geotechnical**

- A. Foundations shall have a clear distance of no less than 1.5 m from the storm tunnels going through Wagner Park, measured perpendicular to the storm tunnel horizontal alignment.

#### 4-3.9.3 **System Requirements**

- A. A dry fire standpipe system shall be provided wherever Emergency Services fire vehicle access to the Davies Elevated Guideway cannot be accommodated, so as to ensure fire protection coverage along all parts of the Davies Elevated Guideway. This system shall:
  1. be a single standpipe loop spanning across each affected Davies Elevated Guideway section, with an FDC provided at each end;
  2. consist of a DN150 (6 inch) galvanized carbon steel standpipe routed across the Structure, containing a series of FHV's spaced at a maximum spacing of 70 m;
  3. contain a series of ARV's spaced equally along the standpipe to allow for the release of air from the pipe when it is being filled from either FDC;
  4. incorporate check valves on each end of the standpipe to enable water to be filled from either of the FDCs located at grade; and
  5. include drain valves at all low points to permit draining of the standpipe after use.

### **4-3.10 WHITEMUD DRIVE LRT BRIDGE**

#### 4-3.10.1 **Geometrics**

##### 4-3.10.1.1 **Structure Headslopes**

- A. The headslopes of the Whitemud Drive LRT Bridge shall be in line with the headslopes of the Existing Whitemud Drive Bridge.

##### 4-3.10.1.2 **Pier Placement**

- A. A pier may only be placed in the median of Whitemud Drive and shall be in line with the pier of the Existing Whitemud Drive Bridge. The pier shall be protected by a barrier and as required by the Road Safety Audit. The pier shall be setback a minimum of 600 mm from the traffic face of the barrier.

##### 4-3.10.1.3 **Abutment Placement**

- A. The abutments of the Whitemud Drive LRT Bridge shall be located so that they have a minimum clear distance of 25 metres from the Whitemud Drive median centreline.

#### 4-3.10.2 Drainage

- A. Water shall be collected on the Structure and discharged at its ends. Water shall not be discharged on to Whitemud Drive or the Structure headslopes.

### 4-3.11 WHITEMUD DRIVE PEDESTRIAN BRIDGE

#### 4-3.11.1 Loads

- A. The Whitemud Drive Pedestrian Bridge shall be designed to support the maintenance vehicle load specified in CAN/CSA S6, Section 3.8.11 as well as pedestrian loads.

#### 4-3.11.2 Geometrics

##### 4-3.11.2.1 Location

- A. The Whitemud Drive Pedestrian Bridge shall be located on the west side of the Existing Whitemud Drive Bridge.
- B. The Whitemud Drive Pedestrian Bridge and Existing Whitemud Drive Bridge shall not be structurally connected as shown in Figure 4-3.11.2.1-1 [Whitemud Drive Pedestrian Bridge Location]. A 10 mm wide joint, filled with expanded polystyrene or other filling material with equivalent Design Service Life, and caulked at the top to prevent water intrusion shall be provided.

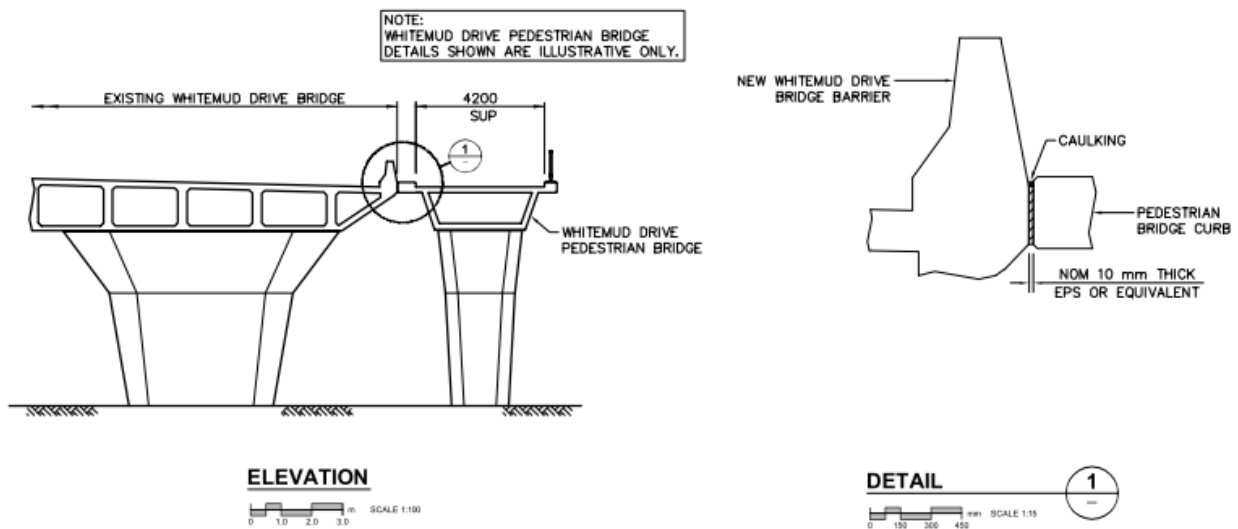


Figure 4-3.11.2.1-1 Whitemud Drive Pedestrian Bridge Location

- C. The Whitemud Drive Pedestrian Bridge shall have a curb on the Existing Whitemud Drive Bridge side of the Structure to restrict water from penetrating the joint between the two Structures.

##### 4-3.11.2.2 Structure Headslopes

- A. The headslopes of the Whitemud Drive Pedestrian Bridge shall be in line with the headslopes of the Existing Whitemud Drive Bridge.



#### 4-3.11.2.3 Pier Placement

- A. A pier may only be placed in the median of Whitemud Drive and shall be in line with the pier of the Existing Whitemud Drive Bridge. The pier shall be protected by a barrier and as required by the Road Safety Audit. The pier shall be setback a minimum of 600 mm from the traffic face of the barrier.

#### 4-3.11.3 Abutment Placement

- A. The abutments of the Whitemud Drive Pedestrian Bridge shall be located so that they have a minimum clear distance of 25 m from the Whitemud Drive median centreline.

#### 4-3.11.4 Durability

- A. The Whitemud Drive Pedestrian Bridge deck and barriers, including the deck and barriers on the abutments, shall be considered to be Splash Zone Surfaces.
- B. Class HPC concrete shall be used for the Whitemud Drive Pedestrian Bridge deck, barrier and girder cast-in-place concrete as well as for any abutment concrete within 300 mm of the SUP surface.
- C. All girder precast concrete shall contain 10% condensed silica fume by weight of cement ( $\pm$  0.5%).
- D. All exposed concrete surfaces to 600 mm below grade shall have a Type 1c sealer applied to them except for the underside of the deck between girders.
- E. Stainless steel reinforcing steel shall be used in all concrete within 300 mm of a Splash Zone Surface.

#### 4-3.11.5 Drainage

- A. Water shall be collected on the Whitemud Drive Pedestrian Bridge and discharged at its ends. Water shall not be discharged on to Whitemud Drive or the Structure headslopes.

### 4-3.12 EXISTING WHITEMUD DRIVE BRIDGE

- A. This Section 4-3.12 [*Existing Whitemud Drive Bridge*] sets out the requirements for the rehabilitation of and modification to the Existing Whitemud Drive Bridge.

#### 4-3.12.1 Description

- A. The Existing Whitemud Drive Bridge is to be widened from 8 lanes to 9 lanes by removing the sidewalk from the bridge. Also the bridge is to be rehabilitated with new deck joints, a new ACP overlay and deck waterproofing membrane system and other work as set out in Section 4-3.12.2 [*Scope of Work*] of this Schedule.

#### 4-3.12.2 Scope of Work

- A. Widening and rehabilitation of the Existing Whitemud Drive Bridge shall be carried out in accordance with drawings S075 141 S01 to S075 141 S08 and *Alberta Transportation Standard Drawings* S-1810-12, S1811-12, S1812-12, S1443-11, S-1411-87 and S-1409-99 (the "**Rehabilitation Drawings**"). The Rehabilitation Drawings are included in the Disclosed Data.
- B. The Rehabilitation Drawings are preliminary drawings and are intended only to define the scope of the bridge widening and rehabilitation work required. Project Co shall prepare the Existing Whitemud Drive Bridge Final Designs in accordance with the requirements of the

Rehabilitation Drawings and shall be responsible for all Design and Construction required for the bridge widening and rehabilitation work.

- C. The scope of work includes the following tasks. Additional information on the scope of work is provided in Section 4-4.14 [*Existing Whitemud Drive Bridge*] of this Schedule.
1. Removal of the existing concrete median on the bridge.
  2. Removal of the existing high density concrete wearing surface on the bridge.
  3. Removal of the existing deck joints at Abutments 1 and 2.
  4. Removal of the existing traffic barrier and pedestrian hand railing on the west side of the bridge.
  5. Removal of the existing concrete transition barriers and sidewalk on the west side of the bridge.
  6. Removal of the existing concrete paving lips and concrete wedges from the bridge deck.
  7. Carrying out of partial depth and/or full depth repairs as required by the City on the existing bridge deck, east bridge barrier, abutments and pier.
  8. Placing of new concrete and mortar mix prefill on the bridge deck.
  9. Constructing new concrete approach slab extensions.
  10. Constructing a new concrete traffic barrier, a new light post, including anchorage and conduit, at the pier, new concrete traffic barrier transitions and new steel pedestrian hand railings.
  11. Supplying and installing new deck joints, including west barrier and median cover plates, at Abutments 1 and 2.
  12. Placing of a new deck waterproofing membrane on the bridge deck, roof slabs and approach slabs.
  13. Placing a new 80 mm thick, two course hot mix asphalt concrete pavement on the bridge deck, roof slabs and approach slabs.
  14. Constructing a new concrete median on the bridge deck.
  15. Rehabilitating the existing bearings.
  16. Cleaning and applying pigmented sealer to concrete surfaces on the vertical faces of the abutments, including the wingwalls, and on the exterior faces of the barriers and deck soffit.
  17. Cleaning and applying penetrating sealer to concrete surfaces on the pier columns and inside faces of the barriers.
  18. Removing and replacing the galvanized flashing between the abutments and concrete slope protection.
  19. Placing of new hot mix asphalt concrete pavement on the bridge approach roads as required to tie the new bridge deck profile into the 66<sup>th</sup>/75<sup>th</sup> Street roadway profile.

20. Relocating and reinstalling existing Utility Infrastructure, including for the new light post, on the bridge as required for Construction.

**4-3.12.3 Loads**

- A. The new concrete traffic barrier, including anchorages, on the west side of the bridge shall be designed for PL-2 loading in accordance with CAN/CSA S6.
- B. The new steel pedestrian hand railings, including anchorages, installed on the east and west traffic barriers shall be designed for pedestrian/bicyclist loads in accordance with CAN/CSA S6.
- C. The anchorage system for the light post on the new west traffic barrier shall be designed in accordance with the requirements of CAN/CSA S6.

**4-3.12.4 Durability**

- A. All new reinforcing steel used in the Existing Whitemud Drive Bridge shall be stainless reinforcing steel.

## SECTION 4-4 – STRUCTURES CONSTRUCTION REQUIREMENTS

### 4-4.1 PILING

#### 4-4.1.1 General

- A. This Section 4-4.1 [*Piling*] sets out the requirements for steel H-piles, steel pipe piles, and cast-in-place concrete piles forming part of a Structure, including minimum requirements for quality, supply, placement, and curing of the piles.

#### 4-4.1.2 Materials

##### 4-4.1.2.1 Steel

- A. Mill certificates for steel piles shall be obtained prior to pile installation.

##### 4-4.1.2.2 Concrete

- A. Pile concrete shall comply with the requirements of Section 4-4.4 [*Cast-In-Place Concrete*] of this Schedule.

##### 4-4.1.2.3 Reinforcing Steel

- A. Reinforcing steel shall comply with the requirements of Section 4-4.8 [*Reinforcing Steel*] of this Schedule.

#### 4-4.1.3 Galvanizing

- A. Galvanizing of steel piling, when required, shall be by the hot dip method, in accordance with ASTM A123/A123M Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
- B. Galvanized piling on which the galvanized coating has been damaged shall be replaced or repaired in accordance with ASTM A780, Method A3 to a minimum thickness of 180 µm.
- C. Where the upper portions of piling are specified to be galvanized on the applicable Final Design, excess piling shall be removed from the ungalvanized portion of the piling to ensure that the galvanized portion extends down to the elevation shown on the Final Design.

#### 4-4.1.4 Handling

- A. Piling shall be handled, hauled and stored in a manner that avoids damage to the piling materials.
- B. Piling shall be handled, hauled and stored in a manner that avoids damage to the galvanized surfaces on galvanized piling.
  - 1. Fabric slings, wood blocking or other methods shall be used to support and separate galvanized piling when handling, hauling or storing.

#### 4-4.1.5 Driven Bearing Piles

##### 4-4.1.5.1 Equipment

- A. Pile driving equipment shall be sized such that piles can be driven to the specified bearing capacity and required elevations without damaging the piles.

1. The adequacy of the pile driving equipment shall be based on wave equation analysis and/or pile driving analyzer testing.
  2. Acceptable pile driving equipment includes diesel hammers, hydraulic hammers, vibratory hammers, and driving frames.
  3. The total energy developed by the hammer shall not be less than 35 kJ per blow.
  4. Drop hammers shall not be used.
- B. The driving of piles with driving extensions shall be avoided if practicable.
1. When driving extensions are used, one pile from each group of 10 shall be a long pile driven without extensions, and shall be used as a test pile to determine the average bearing capacity of the group.

#### 4-4.1.5.2 Tolerances

- A. Piles shall be placed in the positions, orientations and alignments shown on the applicable Final Design.
1. Precautions shall be taken to ensure that the piles are in proper alignment, including the use of installation driving frames, fixed leads or other means.
- B. Piles shall not be out of the horizontal positions shown on the applicable Final Design by more than 100 mm after driving except as noted below.
1. For fully integral abutments the piles shall not be out of horizontal position by more than 50 mm.
  2. For fully integral abutments, the variation in position between a pile casing centre and a pile centre shall not be more than 25 mm.
- C. Piles shall not be driven with a variation of more than 20 mm per metre from the vertical or from the batter shown on the applicable Final Design.
- D. Piles in exposed bents shall not be out of position by more than 50 mm at the ground line or 25 mm in the pier cap.

#### 4-4.1.5.3 Pile Driving

- A. The piles shall be driven to the tip elevations shown on the applicable Final Design, or to an elevation determined by a Professional Engineer, that achieves the required pile stability and specified minimum bearing capacity.
- B. The pile driving resistance (number of blows per 250 mm of pile penetration) at the termination of driving shall meet or exceed the driving criteria specified by a Professional Engineer for the given pile section and length, piling equipment, soil conditions, and required pile capacity.
1. The driving termination criteria shall be determined using wave equation analysis, and if required by the applicable Final Design shall be verified using pile driving analyzer testing.
  2. For pile installation purposes, paint markings shall be painted on each pile at 0.25 m intervals, with a label at each 1.0 m interval, starting from the toe of the pile.
- C. The pile head shall be cut square and a driving cap or follower provided to hold the axis of the pile in line with the axis of the hammer.

1. The follower shall be of adequate dimensions to allow driving of the pile without trimming or reducing the cross-section of the pile.
- D. When damage or buckling is evident at the driving end of the pile before obtaining the required pile capacity or penetration of the pile, the driving end of the piling shall be reinforced, or, other suitable equipment or procedures provided, to prevent further damage.
- E. Piles shall be cut off level at the required elevations shown on the applicable Final Design.
- F. When steel pipe piles are driven open-ended and the interiors cleaned out, the following shall apply.
  1. All loose material and all material adhering to the inside walls of the piles shall be removed.
  2. The removal of material shall be terminated a minimum of 2 m above the pile toe.

#### 4-4.1.5.4 **Steel Pile Splices**

- A. Full strength pile splices shall be used unless specified otherwise on the applicable Final Design.
- B. When splicing steel pipe piles, whatever means necessary shall be employed to match out-of-round piling.
- C. If splicing within the galvanized portion of a steel pile becomes necessary, the damaged galvanized area shall be repaired in accordance with Section 4-4.1.3 [*Galvanizing*] of this Schedule.
- D. Ultrasonic testing shall be performed on a minimum of 20% of all pile splice welds except as noted below.
  1. Ultrasonic testing shall be carried out on all tension splice welds as indicated on the applicable Final Design.
  2. Ultrasonic testing shall be carried out on welds where visual inspection indicates a potential Deficiency or Early Handover Deficiency.
- E. Ultrasonic testing shall be carried out by a company certified to CAN/CSA W178.1.
  1. Ultrasonic testing technicians shall be certified to Level II by the Canadian General Standards Board.
- F. Welds shall be repaired if full strength welds have not been achieved. Ultrasonic testing shall be carried out on the repaired welds.

#### 4-4.1.5.5 **Defective Piles**

- A. A pile damaged by driving or driven out of proper location shall be considered to be a Deficiency or Early Handover Deficiency, which shall be corrected by one of the following methods:
  1. The pile shall be withdrawn and replaced by a new pile; or
  2. A replacement pile shall be driven adjacent to the deficient pile.
- B. All piles, pushed up by the driving of adjacent piles or by any other cause, shall be driven down again to at least the original tip elevation.

#### 4-4.1.6 **Drilled Cast-in-place Concrete Piles**

##### 4-4.1.6.1 **Drilling Pile Holes**

- A. Drilled pile holes shall be stabilized and sealed by means of temporary casings or other methods to prevent possible collapse of the pile holes or ingress of water.
- B. The drilling of pile holes shall not proceed if adjacent piling may be damaged due to the effects of vibration or other reasons.
- C. Every attempt necessary shall be made to obtain "dry" pile holes prior to placing concrete.
  - 1. A pile hole shall be considered "dry" if the depth of water at the bottom of the hole is less than 25 mm.
  - 2. All equipment necessary to achieve a dry hole shall be available on-site and ready for use, including casings of appropriate size and length, bailing buckets, final cleanout buckets and water pumps.
- D. Removal of temporary casing shall not damage the concrete.
  - 1. Temporary casing, if used in drilling operations, shall be removed from the hole as the pile concrete is being placed.
  - 2. The bottom of the casing shall be maintained below the top of the concrete during withdrawal and placing operations.
  - 3. Separation of the concrete during withdrawal operations shall be avoided by hammering or otherwise vibrating the casing.
- E. Drilled pile holes shall extend to the elevations shown on the applicable Final Design or as determined by a Professional Engineer.
- F. Pile reinforcement and pile concrete shall not be placed until the pile hole is deemed acceptable by a Professional Engineer.
  - 1. The walls and bottoms of the pile holes shall be cleaned to remove all loose and extraneous material.
  - 2. The presence of any gas shall be determined and appropriate means and equipment shall be employed to ensure a safe work site.

##### 4-4.1.6.2 **Tolerances**

- A. Piles shall be placed in the positions and alignments shown on the applicable Final Design.
- B. Piles shall not be out of the horizontal positions shown on the applicable Final Design by more than 50 mm.
- C. Piles shall not have a variation of more than 20 mm per metre from the vertical or from the batter

##### 4-4.1.6.3 **Reinforcing Steel Placement**

- A. Reinforcing steel projecting from a pile shall be placed to a tolerance not exceeding 10 mm in any direction

1. Adequate "shoes" or spacers shall be firmly anchored to the reinforcing steel to ensure the reinforcing steel is kept centered in the concrete when placing pile concrete.

#### 4-4.1.6.4 **Concrete Placement**

- A. Pile concrete shall be placed immediately after the completion of drilling and inspection of the pile hole and the placement of reinforcing steel.
  1. Under no circumstances shall the pile holes be left open for periods longer than 2 hours.
  2. If delay in placement of reinforcing steel and concrete is expected, the pile hole shall be properly backfilled and then redrilled when ready. The redrilled hole may be larger and/or deeper than the original pile hole, as determined by a Professional Engineer.
- B. Forms shall be used to maintain the specified dimensions of the portions of concrete piles above ground level.
- C. If a dry pile hole cannot be achieved, as per the requirements of Section 4-4.1.6 [*Drilled Cast-in-place Concrete Piles*] of this Schedule pile concrete shall be placed in accordance with the requirements of Section 4-4.4.13.3 [*Concrete Placed Under Water*] of this Schedule.
  1. Pile concrete placed under water shall be validated by Crosshole Sonic Logging (CSL) in accordance with Section 4-4.4.13.3 [*Concrete Placed Under Water*] of this Schedule.
- D. When the ground against which pile concrete is placed is below -5 degrees Celsius the concrete shall be protected from heat loss as follows.
  1. The pile hole shall be oversized by 100 mm.
  2. Immediately after placing and finishing the concrete, the top exposed surface of the pile shall be protected with insulated tarps or other means to adequately cure the concrete for a minimum period of seven days.
  3. If the top of the pile extends above the ground surface it shall be protected in accordance with Section 4-4.4.16 [*Concreting In Cold Weather*] of this Schedule.

#### 4-4.1.7 **Pile Capacity Testing**

##### 4-4.1.7.1 **Static Load Testing**

- A. Static load tests may be used for the determination of pile capacity.
  1. Static compression load tests shall comply with ASTM D1143/D1143M. Uplift static load tests shall comply with ASTM D3689/D3689M.
- B. Osterberg or Statnamic load tests may be used in place of static load tests.
- C. At least one pile for each group of 100 piles shall be tested.
  1. The frequency of testing shall be increased as necessary to account for changing soil conditions, pile sections and types and construction methods.

##### 4-4.1.7.2 **Pile Driving Analyzer (PDA) Testing**

- A. Pile Driving Analyzer (PDA) testing may be used for the determination of pile capacity.
  1. PDA testing shall comply with ASTM D4945.



2. A minimum of two accelerometers shall be installed on each tested driven pile and four accelerometers on each tested cast-in-place concrete pile.
  3. All accelerometers and transducers shall be calibrated and inspected to ensure proper attachment to the pile.
  4. The impact imparted on the pile shall be sufficient to fully mobilize the pile skin friction and end bearing resistances of the pile, and shall result in a net permanent set per blow of between 3 mm and 8 mm upon impact from the pile hammer.
  5. The hammer energy used during PDA testing shall be such that the required ultimate pile capacity is mobilized in a single blow without additional data interpretation.
  6. Under no circumstances shall the pile capacity be based on the superposition of toe and shaft resistances from different strikes, re-strikes or any combination thereof.
- B. If PDA testing is required by the Final Design, a minimum of 10% of the piles at each Structure shall be tested, including tests at each substructure element associated with the Structure and at each different soil condition encountered.
1. The piles selected for PDA testing shall be representative of other piles in the same Structure.
  2. Where driven piles exhibit lower driving resistances and/or shorter penetrations than normal, or where cast-in-place concrete piles experience extraneous soil, groundwater, and/or installation conditions, additional PDA tests over and above the minimum number of tests specified above shall be required.
  3. Additional PDA tests shall accompany changes in piling equipment, piling procedures and pile requirements.
- C. For driven piles, PDA testing shall be conducted at the end of the initial driving stage.
1. Where time dependant changes in the soil conditions are anticipated, such as pile setup or relaxation, additional re-strike PDA tests shall be conducted on a sample of previously tested piles to determine the bearing parameters after driving induced pore pressures have dissipated.
  2. The re-strike PDA tests shall be conducted no sooner than one week after initial driving, or longer as directed by a Professional Engineer.
  3. Where the capacity of the pile at re-strike is relied upon for design, a minimum of one half of the piles PDA tested during initial driving shall be PDA tested again during re-strike.
- D. For cast-in-place concrete piles, the PDA testing shall be conducted no sooner than one week after the installation of the pile.
- E. If one pile in a pile group does not meet capacity requirements, additional testing shall be carried out to confirm if the pile is an isolated case.
- F. The PDA testing agency shall prepare a field report summarizing the preliminary PDA testing results, including driving stresses, transferred energy and estimated pile capacity, within 24 hours of testing.
- G. The PDA testing agency shall complete a final testing report, complying with ASTM D4945, within seven Business Days of PDA testing. As a minimum, the report shall include the following:

1. pile and driving system information;
  2. pile installation data;
  3. PDA testing equipment and procedure;
  4. energy imparted to the piles;
  5. maximum driving stresses;
  6. hammer blow rate;
  7. CAPWAP input parameters including quake and damping factors; and
  8. shaft friction, end bearing and total pile capacity.
- H. The PDA test results shall be used to confirm/update the pile driving termination criteria and to determine requirements for modification of pile driving procedures or equipment, and pile acceptance.

#### **4-4.2 GROUND ANCHORS**

##### **4-4.2.1 General**

- A. This Section 4-4.2 [*Ground Anchors*] sets out the requirements for all ground anchors and other permanent structural components resisting lateral earth load/surcharge load and forming part of a Structure, including minimum requirements for supply, installation, grouting and stressing.

##### **4-4.2.2 Engineering Data**

###### **4-4.2.2.1 Shop Drawings**

- A. Shop drawings showing fabrication and installation details of the ground anchors shall be prepared and submitted to the City. The shop drawings shall include the following:
1. the type and size of the ground anchor tendons;
  2. the ground anchor design loads;
  3. the minimum tendon bonded lengths, unbonded lengths and total lengths;
  4. tendon anchorage details, including details of any trumpets;
  5. the corrosion protection system for the tendons and anchorages; and
  6. the type and spacing of tendon centralizers and spacers.

###### **4-4.2.2.2 Mill Certificates**

- A. Mill certificates for the tendons, including load/elongation curves, shall be provided.
- B. Mill certificates for the anchorages shall be provided.

##### **4-4.2.3 Materials**

- A. Material for ground anchors shall comply with PTI DC35.1.

#### 4-4.2.4 **Installation**

##### 4-4.2.4.1 **General**

- A. Ground anchor tendons, including anchors and prestressing steel, shall be handled, stored and installed in such a manner as to avoid damage, corrosion or contamination with dirt or deleterious substances.
- B. Ground anchors shall be handled, stored and installed in accordance with the requirements of PTI DC35.1.
- C. Tendon tails shall be cleaned and protected from damage until final testing and lock-off.

##### 4-4.2.4.2 **Installation Tolerances**

- A. Ground anchors shall be placed to a horizontal tolerance of plus or minus 50 mm.
- B. Ground anchors shall not be out of slope, batter or alignment by more than 20 mm per meter.
- C. The ground anchor anchorages shall be installed perpendicular to the tendons, without bending or kinking of the tendons.

##### 4-4.2.4.3 **Grouting**

- A. Grouting of ground anchors shall comply with PTI DC35.1.
- B. The grout shall be free of lumps and undispersed cement.
- C. Admixtures, if used, shall be mixed in accordance with the manufacturer's recommendations.
- D. The grouting equipment shall be sized to enable the grout to be pumped in one continuous operation.
  - 1. The mixer shall be capable of continuously agitating the grout.
- E. A positive displacement grout pump shall be used.
  - 1. The pump shall be equipped with a pressure gauge to monitor grout pressure.
  - 2. The pressure gauge shall be capable of measuring pressures of a least 1.0 MPa or twice the actual grout pressures required, whichever is greater.

##### 4-4.2.4.4 **Load Tests**

- A. The load capacity and overall performance of ground anchors, including load-extension behavior, relaxation and creep, shall be evaluated for acceptance using pre-production tests, performance tests and proof tests in accordance with the requirements of PTI DC35.1.
- B. Performance tests shall be carried out on a minimum of 5% of the production ground anchors to confirm the adequacy of the design, materials and method of construction.
  - 1. The performance tests shall be carried out by cyclically and incrementally loading and unloading the ground anchor to a minimum test load of 1.33 times the design load in accordance with PTI DC35.1.
  - 2. The performance tests shall be carried out on ground anchors constructed under methods and conditions identical to those used on the Project.

3. The frequency of performance tests shall be increased when sub-surface conditions are variable and/or the ground anchor load capacities are in question.
- C. Proof tests shall be carried out on all production ground anchors not subjected to performance tests. The proof tests shall be conducted by incrementally loading the anchor up to 1.33 times the design load in accordance with PTI DC35.1.
  - D. After load testing has been completed, the load in the tendons after seating losses shall be within  $\pm 5\%$  of the specified lock-off load shown on the applicable Final Design.
  - E. After transferring the load to the anchorage, and prior to removing the jack, a lift-off test shall be carried out to confirm the magnitude of the load in the ground anchor tendon.
    1. This load is determined by reapplying load to the tendon to lift off the wedge plate without unseating the wedges.

#### 4-4.2.5 **Ground Anchor Installation Records**

- A. A ground anchor installation record shall be prepared for each ground anchor installed and shall include:
  1. an unique reference number for each ground anchor;
  2. the date of installation and weather conditions;
  3. the on-site reviewing Professional Engineer's name;
  4. the location and orientation of each ground anchor;
  5. pertinent information regarding the ground anchor installation including design load, installation procedure used, anchor type, completed overall anchor length, anchor embedment length, soils encountered during drilling, water table, casing (if used), anchor material(s) used, complete geometric information, stressing information (if stressed elements were used), grouting and post-grouting information, including quantity of grout and grout pressure used, and any difficulties encountered. The information shall be suitable for a complete independent design load, resistance and durability assessment; and
  6. documentation of the load test and load test results.
- B. The ground anchor installation records shall be signed and sealed by a Professional Engineer.

#### 4-4.2.6 **Basis for Rejection**

- A. A Corrective Action Plan shall be prepared in the event of:
  1. Ground anchors being installed out of geometric tolerance;
  2. Ground anchors not meeting the required load resistance or the design performance criteria, including residual movement and creep rate; and
  3. Ground anchors that encounter unforeseen or excessively variable subsurface conditions that detrimentally affect the load resistance or durability of the anchor.

**4-4.3 HEAVY ROCK RIPRAP**

**4-4.3.1 General**

- A. This Section 4-4.3 [*Heavy Rock Riprap*] sets out the requirements for all heavy rock riprap forming part of a Structure, including minimum requirements for the quality, supply and placement of heavy rock riprap.

**4-4.3.2 Material**

**4-4.3.2.1 Heavy Rock Riprap**

- A. Heavy rock riprap shall be hard, durable and angular in shape, resistant to weathering and water action, free from overburden, spoil, shale or shale seams and organic material.
  - 1. Sandstone shall not be used for heavy rock riprap.
- B. The material provided for each class of heavy rock riprap specified in the applicable Final Design shall have a gradation that conforms to the requirements of Table 4-4.3.2-1 [*Gradation of Heavy Rock Riprap*]:
  - 1. The minimum dimension of any single rock shall be not less than one third of its maximum dimension.
  - 2. The minimum acceptable unit weight of the rock shall be 2.5 t/m<sup>3</sup>.

Table 4-4.3.2-1 Gradation of Heavy Rock Riprap

		CLASS			
		1M	1	2	3
<b>Nominal Mass (kg)</b>		<b>7</b>	<b>40</b>	<b>200</b>	<b>700</b>
<b>Nominal Diameter (mm)</b>		<b>175</b>	<b>300</b>	<b>500</b>	<b>800</b>
None greater than:	kg	40	130	700	1800
	or mm <sup>2</sup>	300	450	800	1100
20% <sup>1</sup> to 50% greater than	kg	10	70	300	1100
	or mm	200	350	600	900
50% to 80% greater than	kg	7	40	200	700
	or mm	175	300	500	800
100% greater than:	kg	3	10	40	200
	or mm	125	200	300	500
<sup>1</sup> . Percentages quoted are by mass. <sup>2</sup> . Sizes quoted are equivalent spherical diameters, and are for guidance only.					

- C. Heavy rock riprap shall meet the minimum requirements shown in Table 4-4.3.2-2 [*Minimum Physical Properties for Heavy Rock Riprap*] for specific gravity, absorption and durability unless:
1. reliable performance records are available for the heavy rock riprap. Angular fieldstone may be considered to have a reliable performance record; or
  2. the heavy rock riprap required is Class 1.

Table 4-4.3.2-2 Minimum Physical Properties for Heavy Rock Riprap

Method of Test	Requirements
California Department of Transportation Method of Test for Specific Gravity and Absorption of Coarse Aggregate (California Test 206)	Minimum Specific Gravity = 2.60 Maximum Absorption = 2.0 percent
California Department of Transportation Method of Test for Durability Index (California Test 229)	Minimum Durability Index = 52 Durability Index may be less than 52 if DAR > 23
<sup>1</sup> Durability Absorption Ratio (DAR) = Durability Index / (Absorption % + 1%)	

- D. Specific gravity, absorption and durability testing shall be carried out, if required, on representative samples by an independent certified testing laboratory.
1. A representative sample of not less than 70 kg shall be tested for each type and source of rock to be tested, and shall contain a number of pieces ranging up to 25 kg mass.
- E. Additional testing shall be carried out in the event of material differences between the supplied heavy rock riprap and the tested sample.

#### 4-4.3.2.2 Geotextile Filter Fabric

- A. Non-woven geotextile filter fabric shall be used under all heavy rock riprap and shall comply with Table 4-4.3.2-3 [*Non-Woven Geotextile Filter Fabric*].

Table 4-4.3.2-3 Non-Woven Geotextile Filter Fabric

Non-Woven Geotextile Filter Fabric		
Specifications and Physical Properties		
Property	Class 1M, 1 and 2	Class 3
Grab Strength (ASTM D4632)	650 N	875 N
Elongation (Failure) (ASTM D4632)	50%	50%
CBR Puncture Strength (ASTM D6241)	275N	550 N
Trapezoidal Tear (ASTM D4533)	250 N	350 N
Minimum Fabric Lap to be 300 mm		

#### 4-4.3.3 **Installation**

##### 4-4.3.3.1 **Placing of Geotextile Filter Fabric**

- A. The surface on which heavy rock riprap is to be placed shall be graded to provide a smooth uniform surface conforming to the lines and grades shown on the applicable Final Design.
  - 1. All stumps, large rocks, brush or other debris that could damage the fabric shall be removed. All holes and depressions shall be filled so that the fabric does not bridge them. Loose or unstable soils shall be replaced.
- B. Care shall be taken to prevent puncturing or tearing of the geotextile filter fabric.
  - 1. Any damage to the geotextile filter fabric shall be repaired by the use of patches that extend at least 1 m beyond the perimeter of the tear or puncture.
- C. The geotextile filter fabric shall be laid parallel to the slope direction in a loose fashion. Folds and wrinkles shall be avoided.
  - 1. Adjacent strips of geotextile filter fabric shall be overlapped a minimum of 300 mm, except when placed underwater, the minimum lap width shall be 1 m.
  - 2. Overlaps shall be pinned using 6 mm diameter steel pins fitted with washers and spaced at 1 m intervals along the overlaps.
  - 3. The top edge of the geotextile filter fabric shall be anchored by digging a 300 mm deep trench, inserting the top edge of the fabric into the trench and backfilling with compacted soil.
- D. The geotextile filter fabric shall be covered by heavy rock riprap within sufficient time so that ultraviolet damage does not occur to the fabric.
  - 1. In no case shall this time exceed 7 days for ultraviolet material and 14 days for ultraviolet protected and low ultraviolet susceptible polymer geotextiles.

##### 4-4.3.3.2 **Placing of Heavy Riprap Rock**

- A. The heavy rock riprap shall be placed into position to conform to the specified gradation and to the cross section shown on the applicable Final Design.
  - 1. The finished surface shall be uniform, free from bumps or depressions, and with no excessively large cavities below or individual rocks projecting above the general surface.
- B. Riprap placement shall not damage the geotextile filter fabric or displace it from its intended position.
  - 1. Riprap placement shall commence at the base of the area to be covered and proceed up the slope.
  - 2. The height of drop of riprap shall be limited to 1.0 m or less, and the riprap shall not be allowed to roll down the slope. Heavy equipment shall not operate directly on the geotextile filter fabric.

##### 4-4.3.4 **Inspection of Rock**

- A. Control of gradation shall be by visual inspection.

1. If, during the delivery of the material to the site, a particular load is found to be made up of pieces of predominantly one size, or to be lacking in pieces of one size, it shall be dumped in a suitable location outside the area to be protected. Additional material as required to make up the deficient sizes shall be added to this load such that the combination can then be placed to ensure uniformity.

#### **4-4.4 CAST-IN-PLACE CONCRETE**

##### **4-4.4.1 General**

- A. This Section 4-4.4 [*Cast-In-Place Concrete*] sets out the requirements for all cast-in-place concrete forming part of a Structure, including minimum requirements for quality, sampling and testing of constituent materials of concrete, methods of producing and handling constituent materials, and batching, mixing, handling, transporting, placing, curing and finishing of cast-in-place concrete.

1. Additional requirements for cast-in-place concrete segmental construction are given in Section 4-4.7 [*Concrete Segmental Construction*] of this Schedule.

##### **4-4.4.2 Materials for Cast-in-Place Concrete**

- A. All constituent materials for cast-in-place concrete shall be selected to provide concrete with sufficient durability to meet the Design Service Life requirements of the Structure and sufficient strength to meet structural strength requirements.
- B. Cast-in-place concrete shall consist of hydraulic cement, water, aggregates, admixtures, silica fume, steel fibres and/or fly ash, as follows:

###### **4-4.4.2.1 Portland Cement**

- A. Portland cement shall comply with CAN/CSA A3001. General use (Normal), Type GU, or high sulphate resistant, Type HS or HSb cement, shall be used unless otherwise specified herein.
  1. As an alternative to Type HSb cement, concrete intended for placement in sulphate environments may be produced with combinations of Type GU cement and supplementary cementing materials provided current CAN/CSA A3004-C8 test data demonstrates compliance with CAN/CSA A3001 requirements for high sulphate resistance.

###### **4-4.4.2.2 Water**

- A. Water for mixing concrete, patching products, concrete finishing materials or mortar shall comply with CAN/CSA A23.1 and shall be free from harmful amounts of alkali, organic materials and other deleterious substances.
  1. Slurry water, treated wash water or water from shallow, stagnant or marshy sources shall not be used.

###### **4-4.4.2.3 Aggregates**

- A. Fine and coarse aggregates shall comply with CAN/CSA A23.1.

###### **4-4.4.2.4 Admixtures**

- A. Admixtures shall be compatible with all mix constituents.
- B. Water reducing admixtures and superplasticizing admixtures shall comply with ASTM C494.



- C. Air entraining admixtures shall comply with ASTM C260.
- D. Hydration stabilizing admixtures shall comply with ASTM C494 for Type D water reducing and retarding admixtures.
  - 1. Hydration stabilizing admixtures are only permitted as follows:
    - a. when haul times are reasonably expected to exceed the times specified in Section 4-4.4.7 [Time of Placing] of this Schedule;
    - b. where hydration stabilization is required due to structural considerations; and
    - c. where Project Co has prepared and submitted a report justifying their use.
- E. Calcium chloride, air-reducing admixtures or accelerating admixtures are not permitted.

#### 4-4.4.2.5 **Silica Fume**

- A. Condensed silica fume shall comply with CAN/CSA A3001 for a Type SF supplementary cementing material.
  - 1. A compatible superplasticizing admixture shall be used together with the silica fume.

#### 4-4.4.2.6 **Steel Fibres**

- A. Steel fibres shall comply with ASTM A820/A820M, Type 1 or 5 and shall be 50 mm in length with an aluminum content of no more than 0.020% by mass, when tested in accordance with test method Environmental Protection Agency (EPA) 3050B.
- B. Where the use of steel fibres is specified in the applicable Final Design, Novocon XR or Wiremix W50 steel fibres at a dosage rate of 60 kg per cubic metre of concrete shall be used.
  - 1. Alternative steel fibres and dosage rates may be used provided that their toughness ( $T_{600}^D$ ) determined in accordance with ASTM C1609 is greater than or equal to that of the specified fibres and dosage.

#### 4-4.4.2.7 **Fly Ash**

- A. Fly ash shall comply with CAN/CSA A3001, for Type “F” fly ash with calcium oxide content (CaO) not exceeding 12%.

#### 4-4.4.3 **Storage of Materials**

- A. All constituent materials for cast-in-place concrete shall be stored in a manner that prevents contamination or deterioration.
  - 1. All hydraulic cement, silica fume, fly ash and steel fibres shall be stored in a manner that protects it from dampness.
  - 2. All hydraulic cement, silica fume and fly ash shall be free from lumps at all times during their use.
  - 3. Steel fibres shall be free from balls and clumps at all times during their use.
- B. All aggregates shall be stored and handled so as to prevent segregation, provide uniformity of materials and prevent contamination.
  - 1. Separated aggregates, aggregates secured from different sources, and fine and coarse aggregates shall be stored in separate stockpiles.

2. The sites of all stockpiles shall be cleared of all foreign materials and shall be reasonably level and firm.
3. If aggregates are placed directly on the ground, aggregates shall not be removed from the stockpile within 150 mm of the ground level.

#### 4-4.4.4 **Concrete Mix Design and Aggregate Tests**

##### 4-4.4.4.1 **Concrete Mix Design**

- A. Design all concrete mixes to provide concrete that:
  1. is sufficiently workable, for the applicable placement and finishing requirements;
  2. has sufficient durability to meet the Design Service Life of the Structure; and
  3. has sufficient strength to meet structural strength requirements.
- B. Submit concrete mix design, together with applicable material quality compliance test reports, for each class of concrete to the City before first placement of such concrete.
  1. Each concrete mix design, including the applicable material test reports, shall be signed and sealed by a Professional Engineer engaged by an independent concrete testing laboratory certified to CAN/CSA A283. The certifying Professional Engineer shall also provide a professional opinion confirming that the concrete mix is suitable for the intended use and can be expected to meet all applicable Project Requirements over the Design Service Life of the Structure.
  2. Where concrete will be placed by concrete pump, the concrete mix shall be specifically designed for pumping.
  3. Where concrete will be placed under water, the concrete mix shall be specifically designed for placing concrete under water.
    - a. The concrete shall be designed to have a slump of 170 mm ± 30 mm without segregation.
    - b. An excess of 15% above the cement quantity required by the equivalent conventionally placed concrete mix design shall be provided.
    - c. The concrete mix may contain an “anti-washout” admixture incorporating viscosity modifiers (Whelan gum, etc.) to enhance the performance of the mix.
- C. Any proposed modifications made to the concrete mix design shall be submitted to the City in accordance with the requirements of this Section 4-4.4.4.1.

##### 4-4.4.4.2 **Aggregate Tests**

- A. The sampling and testing of aggregates shall be completed by a concrete testing laboratory certified to CAN/CSA A283 by the Canadian Council of Independent Laboratories (CCIL).
- B. Fine aggregate shall be tested in accordance with CAN/CSA A23.2-7A, “Organic Impurities in Sands for Concrete”.
  1. Fine aggregate producing an organic impurity colour darker than the Standard colour shall be rejected in the absence of a satisfactory record of performance in a similar class of concrete (minimum 30 tests over the last 12 months).

2. Ironstone content in the fine aggregate material (material retained on the 2.5 mm sieve) shall not exceed 1.5 % by the total dry mass of fine aggregate for any class of concrete other than for Pile Concrete.
- C. The potential for deleterious alkali-aggregate reactivity for fine and coarse aggregates shall be assessed in accordance with CAN/CSA A23.2-27A. This assessment shall include the risk level associated with Structure size and environment, the level of prevention required to achieve the Design Service Life of the Structure and the determination of the appropriate preventative measures, including testing in accordance with CAN/CSA A23.2-28A. Current (less than 18 months old) test data evaluating the potential alkali-silica reactivity of aggregates tested in accordance with CAN/CSA A23.2-14A or CAN/CSA A23.2-25A is required.
  - D. Petrographic analysis on the coarse aggregates shall be performed in accordance with CAN/CSA A23.2-15A by experienced personnel employed by a CSA certified laboratory. The petrographic analysis report shall be signed and sealed by either a Professional Engineer or a Geoscientist.
    1. The (weighted) petrographic number of the coarse aggregates shall not exceed 130, and the ironstone content shall not exceed 0.8%.
  - E. Material test reports shall be current according to the required frequency of analysis in Table 4-4.4.4-1 [Material Test Frequency] and fully represent materials to be used in concrete production. For each mix design submission the source(s) of aggregate(s) and following aggregate analysis shall be provided.

Table 4-4.4.4-1 Material Test Frequency

Aggregate Analysis	Standard	Required Frequency of Analysis (maximum days prior to production)
Fine and coarse aggregate sieve	CAN/CSA A23.2-2A	90
Amount of material finer than 80 µm in aggregate	CAN/CSA A23.2-5A	90
Organic impurities in sands for concrete	CAN/CSA A23.2-7A	90
Results of deleterious substances and physical properties of aggregates	Table 12, CAN/CSA A23.1; A23.2-3A, A23.2-4A, A23.2-23A, A23.2-24A, A23.2-29A	180
Potential expansivity of aggregates	CAN/CSA A23.2-14A	18 months
Detection of alkali-silica reactive aggregate by accelerated expansion of mortar bars	CAN/CSA A23.2-25A	12 months
Petrographic examination of coarse aggregate for concrete	CAN/CSA A23.2-15A	180

1. Additional aggregate analyses shall be carried out at the frequencies specified in Table 4-4.4.4-1 [Material Test Frequency] during concrete production to confirm that the aggregates continue to meet Project Requirements.
2. If the aggregate consists of a blend from more than one source, the “fine aggregate sieve” analysis or the “coarse aggregate sieve” analysis, as applicable, shall show the gradation of the blended fine aggregates.

#### 4-4.4.4.3 Trial Batches

- A. Prior to first placement of each class of cast-in-place concrete containing silica fume or hydration stabilizing admixtures and at least once each year, trial batch(es) shall be carried out as follows to demonstrate that the concrete thus produced has the properties required by the concrete mix design.
1. Trial batch(es) shall be prepared at least 42 days prior to placement of concrete at Site.
  2. Each trial batch shall be a minimum of 3 m<sup>3</sup> or 50% of the mixer's rated capacity (whichever is greater).
  3. For concrete mixes containing silica fume:
    - a. slump retention shall be evaluated at 15, 30, 50, and 70 minutes after batching;
    - b. at 70 minutes after batching, samples shall be cast to determine compressive strength at 7 and 28 days;
    - c. rapid chloride ion penetration, and hardened air void spacing analysis shall be carried out in accordance with the requirements of Section 4-1.7.2 [*Additional Requirements for Concrete Containing Silica Fume*] of this Schedule; and
    - d. shrinkage of the trial batch concrete shall be measured in accordance with CAN/CSA A23.2-21C.
  4. For concrete containing hydration stabilizing admixtures:
    - a. The time of initial and final set shall be determined;
    - b. slump retention shall be assessed at 15 minutes after batching, quarter points of the design hydration stabilization period and 30 minutes prior to the anticipated initial set;
    - c. hardened air void spacing analysis shall be carried out in accordance with the requirements of Section 4-1.7.2 [*Additional Requirements for Concrete Containing Silica Fume*] of this Schedule;
    - d. samples shall be cast to determined compressive strength at 3, 7, and 28 days; and
    - e. trial batch(es) containing silica fume shall also meet the requirements of Section 4-1.7.2 [*Additional Requirements for Concrete Containing Silica Fume*] of this Schedule for rapid chloride ion penetration.
  5. The design length of the hydration stabilization period shall be the difference between the anticipated haul time and the allowable haul time as specified in Section 4-4.4.7 [*Time of Placing*] of this Schedule or that required by structural considerations.
- B. For cast-in-place concrete containing silica fume or hydration stabilizing admixtures, only those concrete mix designs for which the trial batch(es) demonstrate compliance with the applicable Project Requirements shall be used.

#### 4-4.4.5 Measurement of Materials

- A. All constituent materials of cast-in-place concrete shall be accurately measured and batched such that the material properties of each concrete batch comply with the properties assumed by the concrete mix design.

1. All constituent materials of cast-in-place concrete shall be accurately measured and batched in accordance with the requirements of CAN/CSA A23.1.
2. Air entraining agent and other admixtures shall be added to the mix in a water-diluted solution.
3. For mix adjustments at the Site, facilities to control the amount of superplasticizer and air entrainment admixtures shall be provided so that the required tolerances are met.

#### 4-4.4.6 **Mixing Concrete**

- A. All materials for the concrete shall be charged concurrently at the proportions which satisfy the mix design.
  1. Variations in water-cement ratio from the applicable concrete mix design shall not be permitted.
- B. All concrete shall be mixed thoroughly until it is uniform in appearance, with all constituent materials uniformly distributed.
  1. Mobile continuous mixers or other such concrete supply equipment are not permitted.
  2. All joints, valves and other parts shall be maintained so that there is no leakage of water into the mixer drum. Mixers that do not have an accurately working and dependable water gauge shall not be used.
  3. Air entraining agents and other admixtures shall be placed in the mixer after the initial water is in the mixer drum but before any other materials are added. Superplasticizer shall be added after initial mixing and as per the superplasticizer manufacturer's recommendation.
  4. In no case shall the mixing time per batch be less than one minute for mixers of one cubic metre capacity or less. The "batch" is considered as the quantity of concrete inside the mixer. The minimum mixing time shall be increased by 15 seconds for each additional half cubic metre capacity or part thereof. The mixing period shall be measured from the time when all materials have entered the mixer drum.
- C. Mixers shall not be loaded above their rated capacity.

#### 4-4.4.6.1 **Truck Mixing**

- A. Truck mixers shall be of the revolving drum type, watertight, and so constructed that the concrete can be mixed at the proportions which satisfy the mix design and ensure uniform distribution of all constituent materials throughout the mass.
  1. The maximum size of batch in truck mixers shall not exceed the maximum rated capacity of the mixer as stated by the manufacturer and stamped on the mixer.
  2. Truck mixing shall commence immediately upon introduction of ingredients into the drum and be continued until the concrete is uniform in appearance, with all constituent material uniformly distributed, but not less than 50 revolutions, with the mixing rate being in accordance with the manufacturer's recommended rate.
  3. When adjustment to the mix by adding air entraining agent or superplasticizer admixtures at the Site is made, the mixer shall rotate to ensure homogeneity of the concrete, but not less than 50 additional revolutions, before discharge. Discharge chutes shall be kept clean and free from hardened concrete and shall be wetted down prior to use.

#### 4-4.4.7 **Time of Placing**

- A. The maximum placing time allowed for all classes of concrete, other than concrete containing silica fume, including delivery to the applicable Site and discharge shall not exceed 90 minutes after batching, unless mix design compatible hydration stabilizing admixtures have been employed to extend the setting time.
  - 1. The maximum placing time allowed shall be reduced in accordance with Good Industry Practice under conditions contributing to quick setting of concrete, including hot weather.
- B. For cast-in-place concrete containing silica fume the maximum placing time allowed, including delivery to the applicable Site and discharge, shall not exceed 70 minutes after batching unless mix design compatible hydration stabilizing admixtures have been employed to extend the setting time.
  - 1. The maximum placing time allowed shall be reduced in accordance with Good Industry Practice under conditions contributing to quick setting of concrete, including hot weather.
- C. The maximum placing time shall be measured from the time when any of the mix ingredients have entered the mixer drum, regardless of whether or not the drum is revolving.

#### 4-4.4.8 **Delivery**

- A. The rate of delivery of concrete during concreting operations shall be such that unplanned cold joints will not develop in the concrete.
- B. Deliver and handle the concrete so as to facilitate placing of the concrete without damage to the Structure or the concrete.

#### 4-4.4.9 **Discharge Temperature**

- A. Unless otherwise specified, the temperature of concrete containing silica fume shall be between 10 degrees Celsius and 20 degrees Celsius at discharge.
- B. Unless otherwise specified, the temperature of all other classes of concrete shall be between 10 degrees Celsius and 25 degrees Celsius at discharge.

#### 4-4.4.10 **Inspection and Testing**

- A. Inspection and testing shall be carried out as required to confirm that the concrete has the required properties.
- B. Sampling of concrete shall comply with CAN/CSA A23.2-1C.
  - 1. When a concrete pump is used to place concrete, sampling shall be at the end of the discharge hose with the exception that when concrete is being placed under water by tremie methods, sampling may occur at the pump's hopper.
- C. Slump tests shall comply with CAN/CSA A23.2-5C.
- D. Air content and density tests shall comply with CAN/CSA A23.2-4C and A23.2-6C.
  - 1. ACI or CCIL certified testers with related experience shall be utilized to test, the air content, density, slump and temperature of each batch of concrete at the Site.
- E. Air content and slump tests shall be carried out on all concrete batches unless the City accepts a lower frequency of testing based on Project Co demonstrating that consistent air content and slump results are being achieved between concrete batches.

1. For concrete containing silica fume as well as for all concrete used in Transportation Structure deck, deck overlay and deck related flatwork, e.g. sidewalks, SUPs, barriers, curbs, medians, the requirements to carry out air content and slump tests on all concrete batches shall not be relaxed.
- F. If any batch of concrete fails to meet slump or air content specifications, attempts at mitigation shall be limited to adjusting the quantities of superplasticizer and air entraining admixtures at Site. Only one check test shall be permitted. Any concrete batch confirmed to be unacceptable by slump, air content or temperature testing shall be rejected.
  - G. Any concrete from a rejected batch already placed in the Structure shall be rejected and immediately removed.
  - H. The test cylinders shall be cast as specified in Section 4-4.4.10.1 [*Test Cylinders*] of this Schedule.
    1. Current summaries of concrete testing results including Structure identification, pour location, cylinder identification, slump, air, and individual and average compressive strengths at 7 days and 28 days shall be kept by concrete class for each Structure.
  - I. The City shall be afforded full access for any inspections at any time that it may carry out relative to the concrete itself and/or the constituent materials. This includes at the Site and at any plant used for the manufacture of concrete wherever this may be situated. The access shall be adequate to permit proper sampling of concrete, making of test cylinders and testing slump and air content. The proper storage of all site cast concrete cylinders in accordance with Section 4-4.4.10.1 [*Test Cylinders*] of this Schedule, including cylinders cast by the City, is the responsibility of Project Co and adequate cylinder storage space shall be provided prior to any concrete pour.

#### 4-4.4.10.1 Test Cylinders

- A. Making and curing concrete test cylinders shall be carried out in accordance with CAN/CSA A23.2-3C.
  1. The test cylinders shall be cast in standard CSA approved heavy duty steel or plastic moulds. Plastic moulds shall have a wall thickness of at least 6 mm. For concrete containing silica fume, the ends of cylinders shall be ground flat prior to testing.
- B. Handling and transporting of the cylinders shall be in accordance with CAN/CSA A23.2-3C. No extra laboratory curing time shall be allowed for cylinders that are delivered late to the laboratory.
- C. Temperature-controlled storage boxes for test cylinders shall be provided, as specified in Section 8.3.2.1 of CAN/CSA A23.2-3C for a period of at least 24 hours and for protection of the cylinders from adverse weather and mishandling until removed from the Site.
  1. A max-min thermometer shall be provided for each storage box and for recording site curing temperatures for all test cylinders.
  2. Storage in a portable building which will be used during the first 24-hour storage period is not permitted.
- D. Test cylinders shall be tested in compression in accordance with CAN/CSA A23.2 by an independent CCIL certified testing laboratory.
- E. If the test cylinders exhibit frost etchings or were stored at temperatures below 10 degrees Celsius or above 25 degrees Celsius, or were otherwise mishandled, the concrete represented

by the test cylinders shall be rejected and replaced unless core testing carried out in accordance with Section 4-4.4.10.2 [*Under Strength Concrete*] of this Schedule confirms the in-situ strength of the cylinder.

1. A “Strength Test” shall consist of the compression tests of four standard test specimens, sampled, made, cured, and tested in accordance with CAN/CSA A23.2-3C as modified herein. One cylinder shall be tested at seven days. The 28-day test result shall be the average of the strengths of the remaining three specimens, except that any specimens in a test showing distinct evidence of improper sampling, molding or testing, shall be discarded and the remaining strengths averaged. Additional cylinders may be cast, at the discretion of Project Co. Additional cylinders used to confirm the strength of structural components shall be cured in the same manner as the structural components they represent.

F. Test cylinders for “Strength Tests” shall be taken from representative batches:

1. for concrete containing silica fume as well as for all concrete used in Transportation Structure deck, deck overlay and deck related flatwork, e.g. sidewalks, SUPs, barriers, curbs, medians, a “Strength Test” shall be taken to represent each approximate 20 m3 portion of the concrete pour except that a minimum of one “Strength Test” shall be taken for every two loads of concrete; and
2. for all other concrete a “Strength Test” shall be taken to represent each Structure element or portion of the element. On larger pours a “Strength Test” shall be taken to represent each approximate 30 m3 portion of the concrete pour except that a minimum of one “Strength Test” shall be taken for every three loads of concrete. The frequency of “Strength Tests” may be decreased from one test for every 30 m3 portion of the concrete pour to one test for every 50 m3 portion of the concrete pour based on Project Co demonstrating to the City that minimum concrete strength requirements are consistently being met for the concrete mix design in question.

#### 4-4.4.10.2 Under Strength Concrete

- A. Concrete with 28 day compressive “Strength Test” results less than 100% of the compressive strengths specified in the applicable Final Design shall be removed and replaced unless otherwise accepted by the City in its discretion.
- B. Where permitted by the City, coring to confirm or contest low concrete “Strength Test” results shall be performed as follows:
  1. the cores shall be taken and tested within seven days of the testing of the 28-day cylinders representing the concrete in question.
  2. three 100 mm diameter cores shall be taken from concrete represented by each non-compliant “Strength Test” previously taken. The cores taken shall represent the same batch of concrete as the under strength cylinders under consideration.
  3. cores shall be tested by an independent CCIL certified testing laboratory and in accordance with the requirements of CAN/CSA A23.2-14C. CAN/CSA A23.1, Clause 4.4.6.6.2 “Cores drilled from a structure” shall not apply. The average strength of the cores as reported by the independent testing laboratory shall constitute a “Strength Test”.
- C. Submit all core results to confirm or contest low concrete “Strength Test” to the City.
- D. In cases where the concrete strength, as indicated by the cores, is higher than the strength based on the concrete cylinder results, the core results shall be used as the basis for



acceptance of the concrete. If the core strengths are lower than the strength from the concrete cylinder tests, the strengths indicated by the cylinder tests shall govern.

#### 4-4.4.11 **Falsework and Formwork**

##### 4-4.4.11.1 **General**

- A. All formwork shall be of sufficient strength and rigidity to ensure that the finished concrete conforms to the design dimensions and contours shown on the applicable Final Design
  - 1. The shape, strength, rigidity, water tightness and surface smoothness of re-used forms shall be maintained at all times. Any warped or bulged formwork shall be repaired or replaced before being used.
  - 2. For narrow walls and columns, where the bottom of the form is inaccessible, removable panels shall be provided in the bottom form panel to enable cleaning out of extraneous material immediately before placing the concrete.
- B. All formwork material shall be compatible with meeting the surface finish requirements of Section 4-4.4.21 [*Concrete Surface*] of this Schedule.
- C. Except for closure pours, all formwork for concrete segmental construction shall be steel.
- D. All formwork shall be removed from the completed Structure.
- E. All falsework shall be designed and constructed to provide the necessary rigidity to meet the lines and grades shown in the applicable Final Design, to account for deflections under load and to support the loads without appreciable settlement or deformation.
- F. All falsework and formwork foundation drawings shall be prepared, signed and sealed by a Professional Engineer.

##### 4-4.4.11.2 **Deck Formwork Supported on Girders**

- A. Deck formwork supported on girders shall be fabricated and installed so that the lines and grades shown in the applicable Final Design are achieved. Adjustments may be made where necessary to compensate for variances in girder dimensions, positioning, alignment and sweep.
  - 1. Prior to commencing deck formwork, all the girders shall be profiled and the deck concrete thickness and girder haunch dimensions required to achieve the specified grade line shall be determined. In the event that actual girder camber values vary significantly from the estimated values indicated on the applicable Final Design, the grade line shall be raised or lowered accordingly.
- B. Formwork support brackets shall be designed and installed to ensure no damage to girder flanges and webs.
  - 1. Where support brackets bear against girder webs, the contact surface shall be protected with timber or neoprene softeners. No drilling of additional holes, or any other modifications including field welding, shall be made to the superstructure elements. Effects of concentrated loads on thin webs shall be checked, and where necessary, sufficient means shall be provided to distribute or carry such concentrated loads to the supporting flanges or stiffeners.

#### 4-4.4.11.3 Forms for Exposed Surfaces

- A. Forms for exposed surfaces shall meet the requirements of Section 4-4.4.11.1 *[General]* of this Schedule as well as the following requirements.
1. All non-steel forms for exposed surfaces shall be all new material consisting of Douglas Fir substrate with resin-impregnated paper overlay and factory treated chemically active release agent.
  2. The minimum acceptable forming for all exposed concrete where the pour height is 1.5 m or less shall have 18 mm plywood, supported at 300 mm maximum centres. Where the pour height is greater than 1.5 m the minimum acceptable forming for all exposed concrete shall have 18 mm plywood supported at 200 mm maximum on centres. The support spacing specified is for the use of new material, closer spacing may be required in case of re-used material. Strong-backs or walers placed perpendicularly to the supports shall be employed to ensure straightness of the form.
  3. The top edges of exposed surfaces shall have chamfers formed by chamfer strips that establish a true line for screeding.
  4. All form material for exposed surfaces shall have all joints and seams filled to produce a seam free surface.
- B. All forms for exposed surfaces shall be mortar-tight, filleted at all sharp corners, and provide for a bevel or draft at all hardware projections to allow the hardware to be subsequently removed to below the concrete surface.
1. Metal bolts or anchorages within the forms shall be so constructed as to permit their removal to a depth of at least 20 mm from the concrete surface.
  2. Break-back type form ties shall have all spacing washers removed and the tie shall be broken back a distance of at least 20 mm from the concrete surface. All fittings for metal ties shall be of such design that, upon their removal, the cavities which are left will be of the smallest possible size. Torch cutting of steel hangers and ties will not be permitted.
  3. When plastic sleeves and removable inner rods are used, the plastic sleeves shall be removed for a distance of 100 mm from the face of the concrete.
  4. The cavities inside plastic sleeves shall be filled with a non-shrink grout to 75 mm from the concrete surface and cured a minimum 24 hours. The remaining 75 mm of the cavity shall then be filled with a concrete patching material from the Alberta Transportation Approved Product List.
- C. Form ties on exposed surfaces shall be regularly spaced and shall not leave holes larger than 25 mm in diameter on the concrete surface.
- D. All forms shall provide for a 20 mm x 20 mm chamfer or fillet at exposed concrete edges unless a larger chamfer or fillet is shown on the applicable Final Design.

#### 4-4.4.11.4 Protection of "Weathering" Steel Bridge Girders

- A. Where steel girders are fabricated of "weathering" steel, rust formation on girder surfaces shall be of uniform colour.
1. All joints between deck formwork and steel members (including interior girders, and diaphragms) shall be sealed to prevent leakage of cement paste or concrete. Caulking, duct tape, ethafoam, or any other suitable means or material, shall be used to achieve the seal.

- B. If marking or staining of the girders occurs, the marks and stains shall be removed and the girder surfaces restored to a uniform colour.
  - 1. Should foreign material spill onto any weathering steel despite the protection provided, the contaminated areas shall be cleaned off, washed, and sandblasted to remove the contamination. Additionally, should the exterior face of an exterior girder become stained or marked, the entire exterior face of the girder line shall be lightly sandblasted and "weathered" so that uniformity of girder color is achieved.
  - 2. "Weathering" shall be achieved by repeatedly fogging the exterior girder faces with clean water and allowing them to dry. Fogging shall leave the girders wet but not "running wet", and shall be repeated when the girders are completely dry.

#### 4-4.4.11.5 **Protection of Concrete Work from Staining**

- A. All concrete work shall be protected from staining. Any staining of concrete surfaces shall be removed.
  - 1. Stained concrete surfaces that have received a Class 3 Finish shall have the entire surface face of the component sandblasted and the Class 3 Finish reapplied; and
  - 2. Stained concrete surfaces that have received a Class 2 Finish shall have the entire surface face of the component refinished.

#### 4-4.4.12 **Handling and Placing Concrete**

##### 4-4.4.12.1 **General**

- A. Concrete shall be placed while fresh and before it has reached its initial set.
  - 1. All the necessary equipment for any particular pour shall be on-site and proven to be in working condition before the pour commences, with backup equipment on-site. The equipment shall be well maintained, suitable in kind and adequate in capacity for the work.
  - 2. In preparation for the placing of concrete, all sawdust, chips and other construction debris and extraneous matter shall be removed from the interior of forms. Temporary members shall be entirely removed from the forms and not buried in the concrete.
  - 3. Struts, stays, and braces, serving temporarily to hold the forms in correct shape and alignment, pending the placing of concrete at their locations, shall be removed when the concrete placing has reached an elevation rendering their service unnecessary.
- B. Re-tempering of partially hardened concrete with additional water is not permitted.
- C. The method of concrete placement shall not have a negative impact on the concrete properties.
  - 1. Concrete shall be placed so as to not cause segregation of the materials or displacement of the reinforcement.
  - 2. When placing operations, other than for the placing of pile concrete, involve the free drop of concrete by more than 1 m, it shall be deposited by metal pipes or equivalent.
  - 3. After initial set of the concrete, the forms shall not be jarred or strain placed on the ends of projecting reinforcing bars.

4. Concrete placing operations shall not work off, or transport concrete directly over concrete already placed, when this concrete is less than 48 hours old, no matter what system of runways, supports or protection is used on the surface of the concrete already placed if it is subjected thereby to live or dead loads.
  5. When concrete placing is discontinued, for whatever reason, all accumulations of mortar splashed on the reinforcing steel and the form surfaces shall be removed.
  6. If the accumulations are not removed prior to the concrete becoming set, care shall be exercised not to injure or break the concrete-steel bond at and near the surface of the concrete, while cleaning the reinforcing steel.
- D. Concrete which would be adversely affected by the presence of freestanding water shall be protected by preventing its occurrence.
1. All necessary steps shall be taken to prevent free water build-up for the first 24 hours.
  2. Water used to keep equipment clean during the pour, or to clean equipment at the end of the pour, shall be discharged clear of the Structure and any water channel.

#### 4-4.4.12.2 Consolidation

- A. Concrete, during and immediately after depositing, shall be thoroughly consolidated.
- B. The concrete shall be thoroughly worked around the reinforcement and embedded fixtures, and into the corners and angles of the forms. Consolidation shall be of sufficient duration and intensity to thoroughly compact the concrete, but shall not cause segregation.
1. Consolidation shall be done by internal mechanical vibration subject to the following provisions:
    - a. Vibrators shall be capable of transmitting vibrations to the concrete at frequencies of not less than 4500 impulses per minute;
    - b. Intensity of vibration shall be such as to visibly affect a mass of concrete of 25 mm slump over a radius of at least 0.5 m;
    - c. Sufficient number of vibrators shall be provided to properly consolidate each batch immediately after it is placed in the forms; and
    - d. Vibrator operators shall be suitably instructed in the use of vibrators, and the importance of adequate and thorough vibration of the concrete.
  2. Vibration shall be applied at the point of deposit and in the area of freshly deposited concrete. The vibrators shall be inserted vertically and withdrawn out of the concrete slowly. Vibration shall not be continued at any point to the extent that localized areas of grout are formed. Application of vibrators shall be at points uniformly spaced and not farther apart than the radius over which the vibration is visibly effective.
  3. Vibration shall not be applied directly or through the reinforcement of sections or layers of concrete which have hardened to the degree that the concrete ceases to be plastic under vibration. Vibration shall not be used to make concrete flow in the forms over distances so great as to cause segregation, and vibrators shall not be used to transport concrete in the forms.
  4. Vibration shall be supplemented by such spading as is necessary to ensure smooth surfaces and dense concrete along form surfaces and in corners and locations impossible to reach with the vibrators.

- C. Once consolidated, concrete shall not be disturbed. No additional concrete shall be added after consolidation.

#### 4-4.4.12.3 Pumping

- A. The operation of the pump shall produce a continuous flow of concrete without air pockets, contamination or segregation.
- B. The equipment shall be so arranged that the freshly placed concrete is not damaged by any form of vibration caused by the pump.

#### 4-4.4.13 Placing Pile Concrete

##### 4-4.4.13.1 General

- A. The placement of Pile Concrete under water will only be permitted in the event that every attempt at obtaining a dry hole fails.

##### 4-4.4.13.2 Concrete Placed in the Dry

- A. Pile Concrete shall be placed in accordance with the requirements of Section 4-4.4.12.1 *[General]* and Section 4-4.4.12.3 *[Pumping]* of this Schedule except that concrete may be placed free fall, providing the fall is vertically down the center of the casing or drilled hole and there are no transverse ties or spacers.
  - 1. Pile Concrete shall be placed by means of a hopper equipped with a centre pipe drop tube. The pipe drop tube shall be a minimum of 200 mm in diameter and 2 m long.
- B. Concrete in the upper 3 m of the piles shall be consolidated in accordance with Section 4-4.4.12.2 *[Consolidation]* of this Schedule.

##### 4-4.4.13.3 Concrete Placed Under Water

- A. Placement of Pile Concrete under water shall be in accordance with Section 4-4.4.17 *[Depositing Concrete Under Water]* of this Schedule.
- B. All Pile Concrete placed under water shall be inspected by Crosshole Sonic Logging (CSL) to check the structural integrity of the drilled piles.
- C. A proposed method for carrying out CSL shall be submitted to the City before placing any concrete under water. The proposed method shall include the following:
  - 1. All concrete piles cast under water shall be equipped with PVC or steel access tubes to permit inspection by CSL in order to test for voids or other abnormalities in the concrete. Four 50 mm inside diameter tubes shall be supplied and securely installed in each drilled pile with a diameter of 1.5 m or less and six tubes in each pile with a diameter greater than 1.5 m. Tubes shall be installed uniformly and equidistantly around the circumference of the pile such that all tubes are parallel for their full length.
  - 2. Tubes shall be water tight, free from corrosion, have clean internal and external faces and form a good bond with the concrete. All coupling locations shall be recorded.
  - 3. All tubes shall be fitted with watertight shoes on the bottom and removable caps on the top. Tubes shall extend to within 150 mm of the pile bottoms, and shall extend a minimum of 600 mm above the pile tops or where they are accessible. Tubes shall be capped to prevent debris from entering the access tubes.
  - 4. The CSL probes shall pass through the entire length of the tubes without binding.

- D. CSL measurements shall be made at depth intervals of 65 mm from the bottom of the tubes to the top of each pile. Upon completion of testing and verification of the acceptability of the Pile Concrete, the tubes shall be filled with a non-shrink grout from the Alberta Transportation Approved Products List.
- E. The CSL tubes shall not be grouted or any further work performed on the CSL tested pile until it has been demonstrated that the pile is acceptable.

**4-4.4.13.4 Qualification**

- A. A testing agency having a minimum of three years' experience in CSL testing and a Professional Engineer on staff to supervise the testing and interpretation of results shall carry out the CSL testing and interpret the results. Written evidence of successful completion of CSL tests by the testing agency on drilled piles in the Province of Alberta shall be submitted prior to carrying out the CSL testing. The submission of such written evidence shall also include personnel qualifications and equipment description.

**4-4.4.13.5 CSL Results**

- A. The condition of the concrete piles shall be evaluated based on the results of the CSL testing according to the criteria listed in Table 4-4.4.13.5-1 [Concrete Condition Rating Criteria].
- B. CSL test results with ratings other than "G" will be considered unacceptable and will result in rejection of the pile.

Table 4-4.4.13.5-1: Concrete Condition Rating Criteria

Rating	Velocity Reduction *	CSL Results
Good ("G")	≤ 10%	Good quality concrete
Questionable ("Q")	>10% & <20%	Minor contamination or intrusion: questionable quality concrete
Poor/Defect ("P/D")	≥ 20%	Deficiencies or Early Handover Deficiencies exist, possible water/slurry contamination, soil intrusion and/or poor quality concrete
No Signal ("NS")	No Signal Received	Soil intrusion or other severe defect absorbed the signal

\* From highest measured signal velocity in the comparable zone

**4-4.4.14 Placing Deck, Deck Overlay, Slab and Floor Concrete**

**4-4.4.14.1 General**

- A. Deck, deck overlay, slab and floor concrete shall be placed and screeded so as to not have a negative impact on the concrete properties, to achieve the lines and grades shown in the applicable Final Design, and to provide drainage of the concrete surface without ponding.
  - 1. Prior to placing concrete, concrete substrate surfaces shall be brought to a saturated surface dry condition with clean water. Substrate surface shall be free of standing water.
  - 2. Prior to placing concrete a meeting shall be held with those responsible for the pour in attendance to review the procedures and accept the conditions of the pour.

3. Proper lighting shall be provided for night pours.
- B. Deck, deck overlay, slab and floor concrete shall not be placed when the air temperature is below 5 degrees Celsius, or expected to fall below 5 degrees Celsius, or when the air temperature is above 25 degrees Celsius. It shall also not be placed in the event of rain or excessive wind and dust, or under any other conditions harmful to the concrete.
1. Concrete containing silica fume shall be placed between the hours of 6:00 pm and 10:00 am of the following day.
  2. Concrete shall not be placed when the evaporation rate exceeds 0.5 kg/m<sup>2</sup>/hr. The evaporation rate shall be determined using Figure D.1, of CAN/CSA A23.1 – Annex D. The rate of evaporation shall be recorded as concrete placing operations progress and all necessary adjustments shall be made to ensure the evaporation rate does not exceed the specified limit.
- C. The temperature of the concrete during discharge shall be between 10 degrees Celsius and 20 degrees Celsius.
1. If the temperature of the mix is maintained below the 20 degree Celsius maximum by the inclusion of ice to the mix, it shall be done in such a way that does not alter the design water cementing materials ratio.

#### 4-4.4.14.2 **Placing/Finishing Machines**

- A. Except for segmental concrete construction, abutment roof slabs and approach slabs placing/finishing machines shall be used to finish all Transportation Structure deck and deck overlay concrete.
1. Screeding shall be by the following concrete placing/finishing machines or equivalents:
    - a. Bidwell Model RF200, 364, 2450, 3600 or 4800; or
    - b. Gomaco Model C450 or C750.
  2. Two work bridges, separate from the placing/finishing machine, of adequate length to completely span the width of the pour shall be provided. The work bridges shall facilitate the operations of concrete finishing and placing of filter fabric.
  3. Work bridges shall be supported essentially parallel to the concrete surface, between 250 mm and 600 mm above the concrete surface, and shall be at least 800 mm wide to permit diverse uses concurrently, and be rigid enough that dynamic deflections are insignificant.
- B. The finishing machine and guide rails shall be adjusted so that the height of the screed will finish the concrete to the lines and grades shown in the applicable Final Design.
1. Steel screed guide rails shall be installed to suit the profile of the required surface and to ensure a smooth and continuous surface from end to end of the deck or deck overlay. Guide rails shall extend beyond the ends of the Structure to accommodate finishing of the entire surface with the finishing machine.
  2. The finishing machine shall be set-up to match the skew angle of the Structure, when the skew angle exceeds 15°. For skewed Structures on vertical curves, this requirement may be altered to suit actual site conditions.
  3. To confirm the adjustment of the machine and guiderails, the screed shall be dry-run prior to the pour and clearance measurements taken at span tenth points.

4. An independent check shall be performed to confirm the design surface profile, deck thickness and rebar cover and the results documented.
  5. Re-setting of the machine and/or screed rails shall be done as necessary, to obtain an acceptable dry-run. Adjustments to the machine or screed rails shall not be done after an acceptable dry-run has been completed.
  6. Where screed rails are supported on cantilevered formwork that could deflect under the weight of the fresh concrete and the deck finishing machine, a section of the cantilevered formwork on each side of the deck shall be pre-loaded to determine deflections that will occur during concrete placement. The formwork, machine and/or screed rails shall be adjusted to compensate for the expected formwork deflection.
- C. All guide rails and supports shall be located outside of the finished surface of the pour and shall be removed with minimal disturbance to the concrete.
- D. All deck and deck overlay concrete shall be consolidated in accordance with Section 4-4.4.12.2 [*Consolidation*] of this Schedule even when placing/finishing machines are used.

#### 4-4.4.14.3 **Screeding Concrete**

- A. Concrete shall be struck off and screeded so as not to have a negative impact on the concrete properties and to achieve the lines and grades shown in the applicable Final Design.
- B. A roll of concrete shall be maintained along the entire front of the screed at all times to ensure the filling and consolidation of the surface concrete.
1. Concrete shall be placed as close as practical ahead of the screed, and at no time more than 6 m in front of the trailing end of the screed.
  2. The screed shall be moved slowly and at a uniform rate. Where possible the direction of the pouring shall be from the low end to the high end.
  3. Screeding shall be completed in no more than two passes. If a placing/finishing machine is used, the screed shall not be allowed to run except when screeding is actually in progress. The screeded surface shall not be walked on or otherwise damaged.
  4. The concrete thickness shall be checked by continually probing the concrete behind the finishing machine.

#### 4-4.4.14.4 **Bull Floating/Surface Texturing**

- A. The concrete surface produced behind the finishing machine and after bull floating/surface texturing shall be free from open texturing, plucked aggregate and local projections or depressions.
1. Bull floating, with a magnesium bull float and surface texturing shall follow as close as practically possible behind the screed. Competent workers shall be employed to carry out bull floating and surface texturing.
- B. The surface shall be checked for tolerance with a 3 m long expanded polystyrene straight edge immediately after final bull floating and before texturing or application of evaporation reducer.
- C. Evaporation reducer or water shall not be worked into the concrete at any time.



#### 4-4.4.15 **Construction Joints**

##### 4-4.4.15.1 **General**

- A. Construction joints shall be provided between adjacent or successive lifts of concrete.
  - 1. Before depositing new concrete on or against concrete that has hardened, the forms shall be re-tightened.
- B. The surface of the construction joints shall be thoroughly cleaned of laitance and loose and foreign material and saturated with water, with all free standing water removed prior to placing concrete against the joint.
  - 1. Construction joints between cast-in-place concrete girder segments shall be roughened to a minimum depth of 10 mm.
- C. Construction joints shall be made only where indicated on the applicable Final Design, unless noted otherwise.
- D. The face edges of all joints that are exposed to view shall be carefully finished true to line and elevation.
- E. Construction joints shall be located to allow a minimum of 50 mm concrete cover on reinforcing steel running parallel to the joint.
- F. The placing of concrete shall be carried out continuously from construction joint to construction joint.

#### 4-4.4.16 **Concreting In Cold Weather**

- A. During cold weather adequate protection of the concrete shall be provided to prevent freezing and to adequately cure the concrete.
  - 1. Cold weather shall include any weather when the ambient air temperature is below 5 degrees Celsius at time of concrete placement, or may be expected to fall below 5 degrees Celsius during the curing period.
- B. In addition to the requirements stated below, all concrete shall be cured in accordance with Section 4-4.4.18 [*Curing Concrete*] of this Schedule.
- C. A procedure for concreting in cold weather shall be prepared and submitted to the City prior to any concrete being placed in cold weather. The following provisions shall be incorporated into the procedure:
  - 1. Provisions for maintaining the concrete discharge temperature within the limits specified in Section 4-4.4.9 [*Discharge Temperature*] of this Schedule, including:
    - a. heating all aggregates and mixing water to a temperature of not more than 65 degrees Celsius.
  - 2. Aggregates may be heated using either dry heat or steam. The quantity of mixing water shall be reduced as necessary to maintain the mix design water cement ratio.
  - 3. Provisions for heating the formwork, reinforcing steel, previously placed concrete, soil or any other surface the concrete will be placed against. The preheat shall be adequate to ensure that no portion of the fresh concrete freezes when placed against adjacent surfaces, or has curing retarded by cold temperatures and shall include:

- a. raising the temperature of all formwork, reinforcing steel, previously placed concrete, soil and any other surfaces the concrete will be placed against to a temperature of between 10 degrees Celsius and 20 degrees Celsius before placing any concrete.
4. Provisions for keeping the concrete temperature above 10 degrees Celsius for a period of 7 days after placing the concrete (except that for concrete containing silica fume, this 7 day period shall be increased to 21 days), including:
    - a. enclosing the concrete in such a way that the concrete and air temperature within the enclosure are maintained above 10 degrees Celsius.
  5. The use of salamanders, coke stoves, oil or gas burners and similar spot heaters that have an open flame or intense heat is prohibited.
  6. The enclosure shall be constructed large enough to accommodate the workers and equipment necessary to place, finish and cure the concrete. A minimum clearance of 300 mm shall be maintained between the enclosure and the concrete.
  7. Fully insulated formwork may be used as an alternative to the provision of further heat during the curing period. Formwork shall be fully insulated such that the initial heat of the mix and the heat generated during hydration of the cement, maintain the specified curing conditions throughout the curing period.
  8. The system of heating and positioning of steam outlets, heaters, and fans shall give a uniform distribution of heat. Adequate ventilation shall be provided to provide air for combustion and to prevent the accumulation of carbon dioxide within the enclosure. Heaters shall be kept well clear of formwork housing:
    - a. the relative humidity within the enclosure shall be maintained at not less than 85%.
  9. Provisions for withdrawing protection and heat in such a manner so as not to induce thermal shock stresses and cracking in the concrete, including:
    - a. gradually reducing the temperature of the concrete at a rate not exceeding 10 degrees Celsius per day to that of the surrounding air; and
    - b. maintaining the temperature differential between the core of the element and the surface of the element below 20 degrees Celsius. In addition, the temperature differential between the surface of the element and the ambient air shall not exceed 15 degrees Celsius. Ambient air temperature is defined as the air temperature at mid-height and 300 mm from the surface of the element.
  10. Provisions for monitoring and recording internal and surface temperatures of the concrete, ambient air temperature and relative humidity inside the enclosure and for making adjustments to protective measures where necessary to meet the requirements of this Section and Section 4-4.4.18 [*Curing Concrete*] of this Schedule.
    - a. Monitoring of concrete temperatures, ambient air temperatures and relative humidity shall be carried out at least every 4 hours for the first 72 hours after placing the concrete and at least every 8 hours thereafter except that during the withdrawal of heat monitoring shall again be carried out at least every 4 hours.

#### 4-4.4.17 **Depositing Concrete Under Water**

- A. When placing concrete under water, precautions shall be taken to prevent the loss of the cementing material paste by the washing action of the water and the introduction of air or water into the concrete.

1. To prevent segregation, concrete placed under water shall be carefully placed in a compact mass, in its final position, by means of a concrete pump. A properly designed and operated tremie may also be used. The concrete shall not be disturbed after being deposited. Still water shall be maintained at the point of deposit and the forms underwater shall be watertight.
  2. The discharge end of the concrete pump line shall be closed to prevent water entering the line and lowered to the bottom of the form or hole. Pumping shall then proceed with the end of the discharge line being continually buried no less than 500 mm below the surface of fresh concrete at all times, to maintain a seal until the form or hole is completely filled with fresh uncontaminated concrete.
  3. A tremie shall consist of a rigid tube having a diameter between 200 mm and 300 mm, and if constructed in sections it shall have flanged couplings fitted with gaskets. The discharge end shall be closed at the start of the work to prevent water entering the tube. The tremie tube shall be kept full to the bottom of the hopper, and water shall be kept out at all times. When a batch is dumped into the hopper, the flow of concrete shall be induced by slightly raising the discharge end, always keeping it in the deposited concrete. The flow shall be continuous until the work is completed. Sufficient tremies shall be used to place the concrete under water such that it is not necessary to move any of the tremies from one portion of the pour to another. The use of non-rigid tremie tubes will not be permitted. The discharge end of the tremie shall be kept buried at least 500 mm in previously placed concrete.
  4. The surface of the concrete shall be kept as nearly horizontal as is practicable at all times.
- B. Concrete shall not be placed in water which is below 4 degrees Celsius.
- C. Concrete shall not be placed under water unless accepted by the City.
- D. Dewatering is not permitted while concrete is being placed. Dewatering may proceed when the concrete seal is sufficiently hard and strong such that dewatering is not harmful to the performance of the concrete.
- E. All laitance or other unsatisfactory material shall be removed from the exposed surfaces of concrete placed under water using means which will not injure the remaining concrete.

#### 4-4.4.18 **Curing Concrete**

##### 4-4.4.18.1 **General**

- A. Freshly deposited concrete shall be protected from freezing, abnormally high temperatures or temperature differentials, high winds, premature drying, excessive moisture, and moisture loss through the curing period. This includes protection from freezing during the full duration of wet cure and for 12 hours after the removal of wet cure.
- B. All concrete surfaces shall be wet cured for a minimum of 72 hours unless otherwise specified.
  1. Concrete surface(s) shall be covered with two layers of clean, white coloured filter fabric as soon as the surface will not be marred by so doing. The filter fabric shall be kept continuously wet during the curing period. Where the formwork is left in place for 72 hours or more, no additional curing will be required for concrete surfaces covered by the formwork.
- C. Deck and deck overlay concrete surfaces, including abutment roof slab and approach slab surfaces, for concrete not containing silica fume shall be wet cured for a minimum of 7 days.

- D. The final tunnel lining of the Mined Tunnel may be cured using a “Type 1” curing compound meeting the requirements of ASTM C309 (or ASTM C1315) as an alternative to wet curing provided the final tunnel lining does not contain silica fume and has a water to cementing materials ratio greater than 0.33.
- E. The temperature of the centre of in-situ concrete shall not fall below 10 degrees Celsius or exceed 60 degrees Celsius and the temperature difference between the centre and the surface, as well as the temperature differential between top and bottom surfaces, shall not exceed 20 degrees Celsius.
  - 1. To monitor the temperature of mass concrete, including any concrete pour with a minimum dimension greater than 2 m, thermocouples shall be installed in the pour as follows:
    - a. two thermocouples shall be placed at each side face (four total) and two thermocouples placed at the center; for a total of 6 per set; and
    - b. one set of thermocouples shall be placed in each pour for each 2 m of pour length where the pour length is the maximum dimension of the pour.
  - 2. The temperatures shall be monitored and recorded every four hours for the first 72 hours after concrete placement and every 8 hours thereafter for the remainder of the specified cure period. Whatever means and actions necessary to ensure that the concrete temperature and the temperature differences within the concrete remain within the limits specified shall be taken.
- F. The requirements of Table 21 of CAN/CSA A23.1 shall apply.
- G. “Type 1” curing compound complying with the requirements of ASTM C309 (or ASTM C1315) may be applied to concrete surfaces after wet curing unless otherwise specified.
  - 1. Concrete slope protection shall receive two coats of a “Type 2” curing compound meeting the requirements of ASTM C309 (or ASTM C1315). The first coat shall be applied immediately after the concrete has been finished, and the second coat within three hours after the application of the first coat. Each application shall be at the rate specified by the manufacturer.
- H. Prepare and submit the procedure for the wet cure of concrete before any concrete containing silica fume is placed. Details shall include information with regards to the type and details of equipment and materials being used, and the work methods/techniques employed to carry out the work. The wet cure procedure shall be demonstrated to be adequate and suitable prior to scheduling placement of these classes of concrete.

#### 4-4.4.18.2 Curing Requirements for Concrete Containing Silica Fume

- A. The requirements of Section 4-4.4.18.1 *[General]* of this Schedule shall apply to the curing of concrete containing silica fume.
- B. Wet curing shall be maintained for a minimum period of 7 days for rehabilitation projects and 14 days for new construction at an average ambient temperature of at least 10 degrees Celsius.
  - 1. When concreting in cold weather, wet curing shall be maintained for a minimum of 14 days followed by 7 days of air drying for both rehabilitation and new construction projects.
  - 2. Immediately after final bull floating and/or surface texturing and prior to installation of the wet filter fabric cure system, an evaporation reducer having a monomolecular film-

forming compound intended for application to fresh concrete for temporary protection against moisture loss, shall be applied by a hand sprayer with a misting nozzle at the manufacturer's recommended concentration and application rate. Evaporation reducer or water shall not be worked into the concrete at any time during the finishing operation.

3. Two layers of white coloured filter fabric shall be placed on the fresh concrete surface as soon as the surface will not be marred as a result of this placement. The filter fabric shall be pre-wet or a fine spray of clean water shall be immediately applied to the filter fabric until the filter fabric is saturated. Edges of the filter fabric shall overlap a minimum of 150 mm and shall be held in place without marring the surface of the concrete. The filter fabric shall be maintained in a continuously wet condition throughout the curing period, by means of soaker hoses or other means. The use of polyethylene sheeting above the filter fabric to reduce moisture loss shall only be permitted if the sheeting is manufactured with regular perforations to permit the adequate application of curing water from above and reduce the heat generated by greenhouse effects.
- C. For those locations where formwork is removed prior to the completion of the specified curing period the resulting exposed concrete surfaces shall be wet cured for the remaining days.
  - D. The temperatures shall be monitored and recorded every four hours for the first 72 hrs after concrete placement and every 8 hours thereafter for the remainder of the specified cure period.
    1. Two thermocouples, one in the centre and one at the surface of the concrete, shall be supplied and installed for every 100 m<sup>2</sup> of deck.

#### 4-4.4.19 Dimensional Tolerances

- A. Except across the crown, deck and deck overlay surfaces of Transportation Structures shall be such that when checked with a 3 m long straight edge placed anywhere in any direction on the surface, there shall not be any gap greater than 5 mm between the bottom of the straight edge and the surface of the deck concrete. Parging or surface patching to correct irregularities will not be permitted.
  1. Areas that do not meet the required surface accuracy shall be clearly marked out and repaired by the following:
    - a. any areas higher than 5 mm but not higher than 10 mm above the correct surface shall be ground down;
    - b. any areas lower than 5 mm but not lower than 10 mm below the correct surface, shall be corrected by grinding down the adjacent high areas; and
    - c. when the deviation exceeds 10 mm from the correct surface, the deck or deck overlay shall be replaced for a length, width and depth which will allow the formation of a new deck or deck overlay, of the required quality, in no way inferior to the adjacent undisturbed slab.
  2. Grinding shall be carried out by a machine, of a type and capacity suitable for the total area of grinding involved, until the surface meets the requirements of this Section 4-4.4.19.
- B. Slab and floor surfaces of Building Structures shall meet the requirements of Section 7.5 of CAN/CSA A23.1.
- C. Formwork misalignment for visible components which can be viewed within a distance of 6 m shall be such that when checked with a 1.5 m long straight edge placed anywhere in any direction on the surface, there shall not be any gap greater than 3 mm between the bottom of

the straight edge and the concrete surface. The gap for formwork misalignment of all other components shall not be greater than 6 mm. Concrete elements with formwork misalignments exceeding the allowable tolerances shall be removed and recast.

- D. Dimensional tolerances for concrete segmental construction shall be in accordance Section 4-4.7.3 [*Dimensional Tolerances*] of this Schedule.
- E. The maximum angular deviation of a concrete surface from that shown on the applicable Final Design shall not exceed 0.001 radians.

#### 4-4.4.20 Concrete Deficiencies or Early Handover Deficiencies

- A. Concrete Deficiencies or Early Handover Deficiencies such as honeycombs, cavities and related defects shall be repaired as required to restore the concrete to its initial intended condition.
  - 1. Concrete Deficiencies or Early Handover Deficiencies are those areas that are greater than 30 mm in depth or 0.05 m<sup>2</sup> in area. Defects less than 30 mm in depth or 0.05 m<sup>2</sup> in area shall be repaired in accordance with Section 4-4.4.21.3 [*Class 2 Rubbed Surface Finish*] of this Schedule.
  - 2. Concrete Deficiency or Early Handover Deficiency repair procedures shall be developed, signed and sealed by a Professional Engineer prior to the commencement of the repair.
  - 3. As a minimum, the repair procedure for concrete Deficiencies or Early Handover Deficiencies shall include removing and replacing the defective concrete with the originally specified class of concrete or a non-shrink patching product on the Alberta Transportation Approved Product List.
  - 4. Repair extents shall be saw cut 25 mm deep in neat perpendicular lines and concrete removed to a depth of 35 mm below reinforcing steel.
  - 5. Repair areas shall be roughened to remove all loose material and laitance. Exposed reinforcing steel shall be cleaned and repaired to its original condition.
  - 6. Repair areas shall be saturated with water for a period of 24 hours prior to repair concrete placement. Repair areas shall be free of standing water immediately prior to concrete placement.
  - 7. Curing shall be in accordance with the requirements of the class of concrete.
- B. Concrete Deficiencies or Early Handover Deficiencies such as cracks with widths equal to or greater than 0.2 mm shall be repaired as required to restore the concrete to its initial intended condition.
  - 1. After the curing period, the dry concrete surface(s) shall be inspected and cracks identified and plotted. The crack widths shall be recorded in millimetres and the crack lengths in metres.
  - 2. Cracks with widths equal or greater than 0.2 mm shall be repaired by epoxy injection or an alternative procedure accepted by the City.
  - 3. All repair procedures shall be developed, signed and sealed by a Professional Engineer prior to the commencement of the repair.
- C. Deficiencies or Early Handover Deficiencies in girders constructed using segmental concrete construction shall be assessed in accordance with Section 4-4.5.11.2 [*Precast Concrete Girder and Girder Segment Deficiencies or Early Handover Deficiencies*] of this Schedule.

#### 4-4.4.21 **Concrete Surface**

##### 4-4.4.21.1 **General**

- A. Prior to concrete surface finishing, all surfaces shall conform to the requirements of Section 4-4.4.20 [*Concrete Deficiencies or Early Handover Deficiencies*] of this Schedule.
- B. The finished surface of the concrete shall conform to the design grades and lines shown on the applicable Final Design.
- C. Building Structure concrete surface finishes shall be at the discretion of the Designer unless an architectural finish is required in accordance with Section 2-11.2.1 [*Concrete Finish*] of this Schedule.
- D. Transportation Structure exposed concrete surfaces to 600 mm below grade or, in the case of river piers, to 600 mm below lowest water level shall receive one of the following finishes.
  - 1. Class 1 Ordinary Surface Finish:
    - a. all exposed formed concrete surfaces unless other finishes are specified; and
    - b. top surfaces of abutment seats, retaining walls and pier caps.
  - 2. Class 2 Rubbed Surface Finish:
    - a. all exposed formed concrete surfaces except for the underside of decks between girders.
  - 3. Class 3 Bonded Concrete Surface Finish:
    - a. none unless otherwise specified.
  - 4. Class 4 Floated Surface Finish:
    - a. top surfaces which are to receive waterproofing membranes and wearing surfaces.
  - 5. Class 5 Floated Surface Finish, Broomed Texture:
    - a. exposed unformed top surfaces unless other finishes are specified;
    - b. approach slab concrete which will be covered by a wearing surface only (without waterproofing membrane); and
    - c. concrete slope protection.
  - 6. Class 6 Floated Surface Finish, Surface Textured:
    - a. top surfaces that will be used by vehicular Roadway traffic but will not be covered with either waterproofing membrane or wearing surface.

##### 4-4.4.21.2 **Class 1 Ordinary Surface Finish**

- A. Unformed Surfaces
  - 1. The concrete shall conform to the required surface elevations, and the surface shall be free from open texturing, plucked aggregate, and local projections or depressions.



2. Concrete surfaces shall be such that when checked with a 1.2 m long straight edge placed anywhere in any direction on the surface, there shall not be any gap greater than 3 mm between the straight edge and the concrete surface.

**B. Formed Surfaces**

1. The cavities produced by form ties, and all other holes, honeycomb areas, broken corners or edges and other such Deficiencies or Early Handover Deficiencies, shall be thoroughly chipped out, cleaned, and filled with a patching product.
  - a. The patching product shall be on the Alberta Transportation Approved Products List, appropriate for the intended application, and placed in accordance with the manufacturer's recommendations.
  - b. All repairs shall be wet cured for a minimum of 72 hours. Curing compounds are not permitted.
2. All fins and irregular projects shall be removed immediately after removal of the forms.

**4-4.4.21.3 Class 2 Rubbed Surface Finish**

- A. The finish shall have a smooth, uniform and closed texture and shall be uniform in color. All cavities in the concrete shall be repaired. Any staining shall be prevented or removed.
1. Prior to finishing, all lines that do not meet tolerance requirements shall be corrected by grinding. Parging or surface patching to correct irregularities are not permitted.
  2. All concrete fins and irregular projections shall be removed from all surfaces immediately following the removal of the forms.
  3. Both sack rub and patching materials shall be wet cured for a minimum of 72 hours. Curing compounds are not permitted.
  4. The cavities produced by form ties, air bubbles and all other holes, honeycomb areas, broken corners or edges and any other such Deficiencies or Early Handover Deficiencies, shall be thoroughly exposed by diamond grinding wheels or similar tools. Surface voids greater than 19 mm diameter but less than 0.05 m<sup>2</sup> area or 30 mm or deeper shall be filled with a non-shrink patching product on the Alberta Transportation Approved Product List.
  5. The surface voids less than 19 mm in diameter and less than 30 mm deep shall be filled with a prebagged sack rub material. Sack rub materials shall be placed over the entire prepared surface in accordance with the manufacturer's recommendations.
  6. When the patching and sack rub materials have adequately cured, a carborundum stone shall be used to finish the surface to a smooth, uniform and closed texture. Any voids or cavities opened during the stone rubbing process shall be refilled.

**4-4.4.21.4 Class 3 Bonded Concrete Surface Finish**

- A. Surface finish requirements shall be as specified in Section 4-4.4.21.3 [*Class 2. Rubbed Surface Finish*] of this Schedule, except that uniformity in colour is not required.
- B. After the surface preparation has been completed, the concrete surfaces shall be cleaned to remove all dust, dirt, laitance and all other bond breaking materials.
1. The concrete surface shall be cleaned by pressure washing.



- C. A pigmented concrete sealer, which meets the requirements for a Type 3 sealer in the Alberta Transportation Approved Product List, shall be applied.
  - 1. The colour(s) of the coating scheme shall be similar to the natural colour of cured concrete. No colour variation shall be visible, and the colour shall match that of any previously painted adjoining surfaces.
  - 2. The pigmented concrete sealer shall not be applied until after the concrete surface has dried for a minimum of 24 hours.
  - 3. The pigmented concrete sealer shall be applied in accordance with the manufacturer's specifications and as a minimum two applications totaling the approved application rate of the pigmented sealer are required.
  - 4. When spray application is used the surface shall be back rolled.

#### 4-4.4.21.5 **Class 4 Floated Surface Finish**

- A. The concrete surface shall be floated and troweled to produce a smooth surface.
  - 1. The surface shall be manually floated with a magnesium bull float.

#### 4-4.4.21.6 **Class 5 Floated Surface Finish, Broomed Texture**

- A. The concrete surface shall be floated and trowelled to produce a smooth surface.
- B. After the concrete has set sufficiently, the surface shall be given a transversely broomed finish to produce regular corrugations to a maximum depth of 2 mm.
  - 1. The surface shall be manually floated with a magnesium bull float.
  - 2. A coarse broom shall be used to give the transversely broomed finish.
- C. An edging tool shall be used at all edges and expansion joints.
- D. Where indicated on the applicable Final Design, sidewalk surfaces shall be laid out in blocks using a grooving tool.

#### 4-4.4.21.7 **Class 6 Floated Finish, Surface Textured**

- A. The surface shall be floated and troweled to produce a smooth surface.
  - 1. The surface shall be manually floated with a magnesium bull float.
- B. After the concrete has been bull floated, the surface shall be given a texture. The texture shall be transverse grooving which may vary from 1.5 mm width at 10 mm centres to 5 mm width at 20 mm centres, and the groove depth shall be 3 mm to 5 mm.
  - 1. The work shall be done at such time and in such manner that the desired texture will be achieved while minimizing the displacement of the larger aggregate particles or steel fibres.
  - 2. The texturing shall be done with a "flatwire" texture broom having a single row of lines.
- C. Following surface texturing, a 300 mm wide strip of concrete along edges generally parallel to the span of the Structure shall be trowelled smooth and the surface left closed.

#### 4-4.4.22 **Type 1c Sealer**

- A. Type 1c sealers used shall be on the Alberta Transportation Approved Product List.
- B. The sealer shall be applied in accordance with the manufacturer's recommendations. However, the application rate shall be increased by 30% from that indicated on the Alberta Transportation Approved Product List.
  - 1. Before applying the sealer the concrete shall be cured for at least 28 days.
  - 2. The concrete surface shall be dry and all dust removed prior to applying sealer.
  - 3. Dust shall be removed by air blasting.
  - 4. In order to ensure uniform and compliant coverage rates measured volumes of sealing compound shall be applied to appropriately dimensioned areas of concrete surface, using a minimum of two coats.
  - 5. Asphalt concrete pavement surfaces shall be adequately protected from overspray and runoff during sealer application.

#### **4-4.5 PRECAST CONCRETE**

##### 4-4.5.1 **General**

- A. This Section 4-4.5 [*Precast Concrete*] sets out the requirements for all precast concrete forming part of a Structure including minimum requirements for the supply, manufacture, delivery and erection of prestressed and precast concrete.
  - 1. Precast concrete units include girders, precast concrete segments, MSE walls panels, full depth deck panels and partial depth deck panels.
  - 2. Requirements for pre-tensioning are given in this Section 4-4.5 [*Precast Concrete*] of this Schedule. Requirements for post-tensioning are given in Section 4-4.6 [*Post-Tensioning*] of this Schedule.
  - 3. Additional requirements for precast concrete segmental construction are given in Section 4-4.7 [*Concrete Segmental Construction*] of this Schedule.

##### 4-4.5.2 **Supply and Fabrication Standards**

- A. The precast concrete fabricator shall be fully certified by the Canadian Precast/Prestressed Concrete Institute (CPCI) Certification Program in the applicable Product Group classification.
- B. The manufacture of prestressed and precast concrete shall be in accordance with CAN/CSA A23.4.

##### 4-4.5.3 **Engineering Data**

###### 4-4.5.3.1 **Shop Drawings**

- A. Shop drawings showing all fabrication details of each precast concrete unit, such as reinforcing steel, blockouts, stressing system, anchorage devices, void support system and screed rail shall be prepared prior to fabrication and submitted to the City.

#### 4-4.5.3.2 **Stressing Calculations**

- A. Stressing calculations showing elongations and gauge pressures as well as the strand release sequence data shall be prepared for each prestressed concrete unit prior to fabrication.

#### 4-4.5.3.3 **Stressing Steel Certificates**

- A. A copy of the load/elongation curve for each lot of stressing steel shall be available at the precast concrete fabricator's plant.

#### 4-4.5.3.4 **Concrete Mix Design**

- A. Design all concrete mixes to provide concrete that:
  - 1. is sufficiently workable, for the applicable placement and finishing requirements;
  - 2. has sufficient durability to meet the Design Service Life of the Structure; and
  - 3. has sufficient strength to meet structural strength requirements.
- B. Submit concrete mix design together with applicable material test reports to the City before first placement of such concrete.
  - 1. The mix design shall indicate the design strength, proportions of the constituent materials, type and brand of cement, type and source of supplementary cementitious materials, origin of aggregates and brand names of all admixtures.
  - 2. The mix design, including sampling and testing of aggregates, shall be signed and sealed by a Professional Engineer engaged by an independent concrete testing laboratory certified to CAN/CSA A283. The certifying Professional Engineer shall also provide a professional opinion confirming that the concrete mix is suitable for the intended use and can be expected to meet all applicable Project Requirements over the Design Service Life of the Structure.
  - 3. Current test data fully representing the materials to be used in production and showing conformance to the required standards shall be submitted with the concrete mix design for the constituent materials.
  - 4. The minimum air content shall be 5% and the maximum air void spacing factor shall be 0.23 mm.
  - 5. The concrete mix design information shall include one microscopic air-void analysis performed by an independent testing laboratory in order to determine the spacing factor of the hardened concrete. If adjustments to the mix design are necessary, the air void analysis shall be repeated.
  - 6. The test sample used for the microscopic air-void analysis shall be made from a trial concrete batch, vibrated into a cylinder mould so as to represent the level of vibration of the production concrete in the forms.
- C. Only the reviewed mix design shall be used to cast precast concrete.
  - 1. Changes in cement type, and/or decreasing cement content shall be construed as a change in mix design and will not be allowed.
- D. Any proposed modifications made to the concrete mix design shall be submitted to the City prior to their use.

#### 4-4.5.4 **Materials**

- A. All constituent materials for precast concrete shall be selected to provide concrete with sufficient durability to meet the Design Service Life requirements of the Structure and sufficient strength to meet structural strength requirements.
- B. Precast concrete shall consist of hydraulic cement, silica fume (if required), aggregates, water and admixtures.

##### 4-4.5.4.1 **Portland Cement**

- A. Portland cement shall comply with the requirements of CAN/CSA A3001.

##### 4-4.5.4.2 **Water**

- A. Water for mixing concrete, patching products, concrete finishing materials or mortar shall comply with CAN/CSA A23.1 and shall be free from harmful amounts of alkali, organic materials and other deleterious substances.
  - 1. Slurry water, treated wash water or water from shallow stagnant or marshy sources shall not be used.

##### 4-4.5.4.3 **Silica Fume**

- A. Condensed silica fume shall comply with CAN/CSA A3001, for a Type SF supplementary cementing material.
  - 1. A compatible superplasticizing admixture shall be used together with the silica fume.

##### 4-4.5.4.4 **Aggregates**

- A. Fine and coarse aggregates shall be normal weight and comply with CAN/CSA A23.1 and Section 4-4.4.4.2 [*Aggregate Tests*] of this Schedule.
  - 1. The maximum coarse aggregate size shall be 14 mm.

##### 4-4.5.4.5 **Admixtures**

- A. Admixtures shall be compatible with all mix constituents.
  - 1. Acceptable admixtures are air-entraining admixtures, superplasticizing admixtures and water-reducing admixtures.
- B. Air entraining admixtures shall comply with ASTM C260.
- C. Water reducing admixtures and superplasticizing admixtures shall comply with ASTM C494.
- D. All chemical admixtures shall be suitable for use in precast concrete, be supplied by the same manufacturer as the air entrainment agent, and be compatible with each other.
- E. Calcium chloride, accelerators, retarders or set controlling admixtures and air reducing admixtures are not permitted.

##### 4-4.5.4.6 **Voids and Ducts**

- A. All void and duct material shall remain dimensionally stable during the casting and curing of the precast concrete units.

1. Voids shorter than 400 mm shall be eliminated except when noted otherwise on the applicable Final Design.

#### 4-4.5.4.7 **Galvanizing**

- A. Galvanizing of steel shall be by the hot dip method, after fabrication, in accordance with ASTM A123/A123M Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products and ASTM A153/A153M Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
  1. A smooth finish shall be provided on all edges and surfaces, and all weld spatter and welding flux residue shall be removed from steel components prior to galvanizing.
- B. Galvanizing repairs shall provide a coating that has a minimum thickness of 180 µm, adheres to the member and has a finished appearance similar to that of the adjacent galvanizing.
  1. Galvanizing repair shall comply with ASTM A780, Method A3 "Metallizing" unless the area requiring repair does not exceed 100 mm<sup>2</sup> in which case the repairs may comply with ASTM A780 Method A1 "Repair Using Zinc-Based Alloy".
  2. Galvanizing repairs shall be tested for adhesion.
  3. Repairs may require complete removal of the galvanized coating and re-galvanizing.

#### 4-4.5.4.8 **Epoxy Bonding Agents**

- A. Epoxy bonding agents shall comply with Section 8.13.7 of the AASHTO LRFD BCS.

#### 4-4.5.5 **Fabrication**

##### 4-4.5.5.1 **Forms**

- A. Precast concrete units shall be manufactured in steel forms which have sufficient strength and rigidity to ensure that the finished precast concrete units conform to the design dimensions. The forms shall be mortar tight and set on a rigid foundation.
  1. The forms shall be designed such that they can be removed without damaging the precast concrete unit.
  2. For all "I" or "T" beam members, the side forms shall be removed horizontally away from the member by a method that prevents any contact of the form with the top flange after release of the form. The top flange shall not be subjected to a vertical force at any time.
- B. Match-cast precast concrete segments shall be separated carefully so as to avoid damage to the mating surface between the segments. New cast segments shall be carefully separated from the bulkhead forms.
  1. A bond breaking material shall be used on the previously cast segment to facilitate separation of the segments.
- C. Precast concrete panels shall be cast flat.

##### 4-4.5.5.2 **Stressing Strand**

- A. Stressing strand shall be free from corrosion, dirt, grease, rust, oil and other foreign material that may impede the bond between the steel and the concrete.
  1. Stressing strand that has sustained physical damage at any time shall be rejected.

2. Stressing strand shall be protected at all times from manufacture through to encasing in concrete or grouting.
  3. Stressing strand with any broken wire shall be removed and replaced. All stressing strands shall be checked for wire breaks before placement of concrete.
- B. Stressing strand splices shall not be placed within a precast concrete unit.
- C. Each strand shall be stressed to a calculated elongation, and a gauge pressure reading shall be taken as a check against the calculated force.
1. During stressing, each strand shall be first pulled to a predetermined pre-pull gauge pressure to eliminate any slack and a reference mark shall be placed at the front of the stressing jack. A second mark shall be placed away from the first with a distance corresponding to the calculated elongation on the stressing sheet. Each strand shall then be pulled to the second reference mark and the gauge pressure reading taken.
  2. This process may be reversed, i.e. each strand shall be stressed to a calculated force (determined by a gauge pressure calibration chart) and the elongation shall be measured as a check against the calculated force. During stressing, each strand shall be first pulled to a predetermined pre-pull gauge pressure to eliminate any slack and a reference mark be placed at the front of the stressing jack. Each strand shall then be stressed to the gauge pressure corresponding to the stressing sheet and a second reference mark be placed at this gauge pressure. The elongation shall be the distance measured between the two reference marks.
  3. The maximum allowable discrepancy between jack pressure and elongation shall be within 5%.
  4. Alternatively, the factors contributing to the difference shall be identified and corrected before proceeding. Changes in strand temperature and slippage at strand anchorages shall be measured between stressing and concrete encasement. Any changes in strand stress due to these effects shall be accounted for in the design.
  5. All stressing jacks shall have been calibrated within six months prior to use.
  6. Elongation and tension of each strand during the stressing operation shall be documented.
  7. Stressing strands shall not be stressed for more than 36 hours prior to being encased in concrete.
- D. Stressing strand ends shall be protected as required to prevent corrosion of the strands.
1. The prestressed concrete unit ends shall have 15 mm deep strand termination recesses formed around the strands, unless otherwise specified. All strands shall be cut flush with the bottom of the recesses.
  2. The recesses shall be filled flush with the ends of the units with a moisture insensitive epoxy paste adhesive meeting the requirements of ASTM C881, Type IV, Grade 3, Class B or C. The paste shall be grey in colour.
  3. Strand termination recesses are not required for precast concrete partial depth deck panels provided the strand ends are sealed with a moisture insensitive epoxy paste adhesive meeting the requirements of ASTM C881, Type IV, Grade 3, Class B or C.

#### 4-4.5.5.3 **Void and Duct Placement**

- A. Voids and ducts shall be tied and securely held in their required positions to prevent movement. Continuous ducts shall align precisely.
- B. The ends of voids shall be sealed. Voids found to be distorted, damaged or of insufficient strength shall be rejected.
  - 1. Blow holes caused by air expanding within the voids and rising to the surface, shall be repaired when the concrete is in the plastic state.

#### 4-4.5.5.4 **Lifting Hooks**

- A. Lifting hooks shall not be located on exposed panel surfaces.

#### 4-4.5.5.5 **Concrete Measuring, Mixing and Placing**

- A. All constituent materials of precast concrete shall be accurately measured, mixed and placed such that the material properties of each concrete batch comply with the properties assumed by the concrete mix design.
- B. The procedures outlined in ACI Standard 304, Guide for Measuring, Mixing, Transporting and Placing Concrete shall be followed.
  - 1. The time from initial mixing of the concrete until placing the concrete in the forms shall not exceed one hour.
  - 2. The elapsed time between the successive placements of concrete onto previously placed concrete shall not exceed 45 minutes.

#### 4-4.5.5.6 **Concrete Temperature**

- A. The concrete temperature shall be between 10 degrees Celsius and 30 degrees Celsius at the time of placing concrete in the forms.

#### 4-4.5.5.7 **Camber Hubs**

- A. Three camber hubs shall be placed in each precast concrete girder, located along the centreline of the girder at the midpoint and 150 mm from each end.
  - 1. The girder camber at the midpoint of each girder shall be recorded within 24 hours of girder de-stressing.
  - 2. The camber hubs shall consist of 10 mm galvanized bars, of sufficient length to project vertically 10 mm above the riding surface.
  - 3. The members shall be stored in such a manner as to provide access for measuring camber.

#### 4-4.5.6 **Fabrication of Precast Concrete Units in Cold Weather**

- A. During cold weather adequate protection of the precast concrete units shall be provided to prevent freezing and to adequately cure the concrete.
  - 1. Cold weather shall include any weather when the ambient air temperature is, or is expected to be, below 5 degrees Celsius during fabrication.
- B. The following provisions for cold weather casting shall be put in place:

1. Before casting concrete, adequate preheat shall be provided to raise the temperature of the formwork, reinforcing steel, stressing strand, miscellaneous iron, etc. to at least 10 degrees Celsius.
2. The precast concrete unit shall be enclosed in such a way that the concrete and air temperature within the enclosure are maintained between 15 degrees Celsius and 30 degrees Celsius. The enclosure temperature shall be constantly monitored.
3. The precast concrete units shall be kept in the enclosure until they are patched, repaired and transferred to the curing enclosure.
4. The enclosure shall be constructed large enough to accommodate steel forms, workers and the casting equipment.
5. The system of heating, shall give a uniform distribution of heat. Adequate ventilation shall be provided to provide air for combustion and to prevent the accumulation of carbon dioxide.

#### 4-4.5.7 **Inspection and Testing**

- A. Inspection and testing shall be carried out as required to confirm that the concrete has the required properties.
- B. Sampling of concrete shall comply with CAN/CSA A23.2-1C.
- C. Air content and density tests shall comply with CAN/CSA A23.2-4C and A23.2-6C.
- D. Air void determination testing shall comply with CAN/CSA A23.2-17C.
- E. The City shall be afforded full and safe access for any independent testing and inspection of the precast concrete units at any time. The following equipment shall be provided by Project Co. at the time of testing or inspection:
  1. cylinder storage box with temperature control and a max/min. thermometer, as per CAN/CSA A23.2-3C; and
  2. a calibrated weigh scale.

##### 4-4.5.7.1 **Test Cylinders**

- A. Test cylinders shall be cast and tested to determine the 28-day compressive strength.
  1. Samples for testing shall be taken from the fresh concrete being placed in the forms at the rate of one set of cylinders for every 20 m<sup>3</sup> of concrete cast continuously. A set shall consist of a minimum of three cylinders.
  2. Making and curing concrete test cylinders shall comply with CAN/CSA A23.2-3C.
  3. Testing of concrete cylinders shall comply with CAN/CSA A23.2-9C.
  4. Testing shall be conducted by an independent CSA certified testing laboratory.

##### 4-4.5.7.2 **Strength Tests**

- A. A "Strength Test" shall be the average of the 28-day strengths of the three cylinders (one set).
  1. Continuous casting shall mean no break in the casting longer than one hour.



- B. Test cylinders for “Release Strength Tests” shall be cast and tested to prove that the required release strength as stated on the applicable Final Design has been attained prior to release of the stressing strand.
  - 1. When one or more units are cast continuously, at least two cylinders shall be taken from the concrete of the last unit poured to represent the release strength for all units. These cylinders shall be cured with the unit. Only testing of the first cylinder will be necessary if the required release strength is obtained.

#### 4-4.5.7.3 Under Strength Concrete

- A. Concrete with 28 day “Strength Test” results less than 100% of the compressive strengths specified in the applicable Final Design shall be removed and replaced unless otherwise accepted by the City in its discretion.
- B. When permitted by the City coring to confirm or contest low concrete “Strength Test” results shall be performed as follows:
  - 1. The cores shall be taken and tested within seven days of the testing of the 28-day cylinders representing the concrete in question.
  - 2. Three 100 mm diameter cores shall be taken for each non-compliant “Strength Test” previously taken. The cores taken shall represent the same batch of concrete as the cylinders under consideration.
  - 3. Cores shall be tested by an independent CSA certified testing laboratory and in accordance with the requirements of CAN/CSA A23.2-14C. CAN/CSA A23.1, Clause 4.4.6.6.2 “Cores drilled from a structure” shall not apply. The average strength of the cores as reported by the independent testing laboratory shall constitute a “Strength Test”.
  - 4. The core test will represent all precast concrete units represented by the “Strength Test”.
  - 5. Alternatively, core tests for “Strength Tests” may be taken from each of the other units in question, in which case each of these “Strength Tests” will then represent a unit.
- C. Submit all core results to confirm or contest low concrete “Strength Test”.
- D. In cases where the concrete strength, as indicated by the cores, is higher than the strength based on the concrete cylinder results, the core results shall be used as the basis for acceptance of the concrete. If the core strengths are lower than the strength from the concrete cylinder tests, the cylinder tests shall govern.

#### 4-4.5.8 Release of Stressing Strand

- A. Stressing strand shall not be released until the specified concrete release strength is attained.
- B. Release of the strands shall be in accordance with the required destressing sequence.
- C. Major honeycombs and spalls shall be repaired prior to release of the strands.

#### 4-4.5.9 Curing

##### 4-4.5.9.1 General

- A. All precast concrete units shall be cured at an elevated temperature. The curing of precast concrete units shall be in accordance with CAN/CSA A23.4 unless otherwise specified.
- B. Precast concrete units shall be protected from thermal shock at all times until fully cured.

1. The ambient curing temperature shall be increased at a rate not exceeding 20 degrees Celsius per hour until a maximum temperature of not more than 60 degrees Celsius is attained.
2. After curing, the temperature of the units shall be reduced at a rate not exceeding 10 degrees Celsius per hour until the temperature of the concrete has fallen to within 10 degrees Celsius of the ambient temperature outside the enclosure.

#### 4-4.5.9.2 Curing Prestressed Concrete

##### A. Curing in the Form

1. The initial application of heat shall commence only after the last of the freshly placed concrete has attained its initial set.
2. Heat shall not be applied directly to the concrete but by a method that will produce a consistent ambient temperature throughout the entire form and enclosure.
3. The increase in temperature and the holding temperature shall be monitored and permanently recorded on a chart at a minimum of 3 quarter points along the form.

##### B. Curing After Removal from the Form

1. Upon removal from the form the unit shall be cleaned, patched and finished within a period not exceeding 12 hours.
2. The unit shall be placed in a manner that will facilitate any clean up or repair work, and that will allow full inspection of all surfaces.
3. Within 24 hours of removal from the form, the unit shall be placed within an enclosure, for curing.
4. The curing enclosure shall provide a minimum of 150 mm of free air space between the concrete surfaces and the coverings. Flexible coverings shall be secured to prevent any moisture loss.
5. The difference in ambient air temperature adjacent to the concrete at different locations within the enclosure shall not exceed 10 degrees Celsius at any time.

##### C. The curing process shall be continued for a period of at least 4 days with one of the following methods:

###### 1. Steam Curing

- a. The steam shall be in a saturated condition maintaining an atmosphere of 95% to 100% relative humidity and a uniform ambient temperature between 40 degrees Celsius and 60 degrees Celsius.
- b. Steam jets shall not directly impinge on the concrete surfaces.
- c. For days with periods of four or more hours within a 24-hour period, where measured temperature or humidity levels do not meet the required limits, these days will not count as a full day of steam cure. An additional full day of steam cure beyond the specified four days will be required for each non-compliant day.

###### 2. Curing with Continuous Misting and Heat

- a. The enclosure shall be heated to a temperature of between 40 degrees Celsius and 60 degrees Celsius at a relative humidity of 95% to 100%.
  - b. A sufficient number of atomizing misting nozzles shall be strategically located to produce a fine mist with 95% to 100% relative humidity in the enclosure.
  - c. The water shall be preheated to a temperature which will produce a misting temperature compatible with the ambient temperature.
  - d. The enclosure shall be heated with radiant heaters.
  - e. Dry heat shall not touch the concrete surface at any time. A control system shall be installed to shut off the heat when the humidity level drops below 90% in the enclosure.
  - f. Should the temperature in the concrete rise above 40 degrees Celsius without the misting, the unit will be rejected.
3. Two continuously recording thermometers and two continuously recording hygrometers shall be provided for each curing enclosure to monitor the concrete and curing rates. All time-temperature and time-humidity recordings shall be clearly shown on a graph.

#### 4-4.5.9.3 Curing Non Prestressed Concrete

- A. Curing of all non prestressed concrete shall be in accordance with one of the following methods unless otherwise specified:
  1. Elevated Temperature Curing:
    - a. Upon removal from the forms the units shall be cleaned, patched, finished and elevated temperature cured for four days as per Section 4-4.5.9.2 [*Curing Prestressed Concrete*] of this Schedule.
  2. Moist Curing:
    - a. Upon removal from the forms the units shall be cleaned, patched, finished, and ready for inspection within a period not exceeding 12 hours;
    - b. Patching shall be performed with a product on the Alberta Transportation Approved Product List and at an ambient temperature of between 15 degrees Celsius to 30 degrees Celsius;
    - c. After completion of patching and finishing and within 24 hours of removal from the form, the unit shall be moist cured at an ambient temperature of not less than 15 degrees Celsius for a minimum period of seven days; and
    - d. Two layers of white coloured filter fabric shall be placed on the concrete and kept in a continuously wet condition throughout the curing period by means of soaker hoses or other means unless otherwise specified.
- B. Curing for MSE wall panels shall also conform to the following requirements:
  1. Saturation of the face of the panels in preparation for the repair of surface cavities shall begin immediately after stripping. During repair of surface cavities, and up to the start of elevated temperature curing or moist curing, panels faces shall be kept in a continuously wet condition; and

2. As an alternative to moist curing with filter fabric, panels may be moist cured in an enclosure with a controlled temperature and humidity environment such that all exposed concrete surfaces remain saturated for the duration of the curing period. If stacked during curing, sufficient space shall be maintained between panels to permit airflow and inspection of surfaces.

**4-4.5.10 Dimensional Tolerances**

- A. Precast concrete unit surfaces shall meet the requirements of Section 4-4.4.19B [*Dimensional Tolerances*] of this Schedule.

**4-4.5.10.1 Dimensional Tolerances of Precast Concrete Girders**

- A. The maximum dimensional deviation in mm, of precast concrete girders from the dimensions shown on the applicable Final Design shall not exceed the following:

Table 4-4.5.10-1 Dimensional Tolerances of Precast Concrete Girders

Length	$\pm 20 \text{ mm} \times \text{length (m)} \div 50$
Width	$\pm 3 \text{ mm}$
Depth	$\pm 5 \text{ mm}$
Camber	$\pm 20 \text{ mm} \times \text{length (m)} \div 50$
Sweep (NU Girders)*	1 mm/m
Sweep (Other Girders)*	deviation from true, $20 \text{ mm} \times \text{length (m)} \div 50$
Projection of Stirrups above Top of Girder	$\pm 12 \text{ mm}$
Bearing Areas	out of flatness of bearing areas, 3 mm
Bulkheads	warpage or tilt of ends, 5 mm
Barrier Anchor Bolts	out of line, 5 mm
	in spacing, 5 mm
	in projection, 5 mm
Dowel Holes	out of plumb, 5 mm
Void Location	surface to void dimension, $\pm 15 \text{ mm}$ after casting

\* Measured in the plant immediately prior to shipping to Site.

**4-4.5.10.2 Dimensional Tolerances of Precast Concrete Girder Segments**

- A. Dimensional Tolerances for precast concrete segmental construction shall be in accordance with Section 4-4.7.3 [*Dimensional Tolerances*] of this Schedule.

**4-4.5.10.3 Dimensional Tolerances of Precast Concrete Full Depth and Partial Depth Deck Panels**

- A. The maximum dimensional deviation in mm, of precast concrete full depth and partial depth deck panels from the dimensions shown on the applicable Final Design shall not exceed the values shown in Table 4-4.5.10-2 [*Dimensional Tolerances of Precast Concrete Full Depth and Partial Depth Deck Panels*]:

Table 4-4.5.10-2 Dimensional Tolerances of Precast Concrete Full Depth and Partial Depth Deck Panels

Length <sup>1</sup>	± 5 mm
Width <sup>2</sup>	± 5 mm
Thickness	+ 5 mm, - 3mm
Maximum difference in plan view diagonal dimensions (squareness) of rectangular panels	10 mm
Location of reinforcing steel projecting out of units	+5, - 0 mm

<sup>1</sup> As measured perpendicular to the girder lines.

<sup>2</sup> As measured parallel to the girder lines.

- B. For prestressed panels, strands shall be located with a vertical tolerance of +0 mm, -3 mm, measured from the soffit and a horizontal tolerance of ± 10 mm.
- C. Deviation from straightness of panel edges along the transverse joint between adjacent panels shall not exceed 1.5 mm per metre length.
- D. For partial depth panels, vertical bowing of panels out of plane, after casting and immediately prior to erection, in the direction of measurement, shall not be greater than the panel length /360 or the panel width /360, whichever is less, and in no case shall it exceed 10 mm maximum.
- E. For full depth panels, the deviations from straightness of the top surface or soffit shall not exceed 3 mm when checked with a 3 m straight edge placed in any direction.
- F. The maximum deviation of any panel corner from a plane formed by the remaining 3 corners shall be 5 mm per metre of distance from the nearest adjacent corner.

#### 4-4.5.10.4 Dimensional Tolerances of Precast Concrete MSE Wall Panels

- A. The maximum dimensional derivations of precast concrete MSE wall panels from the dimensions shown on the applicable Final Design shall meet the requirements of CAN/CSA A23.4.
- B. The variation in panel face trueness for any line across a panel face from a straight edge shall be no more than 2 mm over 1 m.

#### 4-4.5.11 Concrete Deficiencies or Early Handover Deficiencies

##### 4-4.5.11.1 General

- A. Concrete Deficiencies or Early Handover Deficiencies such as cracks, honeycombs, spalls or other defects shall be repaired as required to restore the concrete to its initial intended condition.
- B. Repairs to all concrete Deficiencies or Early Handover Deficiencies shall be carried out in accordance with this Section 4-4.5.11 [*Concrete Deficiencies or Early Handover Deficiencies*].

- C. All repair procedures shall be developed, signed and sealed by a Professional Engineer prior to the commencement of the repair.
- D. All repairs shall be completed prior to curing of the unit and at an ambient temperature of 15 degrees Celsius to 30 degrees Celsius. The unit shall be protected from dehydrating prior to curing.
  - 1. Repair of concrete Deficiencies or Early Handover Deficiencies shall be done in a sheltered environment and repairs shall not be performed in freezing or windy conditions or in direct sunlight.

**4-4.5.11.2 Precast Concrete Girder and Girder Segment Deficiencies or Early Handover Deficiencies**

- A. In this Section 4-4.5.11.2, the “bearing area” of a girder or girder segment used for precast concrete segmental construction is defined as the portion of the girder bottom flange up to the underside of the web, but not including the transition between the bottom flange and the web, directly above the bearing. The bearing area extends from the end of the girder to 75 mm beyond the inside edge of the bearing. The “anchorage area” of a girder is defined as the full-height portion of the girder that is within two times the girder depth from the termination of a stressing strand but is not in the bearing area.
- B. Cracks
  - 1. The following cracks shall result in rejection of the girder or girder segment unless otherwise accepted by the City in its discretion based on an engineering assessment of the effects of the cracks on the ability of the concrete unit to meet the Project Requirements:
    - a. cracks in the bearing area of a girder;
    - b. cracks in the anchorage area of a girder exceeding 0.5 mm in width for pre-tensioning anchorage areas and 0.2 mm in width for post-tensioning anchorage areas; and
    - c. cracks outside of the girder bearing and anchorage areas exceeding 0.2 mm in width or longer than 300 mm.
  - 2. Subject to the City’s acceptance of the engineering assessment for crack repairs, pursuant to Section 4-4.5.11.2B1 [*Precast Concrete Girder and Girder Segment Deficiencies or Early Handover Deficiencies*], all repairable cracks 0.2 mm or greater in width shall be repaired by epoxy injection in accordance with the manufacturer’s instructions. Coring shall be carried out to confirm the penetration of the epoxy into the crack.
- C. Honeycombs and Spalls
  - 1. The following conditions of honeycomb or spall shall result in rejection of the girder or girder segment unless otherwise accepted by the City in its discretion based on an engineering assessment of the effects of the honeycombs or spalls on the ability of the concrete unit to meet the Project Requirements:
    - a. any honeycombs or spalls in the bearing or anchorage areas of a girder or girder segment; and

- b. major honeycombs or spalls in areas outside the bearing or anchorage areas of a girder or girder segment. Major honeycombs and spalls are honeycombs and spalls that are more than 30 mm deep or more than 0.1 m<sup>2</sup> in area.
2. Subject to the City's acceptance of the engineering assessment for honeycomb and spall repairs, pursuant to Section 4-4.5.11.2C1 [*Precast Concrete Girder and Girder Segment Deficiencies or Early Handover Deficiencies*], all repairs for honeycombs and spalls shall be made using a cementitious material.

#### 4-4.5.11.3 Precast Concrete Panel Deficiencies or Early Handover Deficiencies

- A. A panel having any one of the following Deficiencies or Early Handover Deficiencies shall be rejected:
  1. panels with honeycombing, voids, cavities or spalls when the depth exceeds 30 mm or when the area of defect exceeds 150 mm x 150 mm;
  2. panels with cracks that are deeper than 25 mm or wider than 0.3 mm;
  3. panels with any crack located parallel to or over the strands or reinforcing steel;
  4. exposed MSE wall panel faces with honeycombing, voids, spalls or broken corners;
  5. exposed MSE wall panel faces with any surface cavities greater than 10 mm in diameter;
  6. exposed MSE wall panel faces with more than 3 surface cavities per square metre with cavity diameters from 5 mm up to 10 mm; and
  7. exposed MSE wall panel faces with more than 10 surface cavities per square metre with cavity diameters from 2 mm up to 5 mm.

#### 4-4.5.12 Concrete Finish

##### 4-4.5.12.1 General

- A. Prior to concrete surface finishing, all surfaces shall conform to the requirements of Section 4-4.5.11 [*Concrete Deficiencies or Early Handover Deficiencies*] of this Schedule.
- B. The finished surface of the concrete shall conform to the design grades and lines shown on the applicable Final Design and be free from open texturing, plucked aggregate and local projections or depressions.
- C. Building Structure concrete surface finishes shall be at the discretion of the Designer unless an architectural finish is required in accordance with Section 2-11.2.1 [*Concrete Finish*] of this Schedule.
- D. The determination of the applicable Transportation Structure exposed concrete surface classification shall be in accordance with the list provided in Section 4-4.4.21.1 [*General*] of this Schedule. On the basis of this classification, the finish shall meet the requirements set out in this Section 4-4.5.12 [*Concrete Finish*].
- E. Unless otherwise specified, the top riding surface of a precast concrete unit shall have a smooth profile, which incorporates the required camber adjustments.
- F. The top surface of partial depth deck panels shall be clean, free of laitance, and roughened to a 3 mm amplitude with spacing not greater than 15 mm with grooves parallel to strands.

- G. Concrete surfaces that will have field concrete cast against them shall be sandblast roughened. The blasting shall be sufficient to remove all laitance and uniformly expose the aggregate particles.

#### 4-4.5.12.2 **Class 1 Form Surface Finish**

- A. The finished surfaces shall be true and uniform.
- B. All fins, honeycomb, irregularities, cavities over 10 mm diameter and other similar defects shall be thoroughly chipped out and repaired.
- C. All repairs shall be saturated with water for a period of not less than 30 minutes, and pointed and trued with mortar of a colour which will match the adjacent concrete. Mortar used for pointing shall be less than one hour old.
  - 1. After repairs, the finish texture shall be equivalent to a steel form finish and not a washed or rubbed finish.
- D. The repairs shall be cured by placing the repaired precast concrete unit in the curing enclosure for a period of four days immediately after patching.
- E. All surfaces which cannot be repaired shall be finished as specified for Class 2.
  - 1. This finish is essentially that obtained when concrete has been cast and adequately consolidated in a properly oiled steel form.

#### 4-4.5.12.3 **Class 2 Rubbed Surface Finish**

- A. A Class 2 Finish shall be the same as a Class 1 Finish except that all holes, cavities and defects shall be repaired so that the finished surface presents a smooth, true, dense, uniformly coloured, and non-stained appearance.
- B. All residue of form oil shall be removed from the surface.
  - 1. The concrete surfaces shall be thoroughly wire brushed to expose any hole or cavity prior to repairs.

#### 4-4.5.12.4 **Class 3 Bonded Concrete Surface Finish**

- A. Surface preparation shall be as specified for a Class 2 Finish, except that uniformity in colour is not required.
- B. After the surface preparation has been completed, the concrete surfaces shall be cleaned to remove all dust, dirt, laitance and all other bond breaking materials.
  - 1. The concrete surface shall be cleaned by pressure washing.
- C. The pigmented concrete sealer shall meet the requirements for a Type 3 sealer from the Alberta Transportation Approved Product List.
  - 1. The colour of the coating scheme shall be similar to the natural colour of cured concrete. No colour variation shall be visible and the colour shall match that of any previously painted adjoining surfaces.
  - 2. The pigmented concrete sealer shall not be applied until after the concrete surface has dried for a minimum of 24 hours.



3. The pigmented concrete sealer shall be applied in accordance with the manufacturer's specifications. A minimum of two applications, totalling the application rate of the pigmented sealer, are required.
4. When spray application is used the surface shall be back rolled.

#### 4-4.5.12.5 **Class 4 Floated Surface Finish**

- A. The surface shall be floated and trowelled to provide a closed, uniformly textured surface without brooming.

#### 4-4.5.12.6 **Class 5 Floated Surface Finish, Broomed Texture**

- A. The concrete surface shall be floated and trowelled to produce a smooth surface.
- B. After the concrete has set sufficiently, the surface shall be given a transversely broomed finish to produce regular corrugations to a maximum depth of 2 mm.
  1. Brooming shall be done when the concrete has set sufficiently to produce clear, crisp brooming marks which do not sag or slump, without tearing the surface or disturbing coarse aggregate particles.
- C. After final brooming the surface finish shall be free of porous spots, irregularities, depressions, pockets and rough spots.
- D. When measured using a 3 m long straight edge placed anywhere in any direction on the surface, there shall not be any gap greater than 5 mm between the bottom of the straight edge and the concrete surface.
- E. Except for on full depth deck panels, edging tools shall be used on all edges after brooming.

#### 4-4.5.12.7 **Class 6 Floated Finish, Surface Textured**

- A. The surface shall be floated and troweled to produce a smooth surface.
- B. After the concrete has been bull floated, the surface shall be given a texture. The texture shall be transverse grooving which may vary from 1.5 mm width at 10 mm centres to 5 mm width at 20 mm centres, and the groove depth shall be 3 mm to 5 mm.
  1. The work shall be done at such time and in such manner that the desired texture will be achieved while minimizing the displacement of the larger aggregate particles or steel fibres.

#### 4-4.5.13 **Sealers**

- A. Type 1c sealers used shall be on the Alberta Transportation Approved Product List.
- B. The sealer shall be applied in accordance with the manufacturer's recommendations. However, the application rate shall be increased by 30% from that indicated on the Alberta Transportation Approved Product List.
  1. Before applying the sealer the concrete shall be cured for at least 14 days. Patches shall be cured for at least 2 days.
  2. The concrete surface shall be dry and all dust and form oil removed prior to applying sealer.
  3. Dust shall be removed by air blasting.

4. In order to ensure uniform and compliant coverage rates measured volumes of sealing compound shall be applied to appropriately dimensioned areas of concrete surface, using a minimum of two coats.
- C. Sealer shall not be applied in areas of the girders that will have field concrete cast against them.

#### 4-4.5.14 Handling and Storage

- A. Precast concrete units shall be handled and stored in a manner that avoids cracking, warping or any other permanent deformations, staining, chipping, or spalling of the member.
1. Precast concrete units shall be handled by means of lifting devices at designated locations.
  2. Precast concrete units shall be stored clear of the ground on blocking where they will not be exposed to splashing.
  3. Precast prestressed concrete units shall be maintained in an upright position, on stable foundations.
  4. Panels with discoloured or stained exposed surfaces shall not be used.
  5. Precast concrete panels shall be protected from salt spray during shipping.
  6. Precast concrete panels shall be stored flat.

##### 4-4.5.14.1 Precast Concrete Segments

- A. Care shall be exercised in the handling of precast concrete segments to prevent damage to them. Handling shall only be done using the devices shown on the shop/working drawings for this purpose. Lifting devices incorporated into any segment shall be adequate to distribute the handling and erection stresses so as not to damage the segment.
- B. Precast concrete segments shall be stored level in the deck upright position and shall be firmly supported on a symmetrical three point bearing system under the webs at the location's shown on the shop/working drawings. The storage area of the segments shall be of suitable stability to prevent differential settlement of the segment supports, resulting in any unstable storage condition during the entire period of storage. Segments shall be stored in sequential order so that the uniform appearance of the segments is readily apparent.
- C. Prior to shipment, each precast concrete segment shall be inspected for damage. The faces of all match cast joints shall be thoroughly cleaned of laitance, bond breaking compound and any other foreign material by wire brushing or light sandblasting. During transport, firm support of the segment shall be provided and the segments shall be fully secured against shifting. Upon arrival at the erection site, each segment shall again be inspected. Incorporation or utilization of any segments with Deficiencies or Early Handover Deficiencies into the Structure shall not be permitted unless accepted by the City in accordance with Section 4-4.5.11 [*Precast Concrete Girder and Girder Segment Deficiencies or Early Handover Deficiencies*].

#### 4-4.5.15 Erection of Precast Concrete Units

##### 4-4.5.15.1 General

- A. Precast concrete units shall be erected in a manner that does not damage or adversely affect the units.

1. No drilling, coring, nailing, installation of any fastening or anchoring systems, or any other modifications shall be made to the precast concrete units.
2. Precast concrete units shall not be erected until after any concrete that supports them has been cured a minimum of three days and achieved a minimum of 80% of the 28-day specified concrete strength requirements.

#### 4-4.5.15.2 Temporary Supporting Structures and Berms

- A. Temporary supporting structures and berms for the erection of precast concrete units shall be designed and constructed and maintained for the forces which may come upon them.
  1. Drawings for temporary supporting structures and berms shall be signed and sealed by a Professional Engineer.

#### 4-4.5.15.3 Erection of Precast Concrete Girders and Girder Segments

- A. A detailed erection procedure for the erection of precast concrete girders and girder segments shall be prepared in advance of the scheduled start of erection. The erection procedure shall include all drawings and documents necessary to describe the following:
  1. Earth berms, work bridges or other means required to access work;
  2. Type and capacity of equipment required for handling and erecting of precast concrete girders or girder segments;
  3. Sequence of operation, including position of cranes, trucks with precast concrete girders or girder segments, and Transportation Accommodation;
  4. Detailed crane position on the ground, particularly adjacent to substructure elements with details of load distribution on wheels and outriggers;
  5. Details of crane position on the Structure, showing wheel loads and axle spacing of equipment moving on Structure;
  6. Loads and their position from crane wheels and outriggers during all positions of lifting when crane is on Structure;
  7. Details of Temporary Work, including drawings and methods to be used to ensure the required position and stability of the precast concrete girders or girder segments prior to placing concrete, and/or post-tensioning;
  8. Details of lifting of girders or girder segments, showing forces at lifting hooks;
  9. Provisions for control and adjustment of errors in positioning girders or girder segments;
  10. Complete details of blocking for bearings where necessary to constrain movements due to horizontal forces and/or gravity effects; and
  11. Details of release of temporary supporting structures.
- B. The erection procedure shall be signed and sealed by a Professional Engineer, who shall assume full responsibility to ensure that the design is being followed.
- C. Precast concrete girder segments shall not be erected until they are a minimum of 14 days old and have achieved the minimum specified strength shown on the applicable Final Design.

- D. Erection of precast concrete girder segments shall only occur when the substrate temperature of the mating segment surfaces are in accordance with the epoxy manufacturer's requirements.

#### 4-4.5.15.4 Girder Adjustments

- A. Girder position, bearing location and bearing elevation shall be adjusted in order to achieve as closely as possible the lines and grades shown on the applicable Final Design.
- B. All cracks shall be inspected and locations shall be mapped if force is required to bring girders into alignment.

#### 4-4.5.15.5 Erection of Precast Concrete Full Depth Deck Panels

- A. All precast concrete full depth deck panels shall be erected true and installed in place without forcing or in any way that will induce undue stresses or cracking into any part of the Structure.
- B. The precast panels shall be erected so that their top surfaces meet the flatness criteria of Section 4-4.5.10.3 [*Dimensional Tolerances of Precast Concrete Full Depth and Partial Depth Deck Panels*] of this Schedule.
- C. The vertical profile and longitudinal alignment of the precast panels shall be within  $\pm 10$  mm of the design alignment after the entire Structure is constructed.
  - 1. Irregularities in the profile shall be addressed by grinding of the surface. If grinding of a surface is required to achieve tolerances the surface shall be transversely grooved to provide traction and visual uniformity.

#### 4-4.5.15.6 Erection of Precast Concrete Partial Depth Deck Panels

- A. Precast concrete partial depth deck panels shall be erected on temporary supports on the girders.
- B. The precast panels shall be erected so that the transverse joint between adjacent panels is never greater than 5 mm.
  - 1. All transverse joints shall be sealed with a grout on the Alberta Transportation Approved Product List.
- C. Cast-in-place concrete haunches beneath the panels shall be cast monolithically with the deck. The haunches shall be formed to be flush with the edge of the girder flanges.
  - 1. When casting the deck, place the girder haunch concrete first in continuous strips ahead of the rest of the concrete. Vibrate the concrete over the girders to ensure that the concrete completely fills the area under the precast panel overhangs and that trapped air on the vertical and horizontal formed surfaces of the haunch is minimized. Then place and vibrate the remaining deck concrete. This process shall be completed within a sufficiently short timeframe to ensure that a cold joint does not form between the haunch concrete and the rest of the deck concrete.

#### 4-4.5.15.7 Erection of Precast Concrete MSE Wall Panels

- A. The maximum placing deviations in mm, of MSE wall panels from the locations shown on the applicable Final Design shall not exceed the following:
  - 1. The out-of-flatness of wall surfaces measured in any direction shall not exceed 25 mm under a 3 m straight edge;
  - 2. The step in face of adjacent panel edges at joints shall not exceed 10 mm;

3. The joint taper shall not exceed 2.5 mm/m at any location;
  4. The overall out-of-vertical or near vertical alignment of the completed wall shall not exceed 4 mm/m of wall height from top to bottom of wall;
  5. The maximum variation in average joint width from the specified nominal width shall be 10 mm.
- B. To facilitate Construction of the cast-in-place concrete coping, nominal-sized, pre-formed holes in the top row of precast panels are permitted providing the holes are located a minimum 100 mm above the underside of the coping.

#### 4-4.5.15.8 **Lifting Hooks and Lifting Holes**

- A. After the precast concrete units are erected and positioned:
1. All lifting holes shall be filled with a grout listed on the Alberta Transportation Approved Product List; and
  2. All lifting hooks shall be cut off 50 mm below the surface, and filled with grout listed on the Alberta Transportation Approved Product List.

### **4-4.6 POST-TENSIONING**

#### 4-4.6.1 **General**

- A. This Section 4-4.6 [*Post-Tensioning*] sets out the requirements for all post-tensioning and grouting of cable ducts for cast-in-place and precast concrete forming part of a Structure.

#### 4-4.6.2 **Standards**

- A. Post-tensioning and grouting of cable ducts shall comply with the applicable requirements of the following standards:
1. CAN/CSA A23.1/23.2 – Concrete Materials and Method of Concrete Construction;
  2. CAN/CSA A23.4 – Precast Concrete Materials and Construction;
  3. Acceptance Standards for Post Tensioning Systems – PTI M50.1;
  4. Guide Specification for Grouted Post-Tensioning – PTI/ASBI M50.3;
  5. Specification for Grouting of Post Tensioned Structures – PTI M55.1; and
  6. AASHTO LRFD Bridge Construction Specifications (AASHTO LRFD BCS).

#### 4-4.6.3 **Engineering Data**

- A. Shop drawings providing a complete description and details of the post-tensioning system to be used shall be prepared and submitted to the City prior to installation of the ducts. The shop drawings shall include:
1. A description of the specific prestressing steel, anchorage devices, duct material and accessory items to be used;
  2. Properties of each of the components of the post-tensioning system;
  3. Details covering assembly of each type of post-tensioning tendon including ducts, inlets, outlets, anchorage system, grout caps, protection system materials and application limits;

4. Equipment to be used in the post-tensioning sequence;
  5. Procedure and sequence of operations for post-tensioning and securing tendons;
  6. Procedure for release and seating of the post-tensioning steel elements; and
  7. Parameters to be used to calculate the typical tendon force such as expected friction coefficients, anchor set, and prestressing steel relaxation curves.
- B. Stressing calculations showing the prestressing jacking sequence, jacking forces and initial elongations of each tendon at each stage of erection for all prestressing shall be prepared prior to stressing.
1. The stressing calculations shall include calculations to substantiate the prestressing system and procedures to be used including stress-strain curves typical of the prestressing steel to be furnished, friction losses and seating losses.
- C. The grout mix design, including the materials and proportions to be used for the grout, shall be prepared and submitted before first placement of such grout.
1. The grout mix design submission shall also include a description of the grouting procedures to be used as required by Section 4.6.1 of PTI M55.1.

#### 4-4.6.4 **Materials**

##### 4-4.6.4.1 **Prestressing Strand**

- A. Stressing strand shall conform to the requirements of Section 4-4.5.5.2 [*Stressing Strand*] of this Schedule.
- B. Corrosion inhibitor shall be used when the stressing and grouting operations are not completed within 20 calendar days of the installation of the stressing steel.
1. The corrosion inhibitor, when required, shall be water-soluble and shall have no deleterious effect on the steel, grout or concrete; or bond strength of steel to concrete.
- C. For unbonded tendons, two dynamic tests shall be performed on a representative anchorage and coupler specimen. The tendons shall, as a minimum, withstand, without failure, 500,000 cycles from 60 percent to 66 percent of its minimum specified ultimate strength and also 50 cycles from 40 percent to 80 percent of its minimum specified ultimate strength. Each cycle shall be taken as the change from the lower stress level to the upper stress level and back to the lower.
1. Different specimens may be used for each of the two tests.
  2. Systems utilizing multiple strands may be tested utilizing a test tendon of smaller capacity than the full-sized tendon. The test tendon shall duplicate the behavior of the full-size tendon and shall not have less than 10% of the capacity of the full-size tendons.

##### 4-4.6.4.2 **Anchorage**

- A. All stressing steel shall be secured at the ends by means of permanent anchoring devices. These devices shall comply with CAN/CSA S6, Section 8.4.4.1.

##### 4-4.6.4.3 **Ducts**

- A. Ducts shall be capable of withstanding concrete pressures without excessive deformation and shall prevent the entrance of cement paste into the ducts during the placement of concrete.

1. Internal ducts shall be corrugated plastic pipe. Smooth plastic pipe shall be used only for external ducts except that portions of external ducts in deviation blocks shall be galvanized rigid steel pipe.
  2. Ducts shall be positioned within  $\pm 5$  mm of their vertical and transverse positions. Positive methods shall be utilized to ensure that the ducts will not be displaced during concrete placement. Internal ducts shall be securely fastened at intervals not exceeding 600 mm.
  3. The ducts shall have sufficient rigidity to maintain the required profile between points of supports.
  4. Specific duct material properties shall be as follows:
    - a. Galvanized Rigid Steel Pipe: Steel pipe duct shall be galvanized steel pipe conforming to the requirements of ASTM A53, Type 3, Grade B. The nominal wall thickness of the pipe shall not be less than that of Schedule 40. The pipe shall be bent so as to accurately conform to the alignment of the tendon.
    - b. Corrugated Plastic Pipe: Corrugated plastic pipe duct shall be manufactured from polyethylene material meeting the requirements of ASTM D3350 with a cell classification of 345464A. The duct shall contain antioxidant(s) with a minimum Oxidation Induction Time (OIT) according to ASTM D3895 of not less than 20 minutes. The OIT test shall be performed on samples from the finished product. The minimum thickness of the duct shall meet the requirements of Table 10.8.3.1 of the AASHTO LRFD BCS.
    - c. Smooth Plastic Pipe: Smooth plastic pipe duct shall be manufactured from polyethylene material meeting the requirements of ASTM D3350 with a cell classification of 344464A. The duct shall contain antioxidant(s) with a minimum Oxidation Induction Time (OIT) according to ASTM D3895 of not less than 40 minutes. The OIT test shall be performed on samples from the finished product. The minimum thickness of the duct shall meet the requirements of Table 10.8.3.1 of the AASHTO LRFD BCS.
- B. Mortar tight inlets and outlets shall be provided in all ducts and shall have a nominal diameter of 20 mm. They shall be provided at least at the following locations:
1. The anchorage areas;
  2. All high points of the duct, when the vertical distance between the highest and lowest point is more than 500 mm; and
  3. At low points of the duct.
- C. Inlets and outlets shall be provided with valves, caps or other devices capable of withstanding the grouting pressure.
1. The inlets and outlets shall be securely fastened in place to prevent movement.
- D. Ducts shall be protected against ultraviolet degradation, crushing, excessive bending, dirt contamination and corrosive elements during transportation, storage and handling.
1. Ducts shall be furnished with end caps to seal the duct interior from contamination, and shipped in bundles that are capped and covered during shipping and storage.
  2. Supplied end caps with the duct shall not be removed until the duct is incorporated into the Structure.

3. Duct shall be stored in a location that is dry and protected from the sun.
4. Storage shall be on a raised platform and the ducts shall be completely covered to prevent contamination.
5. If necessary, ducts shall be washed before use to remove any contamination.

#### 4-4.6.4.4 **Concrete**

- A. Concrete shall be supplied in accordance with Section 4-4.4 [*Cast-In-Place Concrete*] of this Schedule.
  1. The maximum size of coarse aggregate shall be 10 mm and the 28-day compressive strength shall be a minimum of 50 MPa.

#### 4-4.6.4.5 **Grout**

- A. Grout shall be Class C as described in Table 10.9.3-1 of the AASHTO LRFD BCS. The properties of the grout shall be as described in Table 10.9.3-2 of the AASHTO LRFD BCS.
  1. In addition, a test for wet density shall be performed in accordance with the "Standard Test Method for Density" in ASTM C138.
  2. Materials with a total time from manufacture to usage in excess of six months shall be retested and certified by the supplier before use, or shall be replaced.
  3. Prebagged grouts shall be packaged in plastic lined bags or coated containers, stamped with the date of manufacture, lot number and mixing instructions.
- B. The average minimum compressive strength of 3 cubes at 28 days shall be a minimum of 50 MPa as per CSA A23.2-1B.
- C. Grout testing shall be performed in the field as follows:
  1. Strength Test
    - a. One strength test shall be performed for every four longitudinal ducts, except that a minimum of one strength test shall be performed for every girder line.
    - b. The strength test shall be carried out by an independent CSA certified laboratory.
  2. Bleed Test
    - a. At the beginning of each day's grouting operation, a wick induced bleed test shall be performed in accordance with ASTM C940 and with modifications noted in Table 10.9.3-2 of the AASHTO LRFD BCS.
    - b. The results of the bleed tests shall meet the requirements of Table 10.9.3-2 of the AASHTO LRFD BCS.
  3. Fluidity Test
    - a. For each tendon, a fluidity test shall be performed at both the inlet and the outlet in accordance with the standard ASTM C939 flow cone test or the modified ASTM C939 flow cone test.
    - b. The results of the fluidity tests shall meet the requirements of Table 10.9.3-2 of the AASHTO LRFD BCS.



#### 4. Wet Density Test

- a. For each tendon, a wet density test shall be performed in accordance with American Petroleum Institute Mud Balance Test API Practice 13B-1 "Standard Procedures for Field Testing Water-Based Drilling Fluids".

#### 4-4.6.5 Equipment

##### 4-4.6.5.1 Stressing

- A. Stressing shall conform to the requirements of Section 4-4.5.5.2 [*Stressing Strand*] of this Schedule.
- B. Hydraulic jacks and pumps with sufficient capacity shall be used for tensioning of strands so as to produce the forces in the strands shown on the applicable Final Design.
  1. The forces to be measured shall be within 25 and 75% of the total graduated capacity of the gauge, unless calibration data clearly establishes consistent accuracy over a wider range.
  2. The measuring devices shall be calibrated at least once every six months. The jack and the gauge shall be calibrated as a unit. A certified calibration chart shall be kept with each gauge.
  3. The pressure gauge shall have an accurate reading dial at least 150 mm in diameter.
- C. The force induced in the prestressing strand shall be measured using calibrated jacking gauges, load cells or a calibrated dynamometer.

##### 4-4.6.5.2 Grouting

- A. The grout shall be mixed using a high speed shear mixer that is capable of continuous mechanical mixing.
  1. The water supply to the mixer shall be measured by an accurate gauge.
- B. The grouting equipment shall have sufficient capacity to ensure that grouting of the longest duct can be completed within 30 minutes after mixing.
- C. The holding tank shall be capable of keeping the mixed grout in continuous motion until it is used.
  1. The outlet to the pump shall have a screen with 3 mm maximum clear opening.
- D. A positive displacement type pump shall be used which is capable of producing an outlet pressure of at least 1.0 MPa.
  1. A pressure gauge having a full-scale reading of no greater than 2 MPa shall be placed at some point in the grout line between the pump outlet and the duct inlet.
  2. A spare fully functional pump shall be on-site during all grouting operations.
- E. Grout hoses and their rated pressure capacity shall be compatible with the pump output and the maximum grout pressure. All connections from the grout pump to the duct shall be airtight so that air cannot be drawn into the duct.
- F. Standby flushing equipment with water supply shall be available at the Site prior to commencing grouting.

#### 4-4.6.6 **Construction**

##### 4-4.6.6.1 **Welding**

- A. Welding of stressing tendons shall not be permitted.
- B. Stressing tendons shall not be used as an electrical “ground”.
- C. Where the ends of strands are welded together to form a tendon so that the tendon may be pulled through the ducts, the length of the strands used as an electrical “ground” or 1.0 m, whichever is greater, shall be cut off from the welded end prior to stressing.

##### 4-4.6.6.2 **Tensioning**

- A. All ducts shall be verified as being unobstructed prior to placing post-tensioning steel.
- B. All strands in each tendon shall be stressed simultaneously with a multi-strand jack.
  - 1. The force in the tendons shall be measured by means of a pressure gauge and shall be verified by means of tendon elongation.
  - 2. All tendons shall be tensioned to a preliminary force as necessary to eliminate any slack in the tensioning system before elongation readings are started. This preliminary force shall be between 15 and 25 percent of the final jacking force.
- C. Stressing tails of post-tensioned tendons shall not be cut off until the record of gauge pressures and tendon elongations has been reviewed by a Professional Engineer.
- D. A record of the following post-tensioning operations shall be kept for each tendon installed:
  - 1. Project name;
  - 2. Subcontractor;
  - 3. tendon location and size;
  - 4. date tendon installed;
  - 5. tendon pack/heat number;
  - 6. modulus of elasticity (E);
  - 7. date stressed;
  - 8. jack and gauge identifier;
  - 9. required jacking force and gauge pressures;
  - 10. elongation (anticipated and actual);
  - 11. anchor set (anticipated and actual);
  - 12. stressing sequence;
  - 13. witnesses to stressing operation;
  - 14. grout information (brand name);
  - 15. grout test results;

16. time for grouting each tendon;
17. maximum grout pumping pressure at inlet;
18. date grouted; and
19. identification of any grouting problems encountered and steps taken to resolve them.

#### 4-4.6.6.3 **Concreting**

- A. The anchorage recesses shall be concreted after tensioning but before grouting the tendons.
  1. The concrete surfaces of the anchorage recesses shall be abrasive blasted.
  2. The recesses shall be thoroughly wetted and covered with a thin cement scrub coat immediately before placing fresh concrete.

#### 4-4.6.6.4 **Grouting**

- A. Grouting shall not be carried out when there are any conditions that would be detrimental to the grouting operations including when the ambient air or concrete temperature is or is expected to be below 5 degrees Celsius during placing or curing of the grout.
- B. All ducts and openings shall be clean and free of all deleterious matter that would impair bonding of the grout to the ducts and stressing steel.
  1. After installing the ducts and until grouting is complete, all ends of ducts, connections to anchorages, splices, inlets and outlets shall remain sealed at all times.
  2. Grout inlets and outlets shall be installed with plugs or valves in the closed position.
  3. Low point outlets shall be left open.
  4. All ducts shall be thoroughly flushed out with water and blown out with compressed oil free air. All inlets and outlets shall be checked for their capacity to accept injection of grout by blowing compressed oil free air through the system.
- C. All ducts and duct connections shall be air-tight.
  1. Before stressing and grouting, install all grout caps, inlets and outlets and test each tendon with compressed air to determine whether duct connections need repair.
  2. Pressurise the tendon to 345 kPa (50 psi) and lock-off the outside air source. Record the pressure for 1 minute. A pressure loss of 170 kPa (25 psi) is acceptable for tendons up to 45 m long, and a pressure loss of 100 kPa (15 psi) is acceptable for tendons longer than 45m. If the pressure loss exceeds the acceptable limit, repair the leaking connections, and retest.
- D. The grout shall be mixed so that it is free of lumps and undispersed cement and complies with the properties specified by the grout mix design.
- E. The duct shall be completely filled with grout. Grout shall be injected continuously through the duct until no visible signs of water or air are ejected from the outlet.
  1. All grout vents shall be opened prior to commencement of grouting.

2. Grout shall be injected from the lowest end of the tendon in an uphill direction. A fully operational grout pump shall be on-site for all pumping procedures. A continuous, one way flow of grout shall be maintained at a rate of 5 to 15 lineal metres of duct per minute.
  3. The grouting of each tendon shall be completed within 30 minutes of mixing of the grout.
  4. The pumping pressure at the injection vent shall not exceed 1 MPa.
  5. Normal pumping pressure shall be between 0.1 MPa and 0.4 MPa measured at the inlet.
  6. If the actual pressure exceeds the maximum allowed, the injection vent shall be closed and the grout shall be injected at the next vent that has been or is ready to be closed as long as one-way flow is maintained. Grout shall not be injected into a succeeding vent from which grout has not yet flowed.
- F. For each tendon, immediately after uncontaminated uniform grout discharge begins, a fluidity test shall be performed from the discharge outlet.
1. The measured grout efflux time shall not be faster than the efflux time measured at the inlet or the minimum efflux time established.
  2. If the grout efflux time is not acceptable, additional grout shall be discharged from the outlet. Grout efflux time shall be tested. This cycle shall be continued until acceptable grout fluidity is achieved.
- G. In addition to the fluidity test, the grout density shall be checked using the wet density method. The density at the outlet shall not be less than the grout density at the inlet.
- H. To ensure the tendon remains filled with grout, the ejection and injection vents shall be closed in sequence, respectively under pressure when the tendon duct is completely filled with grout. Valves and caps shall not be removed until the grout has set.
- I. 50 mm deep grout tube termination recesses shall be formed around the tubes projecting to the surface above the tendon ducts. After grouting, all tubes shall be cut flush with the bottom of the recesses, and the recesses grouted flush with the top of the surface.

#### **4-4.7 CONCRETE SEGMENTAL CONSTRUCTION**

##### **4-4.7.1 General**

- A. This Section 4-4.7 [*Concrete Segmental Construction*] sets out additional requirements for portions of Structures constructed using cast-in-place or precast concrete segmental construction. These requirements are in addition to the requirements of Section 4-4.4 [*Cast-In-Place Concrete*], Section 4-4.5 [*Precast Concrete Units*] and Section 4-4.6 [*Post-Tensioning*] of this Schedule.

##### **4-4.7.2 Submittals**

- A. Shop drawings, calculations and manuals which include, but are not necessarily limited to, the items listed in this Section 4-4.7 [*Concrete Segmental Construction*] shall be submitted prior to any segmental concrete construction being carried out. The Review Period shall be 30 Business Days.
- B. Any subsequent deviation from concrete segmental construction methods, materials, or details will not be permitted unless the affected submittals are updated in advance of use.

#### 4-4.7.2.1 Shop/Working Drawings

- A. The shop/working drawings shall include all details necessary for the successful completion of all precast and cast-in-place segmental concrete construction. They shall clearly identify the methods to be used and identify all items to be cast or formed into each concrete pour. They shall include but not necessarily be limited to the following:
1. Fully and accurately dimensioned views showing the geometry of each segment including projections, recesses, notches, openings and blockouts;
  2. Complete details of the segment fabrication system, including the forms, form travelers, temporary supports, falsework, temporary foundations, and geometry control. The total weight and center of gravity of the form travelers including formwork shall be indicated;
  3. Complete details of reinforcing steel, post-tensioning ducts, post-tensioning hardware, stay cable anchorages, inserts, lifting and hold-down devices, and any other items to be embedded in a segment;
  4. Details of mild steel reinforcing shall be clearly shown as to size, spacing and location including any anchorage reinforcing which may be required by the post-tensioning and stay cable anchorage systems;
  5. Details of post-tensioning ducts shall clearly indicate the size, type, horizontal and vertical profiles, duct supports, grout pipes and concrete covers; and
  6. Details of all inserts or holes in segments including any necessary localized strengthening and the materials and methods to fill and finish such holes shall also be included.

#### 4-4.7.2.2 Construction Manual

- A. Prior to preparing the casting and camber curves the construction loads, construction stages and schedule corresponding to the construction sequence shall be documented in the form of a "Construction Manual". The Construction Manual shall include, but is not limited to the following:
1. A detailed step by step description of the construction of the segments, including a description of all intermediate steps relating to any form travelers, construction equipment, falsework, counterweights, support jacking, stressing of temporary post-tensioning bars, stay cable stressing or re-stressing, jacking of closures and cantilever tips, closure operations including any partial stressing across the closure during concrete curing, sequence of tendon stressing including stressing loads and elongations, field survey and alignment control;
  2. For precast segments, complete details of the handling, storing and transporting of the segments. These details shall include, for each type of segment, the method of lifting (location of any inserts, configuration of lifting devices, etc.) and the method of supporting segments during storage and transportation;
  3. Complete details covering equipment to be used for casting segments, providing access for post-tensioning and stay cable stressing equipment, etc, and all loads to be imposed on any portion of the permanent Structure by the construction equipment, temporary supports, and falsework; and
  4. The Construction Manual shall make appropriate reference to the Geometry Control Plan and Procedure. It shall include the sequence in which segments and individual components of each segment will be cast.

- B. A new Construction Manual shall be prepared at any time that there is a deviation from the sequence and schedule of construction contained in the current Construction Manual.

#### 4-4.7.2.3 Design Calculations for Construction Procedures

- A. Calculations signed, and sealed by a Professional Engineer shall be submitted that show that the loads imposed on the permanent Structure by the temporary construction loads and construction sequence will not adversely affect the permanent Structure, nor exceed allowable stresses during the Construction process.

#### 4-4.7.2.4 Casting and Camber Curves

- A. Horizontal and vertical deflection and camber data for each stage of Construction as required to construct the Structure to its final alignment, grade and superelevation shall be prepared.
- B. Bearing offsets and Structure geometry shall be adjusted for time-dependent displacements. Data used shall account for the effect of the time dependent prestress losses, creep and shrinkage which will occur during the Construction phase, and shall be consistent with the intended usage described in the Geometry Control Plan and Procedure. The data for the entire Structure, based on the construction sequence, method and schedule, shall be prepared prior to commencing concrete segmental construction of the applicable Structure.
- C. Construction stage camber data shall be prepared in accordance with the casting, post-tensioning and stay cable installation sequence, schedule, construction techniques, loads, introduction or removal of temporary supports, falsework, construction equipment, closure devices, and material properties documented in the Construction Manual.
  - 1. The camber curves shall have sufficient accuracy to allow for the determination of control point settings for accurately casting the segments with respect to both horizontal and vertical geometry.
  - 2. The preparation of the camber curves shall recognize all deviations and deformations from the final required profile and alignment due to Structure self-weight, future superimposed dead loads, construction loads, post-tensioning and stay cable effects including secondary moments, creep and shrinkage effects, the effects of temperature variations and non-linear pier behavior.
  - 3. Each camber curve shall be accompanied by all information (loads, casting and construction sequence, material properties, traveler deflection, etc.) considered in its development.
- D. Camber and erection elevation tables shall include theoretical elevations and alignment of the geometry control points and form travelers established during casting of each segment and computed at each stage of construction. A summary of elevations for each joint which gives the elevation history of that joint during the various stages of construction shall be furnished. Stages for which theoretical positions of control points are to be computed shall include:
  - 1. Unloaded formwork in position ready to receive concrete;
  - 2. After each concrete segment is placed;
  - 3. After each stage of applying post-tensioning or stay cable forces; and
  - 4. After any change in support conditions.
- E. If the construction sequence is changed, camber curves shall be prepared in the same manner as required for the original camber curve. The revised camber curve shall include the

methods(s) and location(s) for transitioning between the current curve(s) in use and the updated curve(s).

- F. The camber of the structure shall be monitored at each stage according to the Geometry Control Plan and Procedure described below. Corrections shall be performed as required to assure proper construction of the Structure to its final alignment and grade.

#### 4-4.7.2.5 **Geometry Control Plan and Procedure**

- A. A Geometry Control Plan and Procedure which indicates in detail how the survey is to be performed and proper casting and construction of the Structure carried out to achieve the lines and grades shown on the applicable Final Design shall be prepared.
- B. The Geometry Control Plan and Procedure shall provide for regular monitoring of Structure deflections beginning with the addition of the first segments and concluding with the last closure. The Geometry Control Plan and Procedures shall include the adjusting procedure to be utilized for each segment, and shall also include special adjustment procedures should the segments, as constructed, begin to deviate from the predicted alignment by more than 25 mm.
- C. The Geometry Control Plan and Procedures shall be in the form of a "Geometry Control Manual" and shall include the following information:
  - 1. a detailed narrative of the geometry control theory;
  - 2. a detailed narrative of the step-by-step geometry control procedure;
  - 3. detailed calculation forms; and
  - 4. a set of sample calculations.
- D. The Geometry Control Manual shall address all measuring equipment, procedures, the locations of the control points to be established on each segment and the qualifications of personnel who will carry out geometry control.
  - 1. Personnel who directly supervise layout and geometry control measurements shall have previous experience in geometry control techniques for concrete segmental bridges.
- E. The Geometry Control Manual shall cover all geometry control operations necessary for casting and placing the segments and shall be in agreement with the chosen methods of casting, placing and releasing the segments, including surveys for elevation and alignment control before and after segment casting.
  - 1. Casting shall not commence until after the Geometry Control Manual is finalized.
- F. A table of elevations and alignments required at each stage of Construction and at all control points shall be prepared. Any deviation from the table of elevations and alignment shall be corrected so as to prevent the accumulation of deviations.
  - 1. A record of all checks, adjustments and corrections made during Construction shall be maintained.
- G. During segment casting or placing operations, computer generated graphical plots of the vertical and horizontal "as cast" alignments along each vertical and horizontal control line shall be produced and maintained on a daily basis. These plots shall use an exaggerated scale in order to clearly highlight variations. These plots shall be depicted against both the theoretical geometric vertical and horizontal alignment casting curves on a continuous layout along the entire length of the Structure between expansion joints.

1. A printed copy of this plot shall be maintained in good condition at the applicable Site, for use and reference during erection.
- H. Immediately after casting or placing of a segment is completed, references for horizontal and vertical control shall be established at the leading free end of the segment.
- I. Elevations and alignment of segments shall be measured at each stage of construction with instruments capable of providing the degree of accuracy necessary to assure that construction tolerances will be met.
1. The alignment and elevations of the segments shall be checked from established control at a time that will minimize the influence of temperature.
  2. Precaution shall be used to guard against possible false readings and corresponding adjustments due to temperature differentials.
  3. A minimum of two remote permanent horizontal survey control triangulation points and vertical control benchmarks shall be established at each applicable Site. Permanent benchmarks shall be established at locations where they will not be disturbed by construction activities. The horizontal control points and benchmarks shall be located so as to be continuously visible from the survey instrument's location.
  4. Prior to casting or placing a new segment, the position of the previous segment shall be independently verified by two surveys.
- J. The segments shall be positioned to achieve the final longitudinal alignment, grade and cross-slope.
1. Casting of the segments adjacent to the pier table shall not begin until the form travelers are properly tied down to the piers by the means provided.
- K. If segment positions are not as required, corrections to the geometry shall be made to the next segment cast by utilizing the established control points.
1. If measured elevations deviate from the approved table of elevations further casting or placing of segments shall be suspended until the cause of the deviation is discovered and a Corrective Action Plan prepared.

#### 4-4.7.3 Dimensional Tolerances

- A. The maximum dimensional deviations in mm of cast-in-place and precast concrete segments used in segmental concrete construction from the dimensions shown on the applicable Final Design shall not exceed the values shown in Table [4-4.7.3-1 *[Dimensional Tolerances of Concrete Segments]*].

Table 4-4.7.3-1 Dimensional Tolerances of Concrete Segments

Width of Web	± 6 mm
Depth of Bottom Slab	± 5 mm
Depth of Top Slab	± 5 mm
Overall Depth of Segment	± 5 mm
Overall Width of Segment	± 6 mm



Length of Segment	± 10 mm but less than 50 mm total per cantilever
Diaphragm Dimension	± 10 mm
Grade of form edge and soffit	± 3 mm per 3.0 m
Ends (deviation from a plane per 6 m width or depth)	± 6 mm per 6 m not to exceed 12 mm
Flat surface (deviation from a plane at any location)	± 1.5 mm per 1.0 m not to exceed a total of 6 mm

#### 4-4.7.3.1 Erection Tolerances

- A. The following dimensional tolerances shall apply to the erection of cast-in-place or precast concrete segments:
1. The maximum differential between the outside faces of adjacent segments in the constructed position shall not exceed 5 mm.
  2. Transversely, the angular deviation from the theoretical slope difference between two successive segment joints shall not exceed 0.001 radians.
  3. Longitudinally, the angular deviation from the theoretical slope change between two successive segments shall not exceed 0.003 radians.
  4. The difference in top of segment elevations at the connection of two adjacent segments (measured perpendicular to the segment surface) and across closure joints shall be no greater than 3 mm.
- B. Dimensions from segment to segment shall be adjusted so as to compensate for any deviations within a single segment so that the overall dimensions of each completed span and the entire Structure will conform to the dimension shown on the applicable Final Design.
1. The accumulated maximum error shall not exceed 1/1000 of the span length or 100 mm whichever is less, for either the vertical profile and/or horizontal alignment.

#### 4-4.7.4 Closure Pours

- A. For cantilever segmental concrete construction the cantilevers shall be fixed prior to the closure pour between the cantilevers to prevent rotation or movement of one cantilever relative to the other.
1. The system for locking the cantilevers and forming the closure pour and the procedure for placing the concrete for the closure shall be such that the concrete after initial set shall not be subjected to tension which could cause cracking.

### 4-4.8 REINFORCING STEEL

#### 4-4.8.1 General

- A. This Section 4-4.8 [*Reinforcing Steel*] sets out the requirements for all reinforcing steel forming part of a Structure, including minimum requirements for quality, supply, fabrication, handling and placing of plain reinforcing steel, corrosion resistant reinforcing steel (CRR), and stainless reinforcing steel placed in cast-in-place concrete and precast concrete units.

#### 4-4.8.2 **Engineering Data**

- A. Shop drawings showing reinforcing steel details shall be prepared prior to fabrication of reinforcing steel.
- B. Mill test certificates shall be provided prior to the placement of any reinforcing steel.
  - 1. Mill test certificates shall be provided for each lot of reinforcing steel delivered to site.
- C. The following additional information, as applicable, shall be supplied for each lot of stainless reinforcing steel delivered to site:
  - 1. Austenitic grades: Test results verifying compliance with ASTM A262, Practice E.
  - 2. Duplex grades: Test results verifying compliance with ASTM A923, Method A, by demonstrating an unaffected etched structure.

#### 4-4.8.3 **Fabrication**

- A. Reinforcing steel bars shall conform accurately to the dimensions shown on the applicable Final Design, and be within the fabricating tolerances detailed in the RSIC Manual of Standard Practice.
- B. All hooks and bends shall be fabricated using the pin diameters and dimensions recommended in the Reinforcing Steel Institute of Canada (RSIC) Manual of Standard Practice.
- C. Fabrication of stainless reinforcing steel shall be carried out such that bar surfaces are not contaminated with deposits of iron or other non-stainless steels; or suffer damage due to any cause, including straightening or bending.
- D. All reinforcing steel requiring bends shall be cold bent at the fabrication facility.
  - 1. Heating of reinforcing steel to facilitate bending shall not be permitted.
- E. Reinforcing steel shall be cut by shearing or with fluid-cooled saws.
  - 1. Torch cutting shall not be permitted.
- F. Reinforcing steel shall be fabricated without laminations or burrs.
- G. Stainless reinforcing steel shall be pickled to remove all mill scale and surface oxidation.
  - 1. Details of the pickling process shall be included with the mill test certificates.

#### 4-4.8.4 **Shipping, Handling and Storage**

- A. All necessary precautions shall be taken to prevent damage to the reinforcing steel during shipping, handling and storage.
  - 1. Reinforcing steel of differing material types shall be stored separately.
  - 2. All reinforcing steel shall be stored on platforms, skids, or other suitable means of support able to keep the material above the ground surface while protecting it from mechanical damage and deterioration.
  - 3. On-site storage of reinforcing steel shall not exceed 120 days unless protected with polyethylene sheeting or equivalent protective material.
  - 4. Reinforcing steel shall be covered and protected at all times during transportation.

5. Bundles shall be handled with spreaders and non-metallic slings.
- B. Reinforcing steel tags identifying the material type shall be clearly visible and shall be maintained in-place until installation of the material.
- 4-4.8.5 Placing and Fastening**
- A. Reinforcing steel incorporated into the work shall be free from loose rust, scale, dirt, paint, oil or other foreign materials.
- B. Reinforcing steel shall be placed in the positions shown on the applicable Final Design, and shall be securely tied and chaired before placing the concrete.
1. Bars shall be tied at all intersections except that when the bar spacing is less than 250 mm in each direction, alternate intersections may be tied at these locations.
- C. Unless otherwise specified, tie-wire shall be manufactured from the same material type as the reinforcing steel being tied.
1. Plastic coated tie-wire may be used where low carbon/chromium reinforcing steel is being placed.
2. Where stainless reinforcing steel is being placed, tie-wire shall be stainless steel of any grade listed in Section 4-1.7.3 [*Reinforcing Steel and Deformed Welded Wire Mesh*] of this Schedule.
- D. Reinforcing steel cover shall not be less than that specified on the applicable Final Design.
1. Supports used to prevent bars from contact with forms or for separation between layers of bars shall be of adequate strength, shape and dimension.
- E. Specified distances of reinforcing steel from forms shall be maintained by supports, spacers, or other means.
1. Reinforcing steel supports shall be either plastic or precast concrete.
2. Supports shall be staggered and configured to facilitate full concrete consolidation.
3. Precast concrete supports shall be used for all exposed faces of curbs, medians and barriers.
4. Precast concrete supports shall have the compressive strength, rapid chloride permeability, and air content meeting the specification requirements for the class of concrete being placed.
5. Plastic bolster slab supports shall be Aztec Strong Back Slab I Beam Bolster- PSBB manufactured by Dayton Superior or equivalent.
6. Precast concrete supports shall be Total Bond Concrete Supports manufactured by Con Sys Inc or equivalent.
- F. Welding of reinforcing steel shall not be permitted.
- G. Field bending of reinforcing steel, regardless of circumstance, shall not be permitted.
- H. Reinforcing steel showing signs of damage shall be replaced.

#### 4-4.8.6 Splicing

- A. Reinforcing steel splices shall be staggered unless otherwise specified on the applicable Final Design.
- B. For lapped splices, bars shall be placed in contact and wired together while maintaining the minimum required clear distance to other bars and the required minimum distance to the surface of the concrete.

#### 4-4.8.7 Repair of Stainless Reinforcing Steel

- A. Individual stainless steel reinforcing bars exhibiting any of the following Deficiencies or Early Handover Deficiencies shall be repaired or replaced:
  - 1. any single area of iron contamination greater than 100 mm in length;
  - 2. two or more areas of iron contamination greater than 50 mm in length; and
  - 3. frequent small occurrences of iron contamination along the full length of the bar.
- B. Bars exhibiting excessive staining shall have the contaminants identified by energy dispersive x-ray analysis (EDXA).
- C. Methods for the repair of stainless reinforcing steel bars shall be prepared, signed and sealed by a Professional Engineer prior to the repair work commencing.

### 4-4.9 STRUCTURAL STEEL

#### 4-4.9.1 General

- A. This Section 4-4.9 [*Structural Steel*] of this Schedule sets out the requirements for all structural steel forming part of a Transportation Structure, including minimum requirements for the supply, fabrication, delivery and erection of structural steel for Transportation Structures except that Section 4-4.9.12 [*Structural Steel for Building Structures*] of this Schedule sets out the minimum requirements for the supply, fabrication, delivery and erection of structural steel for Building Structures.
  - 1. Structural steel for Transportation Structures shall include piling, steel girders, trusses, diaphragms, bracing, splice plates, deck drains, anchor bolts, dowels, deck joint assemblies, buffer angles, connector angles, anchor bolt sleeves, curb and median cover and trough plates, pier nose plates, pier bracing, bridge rails and miscellaneous steel components.

#### 4-4.9.2 Supply and Fabrication Standards

- A. The fabricator of structural steel for Transportation Structures shall operate a steel fabricating shop that is fully approved by the Canadian Welding Bureau (CWB) as per CAN/CSA W47.1 in the following divisions:
  - 1. fabrication of steel girders, girder components and welded steel trusses – Division 1;
  - 2. all other Structure components – Division 1 or 2; and
  - 3. field welding/repairs – Division 1 or 2.

#### 4-4.9.3 **Engineering Data**

##### 4-4.9.3.1 **Shop Drawings**

- A. Shop drawings showing all fabrication details shall be prepared prior to fabrication and submitted to the City. The shop drawings shall include the following:
  - 1. details of connections not shown on the applicable Final Design, which shall be signed and sealed by a Professional Engineer;
  - 2. all dimensions, which shall be correct at 20° Celsius unless otherwise specified;
  - 3. weld procedure identification, which shall be shown in the tail of the weld symbols;
  - 4. all material splice locations;
  - 5. bearings, which shall be centered at -5° Celsius; and
  - 6. camber and splice joint offsets measured to the top of top flange at a maximum spacing of 4 m.

##### 4-4.9.3.2 **Welding Procedures**

- A. Welding procedures shall be prepared prior to welding for each type of weld used in the Structure.
  - 1. The welding procedures shall bear the approval of the CWB.

##### 4-4.9.3.3 **Fabrication Sequence**

- A. Prior to commencement of fabrication, an outline of the fabrication sequence and details of equipment shall be prepared.
  - 1. The fabrication scheme shall include the order of make-up and assembly of all the component parts, as well as shop assembly, inspection stations, and surface preparation.

##### 4-4.9.3.4 **Mill Certificates**

- A. Mill certificates shall be obtained for all material before fabrication commences.

#### 4-4.9.4 **Materials**

##### 4-4.9.4.1 **Structural Steel**

- A. Structural steel shall conform to the standard specified on the applicable Final Design.
  - 1. Interpretation of equivalent steels shall be as per Appendix "A" of CAN/CSA G40.21 (1976 only).
- B. Mill certificate data and results of impact tests shall be obtained prior to shipment of material from the mill.
- C. Where mill certificates originate from a mill outside Canada or the United States of America, the material shall be tested and the mill certificate verified by a Canadian laboratory.
  - 1. The laboratory shall be certified by an organization accredited by the Standards Council of Canada to comply with the requirements of ISO/IEC 17025 for the specific tests or type of tests required by the material standard specified on the mill certificate.

2. The mill certificates shall be stamped with the name of the Canadian laboratory and the signature of an authorized officer. It shall state that the material is in conformance with the Project Requirements.
- D. The silicon content for exposed galvanized steel shall be as follows:
1. For structural tubing the silicon content shall be less than 0.04%; and
  2. For structural sections and plates the silicon content shall be less than 0.04% or between 0.15% to 0.25%.

#### 4-4.9.4.2 **Bolts**

- A. Bolts, nuts and washers shall be marked as follows:
1. Metric bolts shall be marked with the symbol A325M and those of “weathering” steel shall have the A325M symbol underlined.
  2. Metric nuts shall be marked with three circumferential lines with an “M” between two of them or shall be marked with a “3” if made of a weathering grade.
  3. Washers shall be identified as metric by having an “M” indented in the surface or a “3” for weathering grades.
- B. Mill certificates for bolts supplied from a manufacturer outside Canada or the United States of America shall be verified by a Canadian testing laboratory as outlined in Section 4-4.9.4.1 [*Structural Steel*] of this Schedule.

#### 4-4.9.4.3 **Stud Shear Connectors**

- A. All stud shear connectors shall comply with the chemical requirements of ASTM A108, Grades 1015, 1018 or 1020. In addition, they shall meet the mechanical properties specified in AWS D1.5, Table 7.1 for Type B studs.

#### 4-4.9.5 **Welding**

- A. The deposited weld metal shall provide strength, durability, impact toughness and corrosion resistance equivalent to the base metal.
- B. Low hydrogen fillers, fluxes and low hydrogen welding practices shall be used throughout.
1. Low hydrogen coverings and fluxes shall be protected and stored as specified by AWS D1.5.
  2. Flux cored welding, the use of cored filler wires in the submerged arc process and shielding gas welding processes are not permitted.

##### 4-4.9.5.1 **Submerged Arc Welding (SAW)**

- A. The submerged arc welding process is permitted for all flat and horizontal position welds.
1. All girder flange and web butt joints shall be made by a semi or fully automatic submerged arc welding process.
  2. All girder web to flange welds and all girder longitudinal stiffener to web welds shall be made by a fully automatic submerged arc welding process.

#### 4-4.9.5.2 **Shielded Metal Arc Welding (SMAW)**

- A. The shielded metal arc welding process is only permitted for girder vertical stiffener to flange fillet welds and for miscellaneous steel components such as deck drains, deck joint assemblies, pier nose plates and buffer angles.

#### 4-4.9.5.3 **Metal Core Arc Welding (MCAW)**

- A. The metal core arc welding process utilizing low hydrogen consumables with AWS designation of H4 is only permitted for girder vertical stiffeners and horizontal gussets and miscellaneous steel components such as deck drains, deck joint assemblies, pier nose plates and buffer angles.
- B. Field application of the metal core arc welding process is not permitted.

#### 4-4.9.5.4 **Cleaning Prior to Welding**

- A. Weld areas shall be clean, free of mill scale, dirt, grease and other contaminants prior to welding.

#### 4-4.9.5.5 **Tack and Temporary Welds**

- A. Tack and temporary welds shall not be allowed unless they are incorporated in the final weld.
  - 1. Tack welds, where allowed, shall be of a minimum length of four times the nominal size of the weld. The length shall not exceed 15 times the weld size, and shall be subject to the same quality requirements as the final welds.
  - 2. Tack welds shall be sufficiently ground out prior to final welding in order for the final weld to have a uniform weld bead.
  - 3. Cracked tack welds shall be completely removed prior to welding over.

#### 4-4.9.5.6 **Run-off Tabs**

- A. Run-off tabs shall be used at the ends of all welds that terminate at the edge of a member.
  - 1. The tabs shall be a minimum of 100 mm long.
  - 2. The tabs shall be tack welded only to that portion of the material that will not remain a part of the Structure, or where the tack weld will be welded over and fused into the final joint.
  - 3. Tabs shall be removed by flame cutting after welding.

#### 4-4.9.5.7 **Backing Bars**

- A. The separation of the faying surfaces between backing bars and material to be welded shall not exceed 1 mm.
- B. The weld shall be 100% fused into the backing bar including at the corners of HSS members.

#### 4-4.9.5.8 **Welding at Stiffener Ends**

- A. Stiffeners and attachments fillet welded to structural members shall have the fillet welds terminate 10 mm short of edges.

#### 4-4.9.5.9 Preheat

- A. Preheat requirements shall be performed and maintained as per AWS D1.5, except that all welds on girder flanges shall be preheated to a minimum temperature of 100 degrees Celsius unless a higher temperature is required by AWS D1.5 for the flange thickness.
  - 1. The preheat temperature of the web to flange joint shall be measured 75 mm from the point of welding on the side of the flange opposite to the side where the weld is being applied.

#### 4-4.9.5.10 Methods of Weld Repair

- A. Repair procedures for damaged base metal and unsatisfactory welds shall be prepared, signed and sealed by a Professional Engineer prior to repair work commencing.

#### 4-4.9.5.11 Arc Strikes

- A. Arc strikes shall not be permitted.
  - 1. In the event of accidental arc strikes a repair procedure shall be prepared, signed and sealed by a Professional Engineer.
  - 2. The repair procedure shall include the complete grinding out of the crater produced by the arc strike.

#### 4-4.9.5.12 Grinding of Welds

- A. Flange butt welds shall be ground flush or to a slope on both sides.
- B. Web butt welds which are smooth with a neat appearance and uniform profile shall not require grinding.
- C. Fillet welds not conforming to an acceptable profile shall be ground to the proper profile without substantial removal of the base metal.
- D. Grinding shall be smooth and parallel to the line of stress.
  - 1. Caution shall be exercised to prevent over grinding.

#### 4-4.9.5.13 Plug and Slot Welds

- A. Plug welds or slot welds shall not be permitted.

#### 4-4.9.5.14 Welding to Girder Flanges and Webs

- A. With the exception of longitudinal web to flange welds, all stiffeners, gusset plates, or any other detail material welded to girder flanges shall be a minimum of 300 mm from the flange butt welds.
- B. With the exception of longitudinal web to flange welds and longitudinal stiffener to web welds, all stiffeners, gusset plates and any other detail materials welded to girder webs shall be a minimum of 300 mm from the web butt welds.

#### 4-4.9.5.15 Field Welding

- A. Structural field welds are welds that are required to maintain the integrity of the Structure.
- B. All material to be field welded shall be prepared in the shop.



- C. Where structural field welds are carried out, the following requirements shall be met:
1. all welding, cutting and preparation shall comply with the AWS D1.5;
  2. only welders approved by the CWB in the particular weld category to be carried out shall perform weldments;
  3. welding procedures approved by the CWB shall be prepared for the welds;
  4. low hydrogen fillers, fluxes and welding practices shall be used in accordance with Section 4-4.9.5 [Welding] of this Schedule;
  5. when the air temperature is below 10° Celsius, all materials to be welded shall be preheated to 100° Celsius for a distance of 80 mm beyond the weld and shall be sheltered from the wind;
  6. when the air temperature is below 0° Celsius, welding shall not be permitted unless suitable hoarding and heating is provided. The air temperature inside the enclosure shall be a minimum of 10° Celsius. If the steel temperature is less than 10° Celsius, all materials to be welded shall be preheated to 100° Celsius for a distance of 80 mm beyond the weld and shall be sheltered from the wind; and
  7. all structural field welds shall be visually inspected by an independent welding inspector certified to Level 3 of CAN/CSA W178.2.
- D. Where non-structural field welds are carried out, the following requirements shall be met:
1. journeyman welders with Class B tickets shall perform weldments;
  2. welding procedures shall be prepared, signed and sealed by a Professional Engineer;
  3. low hydrogen fillers, fluxes and welding practices shall be used in accordance with Section 4-4.9.5 [Welding] of this Schedule;
  4. when the air temperature is below 5 degrees Celsius, all materials to be welded shall be preheated to 100 degrees Celsius for a distance of 80 mm beyond the weld and shall be sheltered from the wind; and
  5. when the air temperature is below 0 degrees Celsius, welding shall not be permitted unless suitable hoarding and heating is provided. The air temperature inside the enclosure shall be a minimum of 10 degrees Celsius. If the steel temperature is less than 10 degrees Celsius all materials to be welded shall be preheated to 100 degrees Celsius for a distance of 80 mm beyond the weld and shall be sheltered from the wind.

#### 4-4.9.6 **Fabrication**

- A. The fabrication of structural steel components shall be carried out so as to not adversely affect the performance of the steel including its strength, durability, impact toughness and corrosion protection.
- B. Fabricators of steel girders, girder components and welded steel trusses shall be certified by the Canadian Institute of Steel Construction as meeting the quality compliance requirements in the category of steel bridges.
- C. Fabrication of structural steel, including welding, cutting and preparation, shall comply with the AASHTO LRFD BCS and the American Welding Society (AWS) Bridge Welding Code D1.5.

- D. The fabrication of structural steel tubing shall comply with the American Welding Society (AWS) Structural Welding Code D1.1.
- E. Fabrication shall be performed in a fully enclosed area which is heated to at least 10 degrees Celsius.
- F. Only welders, welding operators and tackers approved by the CWB in the particular weld category to be carried out shall be permitted to perform weldments.

#### 4-4.9.6.1 **Cutting of Plate**

- A. All plate material for main members, such as girders, trusses, splice plates and any plate material welded to main members shall be flame cut using an automatic cutting machine.
  - 1. Shearing shall not be allowed.
- B. All flange material shall be cut so that the direction of the applied stress will be parallel to the direction of the plate rolling.
- C. As plate material is subdivided for main members, all heat numbers shall be transferred to each individual plate.
  - 1. The numbers shall remain legible until such time as the material location in the final assembly has been recorded.
  - 2. Mill identification numbers stamped into the material shall be removed by grinding.
  - 3. Steel stamps shall not be used. The only exception is the match marking of splice plates which may be steel stamped using low stress stamps.
  - 4. The stamps and specific locations of such stamps shall be shown on the shop drawings.

#### 4-4.9.6.2 **Flame Cut Edges**

- A. The flame cut edges of girder flanges shall have a maximum Brinell hardness as stated by Section 4-4.9.9.6 [*Hardness Tests*] of this Schedule.
  - 1. The surface roughness of the flame cut edge shall not be greater than ANSI B46.1 500  $\mu\text{in.}$  (12.5  $\mu\text{m}$ ) and be such as to allow Brinell hardness testing without spot grinding.
  - 2. Brinell hardness tests shall be performed on the as is flame cut edges. If the hardness exceeds the requirements, the edges shall be repaired so that they meet the requirements.
- B. All blow backs or signs of lamination observed during the cutting of the material shall be documented.
  - 1. The extent of the lamination shall be determined by an ultrasonic testing technician certified to Level II of CGSB and employed by a CAN/CSA W178.1 certified non-destructive testing company.
  - 2. A report shall be prepared, signed and sealed by a Professional Engineer indicating whether or not the material is suitable for fabrication.
- C. The surfaces of flame cut edges shall be finished by grinding and shall be free of nicks and gouges.

#### 4-4.9.6.3 **Corner Chamfers**

- A. Corners of all flanges shall be ground to a 2 mm chamfer.
- B. Corners of stiffeners, structural sections and plates shall be ground to a 1 mm chamfer.

#### 4-4.9.6.4 **Vertical Alignment**

- A. The Structure shall be fabricated to account for member deflections and to conform to the lines and grades shown in the applicable Final Design.
  - 1. For rolled shapes, advantage shall be taken of mill camber that may be inherent in the material.

#### 4-4.9.6.5 **Shop Assembly**

##### A. Plate Girders

- 1. Shop assembly of plate girders shall be by the progressive assembly method according to the AASHTO LRFD BCS, except that only two, instead of three, sections need to be assembled.
- 2. The detailed method of assembly, including points of support, dimensional checks, method of trimming to length, drilling and marking of splices, shall be to the procedure prepared as per Section 4-4.9.3.3 [*Fabrication Sequence*] of this Schedule.
- 3. Each individual girder section shall meet the camber requirements for that particular length, with the splices between these sections falling on the theoretical camber line for the entire span.
- 4. Corrections for variation in flange thickness shall be made.
- 5. Camber for plate girders shall be measured on the top of the top flange. The camber of plate girders shall be measured in the “no load” condition.
- 6. The camber of each individual girder section shall be known for the next two girder sections in the girder line prior to shop assembly of any particular girder section, to allow the use of a best fit line to reduce the effect of any camber differences.
- 7. When the camber of the girder fails to meet the required tolerance, a method of repair shall be developed, signed and sealed by a Professional Engineer prior to commencement of repair.

##### B. Box Girders

- 1. The shop assembly of box girders shall be the same as for plate girders.
- 2. The camber of box girders shall be measured on the top of the top flange, and each top flange of a box shall individually meet the required camber.
- 3. Girder sections assembled for splicing shall be supported within 2 m of the end of each section. Girder sections shall be supported in such a manner as to provide the correct angular relationship at the splice between girder sections while the splices are being reamed or drilled.
- 4. Shop drawings shall clearly indicate the expected dead load deflection of each section and the elevations of the sections while supported for the drilling or reaming of each splice.

#### 4-4.9.6.6 **Drilling**

- A. All splices shall be drilled from solid material while assembled or shall be sub-punched or sub-drilled and then reamed to full size while in the shop assembly position.
  - 1. Drilling or reaming shall not take place until after shop assembly has been satisfactorily completed.

#### 4-4.9.6.7 **Splice Plates**

- A. After shop assembly, splice plates and attached members shall be clearly match marked to ensure proper orientation and location of splice material for erection. All holes shall align with holes in the attached members.
  - 1. The match marking system shall be shown on the shop drawings.
- B. After shop assembly and match marking, splice plates shall be removed, de-burred, solvent cleaned to remove all oil and sandblasted to remove all mill scale.
  - 1. Splice plates shall be securely ship-bolted to the girders.

#### 4-4.9.6.8 **Bolt Holes**

- A. Section 11.4.8 in the AASHTO LRFD BCS shall apply except that all bolt holes in load carrying segments of main members and any material welded to main members shall be drilled full size or sub-punched 5 mm smaller and reamed to full size.
- B. Punching of full size holes for secondary members such as bracings which are not welded to main members shall only be allowed for material less than 16 mm thick.
- C. All holes in girder splices shall be circular and perpendicular to the member and shall be deburred to ensure a proper faying surface.

#### 4-4.9.6.9 **Flame Straightening**

- A. Flame straightening shall not be permitted on any material or member except in accordance with a repair procedure prepared, signed and sealed by a Professional Engineer. The repair procedure shall address locations, temperatures and cooling rates.

#### 4-4.9.6.10 **Stress Relieving**

- A. When stress relieving is specified in the applicable Final Design, it shall be performed in accordance with AWS D1.5.

#### 4-4.9.6.11 **Handling and Storage**

- A. All lifting and handling shall be carried out using devices that do not mark, damage, or distort the assemblies or members in any way.
- B. Girders shall be stored upright, supported on sufficient skids and safely shored to maintain the proper section without buckling, twisting or in any way damaging or misaligning the material.
- C. Long members, such as deck joint assemblies, buffer angles, columns and chords shall be placed on blocking to prevent damage.

#### 4-4.9.6.12 **Barrier**

- A. All barrier rail splices shall be completed using properly fitted backing bars.

- B. All barrier rail splices shall be ground flush.
- C. Rail and post sections shall be orientated such that the tube seams are always located at the bottom, except for rectangular tube sections which shall have the tube seams oriented towards the bottom or the outside of the barrier.
- D. Barrier rail sleeves for field splices and expansion joints shall be square and be properly aligned in the rail end. Corners of the sleeves shall be rounded and smooth to ensure a good fit.

#### 4-4.9.7 **Dimensional Tolerances**

##### 4-4.9.7.1 **General**

- A. The normal tolerance for structural steel fabrication and fitting between whole groups shall be  $\pm 3$  mm unless specified otherwise.
- B. The dimensional tolerances for structural members shall comply with AWS D1.5, Section 3.5, unless specified otherwise.
  - 1. Tolerances for box girder camber, sweep and depth shall be measured relative to two imaginary surfaces: a vertical plane passing through the centre line of the girder and a surface located at the theoretical underside of the top flanges following the theoretical camber of the girder.

##### 4-4.9.7.2 **Girder Camber**

- A. Camber of beams and girders shall be uniform, true and accurate to the centerline of the top flange.
- B. Permissible variation in camber shall be within  $\pm (0.2L_t + 3)$  mm; where  $L_t$  is the test length in meters.
  - 1. This applies to fabricated pieces only, prior to shop assembly.
  - 2. During shop assembly, splice points shall be located on the theoretical camber line or at a specified amount from the line.
- C. Where field splices are eliminated by combining girder segments into longer girder lengths, the cambers of the girders at the eliminated splice points shall be within  $\pm 3$  mm of the theoretical camber line or a specified amount from the line.

##### 4-4.9.7.3 **Combined Warpage and Tilt**

- A. Combined warpage and tilt of flanges at any cross section of welded plate girders or beams shall not exceed  $1/200$  of the total width of the flange or 3 mm whichever is greater at bolted splice locations.
  - 1. Combined warpage and tilt shall be determined by measuring the offset at the toe of the flange from a line normal to the plane of the web through the intersection of the centerline of the web with the outside surface of the flange plate.

##### 4-4.9.7.4 **Web Panning**

- A. The maximum variation from flatness for webs shall be  $0.01d$  where  $d$  is the least dimension of the panel formed by the girder flanges and stiffeners.

1. Should the panning in one panel be convex and the panning in the adjacent panel be concave then the sum of the panning in the two adjacent sections shall not exceed that allowed for one panel.

B. Localized deformations in the web shall not exceed 3 mm in 1 m.

#### 4-4.9.7.5 Splices

- A. The difference between similar dimensions of adjoining sections being spliced shall not exceed  $\pm 3$  mm.
- B. Bolted splices of main stress carrying members shall have parallel planes and the surfaces shall be in full contact without any gap.

#### 4-4.9.7.6 Stiffeners

- A. The bearing ends of bearing stiffeners shall be flush and square with the web and shall have at least 75% of the bearing end area in contact with the flanges.
- B. Tolerance for milled to bear stiffeners shall be 0.05 mm with at least 75% of the area in bearing.
- C. Fitted stiffeners may have a gap of up to 1 mm between the stiffener and the flange.

#### 4-4.9.7.7 Bearing to Bearing Dimension

- A. The bearing to bearing distance is a set dimension and therefore has no tolerance.

#### 4-4.9.7.8 Facing of Flanges

- A. Surfaces of flanges which are in contact with bearing sole plates shall have a flatness tolerance of  $0.001 \times$  bearing dimension.

#### 4-4.9.7.9 Deck Joint Assemblies

- A. Tolerances for straightness shall be accounted for over the length of the assembly between the crown and gutter line both before and after galvanizing of the assembly.
  1. Deviation from straightness in a vertical plane shall not exceed  $\pm 6$  mm.
  2. Horizontal sweep or variations in gap setting shall not be greater than  $\pm 3$  mm.
  3. Deck joint assemblies shall be assembled for inspection in a relaxed condition with erection angles removed.

#### 4-4.9.7.10 Barriers

- A. Individual barrier rail sections shall be straight and true with no evidence of kinks or dents and with a minimum variation from straightness not exceeding 3 mm over a 3 m length.
- B. Welded barrier rail splices shall not be evident in the final product, and shall be straight, kink free and conform to the same section as the adjacent section.
- C. Bolted barrier rail shall be straight with no offset due to loose fitting sleeves.
- D. The clearance between barrier rail sections and their sleeves shall be sufficient to ensure an easy fit after galvanizing.

- E. The maximum radial clearance around the sleeve when fitted into the rail section shall be 1 mm (2 mm total) after galvanizing with the tube seam removed.

#### 4-4.9.7.11 **Anchor Bolts**

- A. The bolts in an anchor bolt assembly shall fit in a template comprised of accurately located holes 2 mm greater in diameter than the anchor bolts.
- B. The top of the bolts in the assembly shall be  $\pm 3$  mm from a level plane when the threaded portion is plumb.
- C. The threaded length shall not be less than specified, nor more than 15 mm greater than that specified.
- D. The threaded ends of anchor bolts shall be chamfered.

#### 4-4.9.8 **Surface Preparation and Coating**

##### 4-4.9.8.1 **Blast Cleaning**

- A. Unless otherwise specified in the applicable Final Design, all steel components shall be blast cleaned after fabrication in accordance with the Society for Protective Coating Standard (SSPC) No. SP6.
  - 1. Essentially this is a surface from which all oil, grease, dirt, rust, foreign matter, mill scale and old paint have been completely removed except for slight shadows, streaks or discolorations caused by rust stain or mill scale oxide binder.
  - 2. The exterior faces of exterior girders shall be uniform in appearance.

##### 4-4.9.8.2 **Galvanizing**

- A. Galvanizing of steel shall be by the hot dip method, after fabrication, in accordance with ASTM A123/A123M Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products and ASTM F2329 Standard Specification for Zinc Coating Hot-Dip Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts and Special Threaded Fasteners.
  - 1. A smooth finish shall be provided on all edges and surfaces, and all weld spatter and welding flux residue shall be removed from steel components prior to galvanizing.
  - 2. Nuts shall freely spin on bolt threads after galvanizing.
- B. Exposed galvanized surfaces shall have a continuous outer free zinc layer without any significant zinc-iron alloy showing through the outside surface.
  - 1. Lumps, globules or heavy deposits of zinc shall not be permitted.
  - 2. Members shall be free of any sharp protrusions or edges.
- C. Galvanizing repairs shall provide a coating that has a minimum thickness of 180  $\mu\text{m}$ , adheres to the member and has a finished appearance similar to that of the adjacent galvanizing.
  - 1. Galvanizing repair shall comply with ASTM A780, Method A3 "Metallizing" unless the area requiring repair does not exceed 100 mm<sup>2</sup> in which case the repairs may comply with ASTM A780 Method A1 "Repair Using Zinc-Based Alloy".
  - 2. Galvanizing repairs shall be tested for adhesion.

3. Repairs may require complete removal of the galvanized coating and re-galvanizing.

#### 4-4.9.8.3 **Base Plate Corrosion Protection**

- A. The bottom surface of galvanized base plates in contact with concrete shall be protected by a medium grey colour barrier coating to prevent contact between the zinc and the concrete.
  1. The galvanized surface shall be roughened prior to application of the barrier coating.
  2. The surface preparation of the galvanized surface and the dry film thickness (“DFT”) of the coating shall be in accordance with the coating manufacturer’s recommendations.
  3. The adhesion of the fully cured coating shall be tested as per ASTM D3359. The method selected for testing (Method A or B) shall depend on the dry film thickness of the coating. The adhesion test result shall meet a minimum of “4B” classification, i.e. a maximum allowable flaking of 5%.

#### 4-4.9.8.4 **Prime Coating**

- A. At bearing locations, girder bottom flanges shall be prime coated all around (bottom, top and edges) 100 mm beyond the bearing dimension. In addition, at locations that incorporate deck joints, the prime coat shall be extended up the girder web, including bearing/jacking stiffeners and underside of top flange.
- B. The prime coat shall be an organic zinc epoxy primer that has been qualified by test as a Class B coating, in accordance with the “Testing Method to Determine the Slip Coefficient for Coatings Used in Bolted Joints” as described in Appendix A of the Research Council on Structural Connections “Specification for Structural Joints Using High-Strength Bolts”.

#### 4-4.9.9 **Inspection and Testing**

##### 4-4.9.9.1 **General**

- A. Inspection and testing shall be carried out as required to ensure that the structural steel, including all welds, has the required properties.
- B. Testing and inspection shall comply with the following standards:
  1. radiography – AWS D1.5;
  2. ultrasonic – AWS D1.5;
  3. magnetic particle – ASTM E709;
  4. dye-penetrant – ASTM E165; and
  5. hardness tests – ASTM E103.
- C. Visual inspections of welds shall be carried out by an independent welding inspector certified to Level 3 of CAN/CSA W178.2.
- D. Non-destructive testing shall be carried out by a company certified to CAN/CSA W178.1.
  1. Radiographic testing and magnetic particle testing technicians shall be certified to Level II of CGSB.
- E. Full access for the inspection of material and workmanship shall be provided to the City.



1. When required by the City, Project Co shall provide needed manpower for assistance in inspection duties.

#### 4-4.9.9.2 Radiographic Inspection of Girders

- A. Unless otherwise specified, radiographic inspection of girders shall be performed in accordance with the following schedule:
  1. 100% of all tension and stress reversal flange butt welds, all stiffener butt welds and all diaphragm butt welds, and any groove welded attachments to flange plates;
  2. a minimum of 25% of all other flange butt welds randomly selected for each Transportation Structure;
  3. all web butt welds in tension and stress reversal zones plus additional 300 mm of web butt weld in compression zone at the end of the web; and
  4. additional testing shall be carried out if required to ensure the quality of welds.
- B. Deficiencies or Early Handover Deficiencies discovered shall be repaired and the suspect area re-inspected.

#### 4-4.9.9.3 Radiographic Inspection of Members Other than Girders

- A. Unless otherwise specified, radiographic inspection of butt welds in members other than girders shall be performed in accordance with the following schedule:
  1. 100% of all tension members;
  2. 100% of all barrier rail splices; and
  3. 50% of all other members.
- B. Deficiencies or Early Handover Deficiencies discovered shall be repaired and the suspect area re-inspected.

#### 4-4.9.9.4 Magnetic Particle Inspection

- A. Unless otherwise specified, magnetic particle inspection of girders shall be performed for each girder section in accordance with the following schedule:
  1. 50% of the web to flange welds or any fillet welds placed on flange plates;
  2. 10% of the web to stiffener welds;
  3. 100% of the stiffener to flange welds;
  4. 100% of the bearing sole plate to flange welds;
  5. 20% of the diaphragm connector plate welds; and
  6. 100% of all manual (SMAW) welds.
- B. Deficiencies or Early Handover Deficiencies discovered shall be repaired and the suspect area re-inspected.

#### 4-4.9.9.5 **Dye Penetrant Inspection**

- A. Dye penetrant inspection shall be performed at the ends of the weld metal of all flange butt welds after the removal of run-off tabs.
- B. Deficiencies or Early Handover Deficiencies discovered shall be repaired and the suspect area re-inspected.

#### 4-4.9.9.6 **Hardness Tests**

- A. Hardness tests shall be performed on the flame cut edges of girder flanges prior to assembly.
- B. Unless otherwise specified, the hardness of the flame cut edges shall not exceed the following maximum Brinell hardnesses:
  - 1. for carbon steels with a yield strength less than and including 300 MPa, the maximum Brinell shall be 200 BHN; and
  - 2. for carbon steels with a yield strength greater than 300 MPa, the maximum Brinell shall be 220 BHN.
- C. Remedial work to the edges which exceed the specified hardness shall be performed and the edges re-inspected prior to assembly.

#### 4-4.9.9.7 **Testing Stud Shear Connectors**

- A. Stud shear connectors shall meet all requirements as outlined by AWS D1.5.
  - 1. Bend testing shall be performed in accordance with AWS D1.5.
  - 2. When bend testing occurs, the studs shall be bent towards the centre of the girder.

#### 4-4.9.9.8 **Testing of Deck Joint Strip Seal**

- A. Installation of strip seals in deck joints shall be tested for leakage.
- B. Failed areas that leak shall be deemed to be Deficiencies or Early Handover Deficiencies, to be corrected and retested.
  - 1. Leaking strip seals shall be replaced.

#### 4-4.9.10 **Structural Steel Erection**

##### 4-4.9.10.1 **General**

- A. Structural steel shall be erected in a manner that does not damage or adversely affect the steel.
- B. Drilling of additional holes and any other modifications including field welding shall not be made to steel elements other than deck joints.
  - 1. Lifting devices shall not be welded to girders.
  - 2. Structural steel shall not be erected until the substructure concrete has been cured a minimum of three days and achieved 80% of the 28 day specified concrete strength requirement.

#### 4-4.9.10.2 **Transporting Materials**

- A. Girders and beams shall be transported in the vertical position unless specified otherwise.
- B. Girders and beams may be transported in other positions provided:
  - 1. A Professional Engineer performs an analysis and provides a written statement that the transportation method will not damage the elements. The analysis shall account for all static and dynamic forces experienced by the girders during handling, transportation and storage including a dynamic load allowance of at least 100%. The maximum cyclic stress range shall not exceed the constant amplitude fatigue threshold for the appropriate fatigue categories specified in CAN/CSA S6.
  - 2. Upon arrival at the Site and prior to erection, the elements shall be checked to ensure all tolerances are met.
  - 3. An adequate flat storage area shall be provided for the inspection.
  - 4. Any element damaged during transportation, handling, storage or erection shall be immediately reported to the City and an engineering assessment of the damage prepared by a Professional Engineer experienced in the evaluation and inspection of damaged steel members shall be submitted to the City.
- C. All members shall be lifted and handled using devices that do not mark, mar, damage or distort the members and assemblies in any way.
- D. Galvanized material shall be stacked or bundled and stored to prevent wet storage stain as per the American Hot Dip Galvanizers Association (AHDGA) publication "Wet Storage Stain".

#### 4-4.9.10.3 **Temporary Supporting Structures and Berms**

- A. Temporary supporting structures and berms for the erection of structural steel shall be designed and constructed and maintained for the forces that may come upon them.
  - 1. Drawings for temporary supporting structures and berms shall be prepared, signed and sealed by a Professional Engineer.

#### 4-4.9.10.4 **Erection of Structural Steel Girders**

- A. A detailed erection procedure for the erection of structural steel girders shall be prepared in advance of the scheduled start of erection. The erection procedure shall include all drawings and documents necessary to describe the following:
  - 1. earth berms, work bridges or other means required to access work;
  - 2. type and capacity of equipment required for handling and erecting of girders;
  - 3. cranes to be used for handling and erecting structural steel girders.
  - 4. sequence of operation including positions of cranes, trucks with structural steel girders and Transportation Accommodation;
  - 5. position of cranes relative to substructure elements such as abutment backwalls, with details of load distribution of wheels and outriggers;
  - 6. lifting devices and lifting points;

7. details of temporary work, including drawings, and method to be used to ensure the required splice elevations and Structure shape prior to bolt torquing, method of providing temporary supports for stability, top of girder elevations at each bearing and each splice location where appropriate;
  8. bolt tightening sequence; and
  9. details of release of temporary supporting structures.
- B. The erection procedure shall be prepared, signed and sealed by a Professional Engineer who shall assume full responsibility to ensure that its erection procedure is being followed.

#### 4-4.9.10.5 Erection of Barrier Railings

- A. The lines and grades of the barrier railings shall be true to that shown on the applicable Final Design, and not follow any unevenness in the Structure.
1. It may be necessary to adjust the height of the barrier railing, in order to compensate for normal superstructure variations, and achieve the desired line and grade on the barrier railing.

#### 4-4.9.10.6 Straightening Bent Material

- A. Straightening of plates, angles or other shapes shall only be permitted based on a detailed procedure signed and sealed by a Professional Engineer.
1. Following the straightening of a bend or buckle, the surface of the metal shall be inspected for evidence of fractures.
  2. Inspection may include non-destructive testing.

#### 4-4.9.10.7 Assembly

- A. The structural steel parts shall be assembled as shown on the shop drawings and all match-marks shall be followed.
1. Hammering shall not be permitted.
  2. Bearing surfaces and surfaces to be in permanent contact shall be clean before the members are assembled.
  3. Splices and field connections shall have one half of the holes filled with bolts and cylindrical erection pins (half bolts and half pins evenly distributed throughout the splice or connection) before bolting. Splices and connections carrying traffic during erection shall have at least 75% of the holes filled.
  4. Fitting-up bolts shall be sized to the same nominal diameter as the bolts, and cylindrical erection pins shall be sized to accurately fit the holes.
  5. Should adjustments in elevation of the girder splices become necessary to allow free rotation of the joint, only enough pins or bolts to allow rotation shall be removed.

#### 4-4.9.10.8 Grout Pads

- A. Grout pads shall comply with Sections 4-4.11.9.3 [*Grout Pads*] and 4-4.11.9.4 [*Grouting in Cold Weather*] of this Schedule.

#### 4-4.9.11 High-Tensile-Strength Bolted Connections

##### 4-4.9.11.1 General

- A. All girders shall be erected with elevations and alignments checked for conformance to the lines and grades shown on the applicable Final Design prior to any bolt tightening.
- B. Bolted parts shall fit solidly together when assembled.
  - 1. Contact surfaces, including those adjacent to the washers, shall be descaled or carry the normal tight mill scale.
  - 2. Contact surfaces shall be free of dirt, paint, oil, loose scale, burrs, pits and other defects that would prevent solid seating of the parts.
- C. Unless otherwise specified, bolts in exterior girders shall be installed with the heads on the outside face of the girder web and bolts in all girders shall be installed with the heads on the bottom faces of lower flanges.
- D. Nuts for bolts that will be partially embedded in concrete shall be located on the side of the member that will be encased in concrete.
- E. Connections shall be assembled with a hardened washer under the bolt head or nut, whichever is the element turned in tightening.
  - 1. Surfaces of bolted parts in contact with the bolt head and nut shall be parallel.
  - 2. For sloped surfaces, bevelled washers shall be used. The bevelled washers shall produce a bearing surface normal to the bolt axis.
- F. Bolts shall be new and stored in weatherproof containers to prevent loss of lubrication or accumulation of dirt.

##### 4-4.9.11.2 Bolt Tension

- A. Tightening of all high strength bolts shall be by the turn-of-nut method.
- B. Before final tightening there shall be a sufficient number of bolts brought to a “snug tight” condition to ensure that the parts of the joint are brought into full contact with each other. Following this initial operation, bolts shall be placed in any remaining holes in the connection and brought to snug tightness.
  - 1. For the purposes of this Section 4-4.9.11.2 [*Bolt Tension*], “snug tight” shall mean the tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench.
- C. After all bolts have been taken to the snug tight condition, the outer face of each nut and end of bolt shall be match marked to have a common reference line to determine the relative rotation. All bolts in the joint shall then be tightened additionally by the applicable amount of nut rotation specified below, with tightening progressing systematically from the most rigid part of the joint to its free edges. During this operation there shall be no rotation of the part not turned by the wrench.
- D. The amount of rotation of the nut relative to the bolt from snug tight, regardless of which is turned shall be:
  - 1. 1/3 turn where the bolt length is 4 bolt diameters or less;

2. 1/2 turn where the bolt length is over 4 bolt diameters and not exceeding 8 bolt diameters; and
  3. 2/3 turns where the bolt length exceeds 8 bolt diameters.
- E. The tolerance shall be 1/6 turn (60°) over and shall not be under.
- F. The length of the bolt shall be measured from the underside of the bolt head.

#### 4-4.9.11.3 Reuse of Fasteners

- A. High strength bolts shall be tensioned only once and shall not be reused.
- B. Retightening previously tightened bolts, which may have been loosened by tightening adjacent bolts shall not be considered as reuse.

#### 4-4.9.11.4 Misfits

- A. The correction of minor misfits involving reaming, cold cutting and chipping for secondary members will be allowed.
1. If such field corrections are required, a repair procedure signed and sealed by a Professional Engineer shall be prepared prior to the corrections being carried out.

#### 4-4.9.11.5 Girder Adjustment

- A. Adjustments to girder positions, bearing locations and bearing elevations shall be made as required to achieve as closely as possible the lines and grades shown on the applicable Final Design.
- B. Structural steel shall be maintained in correct alignment until the adjoining or encasing concrete components have been completed.

#### 4-4.9.12 Structural Steel for Building Structures

##### 4-4.9.12.1 General

- A. This Section 4-4.9.12 sets out the requirements for all structural steel forming part of a Building Structure, including minimum requirements for the supply, fabrication, delivery and erection of structural steel for Building Structures.
1. Structural steel for Building Structures includes metal decking, cold formed sections, open web steel joists, beams, girders, purlins, wall girts, columns, frames, bracing, bridging, edge angles, respective attachments, plates, bolts, metal studs, metal stair stringers, open grid floor grating, handrails, floor trenches, stair and landing pans and ladders.

##### 4-4.9.12.2 Standards

- A. Structural steel shall comply with the applicable requirements of the following standards:
1. ASTM A325/A325M – Specification for High-Strength Bolts for Structural Steel Joints.
  2. ASTM A653/A653M – Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.

3. Canadian Institute of Steel Construction/Canadian Paint Manufacturer's Association (CISC/CPMA) CISC/CPMA 1-73b, Quick-Drying, One-Coat Paint for Use on Structural Steel - Grey;
4. CISC/CPMA 2 – Quick-Drying, Primer for use on Structural Steel - Grey;
5. CAN/CSAG164 M92 – Hot Dip Galvanizing of Irregularly Shaped Articles;
6. CAN/CSA W47.1 – Certification of Companies for Fusion Welding of Steel Structures;
7. CAN/CSA W48 – Filler Metals and Allied Materials for Metal Arc Welding;
8. CAN/CSA W55.3 – Certification of Companies for Resistance Welding of Steel and Aluminum;
9. CAN/CSA W59 – Welded Steel Construction (Metal Arc Welding);
10. The Society for Protective Coatings (SSPC) SSPC-SP 3 – Power Tool Cleaning;
11. SSPC-SP 6/NACE No. 3 – Commercial Blast Cleaning; and
12. SSPC-SP 8 – Pickling.

#### 4-4.9.12.3 **Engineering Data**

- A. Shop drawings and design briefs shall be signed and sealed by a Professional Engineer.
  1. Shop drawings shall include erection drawings, elevations and details.
  2. Shop drawings shall indicate welded connections using welding symbols in compliance with CISC Welding Standards. Net weld lengths shall be clearly indicated.
- B. All sketches and design calculations for non-standard connections shall be signed and sealed by a Professional Engineer.
- C. For metal deck shop drawings, clearly indicate design loads, material specifications, decking plan, deck profile dimensions and thicknesses, anchorage, supports, projections, openings and reinforcement, closures, flashings, applicable details and accessories.
- D. Shop drawings for joists and connections shall be signed and sealed by a Professional Engineer.
- E. Structural steel design shall comply with the following standards:
  1. CAN/CSA S16 – Design of Steel Structures;
  2. CAN/CSA S136 – North American Specification for the Design of Cold-formed Steel Structural Members;
  3. CISC – Code of Standard Practice for Building; and
  4. CISC – Steel Joist Facts.
- F. Shop drawings, procedures and calculations shall be submitted to the City.

#### 4-4.9.12.4 **Materials**

- A. Steel for open web steel joists shall comply with CAN/CSA G40.21, Type W with a minimum yield strength of 260 MPa for chord sections and web material.

- B. Cold formed steel shall comply with CAN/CSA S136 with a minimum yield strength of 230 MPa.
- C. Other steel shall comply with CAN/CSA G40.21, Grade 300W with a minimum yield strength of 300 MPa.
- D. Bolts, nuts and washers shall comply with ASTM A325M (minimum) and be finished to match the members to which they attach.
- E. Anchor rods shall comply with CAN/CSA G40.21, Grade 300W with a minimum yield strength of 300 MPa. Nuts and washers shall be of equal or greater strength than the anchor rods.
- F. Welding materials shall comply with CAN/CSA W48 and W59.
- G. Galvanizing shall comply with CAN/CSA G164 and shall have a minimum 600 g/m<sup>2</sup> coating.
- H. Galvanizing shall be touched up with a minimum of 2 coats of zinc rich primer.
- I. Metal deck shall be galvanized sheet steel conforming to ASTM A653, Grade 230 with a zinc coating that protects the steel for the Design Service Life of the Structure.

#### 4-4.9.12.5 Fabrication

- A. Fabrication of structural steel members shall comply with CAN/CSA S16 and CAN/CSA S136.
- B. Fabrication of metal deck shall comply with CAN/CSA S136 and Canadian Sheet Steel Building Institute (CSSBI) Standards and Drawings.
- C. All work shall be performed by a firm certified by the CWB to the requirements of CAN/CSA W47.1 in Division 1 or Division 2.1.
- D. All welders employed for erection shall possess valid "S" Classification Class "O" certificates issued by the CWB.
- E. All gaps, butt joints and connections exposed to the exterior of a Building Structure shall be closed and weatherproofed. All exposed welds shall be ground flush with surface of welded members.
- F. Connections for structural steel shall be designed and detailed so that the potential for corrosion is minimized. All exposed ends of HSS sections shall be capped and seal welded.

#### 4-4.9.12.6 Inspection & Testing

- A. Radiographic and magnetic particle inspection of all full penetration welds and column splices shall be performed in accordance with CAN/CSA W59 and ASTM E109.
- B. All welds shall be visually inspected.
- C. Welds shall be considered to be Deficiencies or Early Handover Deficiencies if they fail to meet the quality requirements of CAN/CSA W59.
- D. High strength bolted connections shall be inspected and tested in accordance with Clause 23.9 of CAN/CSA S16.
- E. Free access shall be provided to the City to all portions of work in the shop and in the field.

#### 4-4.9.12.7 Erection

- A. All members damaged during transit or erection shall be repaired or replaced.



- B. Structural steel shall be erected in accordance with CAN/CSA S16 and the applicable Final Design.
- C. Welding shall not be carried out at temperatures below 5 degrees Celsius except with express permission of a Professional Engineer.
- D. The requirements of CSA W59 for minimum preheat and interpass temperatures shall apply.
- E. Erection errors shall not exceed the requirements of CAN/CSA S16.
- F. Steel joists shall be erected in accordance with CAN/CSA S16 and the applicable Final Design.
- G. Metal deck shall be erected in accordance with the requirements of CSSBI and the applicable Final Design. The deck shall be aligned and leveled on the structural supports.
- H. All end joints shall be located over supports.
- I. The lines of supporting steel shall be laid out on the top surface of the deck to produce accurate welds and prevent burns through the deck from improper weld locations.
- J. Openings up to 400 mm in any dimension shall be reinforced with 65 x 65 x 6 mm steel angles. Angles shall be placed at right angles to the ribs, extended out two ribs on each side and welded.
- K. Immediately after installation, welds, burned areas and damaged areas of zinc coating shall be touched up with zinc rich primer.
- L. If two or more adjacent flanges on any deck section are concave or convex so that only the edges or crowns touch a straight edge, the deck sections shall be repaired or replaced.
- M. A Professional Engineer's written permission shall be obtained prior to field cutting or altering steel members.
- N. After erection, welds, nuts, bolts and washers shall be field primed. Abrasions and damage to shop primed and galvanized surfaces shall be touched up with field primer.

#### **4-4.10 STAY CABLES**

##### **4-4.10.1 General**

- A. This Section 4-4.10 [*Stay cables*] sets out requirements for all stay cables forming part of a Structure including minimum requirements for the supply, fabrication, delivery and installation of stay cables.
  - 1. Stay cables include main tensile elements (strands), strand sheathing, anchorage assemblies, saddles, damping devices, anti-vandalism tubes and corrosion protection provisions.
- B. References in PTI DC45.1 to the terms "Contractor" and "Professional Engineer" shall be taken to mean "Project Co" and "Designer" respectively.
  - 1. All submissions made to the "Designer" shall also be made to the City.

##### **4-4.10.2 Engineering Data**

- A. Shop drawings, procedures and calculations shall be submitted to the City. The Review Period shall be 30 Business Days.

- B. Any subsequent deviation from methods, materials, or details will not be permitted unless the affected submittals are updated in advance of use.
- C. Shop drawings shall be prepared showing all dimensions, materials and operations for fabrication, assembly and installation of the stay cables.
- D. Detailed step by step procedures shall be provided for installing all stay cable components and for stressing, adjusting the force in and de-stressing the stay cables. The procedures shall be consistent with the actual loads, sequences, schedules, material properties, cable forces and all other aspects of the Construction of the Structure.
- E. Supporting calculations shall be prepared showing the forces and elongations required for each stay cable.
- F. All submittals shall be signed and sealed by a Professional Engineer.

#### 4-4.10.3 **Materials**

##### 4-4.10.3.1 **Individual Strand Sheathing**

- A. The sheathing around the individual stay cable strands shall be HDPE sheathing and shall comply with the requirements of PTI DC 45.1, Section 3.3.

##### 4-4.10.3.2 **Corrosion Inhibiting Coating**

- A. The intermediate spaces between the strand wires and between the wires and the individual sheath of each stay cable strand shall be filled with a corrosion inhibiting coating meeting the requirements of PTI DC45.1, Section 3.3.

- 1. The filler shall be continuous and durably stable.

##### 4-4.10.3.3 **Outer Stay Pipe**

- A. The outer stay pipe shall be a HDPE pipe and as a minimum shall comply with the requirements of PTI DC45.1, Section 3.5.
- B. In addition, the outer stay pipe shall meet strength and durability requirements under all anticipated cold weather conditions.

#### 4-4.10.4 **Fabrication**

##### 4-4.10.4.1 **General**

- A. The fabrication of stay cables shall comply with Section 6.0 of PTI DC45.1.
- B. The fabrication of stay cables shall conform to Section 4-4.9 [*Structural Steel*] of this Schedule and to the AASHTO LRFD BCS where applicable.

##### 4-4.10.4.2 **Stay Cables**

- A. Stay cable components shall be protected from corrosion, heat, abrasion and other harmful effects throughout fabrication, shipping, delivery, storage and installation.
- B. All damage to stay cables or components thereof shall be evaluated and remedied prior to installation of the stays.
  - 1. Any damaged strand or corrosion protection barrier shall be replaced.

#### 4-4.10.4.3 Strand

- A. During the process of manufacture of individual wires for “weldless” strand, welding shall be permitted only prior to or at the site of the last thermal treatment of the wire, e.g. patenting or controlled cooling.
  - 1. There shall be no welds in the wire after it has been drawn through the first die in the wire drawing process.
- B. Strand shall be supplied in coils and each strand coil shall be protected with a manufacturer approved method so that the strand has no adhering foreign matter or damage to the corrosion protective coating, including that from ultraviolet exposure.
  - 1. The ends of the strands shall be sealed to prevent intrusion of moisture into the annular space between the wires.
  - 2. When uncoiled the strand shall lay straight with a maximum deviation of 100 mm from a theoretical centreline in any 1800 mm length.
  - 3. Handling of the strands shall not result in sharp kinks or short radius bends less than the coil radius.
  - 4. The strand coils shall be supported on wooden or steel reels with padded contact areas, wherever possible.
  - 5. Upon delivery, the strand shall be stored in a weatherproof enclosure to prevent corrosion or other damage.
- C. Welds or joints shall not be permitted in the finished strand.
- D. Each strand coil shall be marked with the order number, coil number, heat number and the starting end.
- E. Individual strands comprising the stay cable shall be cut to their precalculated lengths while fully supported on a rigid calibrated cutting bed.
  - 1. Strands shall be cut using abrasive saws or shears.
  - 2. Flame cutting shall not be permitted.

#### 4-4.10.4.4 Outer Stay Pipe Fusion Welds

- A. When the outer stay pipe is made up of sections assembled end-to-end, the sections shall be assembled by butt fusion welding in accordance with ASTM D2657 (Hot-Plate Welding).
  - 1. The cut ends of sections of the joined pipe shall be perpendicular to the pipe axis.
  - 2. The pipe welds shall be flush with the pipe inside and outside.
  - 3. Welding of the pipe when the stay strands are in the pipe shall not be permitted.
- B. The welds shall be performed on a test section of pipe for the cable cross section as shown on the applicable Final Design.
  - 1. The necessary tests shall be performed to ensure that the weld develops the required strength and that the joint is hydrostatically sealed.

#### 4-4.10.5 **Testing and Qualification**

- A. Testing and qualification of the stay cables, including strands, strand sheathing, anchorage assemblies, saddles and corrosion protection provisions shall comply with the requirements of PTI DC45.1.

#### 4-4.10.5.1 **Anchorage Testing**

- A. Testing of the stay cable anchorages shall be carried out in accordance with the AASHTO LRFD BCS, Section 10.3.2.3.
  - 1. The crack width requirements of AASHTO LRFD BCS Section 10.3.2.3 shall be met.

#### 4-4.10.6 **Installation**

##### 4-4.10.6.1 **General**

- A. Stay cables shall be installed in a manner that does not damage the stay cables including strands, strand sheathing, anchorages assemblies, saddles and corrosion protection.
  - 1. Stay cables shall be stored, handled, transported, assembled and installed in accordance with the procedures prescribed by the stay cable supplier.
  - 2. The installation of stay cables shall be in accordance with Section 6.0 of PTI DC 45.1.
  - 3. During installation the leading ends of the strands shall be prevented from damaging the stay pipe or the sheaths of the strands installed previously.
  - 4. The stay cable anchorages, saddles, guidance systems, etc. shall be fitted with protection to avoid damaging the individual protection of strands during installation.
  - 5. The strands shall be parallel throughout their length and shall pass through matching holes in the anchorage heads.
- B. Stay cables, anchorages, and guide systems shall be installed and aligned based on a geometric control plan that accounts for changes in Structure geometry after their installation.

##### 4-4.10.6.2 **Stressing**

- A. Stay cables shall be stressed in accordance with the procedures prescribed by the stay cable supplier and so as to produce the forces in the cables shown on the applicable Final Design.
  - 1. Stay cable strands may be tensioned one-by-one provided that it can be demonstrated that the final tension and elongation of each strand is equalized within a range of  $\pm 2.5\%$  GUTS.
  - 2. All stressing results shall be recorded automatically with a computer system connected to load cells.
- B. Jacks and gauges for stay cable installation shall be calibrated with reference to a standard pressure gauge or load cell within one month prior to the beginning of cable installation, and every 6 months thereafter, or for 500 strands maximum, for the duration of cable installation.
  - 1. The standard gauge shall have a relative accuracy of at least  $\pm 0.5\%$ .
- C. Stay cables shall be capable of being tensioned, de-tensioned and re-tensioned more than once during the Construction of the Structure.

1. These operations may be carried out either by full jacking of the live anchorage or strand by strand.
2. Stay cables shall not be de-tensioned in such a way that during de-tensioning the "gripping" zone is incorporated in the stressed portion of the stay. The "gripped" zone shall not be left permanently on the stressed portion of the stay.

#### 4-4.10.6.3 **Monitoring & Adjustment**

- A. Stay cables shall be adjusted in the final dead load condition such that each individual cable does not deviate from the stay cable dead load force values shown on the applicable Final Design by more than  $\pm 5\%$ .
  1. Force verification shall be performed with full head lift off tests.
- B. Strands extending through the stay cable saddles shall be monitored for any possible slippage during Construction and adjusted if needed in accordance with procedures prescribed by the stay cable supplier.

#### 4-4.10.6.4 **Documentation**

- A. Permanent records of the stay cable installation shall be prepared in accordance with the requirements of PTI DC45.1, Section 6.9.6.2.
  1. The permanent records shall include the As Built deck profiles and final cable loads that constitute the base line survey.

### **4-4.11 BEARINGS**

#### 4-4.11.1 **General**

- A. This Section 4-4.11 [*Bearings*] sets out the requirements for all plain and steel reinforced elastomeric bearings and pot bearings forming part of a Structure, including minimum requirements for the supply, fabrication, delivery and installation of bearings.

#### 4-4.11.2 **Engineering Data**

##### 4-4.11.2.1 **Shop Drawings**

- A. Shop drawings meeting the requirements of Section 4-4.9.3.1 [*Shop Drawings*] of this Schedule and the following shall be prepared and submitted to the City:
  1. The shop drawings shall identify the bearing and clearly indicate all bearing material properties, dimensions, connection attachments, fasteners and accessories.
  2. The shop drawings shall show the bearing load capacity at the serviceability and ultimate limit states as follows:
    - a. maximum vertical permanent and total load;
    - b. maximum lateral load and corresponding vertical load; and
    - c. maximum rotational capacity about any horizontal axis and about the vertical axis at the centre of the bearing.
  3. Shop drawings shall be signed and sealed by a Professional Engineer.

#### 4-4.11.2.2 **Welding Procedures**

- A. Welding procedures for the fabrication and field installation of bearings shall be prepared prior to welding for each type of weld used in the bearings.
  - 1. The welding procedures shall bear the approval of the CWB.

#### 4-4.11.2.3 **Mill Certificates and Quality Assurance Test Results**

- A. Mill certificates and quality assurance test results shall be obtained for all materials and fabricated components prior to shipping of the finished bearings from the facility of manufacture.

#### 4-4.11.3 **Materials**

##### 4-4.11.3.1 **Elastomer**

- A. Except for fully integral abutments and piers, elastomeric compounds shall be low temperature AASHTO Grade 5 and shall meet the physical and low temperature brittleness requirements listed in Table 1 and Section 8.8.4 of AASHTO M251.
- B. Elastomeric compounds for fully integral abutments and piers shall be low temperature AASHTO Grade 3, 4, or 5 and shall meet the physical and low temperature brittleness requirements listed in Table 1 and Section 8.8.4 of AASHTO M251.

##### 4-4.11.3.2 **Lubricant**

- A. Lubricant for bearings shall be silicone grease, effective to -40° Celsius, and shall comply with U.S. Department of Defense MIL-S-660C.

##### 4-4.11.3.3 **Adhesives**

- A. Adhesive for bonding PTFE to metal shall be an epoxy resin producing a bond with a minimum peel strength of 4 N/mm, when tested according to ASTM D 429, Method B.
  - 1. Adhesives shall not degrade in the service environment.

#### 4-4.11.4 **Base Plate Corrosion Protection**

- A. Bearing base plate corrosion protection requirements shall be as per Section 4-4.9.8.3 [*Base Plate Corrosion Protection*] of this Schedule.

#### 4-4.11.5 **Welding**

##### 4-4.11.5.1 **General**

- A. The deposited weld metal shall provide strength, durability, impact toughness and corrosion resistance equivalent to the base metal.
- B. Low hydrogen fillers, fluxes and low hydrogen welding practices shall be used throughout.
  - 1. Low hydrogen coverings and fluxes shall be protected and stored as specified by AWS D1.5.
  - 2. Flux cored welding, the use of cored filler wires in the submerged arc process and shielding gas processes are not permitted.
  - 3. Metal core welding processes utilizing low hydrogen electrodes with AWS designation of H4 are allowed.

4. Field application of metal core arc welding is not permitted.

#### 4-4.11.5.2 **Cleaning Prior to Welding**

- A. Weld areas shall be clean, free of mill scale, dirt, grease, and other contaminants prior to welding.

#### 4-4.11.5.3 **Tack and Temporary Welds**

- A. Tack and temporary welds are not allowed unless they are incorporated in the final weld.
  1. Tack welds, where allowed, shall be of a minimum length of four times the nominal size of the weld and shall be subject to the same quality requirements as the final welds.
  2. Cracked tack welds shall be completely removed prior to welding over.

#### 4-4.11.5.4 **Arc Strikes**

- A. Arc strikes shall not be permitted.
- B. In the event of accidental arc strikes, a repair procedure shall be prepared, signed and sealed by a Professional Engineer prior to repair work commencing. The repair procedure shall include the complete grinding out of the crater produced by the arc strike.

#### 4-4.11.5.5 **Methods of Weld Repair**

- A. Repair procedures for damaged base metal and unsatisfactory welds shall be prepared, signed and sealed by a Professional Engineer prior to repair work commencing.

#### 4-4.11.5.6 **Plug and Slot Welds**

- A. Plug welds or slot welds shall not be permitted.

#### 4-4.11.6 **Fabrication**

##### 4-4.11.6.1 **General**

- A. The fabrication of bearings shall be carried out as required to achieve the required performance of the bearings.
- B. Fabrication of plain and steel reinforced elastomeric bearings and pot bearings shall comply with the following:
  1. AASHTO LRFD Bridge Construction Specifications (AASHTO LRFD BCS);
  2. AASHTO M251 – Standard Specifications for Transportation Materials and Methods of Sampling and Testing – Standard Specification for Plain and Laminated Elastomeric Bridge Bearings; and
  3. AWS – Bridge Welding Code D1.5.
- C. The fabricator for the steel bearing components shall be approved by the Canadian Welding Bureau (CWB) as per CAN/CSA W47.1 in Divisions 1 or 2.
- D. Fabrication shall be performed in a fully enclosed area which is heated to at least 10 degrees Celsius.
- E. Only welders, welding operators and tackers approved by the CWB in the particular weld category to be carried out shall be permitted to perform weldments.

#### 4-4.11.6.1 Plain Bearings

- A. Plain bearing pads shall be molded individually, cut from molded strips or slabs of the required thickness, or extruded and cut to length.

#### 4-4.11.6.2 Steel Laminated Bearings

- A. Steel laminated bearings shall be molded under pressure as a single unit and heated in molds that have a smooth surface finish.
- B. The steel laminates shall be of uniform thickness without any sharp edges.
- C. The bond between the elastomer and the steel laminates shall be such that when a sample is tested for separation, failure shall occur within the elastomer and not between the elastomer and steel laminate.
- D. The 2.5 mm deep recess in the top 10 mm steel laminate for sliding bearings shall be machined as per Section 4-4.11.6.4 [*Machining*] of this Schedule.

#### 4-4.11.6.3 Pot Bearings

- A. Stainless steel sheets in contact with PTFE shall be continuously welded around the perimeter to the backing plate to prevent ingress of moisture.
  - 1. The weld shall be clean, uniform, and without overlaps and shall be located outside the area in contact with PTFE.
- B. The threaded portion of the bolts shall be coated with silicone grease prior to installation.
- C. Virgin or glass filled PTFE elements shall be recessed in a rigid backing material and shall be bonded over the entire area with an adhesive.
  - 1. The rigid backing material shall be grit blasted and cleaned with oil free compressed air prior to applying the adhesive.
- D. The PTFE elements used as mating surfaces for guides for lateral restraint shall extend to within 10 mm from the ends of the backing plates.

#### 4-4.11.6.4 Machining

- A. All metal to metal contact surfaces shall be machined.
  - 1. Machining shall be done after welding.
  - 2. For pot bearings, the pots and pistons shall be machined from solid metal plate or castings.
- B. There shall be no openings or discontinuities in the metal surfaces in contact with the confined elastomer or PTFE.
- C. The surface finish of metal plate in contact with any metal plate or confined elastomer in pot bearings shall be machined to a surface finish of 6.4  $\mu\text{m}$  and a flatness tolerance of 0.001 x bearing dimension.

#### 4-4.11.6.5 Coating

- A. Unless otherwise specified, metal components, except weathering steel (CAN/CSA G40.21 350A and 350AT) and stainless steel, shall be hot dip galvanized after fabrication in



accordance with ASTM A123/A123M Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products and ASTM F2329 Standard Specification for Zinc Coating Hot-Dip Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners.

- B. For pot bearings, the pot and piston plates, except surfaces in contact with elastomer, shall be metallized as per ASTM A780, Method A3.
  - 1. The thickness of metallizing shall not be less than 180  $\mu\text{m}$ .
- C. Galvanizing repairs shall provide a coating that has a minimum thickness of 180  $\mu\text{m}$ , adheres to the member and has a finished appearance similar to that of the adjacent galvanizing.
  - 1. Galvanizing repair shall comply with ASTM A780, Method A3 "Metallizing" unless the area requiring repair does not exceed 100 mm<sup>2</sup> in which case the repairs may comply with ASTM A780 Method A1 "Repair Using Zine-Based Alloy".
  - 2. Galvanizing repairs shall be tested for adhesion.
  - 3. Repairs may require complete removal of the galvanized coating and re-galvanizing.
- D. The galvanized top surfaces of bearing plates shall be hand wire brushed to a Class C slip coefficient surface condition.
  - 1. Slip coefficient surface conditions shall meet the requirements of CAN/CSA S6 Table 10.9.

#### 4-4.11.7 Tolerances

- A. Plain and steel laminated bearing tolerances shall comply with AASHTO M251.
  - B. Pot bearing tolerances shall be as follows:
    - 1. The deviation from flatness of PTFE surfaces shall not exceed:
      - a. 0.2 mm, when the diameter or diagonal is equal to or less than 800 mm; or
      - b. 0.00025 of the diameter or diagonal, when the diameter or diagonal is greater than 800 mm.
    - 2. The deviation from flatness of stainless steel surfaces in contact with PTFE for plane surfaces and from the theoretical surface for spherical surfaces shall not exceed:
      - a. 0.0003 LH mm for a rectangular PTFE element; or
      - b. 0.0006 RH mm for a circular PTFE element.
- where:
- L = the greater plan dimension for a rectangular bearing;
- R = the radius of a circular bearing; and,
- H = the free height of PTFE element.
- 3. For confined elastomer bearings, the tolerance of fit between the piston and the pot shall be + 0.75 to + 1.25 mm. The inside diameter of the pot cylinder shall be the same as the nominal diameter of the elastomer and shall be machined to a tolerance of:

- a. 0 to + 0.125 mm for diameters up to and including 500 mm; or
  - b. 0 to + 0.175 mm for diameters over 500 mm.
4. The plan dimensions of the recess for PTFE shall be the same as the nominal plan dimensions of the PTFE and shall be machined to a tolerance of 0 to + 0.2% of the diameter or diagonal:
    - a. overall bearing plan dimension  $\pm 3$  mm;
    - b. overall bearing height  $\pm 3$  mm; and
    - c. machined surface dimensions  $\pm 0.4$  mm.
  5. Elastomeric components shall meet the following requirements:
    - a. diameter:
      - i. 0.0 to - 1.5 mm for diameters  $\leq 500$  mm; or
      - ii. 0.0 to - 2.0 mm for diameters  $> 500$  mm; and
    - b. thickness 0.0 to + 1.0 mm
  6. Brass rings shall meet the following requirements:
    - a. difference between internal diameter of brass ring and diameter of recess in the moulded elastomer shall be 0 to + 0.5 mm; and
    - b. difference between sum of thicknesses of brass rings and recess depth in the moulded elastomer 0 to + 0.25 mm.
  7. Recessed guide bars shall meet the requirements of the American Standard Clearance Locational Fit Class LC3 according to ANSI B4.1.
  8. Guides for lateral restraints shall have a 0.50 mm  $\pm$  0.25 mm gap between metal restraints surfaces and mating PTFE elements.
  9. PTFE components shall meet the following requirements:
    - a. the plan dimension of the PTFE shall be 0 to - 0.2% of the design diameter or diagonal;
    - b. the thickness of the PTFE shall be within 0 to + 10.0% of the design thickness; and
    - c. the depth of recess of the PTFE shall be 0 to + 0.3 mm.

#### 4-4.11.8 Inspection and Testing

- A. Inspection and testing shall be carried out as required to ensure that the bearings have the required properties.
- B. An independent accredited testing company shall be engaged to perform the testing of the bearing materials and the finished bearings.
  1. The inspection and testing results and the manufacturer's certification, as a written affidavit that the material supplied meets the Project Requirements, shall be provided.
- C. Elastomeric Bearings

1. Testing of elastomeric compounds shall be completed in accordance with AASHTO M251.
2. Testing of the completed bearings shall be in accordance with AASHTO M251 with the exception that contrary to Sections 8.8.1 and 8.8.2 of AASHTO M251, testing of all bearings is required.
  - a. The optional testing described in Section 8.9 of AASHTO M251 is not required.
3. The increment in compressive deformation of laminated bearings shall not exceed 0.05 of the effective rubber thickness, when the bearing load is increased from an initial pressure of 1.5 MPa to a pressure of 7 MPa when tested in accordance with the requirements of Section 9.1 of AASHTO M251.

#### D. Pot Bearings

1. Testing of elastomeric compounds shall be completed in accordance with AASHTO M251.
2. Testing of the finished bearings shall be completed in accordance with the requirements of Section 18.3.4 of the AASHTO LRFD BCS.
3. The long-term deterioration test described in Section 18.3.4.4.3 of the AASHTO LRFD BCS is not required.
4. The proof load test described in Section 18.3.4.4.4 of the AASHTO LRFD BCS shall be carried out as per the long-term proof load test requirements.

#### 4-4.11.9 Installation

##### 4-4.11.9.1 General

- A. Bearings shall be installed in a manner that does not damage them or affect their performance.
- B. A bearing installation procedure shall be prepared prior to installation.

##### 4-4.11.9.2 Bearing and Anchorage

- A. Bearing base plates shall not be placed upon surfaces which are improperly finished, deformed or irregular.
- B. Field welding adjacent to elastomeric pads shall be performed so as not to damage the elastomer.
  1. The temperature of the steel adjacent to the elastomer shall be kept below 120° Celsius.
  2. The distance between the weld and the elastomer shall be at least 40 mm.
- C. The tops of bearing sole plates shall be within a tolerance of  $\pm 3$  mm of the correct elevation prior to girder erection.
- D. The attachment of sole plates to girders by welding shall be in the longitudinal direction along the edge of the bottom flange or shoe plate.
  1. Transverse welding shall not be permitted.
  2. Transverse ends shall be sealed with Sikaflex 1a or equivalent caulking material.

- E. Galvanizing or metallizing damaged during bearing installation shall be repaired in accordance with the requirements of ASTM A780, Method A3.

#### 4-4.11.9.3 Grout Pads

- A. Grout pads shall be constructed using Sika 212 flowable grout or an equivalent on the Alberta Transportation Approved Product List.
  - 1. Dry-pack methods of constructing grout pads are not permitted.
  - 2. Filling of anchor rod voids and construction of grout pads shall be done by workers competent in this work.
- B. Grout shall be packaged in waterproof containers with the production date and shelf life of the material shown.
- C. Grout shall be mixed, placed, and cured in accordance with the manufacturer's recommendations stated on their published product data sheet.
- D. A set of compressive strength cubes shall be taken to represent each days grout production or each 0.25 m<sup>3</sup> of grout placed, whichever is more frequent.
- E. Prior to casting deck concrete, the average minimum compressive strength of 3 grout cubes at 28 days shall be a minimum of 30 MPa measured in accordance with CAN/CSA A23.2-1B.

#### 4-4.11.9.4 Grouting in Cold Weather

- A. When the daily minimum air temperature or the temperature of the girders, bearings or substructure concrete in the immediate area of the grouting is, or is expected to be below 5 degree Celsius during the placing and curing period, the following provisions for cold weather grouting shall be applied:
  - 1. Before grouting, adequate preheat shall be provided to raise the temperature of the adjacent areas of the girders, bearings and substructure concrete to at least 15 degrees Celsius.
  - 2. The temperature of the grout during placing shall be between 10 degrees Celsius and 25 degrees Celsius.
  - 3. The grout pads shall be enclosed and kept at 15 degrees Celsius to 25 degrees Celsius for a minimum of five days.
  - 4. The enclosure shall meet the requirements of Section 4-4.4.16 [*Concreting In Cold Weather*] of this Schedule.

### 4-4.12 CSP AND SPCSP STRUCTURES

#### 4-4.12.1 General

- A. This Section 4-4.12 [*CSP and SPCSP Structures*] sets out the requirements for all corrugated steel pipe (CSP) and structural plate corrugated steel pipe (SPCSP), with a diameter or opening dimension of 1.5 m or greater, forming part of a Structure, including minimum requirements for the supply, fabrication, delivery and installation of the CSPs/SPCSPs.

#### 4-4.12.2 **Engineering Data**

##### 4-4.12.2.1 **Shop Drawings**

- A. Shop drawings shall be prepared for SPCSP Structures as well as for any non-standard components of CSP and SPCSP Structures such as elbows, bottomless arch details, horizontal ellipses and bevel end details.
  - 1. The shop drawings shall show all dimensions, materials and operations required for fabrication and assembly of the pipes.
  - 2. The shop drawings shall indicate that the bolts in the valley of each longitudinal seam are nearer to the visible edge of the plate than the bolts in the crest.
  - 3. With the exception of “change of radii” locations, the shop drawings shall show all longitudinal seams staggered a minimum of 2N.
  - 4. Shop drawings shall be submitted to the City.

##### 4-4.12.3 **Materials**

- A. All pipe supplied shall be clearly marked with the following information at intervals of not less than 3 m:
  - 1. manufacturer’s name or trade mark;
  - 2. nominal thickness and type of metal;
  - 3. plate/metal coating (for non-standard coating);
  - 4. specification designation;
  - 5. plant designation code; and
  - 6. date of manufacture.

##### 4-4.12.4 **Fabrication of CSP**

- A. The supply and fabrication of all galvanized, polymer coated and aluminum coated corrugated steel CSP, including couplers and appurtenances, shall be in accordance with CAN/CSA G401 with additions and exceptions as described in this Section 4-4.12 [*CSP and SPCSP Structures*] of this Schedule.

##### 4-4.12.4.1 **Sloped Ends**

- A. Sloped end sections are required at the end of each CSP unless otherwise specified on the applicable Final Design.

##### 4-4.12.4.2 **Cut Ends**

- A. All cut edges of a sloped or square end section shall be made smooth by grinding.
- B. For CSPs with a diameter of 1.0 m or larger, all lockseams terminating at the cut edges of a sloped or square end section shall have a 75 mm length of fillet weld run along both sides of the lockseam (staggered 300 mm apart) at each cut edge.
  - 1. Any damaged areas shall be zinc coated after cutting and welding in accordance with CAN/CSA G401.

#### 4-4.12.4.3 Couplers

- A. Couplers between CSP sections shall be sealed and firmly connect the adjacent sections of CSP together.
  - 1. Couplers shall be annular corrugated couplers.
  - 2. The couplers for CSPs 1.6 m and over in diameter shall be a minimum of 600 mm wide.
  - 3. There shall be a minimum of five bolts per coupler.
- B. CSPs shall have their ends re-corrugated to provide annular corrugations for the couplers.

#### 4-4.12.5 Fabrication of SPCSP

- A. The supply and fabrication of all galvanized, polymer coated and aluminum coated structural plate corrugated steel pipe shall be in accordance with CAN/CSA G401 with additions and exceptions as described in this Section 4-4.12 [CSP and SPCSP Structures] of this Schedule.

#### 4-4.12.5.1 Sloped Ends

- A. Sloped end sections are required at the end of each SPCSP unless otherwise specified on the applicable Final Design.

#### 4-4.12.6 Storage of Material

- A. All material shall be stored in a manner that preserves the quality and fitness of the material.
- B. In addition to the requirements of CAN/CSA G401, SPCSP material shall be stored concave down.

#### 4-4.12.7 Handling of Material

- A. CSP and SPCSP material shall be handled in such a manner as to prevent bruising, scaling or breaking of the galvanized coating.
- B. CSP and SPCSP material shall be handled without undue stress in the material and in such a manner that the radii or dimensions of the CSP or SPCSPs remain true.
  - 1. Where the material supplied is damaged, nested sections of SPCSP plate or CSP shall be separated immediately to facilitate a detailed inspection.

#### 4-4.12.8 Installation of Bedding Material

- A. Excavations required for the installation of CSPs and SPCSPs shall extend a minimum of 600 mm below the CSP or SPCSP invert and shall be kept dewatered to the bottom of the excavation until all backfilling is complete.
- B. The bedding material placed below the CSP or SPCSP shall provide adequate support for the CSP or SPCSP respectively so that the CSP or SPCSP is not damaged and so that the final shape of the CSP or SPCSP is within 2 % of its design dimensions.
- C. The bedding material shall extend the width of the CSP or SPCSP and a minimum of 600 mm below the CSP or SPCSP invert.
- D. The top of the bedding material below the CSP or SPCSP invert shall be placed to the lines and grades shown on the applicable Final Design.

1. Where camber is specified on the applicable Final Design, the top of the bedding shall be constructed on a gradual crest curve conforming to the required camber with no sudden breaks in the grade.
  2. Where preshaping is specified on the applicable Final Design, the top of the bedding shall be constructed to the exact curvature of the bottom plates. The top of the preshaping shall be 200 mm to 300 mm below the horizontal seam which joins the sidewall plates to the bottom plates, or as shown on the applicable Final Design.
  3. The top of the bedding material is that portion of the structural fill in contact with the bottom of the CSP or SPCSP.
  4. Metal CSPs and SPCSPs are flexible, and their resistance to deformation depends on careful bedding and backfilling. As they deflect under vertical load they build up wide support and therefore, to obtain maximum load bearing capacity, it is essential that the material under and beside the CSP or SPCSP be of good quality, carefully placed and properly shaped and compacted as specified on the applicable Final Design.
- E. The bedding material shall be Des 2, Class 40 material as specified in Section 4-4.13.3.4 [Backfill] of this Schedule.
- F. The bedding material shall be compacted to a minimum of 95% of Standard Proctor Density at optimum moisture content except that material within 150 mm of the invert of the CSP or SPCSP shall be placed in a loose uncompacted state.
1. The bedding material shall be placed in lifts not exceeding 150 mm in thickness when compacted.
- G. When foundation conditions are soft and unstable, woven geotextile filter fabric shall be supplied and placed at the base of the excavation beneath the bedding material. The woven geotextile filter fabric shall comply with Table 4-4.12.8-1 [Requirements for Woven Geotextile Filter Fabric]:

Table 4-4.12.8-1 Requirements for Woven Geotextile Filter Fabric

Woven Geotextile Filter Fabric	
Specifications and Physical Properties	
Grab Strength	1275 N
Elongation (Failure)	15%

Woven Geotextile Filter Fabric	
Specifications and Physical Properties	
Puncture Strength	275 N
Burst Strength	3.6 MPa
Trapezoidal Tear	475 N
Minimum Fabric Lap to be 1.0 m	

#### 4-4.12.9 **Assembly**

##### 4-4.12.9.1 **Assembly of CSP**

- A. CSP sections shall be assembled so that their ends are in close contact.
- B. Couplers between sections shall be well fitted and evenly tightened all around the CSP.

##### 4-4.12.9.2 **Assembly of SPCSP**

- A. SPCSPs shall be assembled on the bedding material as shown on the shop drawings.
- B. All bolted seams shall be lapped with plates in contact for the full width and length of the seams.
  1. The bolts in the valley of each longitudinal seam shall be nearer to the visible edge of the plate than the bolts in the crest.
- C. The shape of the SPCSP shall be maintained to within 2% of design dimensions. This includes the rise, the span, and any chords or chord offsets.
- D. Adjustments shall be made as required to achieve the design dimensions with fully nested seams.
  1. Where horizontal tie cables are used for shape adjustment, adequate means shall be taken to ensure distribution of the concentrated forces at the SPCSP walls.
  2. Distortion of the SPCSP side walls at the cable points is not permitted.
  3. Horizontal struts shall not be used for shape adjustment.
  4. After two complete rings have been loosely assembled, the vertical dimensions shall be checked and where necessary adjusted with horizontal cables and/or supports to obtain the design dimensions.
  5. Each adjacent ring shall be assembled and adjusted in a similar manner until the entire Structure is loosely assembled and conforms to the design geometry with all plates fully nested.
- E. After assembly of the SPCSP is complete, the vertical axis of the SPCSP shall be upright and all longitudinal seams shall be straight.



- F. Unless otherwise specified by the manufacturer's specifications, bolts shall be torqued to not less than 200 Nm and not more than 340 Nm. This includes bolts which connect special features to the SPCSP.
  - 1. Distortion of bolt holes caused by over-torquing, or poor assembly methods is not permitted.
- G. Where additional bolt holes are required they shall be drilled.
  - 1. Torch cutting of holes or welding on the SPCSP is not permitted.

#### 4-4.12.10 **Backfill**

- A. When the assembly of the CSP or SPCSP has been completed, backfilling with granular and non-granular backfill as specified on the applicable Final Design may proceed.
- B. Granular backfill shall be Des 2, Class 40 material as specified in Section 4-4.13.3.4 *[Backfill]* of this Schedule.
- C. Non-granular backfill shall consist of clay or till materials.
  - 1. Highly plastic clay material or material with a high silt content is not permitted.
- D. Backfill shall be placed in a manner such that the CSP or SPCSP is not damaged, has adequate support from the backfill and has a final shape within 2% of its design dimensions.
  - 1. Backfill under the CSP or SPCSP haunches shall be compacted in thin layers filling all corrugations to ensure firm contact with the entire bottom surface of the CSP or SPCSP respectively.
  - 2. Backfill shall be compacted to a minimum of 95% Standard Proctor Density at optimum moisture content unless otherwise specified in this Section 4-4.12.10 *[Backfill]*.
  - 3. Backfill shall be placed in lifts not exceeding 150 mm in thickness when compacted unless otherwise specified in this Section 4-4.12.10 *[Backfill]*.
  - 4. The backfill shall be placed such that the level of fill on one side of the CSP or SPCSP does not exceed the level of fill on the other side of the CSP or SPCSP respectively by more than 150 mm.
  - 5. Backfill placed adjacent to the CSP or SPCSP shall be placed, levelled and compacted by equipment moving parallel to the CSP or SPCSP with simultaneous handwork along the CSP or SPCSP. Large earth moving equipment and large compaction equipment shall not be used within 1.0 m of the CSP or SPCSP.
  - 6. The first 300 mm of backfill over the CSP or SPCSP shall be placed, levelled and compacted without vibration. Subsequent backfill over the CSP or SPCSP shall be placed and compacted by equipment moving perpendicular to the longitudinal axis of the CSP or SPCSP respectively.
- E. When the air temperature is below 0 degrees Celsius, backfilling is not allowed.
  - 1. Backfill materials, including bedding materials, shall be in a thawed state when placed and compacted.
  - 2. Backfill material, including bedding materials, shall not be placed on frozen substrate.

#### 4-4.12.11 **Concrete Work**

- A. Concrete work shall be constructed as shown on the applicable Final Design and shall comply with Section 4-4.4 [*Cast-In-Place Concrete*] and Section 4-4.8 [*Reinforcing Steel*] of this Schedule.

#### 4-4.12.12 **Heavy Rock Riprap**

- A. Heavy rock riprap shall be placed as shown in the applicable Final Design and shall comply with Section 4-4.3 [*Heavy Rock Riprap*] of this Schedule.

### **4-4.13 MECHANICALLY STABILIZED EARTH WALLS**

#### 4-4.13.1 **General**

- A. This Section 4-4.13 [*Mechanically Stabilized Earth Walls*] sets out the requirements for all mechanically stabilized earth (MSE) retaining walls forming part of a Structure, including minimum requirements for the supply, fabrication and construction of the walls.

#### 4-4.13.2 **Engineering Data**

##### 4-4.13.2.1 **Shop Drawings**

- A. Shop drawings shall be prepared for all MSE walls and as a minimum, the shop drawings shall show the following:
  - 1. MSE wall design criteria and material lists;
  - 2. MSE wall backfill properties;
  - 3. MSE wall layout plans and elevations complete with dimensions, elevations and typical wall cross-sections;
  - 4. all MSE wall component and connection details; and
  - 5. drainage and site drainage details.
- B. Shop drawings shall be signed and sealed by a Professional Engineer and shall be submitted to the City.

#### 4-4.13.3 **Materials**

##### 4-4.13.3.1 **Concrete**

- A. Concrete shall comply with Section 4-4.4 [*Cast-In-Place Concrete*] and Section 4-4.5 [*Precast Concrete*] of this Schedule as applicable.

##### 4-4.13.3.2 **Reinforcing Steel**

- A. Reinforcing steel shall comply with Section 4-4.8 [*Reinforcing Steel*] of this Schedule.

##### 4-4.13.3.3 **Soil Reinforcing**

- A. Steel soil reinforcing, including inspection wires, shall comply with ASTM A1064.
- B. Galvanizing of steel soil reinforcing shall comply with ASTM A123/A123M, and ASTM A153/A153M.
  - 1. All damage to galvanizing shall be repaired in accordance with ASTM A780.

- C. Geosynthetic soil reinforcing shall meet the requirements of AASHTO LRFD, Section 11.10.6.4.3b.
1. The requirements “for applications involving severe consequences of poor performance or failure” shall be applied.
  2. Product specific durability studies shall be carried out to determine the product specific long term strength reduction factor (RF). These studies shall be used to estimate the short term and long term effects of the environment factors on the strength and deformational characteristics of the geosynthetic soil reinforcing throughout the Design Service Life.
- D. Geosynthetic soil reinforcing materials shall meet the requirements of the following tests:
1. GG 1-87 “Standard Test Method for Geogrid Rib Tensile Strength”;
  2. GG 2-87 “Standard Test Method for Geogrid Rib Junction Strength”;
  3. GG 3-90 “Standard Test Method for Tensile Creep Testing of Geogrids”; and
  4. GG4-05 “Standard Practice for Determination of the Long Term Creep Design Strengths of Geogrids”.
- E. Geosynthetic soil reinforcing materials shall contain stabilizers or inhibitors to prevent degradation of properties due to ultraviolet light exposure.
- F. The nominal long-term reinforcement design strength ( $T_{al}$ ) values for specific products shall be determined by an independent agency such as the Highway Innovative Technology Evaluation Centre (HITEC) or AASHTO National Transportation Product Evaluation Program (NTPEP)
1. Product lines shall have been tested within the last 3 years.

#### 4-4.13.3.4 Backfill

- A. MSE wall reinforced backfill shall be “Crushed Aggregate Material” complying with Table 4-4.13.3-1 [Class Designation of MSE Wall Backfill Materials], and shall be free of organic matter and other deleterious substances:

Table 4-4.13.3-1 Class Designation of MSE Wall Backfill Materials

Metric Sieve Size (CGSB 8-GP-2M)	Crushed Aggregate Material Des 2 Class 20	Crushed Aggregate Material Des 2 Class 25	Crushed Aggregate Material Des 2 Class 40
Sieve Size µm	Percent Passing	Percent Passing	Percent Passing
40 000			100
25 000		100	70 - 94
20 000	100	82 - 97	
16 000	84 - 94	70 - 94	55 - 85
10 000	63 - 86	52 - 79	44 - 74
5 000	40 - 67	35 - 64	32 - 62

Metric Sieve Size (CGSB 8-GP-2M)	Crushed Aggregate Material Des 2 Class 20	Crushed Aggregate Material Des 2 Class 25	Crushed Aggregate Material Des 2 Class 40
Sieve Size µm	Percent Passing	Percent Passing	Percent Passing
1 250	22 - 43	18 - 43	17 - 43
630	14 - 34	12 - 34	12 - 34
315	9 - 26	8 - 26	8 - 26
160	5 - 18	5 - 18	5 - 18
80	2 - 10	2 - 10	2 - 10
% fractures by weight (2 faces)	60+	60+	50+
Plasticity Index		NP - 6	NP - 6
L.A. Abrasion Loss Percent Maximum		50	50

B. MSE wall backfill material placed within 2.0 m of the MSE wall face shall be free draining, and have no more than 5% passing the 80 µm sieve size.

1. Soil filters between soil zones shall be designed to prevent infiltration of soil between the zones.

C. MSE wall backfill material containing steel soil reinforcing shall comply with Table 4-4.13.3-2 [Electrochemical Parameter for MSE Wall Steel Soil Reinforcing]:

Table 4-4.13.3-2 Electrochemical Parameter for MSE Wall Steel Soil Reinforcing

Select Backfill Requirements		Test Method (ASTM)	Test Method (AASHTO)
Resistivity	≥ 3000 ohm-cm	G57	T 288
pH	5 - 10	G51	T 289
Chlorides	≤ 100 ppm	G512	T 291
Sulphates	≤ 200 ppm	G516	T 290
Organic Content	≤ 1.0%	D2974	N/A

D. MSE wall backfill material containing geosynthetic soil reinforcing shall comply with Table 4-4.13.3-3 [Requirements for Geosynthetic Reinforcing]:

Table 4-4.13.3-3 Requirements for Geosynthetic Reinforcing

Select Backfill Requirements		Test Method (ASTM)	Test Method (AASHTO)
pH	3 - 12	G51	T 289
Organic Content	≤ 1.0%	D2974	N/A
Design Temperature at the Wall Site	≤ 30°C	N/A	N/A

- E. The collection of backfill samples for testing shall be from the stockpiles at the top, middle and bottom portions and approximately 0.6 m from the face of the stockpile.
1. Resistivity testing shall be carried out on 6 samples (2 top, 2 middle, 2 bottom).
  2. pH, chloride, sulphate, and organic content testing shall be carried out on 9 samples (3 top, 3 middle, 3 bottom).

#### 4-4.13.3.5 Geotextile Filter Fabric

- A. Non-woven geotextile filter fabric shall comply with Table 4-4.13.3-4 [*Specification for Non-Woven Geotextile Filter Fabric*]:

Table 4-4.13.3-4 Specification for Non-Woven Geotextile Filter Fabric

<b>Non-Woven Geotextile Filter Fabric</b>		
<b>Specifications and Physical Properties</b>		<b>Test Method (ASTM)</b>
Grab Strength	≥ 650 N	D4632
Elongation (Failure)	≥ 50%	D4632
CBR Puncture Strength	≥ 275 N	D6241
Trapezoidal Tear	≥ 250 N	D4533
Minimum Fabric Lap to be 300 mm		

#### 4-4.13.3.6 Impermeable Geomembrane

- A. Impermeable geomembrane shall be PVC, HDPE or LLDPE geomembrane with a minimum thickness of 0.75 mm, and shall comply with Table 4-4.13.3-5 [*Specification for Impermeable Geomembrane*]:

Table 4-4.13.3-5 Specification for Impermeable Geomembrane

<b>Impervious Geomembrane</b>		
<b>Specifications and Physical Properties</b>		<b>Test Method (ASTM)</b>
Tear Strength	≥ 45 N	D1004
CBR Puncture Strength	≥ 140N	D6241

1. All seams in the membrane shall be welded or bonded in accordance with the manufacturer's recommendations to prevent leakage.

#### 4-4.13.4 Storage and Handling

- A. All materials shall be protected from damage during storage and handling.
1. All materials shall be stored above ground and covered and protected from rain, snow, dirt and ultraviolet light.
  2. Precast concrete fascia panels shall be stored such that the uniform color of the panels is maintained and protected from staining or discoloration.

#### 4-4.13.5 MSE Wall Panel Production

- A. The fabrication of precast concrete MSE wall panels shall comply with Section 4-4.5 [*Precast Concrete*] of this Schedule.

#### 4-4.13.6 Inspection and Testing

- A. Backfill compaction testing of the reinforced backfill shall be carried out at a minimum frequency of one test per lift for every 45 m of wall length or part thereof with no less than one test per day.
- B. The backfill shall be tested for compliance with the requirements of Table 4-4.13.6-1 [*Sampling and Testing of Backfill Properties During Construction*].

Table 4-4.13.6-1 Sampling and Testing of Backfill Properties During Construction

Range of Resistivity (ohm-cm)	Sample Interval for Resistivity Testing (m3)	Sample Interval for PH, Chlorides, Sulphates, Organic Testing (m3)
> 5000	3000	1500
< 5000	1500	750

#### 4-4.13.7 Construction

##### 4-4.13.7.1 General

- A. The construction of the MSE wall system shall conform to the details on the shop drawings and be in compliance with the supplier's recommendations.
1. The supplier of the MSE wall system shall provide a full-time qualified representative on-site during construction to advise regarding construction procedures and to monitor that the MSE wall construction is being carried out in accordance with the shop drawings and supplier's recommendations.

##### 4-4.13.7.2 Levelling Pads

- A. The foundation subgrade shall be proof rolled to identify any soft spots. Soft material shall be removed and replaced with compacted granular material to the satisfaction of a Professional Engineer.
- B. The concrete levelling pads shall be placed to the grades and lines shown on the applicable Final Design.
1. When checked with a 3 m long straight edge there shall not be a gap greater than 3 mm between the top of the levelling pad and the straight edge.
- C. Concrete levelling pads shall project at least 75 mm past each side of the precast concrete MSE wall panels.
- D. After the erection of the first row of MSE wall panels, any openings between the levelling pad steps shall be filled.

#### 4-4.13.7.3 **Backfill**

- A. Backfill shall be placed in conformance with the MSE wall supplier's specifications.
  - 1. Backfill placement shall closely follow erection of each course of MSE wall panels.
- B. Backfill shall be placed in such a manner as to avoid any damage, disturbances or misalignment of the MSE wall face panels and soil reinforcing.
  - 1. Any MSE wall components that are damaged shall be removed and replaced.
  - 2. Any misalignment or distortion of the precast concrete MSE wall panels shall be corrected before continuing with the work.
- C. Backfill shall be compacted to a minimum of 98% of Standard Proctor Density at optimum moisture content.
- D. Backfill shall be compacted in lifts not exceeding 150 mm in thickness when compacted.
- E. Overlapping geosynthetic reinforcement layers shall be separated by a minimum 75 mm of compacted backfill.
- F. Backfill compaction shall be performed in such a manner that the equipment moves in a direction parallel to the MSE wall panels or away from the MSE wall panels toward the end of the soil reinforcing.
  - 1. Equipment shall not be allowed to run directly on the soil reinforcing.
  - 2. Only hand operated power tampers and vibrators shall be used for compaction within 1000 mm of the MSE wall panels.
  - 3. At the completion of each day's work, the backfill material shall be sloped away from the MSE wall panels, so as to direct potential run-off away from the wall face.
  - 4. Surface runoff from adjacent areas into the MSE wall construction site is not permitted.

#### 4-4.13.7.4 **Precast Concrete MSE Wall Panel Placement Tolerances**

- A. Precast concrete MSE wall panel placement tolerances after installation shall be:
  - 1. the out-of-flatness of wall surfaces measured in any direction shall not exceed 25 mm under a 3 m straight edge;
  - 2. the offset of adjacent panel edges at joints shall not exceed 10 mm;
  - 3. the overall vertical alignment of the completed wall shall not be out of vertical by more than 4 mm/m of wall height; and
  - 4. the joint width between MSE wall panels shall be between 10 mm and 30 mm.

#### 4-4.13.7.5 **Impermeable Geomembrane**

- A. Where required, impermeable membrane shall be installed so as to prevent leakage through the membrane and to direct drainage away from the MSE wall panels and soil reinforcing.
- B. Seams of impermeable geomembranes shall be placed parallel to the MSE wall and lapped in the direction of Positive Drainage to produce a shingling effect.

#### **4-4.14 EXISTING WHITEMUD DRIVE BRIDGE**

##### **4-4.14.1 General**

- A. The Section 4-4.14 [*Existing Whitemud Drive Bridge*] sets out the requirements for rehabilitation of the Existing Whitemud Drive Bridge which are in addition to the requirements of the other Sections of this Part 4 [*Transportation and Building Structures*].

##### **4-4.14.2 Deck Survey**

- A. A detailed survey shall be conducted on the deck of the Existing Whitemud Drive Bridge to assist in designing the new gradeline of the deck. In addition to the requirements of Section 4-4.15.4.2 [*Gradeline Profiles/Dry Run*] of this Schedule profile lines shall be located at lane lines and 1.0 m from the face of median locations. The profile lines shall be surveyed at the following times:
  - 1. prior to removal of the median and wearing surface;
  - 2. after removal of the median and wearing surface;
  - 3. following prefill and mortar fill placement; and
  - 4. following deck placement.
- B. The final design gradeline shall be determined and submitted to the City prior to prefill or mortar fill placement. The Review Period shall be 5 Business Days.

##### **4-4.14.3 Removal of Existing Concrete Median**

- A. The existing concrete median on the bridge deck shall be completely removed.
- B. A detailed removal procedure shall be prepared and submitted to the City prior to the work commencing.

##### **4-4.14.4 Removal of Existing High Density Concrete and Asphalt Wearing Surface**

- A. The existing high density concrete wearing surface and the existing asphalt shall be removed from the bridge deck, roof slabs and approach slabs as shown on the applicable Final Design in accordance with Section 4-4.15.2.2 [*Surface Removal*] of this Schedule except as specified in this Section.
- B. The actual depth of the existing nominally 50 mm thick high density concrete wearing surface shall be verified prior to removal.
- C. The surface shall be cold milled using micro-milling equipment to obtain a smooth finish with a maximum roughness not exceeding 3 mm.
  - 1. Micro-milling equipment shall be capable of removing concrete to an accuracy of 1.5 mm producing a surface texture of 3 mm or less, and have a maximum tooth spacing of 5 mm. The milling machine specifications including the tooth size and spacing, the recommended drum revolutions per minute (RPM), and the machine advancing speed shall be submitted to the City as part of the surface removal described in Section 4-4.15.2.2 [*Surface Removal*] of this Schedule.
- D. At the beginning of the removal process it shall be demonstrated to the satisfaction of the City that the desired depth of removal and surface texture is achieved on a consistent basis.



#### 4-4.14.5 **Removal of Existing Deck Joints at Abutments**

- A. The existing deck joint assemblies, including all associated hardware, such as barrier and median cover plates, shall be removed to the limits shown on the applicable Final Design.
  - 1. Removal of the deck joint assemblies shall not result in damage to the east traffic barrier cover plates.
- B. Concrete removal shall comply with the requirements of Section 4-4.15.3 [*Concrete Repair*] of this Schedule
- C. A removal procedure shall be prepared and submitted to the City prior to the work commencing.

#### 4-4.14.6 **Removal of Existing West Traffic Barrier and Pedestrian Hand Railing**

- A. The existing west traffic barrier and pedestrian hand railing shall be removed by means that will not damage the existing bridge.
- B. Concrete removal shall comply with the requirements of Section 4-4.15.3 [*Concrete Repair*] of this Schedule.
- C. A removal procedure shall be prepared and submitted to the City prior to the work commencing.
- D. At the beginning of the removal process it shall be demonstrated to the satisfaction of the City that no damage will occur to the bridge deck or other existing components.
- E. All anchorage posts and reinforcing steel shall be ground flush to the existing deck.

#### 4-4.14.7 **Removal of Existing West Concrete Transition Barriers and Sidewalk**

- A. The existing west transition barriers and sidewalk shall be removed to the limits shown on the applicable Final Design.
- B. Concrete removal shall comply with the requirements of Section 4-4.15.3 [*Concrete Repair*] of this Schedule.
- C. A removal procedure shall be prepared and submitted to the City prior to the work commencing.

#### 4-4.14.8 **Removal of Deck Concrete Paving Lips and Concrete Wedges**

- A. 20 mm deep wedges shall be removed from the existing concrete deck at the locations of the mortar mix prefill areas as shown on the applicable Final Design by saw cutting and cold micro-milling or other acceptable methods.
  - 1. This shall also include the removal of existing paving lips.
- B. A smooth surface finish as noted in Section 4-4.14.4 [*Removal of Existing High Density Concrete and Asphalt Wearing Surface*] of this Schedule is required.
- C. At the beginning of the removal process it shall be demonstrated to the satisfaction of the City that the desired depth of removal is achieved on a consistent basis.
- D. The concrete removal process shall be supplemented with sufficient hand demolition to ensure a uniform depth of demolition across the bridge.

1. If any longitudinal or transverse reinforcing steel is exposed, the existing concrete shall be removed to a clearance of 25 mm below the reinforcing steel.
2. Concrete removal shall not cause damage to the remaining sound concrete or to the bond to the reinforcing steel.

#### 4-4.14.9 **Partial and Full Depth Repairs**

- A. Without limiting the repair locations, all unsound, deteriorated, or spalled concrete shall be removed and patched at the following locations as determined by the City:
  1. top surface of concrete deck after wearing surface removal;
  2. all exposed faces of the east barrier of the Structure;
  3. abutment surfaces, including wingwalls, vertical surfaces, and exposed sides of backwalls; and
  4. piers, including horizontal and vertical surfaces.
- B. Safe access shall be provided to the City to all elements of the Structure to determine the required extent of concrete repairs.
  1. All loose materials, including sealer and parging, shall be completely removed from the various concrete surfaces to the satisfaction of the City prior to the City determining the extent of repairs required.
- C. Concrete removal and replacement shall be carried out in accordance with Section 4-4.15.3.1 *[General]* and Section 4-4.15.3.2 *[Partial Depth Repair]* of this Schedule except that where concrete deterioration extends completely through the component, concrete removal and replacement shall be carried out in accordance with Section 4-4.15.3.1 *[General]* and Section 4-4.15.3.3 *[Full Depth Repair]* of this Schedule.
- D. The surface finish (texture) of the repaired areas shall match that of the adjacent concrete.

#### 4-4.14.10 **Prefill**

##### 4-4.14.10.1 **Concrete Prefill**

- A. The placement of the concrete prefill shall be carried out in accordance with the requirements of Section 4-4.4 *[Cast-In-Place Concrete]* and Section 4-4.15 *[Concrete Deck Overlays and Concrete Rehabilitation]* of this Schedule for concrete deck overlay, except as modified in this Section.
- B. The concrete prefill shall be a Class HPC concrete with non-metallic, synthetic macro fibres.
- C. The synthetic macro fibres shall be Grace *STRUX® 90/40*, *FORTAFERRO®* or equivalent accepted by the City.
  1. The fibres shall comply with ASTM C1116, Paragraph 4.1.3, Type III and be 35 to 45 mm in length.
- D. The Class HPC concrete with fibres shall contain at least 4.5 kg/m<sup>3</sup> of 38 mm *FORTAFERRO®* or, 4.5 kg/m<sup>3</sup> of 40 mm *Grace STRUX® 90/40*, or equivalent accepted by the City.
- E. Trial batch(es) of the concrete shall be performed at least 35 days prior to placement of concrete at site to verify that the requirements pertaining to compressive strengths at 7 and 28

days, resistance to rapid chloride ion penetration and air void system parameters of hardened concrete have all been met.

1. All mix trial batches, mix designs and associated test results shall comply with Section 4-4.4 [*Cast-In-Place Concrete*] of this Schedule.
- F. The possibility of non-uniform fibre dispersion in the concrete shall be estimated by comparing the compressive strength of the fibre reinforced concrete with that of the corresponding plain concrete using 7-day compressive strength tests that comply with CAN/CSA A23.1.
1. If the Class HPC mix with synthetic macro fibres has a compressive strength less than 95% of the corresponding Class HPC mix, corrective measures to achieve proper fibre dispersion shall be determined by a Professional Engineer.
- G. In addition test slab(s), at least 2 m by 2 m, shall be placed to evaluate the finishing characteristics of the Class HPC concrete with synthetic macro fibres mix.
1. Finishing of slab(s) shall demonstrate a proper finish without an excess amount of exposed fibres.
  2. Trial slab pours shall be repeated until the results demonstrate proficiency in meeting the requirements of this Section 4-4.14.10.1 [*Concrete Prefill*].
  3. Synthetic macro fibres may affect the apparent workability of concrete and require expertise to properly place and finish. The fibre manufacturer shall be contacted for technical assistance related to mixing, placing, and finishing.
- H. The concrete prefill shall be mixed at a qualified batch plant.
- I. Experienced finishers shall be employed to finish the concrete reinforced with synthetic macro fibre.
1. Fibres at the surface are often caused by beginning finishing too late.

#### 4-4.14.10.2 **Mortar Mix Prefill**

- A. The mortar mix prefill shall comply with the requirements shown on the applicable Final Design.
- B. The mortar mix shall be extended using pea gravel less than 6 mm in diameter.
  1. Addition of the pea gravel shall comply with the manufacturer's recommendations.
- C. Prior to placement of the mortar mix prefill, the surface shall be prepared as per the manufacturer's specified recommendations.

#### 4-4.14.11 **Construct Concrete Approach Slab Extensions**

- A. Concrete approach slab extensions shall be constructed as shown on the applicable Final Design.
- B. The current fill below the existing sidewalk shall be excavated as required to complete the approach slab work and ensure a proper foundation for the approach slab extensions but to not less than the limits shown on the applicable Final Design.
- C. All compacted backfill shall be Des 2 Class 25 aggregate meeting the requirements of Section 4-4.13.3.4 [*Backfill*] and compacted to a minimum of 98% of Standard Procter Density at Optimum Moisture Content.

1. Backfill shall be compacted in lifts not exceeding 150 mm in thickness when compacted.
  - D. The backfill shall be extended a minimum of 1 m past the outside face of the new approach slab extension.
  - E. The dowels into the existing approach slabs shall be AISI Type 316 stainless steel.
- 4-4.14.12 **Construct West Concrete Traffic Barrier, Concrete Traffic Barrier Transitions and Steel Pedestrian Hand Railings**
- A. Concrete barriers, concrete barrier transitions and steel pedestrian hand railings shall be constructed as shown on the applicable Final Design.
    1. A new light post, including light post anchorage and conduit shall be constructed with the west concrete traffic barrier.
  - B. The alignment of the concrete barrier transitions shall suit the widened roadway geometry.
  - C. The post tensioning duct located directly below the new location of the west barrier shall be located with a pachometer or other non-destructive means prior to installing the west barrier of the Structure.
    1. The post tensioning duct shall be avoided when installing the west barrier.
  - D. All steel for the pedestrian hand railings shall be hot dip galvanized.
  - E. The dowels into the existing deck shall be AISI Type 316 stainless steel.
- 4-4.14.13 **Supply and Install Deck Joints at Abutments**
- A. A new Type 1 strip seal deck joint assembly shall be supplied and installed at each abutment.
  - B. The deck joint assemblies shall include the following:
    1. two strip seal expansion joint assemblies;
    2. two barrier joint cover plates (west side of bridge). The barrier cover plates on the east side of the bridge shall also be replaced if required to install the new strip seal expansion joint assemblies;
    3. two median joint cover plates; and
    4. all associated hardware.
  - C. The entire joint shall be leak free at all times throughout the duration of the work.
    1. This may involve the installation of temporary seals during periods when the steel extrusion of the expansion assembly is not continuous across the full width of the bridge.
  - D. Flood tests shall be carried out on the completed deck joints and surrounding concrete to check for leakage.
    1. All leaks shall be repaired.
  - E. Project Co and the deck joint supplier shall jointly warranty satisfactory performance of the deck joint assemblies for a period of five years from the date of the Early Handover Completion Certificate for the Existing Whitemud Drive Bridge.

1. The joint warranty, signed by both Project Co and the supplier shall be provided to the City as a condition precedent to issuance of the Early Handover Completion Certificate.
2. The deck joint warranty shall provide for the replacement and/or repair of the joint assemblies, including all necessary traffic control at no cost to the City, should unsatisfactory performance of the deck joints, such as deck joint leakage, occur during the five-year period.

**4-4.14.14 Deck Waterproofing Membrane**

- A. A deck waterproofing membrane shall be installed on the bridge deck, roof slabs and approach slabs as shown on the applicable Final Design.
- B. The deck waterproofing membrane shall comply with Section 4-4.16 [*Deck Waterproofing Membrane System*] of this Schedule unless otherwise specified in this Section.
- C. Wicks along the barrier faces and drains at the abutments shall be included as shown on the applicable Final Design.
- D. The primary asphalt membrane shall be applied in two layers with a membrane reinforcing fabric placed on the top of the first layer.
  1. The first layer shall be 3 to 4 mm thick and shall completely fill the grooves and cover all the high ridges in the prepared deck.
  2. The second layer shall be a uniform film with a thickness of 3 mm.
  3. The membrane reinforcing fabric shall be Reemay 2016 spun bonded polyester or equivalent accepted by the City.

**4-4.14.15 Asphalt Concrete Pavement (ACP)**

- A. ACP shall be installed on the bridge deck, roof slabs and approach slabs as shown on the applicable Final Design.
  1. Asphalt concrete pavement shall be mix type ACF-HT as specified in the *Valley Line LRT Project Roadways Design and Construction Standards*.
  2. Reclaimed asphalt pavement (RAP) shall not be permitted.
- B. ACF-HT aggregate shall be provided to the gradation band shown on *Table 4-4.14.15-1: ACF-HT Gradation Band*.

Table 4-4.14.15-1: ACF-HT Gradation Band

<b>Designation</b>	<b>1</b>
<b>Class</b>	<b>10.0</b>
<b>Application</b>	<b>ACF-HT</b>
<b>Sieve Size (µm)</b>	<b>% Passing by Mass</b>
12 500	100
10 000	97-100
8 000	70-90
6 300	45-73
5 000	32-56
2 500	23-42
1 250	16-34
630	11-26

315	8-19
160	5-13
80	3-8

- C. The asphalt mix design shall be prepared by a qualified laboratory following the Superpave Gyrotory Compactor (SGC) and the Bailey Method of Mix Design as set out in the Asphalt Institute Manual Series No. 2 (MS 2) to the criteria shown on Table 4-4.14.15-2 [Requirements for ACF-HT Mix Design].

Table 4-4.14.15-2 Requirements for ACF-HT Mix Design

Mix Type	ACF-HT
Selected Parameters	
Number of Gyration	
Gyrations $N_{design}$	100
Gyrations $N_{maximum}$	160
Density at $N_{maximum}$ (% $G_{mm}$ )	98.0 max
Bailey CA-CUW	>95 to 105 max
Air Voids, % of total mix (virgin mix)	4.0 ± 0.4%
VMA, %	13 min
Voids Filled, %	70 - 80
Tensile Strength Ratio, % (AASHTO T283) <sup>1</sup>	80 min
Minimum Film Thickness <sup>2</sup> , mm	7.5 min
APA (mm, 52 degrees Celsius, 8,000 cycles)	5.0 max

Note 1: Minimum Tensile Strength Ratio shall be determined in accordance with AASHTO T283 at air void content of 7.0 ± 0.5%.

Note 2: Minimum film thickness shall be determined in accordance with Appendix 02065.B.

- D. The asphalt cement shall be 150-200 (A) or PG 58-28.
- E. The tack coat shall be SS-1 or MS-1. When SS-1 is used it shall be diluted with an equal volume of water.

#### 4-4.14.16 Construct Concrete Median

- A. Upon completion of placing of the ACP wearing surface on the entire deck, a new concrete median shall be constructed at the location shown on the applicable Final Design.
- B. Median construction shall comply with Section 02770, Concrete Curb/Gutter/Walk/Slabs, of the Valley Line LRT Project Roadways Design and Construction Standards.

#### 4-4.14.17 Bearing Rehabilitation

- A. The 30 existing abutment pot bearings shall be rehabilitated after the existing wearing surface, west traffic barrier and west pedestrian hand railing are removed and before the construction of the new west traffic barrier, placing of the concrete prefill and mortar mix prefill and placing of the ACP wearing surface.
- B. The concrete deck shall be jacked slightly at the bearing locations to allow rehabilitation of the bearings.
1. Jacking shall be coordinated with the appropriate Utility Companies as bridge jacking may have an impact on the existing Utility Infrastructure on the bridge.

2. Jacking procedures and temporary structural components required to transfer the loads to the deck and abutment during jacking shall be prepared, signed and sealed by a Professional Engineer.
  3. The jacking procedures shall be designed so that the existing Structure is not overloaded when the bearings are rehabilitated.
  4. A detailed jacking procedure shall be submitted to the City prior to the work commencing.
- C. The bearing components shall be cleaned by abrasive blasting to the requirements of SSPC Standard SP5.
1. Containment during sandblasting shall be provided locally around the bearing components.
  2. The existing Structure, including the existing elastomeric bearing pads, sealing rings, stainless steel plates, and PTFE pads, shall be protected from damage during abrasive blasting operations.
- D. A field applied zinc coating system shall be applied to the bearings after sandblasting.
1. The zinc coating system shall be a single component zinc coating containing 96% electrolyte zinc dust, synthetic resins, pigments and solvents. It shall not contain lead, cadmium metals, toluene, xylene, methylene chloride or methyl-ethyl-ketone.

#### 4-4.14.18 **Clean and Seal Concrete**

##### 4-4.14.18.1 **Pigmented Sealer**

- A. The following locations shall be cleaned by pressure washing:
  1. vertical faces of abutments, including wingwalls; and
  2. exterior faces of east barrier and east and west deck soffits.
- B. All loose or peeled coatings shall be removed and disposed of.
- C. After the surface preparation has been completed, the cleaned surfaces shall be sealed with a Type 3 pigmented sealer on the Alberta Transportation Approved Product List and applied in accordance with Section 4-4.4.21.4 [*Class 3 Bonded Concrete Surface Finish*] of this Schedule.
- D. All existing attachments, including lighting and drains, shall be protected during cleaning and sealing.

##### 4-4.14.18.2 **Penetrating Sealer**

- A. A clear Type 1C sealer on the Alberta Transportation Approved Product List shall be applied to the following surfaces of the Structure in accordance with Section 4-4.4.22 [*Type 1c Sealer*] of this Schedule:
  1. inside vertical faces of barriers;
  2. exterior face of west barrier; and
  3. faces of pier columns.

- B. Prior to application of sealer to existing concrete surfaces, the concrete shall be cleaned by pressure washing to the satisfaction of the City.

#### 4-4.14.19 **Replacement of Galvanized Flashing between Abutments and Concrete Slope Protection**

- A. The existing galvanized flashing between the abutments and concrete slope protection shall be removed and replaced as shown on the applicable Final Design.

#### 4-4.14.20 **Approach Road Pavement**

- A. The approach road pavement shall be smoothly transitioned over a minimum length of 10 m between the elevation of the ACP on the bridge abutments and the elevation of the ACP on 66<sup>th</sup>/75<sup>th</sup> Street.
  - 1. The existing approach road pavement shall be removed as required to provide for a minimum thickness of 40 mm in the new approach road pavement.
  - 2. The existing pavement at the joint between the new approach road pavement and the existing approach road pavement shall be saw cut a minimum of 40 mm deep.

#### 4-4.14.21 **Existing Utilities**

##### 4-4.14.21.1 **General**

- A. The existing Utility Infrastructure on the Existing Whitemud Drive Bridge shall be relocated to the new west traffic barrier.

### **4-4.15 CONCRETE DECK OVERLAYS AND CONCRETE REHABILITATION**

#### 4-4.15.1 **General**

- A. This Section 4-4.15 [*Concrete Deck Overlays and Concrete Rehabilitation*] sets out the requirements for all concrete deck overlays forming part of the Existing Whitemud Drive Bridge and concrete rehabilitation carried out on the Existing Whitemud Drive Bridge, including minimum requirements for deck surface removal, concrete repair, surface preparation, and concrete deck overlay.

#### 4-4.15.2 **Construction**

##### 4-4.15.2.1 **General**

- A. Jack hammers heavier than nominal 14 kg class and chipping hammers heavier than nominal 7 kg class shall not be used for concrete removal.

##### 4-4.15.2.2 **Surface Removal**

- A. Deck surface removal shall be completed to the depth(s) shown on the applicable Final Design.
- B. Procedures for deck surface removal shall be prepared and submitted to the City prior to commencing the surface removal.
  - 1. Debris removal and surface cleaning details shall be included in the deck surface removal procedure.
- C. When the specified deck surface removal depth is more than 5 mm and the concrete is to be removed using cold-milling methods, small milling machines having a maximum removal width of 1.2 m shall be used.



1. Adjustments to the deck surface removal depth shall be carried out on an ongoing basis during removal to ensure an accurate depth of material removal is maintained throughout milling operations.
  2. Reinforcing steel and other Structure components damaged as a result of deck surface removal operations shall be repaired or replaced.
- D. Deck surface removal shall be carried out as close as possible to all curbs, medians, barriers, deck drains, deck joints, and other Structure components without causing damage.
1. Chipping equipment shall be used adjacent to these areas as required to complete deck surface removal operations.
  2. Concrete curb, barrier, median and deck joint paving lips within the limits of the deck surface removal area, including reinforcing steel projecting into these components, shall be removed.
- E. Milling debris shall be removed from behind the cold-milling machine and the milled surface cleaned on a continuous basis, as close to the milling machine as is safely practicable.
1. All debris from deck surface removal operations shall be disposed of.
- F. Upon completion of deck surface removal operations, including thorough cleaning and drying of the deck surface and removal of all equipment, the concrete deck surface shall be inspected by the City to identify the areas of unsound concrete to be repaired.
1. Concrete deck surface repairs shall be carried out in accordance with Section 4-4.15.3 [*Concrete Repair*] of this Schedule.

#### 4-4.15.3 **Concrete Repair**

##### 4-4.15.3.1 **General**

- A. The limits of concrete removal required for concrete repairs shall be determined by the City.
- B. The perimeters of repair areas shall be saw cut with neat, perpendicular, 25 mm deep cuts.
- C. Unsound concrete shall be removed from repair areas by chipping or scabbling.
  1. Concrete removal operations shall result in a sound surface suitable for bonding to concrete or repair material.
- D. All debris resulting from concrete removal operations shall be contained and disposed of.
  1. Methods of containment shall not result in damage to the existing Structure or surrounding areas.

##### 4-4.15.3.2 **Partial Depth Repair**

- A. Partially exposed reinforcing steel shall be entirely exposed by removal of the concrete to a depth of 25 mm below the bars.
- B. Exposed reinforcing steel and bonding surfaces shall be sandblasted and the areas blown clean with oil free compressed air prior to the placement of repair material.
  1. Reinforcing steel shall be sandblasted to a white metal finish.

- C. For repair areas where epoxy coated reinforcing steel are exposed, the epoxy coating shall be completely removed from the reinforcing steel by sandblasting.
  - 1. The exposed reinforcing steel shall be protected by the installation of discrete galvanic anodes installed at a minimum of 1 anode per 300 mm of perimeter of the patch area.
  - 2. Galvanic anodes shall be a product on the Alberta Transportation Approved Product List for Galvanic Corrosion Protection.
  - 3. Galvanic anodes shall be embedded in a low resistivity mortar and shall have the concrete cover specified on the applicable Final Design.
- D. Additional reinforcing steel shall be installed at locations where the existing reinforcing steel has suffered sectional loss greater than 20%.
  - 1. Additional reinforcing steel shall be corrosion resistant reinforcing steel.
  - 2. Splicing and/or development length requirements shall be determined by a Professional Engineer.
- E. Once a repair area has been accepted by the City and prior to placement of repair material, the bonding surfaces shall be saturated with clean water for a minimum of 30 minutes.
  - 1. The repair area shall be blown free of any surface water immediately prior to placement of the repair material.
  - 2. Repairs shall be trowelled smooth, leveled flush to adjacent surfaces, and given the concrete finish of the adjacent concrete.
- F. The original design concrete cover shall be re-established at each repair location.
- G. Partial depth repair areas located on the deck surface shall be poured monolithically with the concrete deck overlay.
- H. Other partial depth repair areas shall be formed and recast with a concrete patching product on the Alberta Transportation Approved Product List, extended with aggregates that meet the requirements of CAN/CSA 23.1 or ASTM C33.
- I. Where the volume of the concrete patching product required for an individual partial depth repair area exceeds the volume produced by three 25 kg bags, a rubber paddled mortar mixer of adequate size shall be used for mixing the product.
  - 1. The use of free fall mixers is not permitted.
- J. Where the repair area is large enough such that placement of a concrete patching product becomes impractical, concrete shall be used.
  - 1. Class C concrete shall be used for substructure elements and Class HPC for all other elements.
  - 2. Repair procedures shall be in accordance with Section 4-4.15.3.3 *[Full Depth Repair]* of this Schedule. In the case of conflict, the more stringent requirements shall apply.

#### 4-4.15.3.3 Full Depth Repair

- A. Where concrete deterioration extends completely through the deck, barriers, or other Structure elements as determined by the City, all unsound concrete shall be removed and replaced with new concrete.

- B. Exposed reinforcing steel and bonding surfaces shall be sandblasted and the areas blown clean with oil free compressed air prior to the placement of repair material.
  - 1. Reinforcing steel shall be sandblasted to a white metal finish.
- C. For repair areas where epoxy coated reinforcing steel are exposed, the epoxy coating shall be completely removed from the reinforcing steel by sandblasting.
  - 1. The exposed reinforcing steel shall be protected by the installation of discrete galvanic anodes installed at a minimum of 1 anode per 300 mm of perimeter of the patch area.
  - 2. Galvanic anodes shall be a product on the Alberta Transportation Approved Product List for Galvanic Corrosion Protection.
  - 3. Galvanic anodes shall be embedded in a low resistivity mortar and shall have the concrete cover specified on the applicable Final Design.
- D. Additional reinforcing steel shall be installed at locations where the existing reinforcing steel has suffered sectional loss greater than 20%.
  - 1. Additional reinforcing steel shall be corrosion resistant reinforcing steel.
  - 2. Splicing and/or development length requirements shall be determined by a Professional Engineer.
- E. The underside of the deck, barriers, and other areas requiring full depth repair shall be formed to neatly restore the original lines of the concrete.
  - 1. Forms shall not be hung or suspended from existing reinforcing steel.
- F. Once a repair area has been accepted by the City and prior to concrete placement, the bonding surfaces shall be saturated with clean water for a minimum of 30 minutes prior to concrete placement.
  - 1. The area shall be blown free of any surface water immediately prior to concrete placement.
  - 2. Repairs shall be adequately vibrated, trowelled smooth, leveled flush to adjacent surfaces, and given the concrete finish of the adjacent concrete.
- G. Class C concrete shall be used to repair substructure elements and Class HPC for all other elements.
- H. Full depth repairs located on the deck surface shall be recast monolithically with the concrete deck overlay.
  - 1. When conditions do not permit a monolithic pour with the concrete deck overlay, full depth repair concrete shall be placed to a depth such that, once the subsequent concrete overlay has been placed, the specified overlay thickness is achieved.
  - 2. Concrete shall be cured in accordance with Section 4-4.4.18 [*Curing Concrete*] of this Schedule.
- I. Full depth repair deck concrete not poured monolithically with the concrete deck overlay shall be wet cured for a minimum of 7 days or until it has attained sufficient strength so it is not adversely affected by subsequent placement of the concrete deck overlay.

- J. Compressive strength tests shall be completed on each batch of concrete placed, in accordance with Section 4-4.4.10 [*Inspection and Testing*] of this Schedule.

#### 4-4.15.3.4 **Surface Preparation**

- A. Prior to placement of the concrete deck overlay, the entire deck surface and the vertical faces of the curbs, medians and barriers shall be sandblasted up to a height equal to the overlay thickness.
1. Adequate shielding shall be provided to protect any galvanic anodes from damage.
  2. Sandblasting shall be carried out to the extent necessary to uniformly expose the fine aggregate.
- B. Following sandblasting, the deck surface shall be cleaned so that it is free of all sand, dust and other contaminants to the satisfaction of the City.
1. Debris from the cleaning operations shall be disposed of.
- C. The deck shall be maintained clean until placement of the concrete deck overlay.
1. Additional preparation or cleaning, including sandblasting, that may become necessary prior to placing the concrete deck overlay shall be carried out.

#### 4-4.15.4 **Deck Overlay Concrete**

##### 4-4.15.4.1 **General**

- A. Deck overlay concrete shall be placed as specified on the applicable Final Design, in accordance with the requirements of this Section 4-4.15 [*Concrete Deck Overlays and Concrete Rehabilitation*] and Section 4-4.4 [*Cast-In-Place Concrete*] of this Schedule.

##### 4-4.15.4.2 **Gradeline Profiles/Dry Run**

- A. The concrete deck overlay gradeline shall be designed to provide a smooth riding surface on the finished deck overlay and approach roadway ACP, to achieve the nominal overlay thickness shown on the applicable Final Design and to provide for positive longitudinal and transverse deck drainage.
1. The design gradeline shall be used to determine the concrete deck overlay thickness and the height of the deck screed above the deck concrete surface at each control point.
  2. A summary of the design gradeline and overlay thickness, to the nearest mm, at each control point shall be prepared and submitted to the prior to setting the screed guide rails. The Review Period shall be 5 Business Days.
- B. The concrete deck and approach roads shall be profiled prior to and after deck surface removal to assist in designing the gradeline. The following profile lines shall be produced:
1. Two parallel profile lines shall be surveyed along the entire length of the deck for each construction stage as follows:
    - a. line No. 1 located 1.0 m from the barrier face; and
    - b. line No. 2 located 0.3 m in from the opposite edge of the concrete deck overlay pour.
  2. Additional profile lines shall be surveyed as required to develop the design gradeline.

3. The stations of the profile lines shall be square to each other.
  4. Profiles shall include at least 30 m of approach road at each end of the deck.
  5. Stations shall be established on each profile line at 3.0 m intervals and at the edges of deck joints.
  6. Profiles shall be plotted to the following scales:
    - a. horizontal: 10 mm = 1 000 mm; and
    - b. vertical: 1 mm (normal) or 1 mm = 5 mm (minimum).
- C. Fluorescent paint shall be used to mark the locations of the profiles on the deck surface, curbs, barriers, medians and approaches.
1. The markings shall be approximately 40 mm in diameter.
  2. All exposed markings remaining shall be removed after the concrete deck overlay is placed.
- D. Guide rails sufficient for the entire contemplated pour shall be set out and adjusted for height.
1. The screed guide rails shall be placed outside the area of concrete deck overlay placement.
- E. The screed guide rails shall be horizontally and vertically stable.
1. Hold down devices for the screed guide rails shall not be permitted to be shot into the concrete.
- F. The screed machine and guide rails shall be adjusted so that the height of the screed above the deck concrete surface at each point conforms to the profile requirements.
- G. To confirm proper adjustment of the screed machine and guide rails, the screed shall be "dry-run" prior to placing the concrete deck overlay and clearance measurements taken at each control point.
1. Re-setting of the screed machine and/or guide rails shall be carried out as necessary, to provide an acceptable dry-run.
  2. The clearance measurements shall be submitted to the City prior to concrete deck overlay placement.
  3. Adjustments to the screed machine and/or the guard rails shall not be permitted after an acceptable dry-run has been made.
- H. Longitudinal concrete deck overlay construction joint locations shall be submitted prior to concrete deck overlay placement.
1. Longitudinal bulkheads shall be provided at concrete deck overlay construction joint locations.
  2. Construction joints shall be located as close to the crown as possible. Where the crown is located at or near a connection joint between two adjacent girders, the longitudinal overlay construction joint shall be offset by a minimum of 300 mm.

#### 4-4.15.4.3 **Cement/Silica Fume Slurry Grout**

- A. After all deck preparation has been completed and accepted by the City, deck surfaces to be overlaid shall be continuously saturated with clean water for a minimum of 3 hours prior to concrete placement.
- B. Immediately prior to concrete deck overlay placement operations, deck surfaces shall be blown free of all excess water, and a cement/silica fume slurry grout applied to the deck surface to enhance the bond between the prepared surfaces and the overlay concrete.
- C. The slurry grout shall consist of 4% silica fume, 46% Type GU Portland cement and 50% sand (maximum 2.5 mm aggregate size) by weight, mixed with sufficient water to form a slurry.
  - 1. The slurry grout shall be mixed in a rubber paddled mortar mixer.
  - 2. The consistency of the mixed slurry grout shall be such that it can be applied with a stiff brush or broom to the deck concrete surface without running or puddling in low spots.
- D. The slurry grout shall be continuously mixed to prevent segregation, and shall be applied within 45 minutes of initial mixing.
  - 1. Slurry grout in excess of 45 minutes old shall be rejected.
  - 2. A minimum of two grout mixers shall be available on-site during concrete deck overlay placement.
- E. The slurry grout shall be applied in a thin, even coat with no puddling. The rate of application shall be controlled to keep pace with the rate of concrete placement, and be limited such that slurry grout is applied immediately ahead of concrete deck overlay placement.
  - 1. The slurry grout shall not be permitted to dry before concrete deck overlay placement.

#### 4-4.15.5 **Conveyance of Concrete on Deck**

- A. Provided the deck surface is continually protected and if accepted by the City, concrete mixer trucks shall be permitted onto the deck to discharge concrete directly ahead of the finishing machine.
  - 1. Deck protection shall be sufficient to protect the saturated deck surface from becoming contaminated with water, oil, spilled concrete and/or other substances.
  - 2. The protection shall remain in place for as long as practicable prior to air blasting and slurry grouting.
  - 3. Deck protection shall consist of plywood, heavy tarps or other protective devices accepted by the City.

#### 4-4.15.6 **Mixing Deck Overlay Concrete**

##### 4-4.15.6.1 **General**

- A. Deck overlay concrete shall be mixed at a concrete batch plant or on-site in mixer trucks.
- B. Site batching shall be in accordance with the requirements of this Section 4-4.15.6 [*Mixing Deck Overlay Concrete*] of this Schedule.

#### 4-4.15.6.2 Pre-bagging for Site Batching

- A. Fine and coarse aggregates, cement, steel fibres, if applicable, and silica fume for deck overlay concrete shall be measured and pre-mixed together before being packaged into bags.
  - 1. The bags shall be constructed of moisture proof material, and shall be securely closed after filling.
  - 2. The bags shall have adequate lifting hooks or straps attached to the tops, and shall be designed to suitably discharge the material from the bottom of the bag through a discharge opening with a minimum diameter of 460 mm.
  - 3. Each bag shall have a minimum nominal 1100 kg capacity.
  - 4. Each bag delivered to the Site shall be in good condition, free of holes or tears, and with all seams fully sealed.
  - 5. Partially filled bags shall not be accepted for use.
- B. Concrete materials shall be proportioned by weight.
  - 1. The accuracy of all weighing devices shall be such that successive quantities can be measured to within 1% of the desired amount.
  - 2. As a minimum quantity, 1100 kg of dry materials, in the correct proportions, shall be mixed together until the materials are fully dispersed before being placed in a bag.
- C. All necessary precautions shall be taken to protect the bagged pre-mix from exposure to the elements during hauling and storage.

#### 4-4.15.6.3 Mixer Trucks and Water Supply for Site Batching

- A. Pre-bagged deck overlay concrete shall be mixed on-site in mixer trucks.
- B. Equipment shall be provided as required to mix the deck overlay concrete at a rate sufficient to ensure continuous concrete placement.
  - 1. A minimum of three mixer trucks shall be brought to the Site prior to each concrete deck overlay pour and shall be utilized in mixing operations.
  - 2. The mixer trucks shall be revolving drum type, watertight and constructed so that concrete can be mixed to ensure uniform distribution of materials.
  - 3. Materials for the deck overlay concrete shall be loaded into the mixer truck drum at the Site.
- C. A suitable water source or tank shall be provided on-site for the dedicated purpose of batching concrete.
  - 1. The water supply shall have sufficient capacity for each pour.
  - 2. The water supply shall be equipped with an accurate water measuring device calibrated in 0.1 L increments.

#### 4-4.15.6.4 Mixing of Deck Overlay Concrete for Site Batching

- A. Initially, approximately two thirds of the required mixing water shall be released into the drum, after which the air entraining admixture, super-plasticizing admixture and other admixtures

shall be added. The remaining required water shall continue to flow into the drum as the solid materials are being loaded into the mixer. The mixing time shall be as specified in the concrete mix design.

1. The water supply pipe shall be adequate to ensure that all remaining water addition into the mixer is completed within the first quarter of the mixing time and the outlet situated at a location within the mixer where the water can quickly mix with the entire batch.
- B. All necessary steps shall be taken to ensure that the full contents of each pre-mix bag enter the mixer in an even and uniformly proportioned manner.
1. Segregation, spillage and/or other loss of material shall not be permitted. Particular care shall be taken to avoid the loss of cement and silica fume.
  2. The batch constituent materials shall be accurately proportioned and an increase in the water-cement ratio shall not be permitted.
  3. The mixers shall be maintained in good condition at all times while the work is being carried out. Inner surfaces of the mixer shall be kept free of hardened concrete and mortar. Mixer blades which are bent or worn to the point that mixing efficiency is affected shall be replaced or refurbished. Mixers leaking mortar or causing waste of materials through faulty charging shall be removed from service until the equipment has been repaired.
- C. The mixers shall not be loaded with more than 3 m<sup>3</sup> of concrete or in excess of 85% of their rated capacity, whichever is less.
1. The manufacturer's certification of the mixing capacity for each machine shall be available.
  2. Mixers shall only be operated at the speeds recommended by the manufacturer.
- D. The pre-mix bag production dates/numbers shall be recorded and the air content, slump, and temperature of each batch shall be tested at the mixing site. Results of all tests shall be documented.
1. In the case of an unacceptable test result, only the quantities of superplasticizing admixture and air entraining admixture shall be adjusted.
  2. Adding additional water to the batch shall not be permitted.
  3. All batch adjustments shall be completed at the batching site and shall not be permitted on the deck or at the discharge area.
- E. Concrete shall be discharged within 70 minutes after initial introduction of water to the pre-mixed material.
- F. Discharge chutes shall be kept clean, free from hardened concrete, and wetted down prior to use.
- G. After each batch is discharged, the drum shall be thoroughly cleaned and excess water removed before a subsequent batch is mixed.



#### 4-4.15.7 Concrete Placement

##### 4-4.15.7.1 General

- A. Deck overlay concrete placement shall be carried out in accordance with Section 4-4.4 [*Cast-In-Place Concrete*] of this Schedule, and the following requirements:
  - 1. The concrete placement operations shall be carried out in such a manner that a smooth riding surface within the tolerances specified in Section 4-4.4 [*Cast-In-Place Concrete*] of this Schedule are achieved.
- B. Adequate lighting shall be provided in front of and behind the finishing machine. Additional tower lights shall be placed at each end of the deck and at the sampling and testing area.
- C. The deck overlay concrete shall be placed in such a manner that segregation of materials does not occur. The concrete finishing machine shall meet the requirements of Section 4-4.4.14.2 [*Placing/Finishing Machines*] of this Schedule.
  - 1. Concrete placement shall be carried out in a continuous operation for the duration of the pour.
  - 2. No more than 5 minutes shall be allowed to elapse between individual truck mixer discharges.
  - 3. The widths of the concrete deck overlay sections placed shall extend to the construction joint locations.
  - 4. Subsequent concrete deck overlay pours shall not occur until the initial pour has cured a minimum of 72 hours.
- D. In the event of equipment breakdown and the suspension of concrete deck overlay placement for a section of deck for a period of 60 minutes or more, further concrete placement for the affected section shall be discontinued and shall not resume for a minimum of 12 hours.
  - 1. Notwithstanding this restriction, concrete deck overlay placement may continue on a subsequent section of the deck provided that a gap sufficient in length for the finishing machine to clear the previously placed concrete is left between the two sections.
  - 2. Prior to continuing concrete placement at a discontinued concrete deck overlay section, a clean, straight vertical edge shall be cut at the edge of the previously placed concrete. Material beyond the saw cut shall be removed and disposed of.
  - 3. Concrete shall be placed in the gap section between 12 hours and 36 hours after suspension of the pour at the affected section.

##### 4-4.15.7.2 Deck Surface Texture

- A. Deck overlay concrete shall receive a Class 6 Finish when the overlay concrete is the final wearing surface and a Class 4 Finish when a waterproofing membrane will be applied.
  - 1. Following surface texturing, a 400 mm wide strip of deck overlay concrete adjacent to the barriers and medians shall be trowelled smooth and the surface left closed.
- B. Depressions in the concrete surface resulting from deficient finishing procedures which may result in ponding water shall be repaired.

- C. At locations where a satisfactory finish has not been achieved, in the opinion of the City, transverse grooves shall be made. Grooves shall be cut to the dimensions described in Section 4-4.4.21.7 [*Class 6 Floated Finish, Surface Textured*] of this Schedule.

#### 4-4.15.7.3 Ends of Concrete Deck Overlay

- A. Concrete deck overlays shall be terminated at a deck joint or as specified below in this Section 4-4.15.7.3 [*Ends of Concrete Deck Overlay*].
- B. At locations where the concrete deck overlay does not terminate at a deck joint, such as on abutment roof slabs, the overlay shall be extended for a distance of 150 mm beyond the required end of the overlay to a bulkhead.
  - 1. After adequate curing time, the 150 mm over pour shall be saw cut, and the material removed and disposed of.

#### 4-4.15.7.4 Longitudinal and Transverse Overlay Construction Joints

- A. Bulkheads shall be constructed at construction joint locations to maintain horizontal and vertical alignments during deck overlay concrete placing and finishing.
  - 1. The resulting vertical faces of concrete shall be sandblasted as described in Section 4-4.15.3.4 [*Surface Preparation*] of this Schedule.
- B. For longitudinal and transverse construction joints, the top edge of the deck overlay concrete at the faces of curbs, barriers, medians, previously placed overlay concrete, and/or existing concrete shall be tooled to a depth of 12 mm and a width of 6 mm.
- C. Tooled grooves shall be filled with an epoxy resin type gravity flow concrete crack filler listed on the Alberta Transportation Approved Product List.
  - 1. Prior to epoxy application, the grooves shall be blown clean to remove all deleterious materials and the concrete contact surfaces prepared in accordance with the epoxy manufacturer's recommendations.
  - 2. Tooled grooves shall be completely filled with epoxy material to a level equal to the adjacent concrete. Multiple applications of epoxy may be required.

#### 4-4.15.7.5 Curing Concrete

- A. Curing of deck overlay concrete shall be in accordance with Section 4-4.4.18.2 [*Curing Requirements for Concrete Containing Silica Fume*] of this Schedule.
- B. The deck overlay concrete shall be rejected if wet curing procedures are deficient in any way and/or any portion of the overlay becomes surface dry during the curing period.

#### 4-4.15.7.6 Application of Sealer

- A. Type 1c sealer shall not be applied until the concrete has cured for a minimum of 14 days.
- B. Sealer shall be applied in accordance with Section 4-4.4.22 [*Type 1c Sealer*] of this Schedule.
  - 1. In the event the concrete surfaces become contaminated with dirt, debris or other deleterious material prior to sealer application, the affected areas shall be cleaned to the satisfaction of the City.

#### 4-4.15.7.7 **Opening to Traffic**

- A. The concrete deck overlay shall not be opened to traffic until the concrete has been cured in accordance with Section 4-4.4.18 [*Curing Concrete*] of this Schedule and has reached a minimum strength of 35 MPa.

#### **4-4.16 DECK WATERPROOFING MEMBRANE SYSTEM**

##### 4-4.16.1 **General**

- A. This Section 4-4.16 [*Deck Waterproofing Membrane System*] sets out the requirements for all deck waterproofing membrane and asphalt concrete pavement (ACP) forming part of the Existing Whitemud Drive Bridge, including minimum requirements for quality, supply, handling and placing of deck waterproofing membrane and ACP.
  - 1. This includes the supply and installation of the deck waterproofing membrane and ACP system shown on *Alberta Transportation Standard Drawing S-1443-11 (Deck Water Proofing System with 80 mm Two Course Hot Mix ACP)*.

##### 4-4.16.2 **Engineering Data**

- A. Documentation showing that the deck waterproofing membrane materials comply with the requirements of Section 4-4.16.3 [*Materials*] of this Schedule shall be obtained prior to the installation of the deck waterproofing membrane.
- B. An asphalt mix design for the Existing Whitemud Drive Bridge, with applicable material quality compliance test reports for each type of ACP, shall be submitted before first placement of such ACP.

##### 4-4.16.3 **Materials**

###### 4-4.16.3.1 **General**

- A. Materials supplied shall be able to withstand the heat generated during the deck waterproofing membrane and ACP installation processes without affecting the performance of the material.

###### 4-4.16.3.2 **Deck Waterproofing Membrane Tack Coat**

- A. The tack coat shall be a primer type meeting the requirements of CAN/CGSB-37-GP-9MA.

###### 4-4.16.3.3 **Asphalt Membrane**

- A. Asphalt membrane shall be hot applied rubberized asphalt complying with the Ontario Ministry of Transportation's OPSS 1213 Specification.
  - 1. Asphalt membrane materials shall be supplied in cakes that are sealed and labeled by the manufacturer.

###### 4-4.16.3.4 **Rubber Membrane**

- A. Rubber membrane shall consist of 1.2 mm thick butyl and ethylene propylene diene monomer (EPDM) rubber.
  - 1. The rubber membrane shall comply with CAN/CGSB 37.52M.

#### 4-4.16.3.5 Membrane Reinforcing Fabric

- A. Membrane reinforcing fabric shall consist of spun bonded sheet structure composed of 100% continuous filament polyester fibres bonded together at their crossover points.
  - 1. Membrane reinforcing fabric shall be supplied in minimum widths of 300 mm.

#### 4-4.16.3.6 Wick Drain

- A. Wick drain shall consist of composite polypropylene with a total thickness of 3.6 mm and supplied in 100 mm widths.
  - 1. The wick drain puncture strength shall be a minimum of 45 N measured in accordance with ASTM D4833.

#### 4-4.16.3.7 Waterproofing Protection Board

- A. Waterproofing protection board shall comply with the Ontario Ministry of Transportation's OPSS 1215 Specification for Protection Board.
  - 1. Waterproofing protection board shall consist of panels that provide a protective cushion between the hot mix ACP and the asphalt membrane.

#### 4-4.16.3.8 ACP

- 1. ACP materials shall comply with Section 4-4.14.15 [*Asphalt Concrete Pavement (ACP)*] of this Schedule and the *Valley Line LRT Project Roadways Design and Construction Standards* unless otherwise specified in this Section 4-4.16 [*Deck Waterproofing Membrane System*] of this Schedule.

#### 4-4.16.4 Equipment

##### 4-4.16.4.1 General

- A. Equipment and methods used to place the deck waterproofing membrane and ACP shall be adequate to produce and place the materials as specified in this Section 4-4.16 [*Deck Waterproofing Membrane System*] of this Schedule.

##### 4-4.16.4.2 Heating and Mixing Kettle

- A. A heating and mixing kettle shall be used to heat the asphalt membrane.
  - 1. The kettle shall be capable of keeping the contents continuously agitated, free flowing and lump free until the material is drawn for application.
  - 2. The kettle shall be a double boiler oil transfer type with a built in agitator and shall be equipped with permanently installed dial type thermometers with an accuracy of  $\pm 2$  degrees Celsius to measure the temperature of the melted compound and oil.
  - 3. A separate calibrated thermometer with an accuracy of  $\pm 2$  degrees Celsius shall be available on -site to verify material temperatures.

##### 4-4.16.4.3 ACP Mixing Plant

- A. The ACP mixing plant used for the preparation of ACP shall conform to the *Valley Line LRT Project Roadways Design and Construction Standards*.

1. The ACP mixing plant shall have a certificate of calibration certifying that the plant has been calibrated to produce a uniform mixture complying with the asphalt mix design.
- B. The asphalt tank supplying the ACP mixing plant shall be equipped with a heating apparatus capable of producing asphalt temperatures up to but not greater than 155 degrees Celsius uniformly throughout the entire contents of the tank.
  1. The asphalt temperature shall be maintained within  $\pm 10$  degrees Celsius of the specified mixing temperature.

#### 4-4.16.4.4 **ACP Transportation Equipment**

- A. ACP shall be transported from the ACP mixing plant to the Site in trucks with smooth metal boxes in good and leak proof condition which have been previously cleaned of all foreign materials and hardened ACP mixture.
  1. Excess truck box lubricants, such as detergent or lime solutions, shall not be allowed to contaminate the ACP.
  2. Petroleum based truck box lubricants shall not be used.
- B. Trucks shall be equipped with tarpaulins of suitable material and sufficient size to cover the ACP completely and overhang the sides of the truck box when the truck is fully loaded.
  1. Tarpaulins shall be securely fastened on all sides of the truck box.
  2. Tarpaulins shall be on the truck box whenever ACP is being transported.

#### 4-4.16.4.5 **Pavers**

- A. Pavers shall be acceptable to the City, self-propelled and operated to maintain the lines and grades shown on the applicable Final Design.

#### 4-4.16.4.6 **Compaction Equipment**

- A. Self-propelled compaction equipment shall be used to obtain the required degree of compaction of the ACP.
- B. The compaction capability of the equipment used shall equal or exceed the placing rate of the spreading operations and shall be capable of obtaining the required compaction before the temperature of the ACP falls below specified levels.
- C. Compaction equipment shall be of a suitable size, weight and type, such that displacement of the ACP and/or disruption of underlying materials will not occur.
  1. Specialized compaction equipment shall be used as required to achieve adequate compaction and smoothness in tight corners, such as adjacent to deck joints.
- D. Compaction equipment shall be in proper mechanical condition and operated such that uniform and complete compaction is obtained throughout the entire width, depth and length of the ACP being constructed.
- E. A minimum of two pieces of compaction equipment shall be used. They shall be rollers of at least 10 tonnes mass, one rubber tired roller and one smooth steel drum type roller.
  1. Rollers shall be configured to ensure uniform and complete compaction up to the face of barriers, curbs, medians and deck joints.

2. Vibrators on vibratory rollers shall not be activated.
- F. Rollers provided shall leave a smooth, properly finished surface, true to grade and cross-section without ruts or other irregularities.
  - G. Compaction equipment shall be equipped with methods of wetting the tires or drums to prevent adhesion or pickup of the ACP.

#### 4-4.16.5 **Inspection and Testing**

##### 4-4.16.5.1 **Deck Waterproofing Membrane**

- A. The asphalt membrane, rubber membrane, membrane reinforcing fabric and protection board shall be tested to verify compliance with Ontario Provincial Standard Specifications OPSS 1213 and OPSS 1215.

##### 4-4.16.5.2 **ACP**

- A. Inspection and testing of ACP shall comply with the *Valley Line LRT Project Roadways Design and Construction Standards* unless otherwise specified in this Section 4-4.16 [*Deck Waterproofing Membrane System*] of this Schedule.
- B. The ACP shall meet the quality control requirements of the *Valley Line LRT Project Roadways Design and Construction Standards* unless otherwise specified in this Section 4-4.16 [*Deck Waterproofing Membrane System*] of this Schedule.

#### 4-4.16.6 **Installation of Deck Waterproofing Membrane**

##### 4-4.16.6.1 **General**

- A. Installation of the deck waterproofing membrane shall only be carried out when the air and concrete surface temperatures are 5 degrees Celsius or higher.
- B. The operations involved in installing the deck waterproofing membrane shall be performed in sequential order, such that there are no delays between individual operations except those necessary to meet the requirements of this Section 4-4.16 [*Deck Waterproofing Membrane System*] of this Schedule.
- C. All traffic, other than the construction equipment directly associated with the installation of the deck waterproofing membrane and ACP shall be restricted from travelling over the prepared deck waterproofing membrane areas.
  1. These restrictions shall remain in place until after the final lift of ACP has been placed over the deck waterproofing membrane and cooled to ambient temperature.

##### 4-4.16.6.2 **Surface Preparation**

- A. Concrete surfaces receiving a deck waterproofing membrane shall be cured at least 14 days and then allowed to dry for a minimum of 3 days before commencing installation of the deck waterproofing membrane.
  1. Drying of the concrete deck surface by use of torches or other means that might be harmful to the deck is not permitted.
  2. Installation of the deck waterproofing membrane, including tack coating shall not commence until the concrete surface is fully dry and clean.

- B. Once the surface of the concrete is completely dry it shall be sandblasted or shotblasted as required to expose sound, laitance free concrete over the entire installation area.
  - 1. All dirt and debris on the concrete surface shall be removed and disposed of leaving a prepared surface satisfactory for tack coating.

#### 4-4.16.6.3 Tack Coating for Deck Waterproofing Membrane

- A. Tack coat shall be applied after the City has accepted the surface preparation work.
- B. Tack coat shall be applied to the concrete surface wherever deck waterproofing membrane is required.
- C. Immediately prior to the application of the tack coat, the concrete surface shall be blown clean with oil and water free compressed air to remove all dust and any other foreign material.
- D. The tack coat shall be cut back with an equal volume of gasoline type solvent or alternative cut back asphalt product that is compatible with the asphalt membrane.
  - 1. The tack coat application rate shall be such that the tack material will be absorbed into the concrete, resulting in a surface that is dull and black in appearance.
  - 2. Excess application of tack coat, indicated by a shiny black surface, is not permitted.
  - 3. Tack coat material shall be applied at an approximate rate of 0.25 L/m<sup>2</sup>.
- E. Waterproofing equipment or material shall not be permitted on the tack coat until it has fully cured and is completely tack-free.

#### 4-4.16.6.4 Waterproofing of Joints and Cracks

- A. After tack coat application and prior to application of the primary asphalt membrane to the deck, a coat of asphalt membrane 3 to 4 mm thick shall be applied over each joint and crack including over construction joints, lifting hook pockets and concrete patch joints. The membrane shall be wide enough to extend 200 mm on either side of each joint or crack and shall be applied in accordance with Section 4-4.16.6.5 [*Application of Asphalt Membrane*] of this Schedule.
- B. Membrane reinforcing fabric shall be placed in the asphalt membrane over the joints and cracks.
  - 1. The strips of membrane reinforcing fabric material shall be wide enough to extend 150 mm on either side of the joints and cracks and shall be applied while the asphalt membrane is still hot and tacky.
  - 2. Membrane reinforcing fabric strips shall be overlapped a minimum of 100 mm where multiple strips are used.
  - 3. The membrane reinforcing fabric shall be covered with an additional layer of asphalt membrane 2 to 3 mm thick.
- C. Along curbs, barriers, medians, deck drains and deck joints asphalt membrane 3 to 4 mm thick shall be applied to the height of the top of the ACP surface course, and 150 mm onto the deck.
  - 1. Rubber membrane shall be applied into the first coat of asphalt membrane while it is still hot and sticky.

2. The rubber membrane shall extend 50 mm up the vertical face of the curbs, barriers, medians, deck drains and deck joints, and 100 mm onto the deck surface.
3. Rubber membrane shall be overlapped a minimum of 100 mm where multiple strips are used.
4. A second coat of asphalt membrane 2 to 3 mm thick shall be applied to fully cover the rubber membrane.

#### 4-4.16.6.5 Application of Asphalt Membrane

- A. Asphalt membrane shall not be applied until the tack coat has cured completely.
- B. Cakes of asphalt membrane shall be melted in the heating and mixing kettle to a temperature not exceeding that recommended by the membrane manufacturer.
  1. The asphalt membrane shall be applied within the temperature range recommended by the manufacturer.
- C. The membrane shall be applied in a uniform film having a minimum thickness of 4 mm and a maximum thickness of 6 mm.
- D. The asphalt membrane shall be applied in a continuous manner.
  1. Where joints in the asphalt membrane are unavoidable they shall be overlapped by a minimum of 150 mm.
- E. The asphalt membrane shall be applied over all waterproofed joints and cracks, and shall extend up the face of curbs, barriers, medians, deck drains and deck joints, to the height of the top of the ACP surface course.
- F. Deck drains and drainage tubes shall not be plugged by the asphalt membrane.

#### 4-4.16.6.6 Installation of Wick Drain

- A. Wick drains shall be installed along the full length of gutters when the asphalt membrane is still hot and tacky.
  1. Special attention shall be given to waterproofing and wick drain modifications required at deck drain locations.

#### 4-4.16.6.7 Application of Protection Board

- A. The asphalt membrane thickness shall be checked and documented to confirm conformance to the requirements of Section 4-4.16.6.5 [*Application of Asphalt Membrane*] of this Schedule, prior to placing the protection board.
- B. Protection boards shall be laid on the asphalt membrane while the membrane is still hot, with the length of the board running transversely on the deck.
- C. The protection boards shall be placed with edges overlapping a minimum of 12 mm and a maximum of 25 mm both longitudinally and transversely. The protection board edges shall be within 5 mm of all wick drains, faces of deck drains and faces at deck joints.
  1. Protection boards shall be lapped to produce a shingling effect in both the longitudinal and transverse directions.



2. Holes shall be cut through the protection boards as required to allow water to drain freely through drainage tubes.
- D. Protection boards shall be placed such that the longitudinal (direction of traffic flow) joints are staggered at least 150 mm.
- E. Boards shall be rolled by means of a linoleum or lawn type roller while the asphalt membrane is still warm, in order to ensure good contact with the membrane.
  1. At locations where the edges of the protection board have curled up, the curled up edges shall be cemented down using hot asphalt membrane material.
- F. Protection boards that are warped, distorted or damaged in any way, whether by manufacture, storage, handling or exposure to weather, shall be rejected.

#### 4-4.16.7 **Placement of ACP**

##### 4-4.16.7.1 **General**

- A. The Structure shall be protected to prevent splatter or staining from asphaltic materials.
- B. Placement of the first lift of ACP shall commence within 7 days of installation of the deck waterproofing membrane.

##### 4-4.16.7.2 **Tack Coat**

- A. Asphalt tack coat shall be applied to the protection board and between lifts of ACP.
  1. Tack coat shall not be applied to wick drains.
- B. The surface to be tacked shall be dry and free of loose or deleterious material when the tack is applied.
- C. The asphalt tack coat shall be applied in a uniform manner at an application rate of 0.5 L/m<sup>2</sup>.
  1. The ambient air temperature at the time of application shall be 5 degrees Celsius or higher.

#### 4-4.16.8 **Spreading and Compaction**

##### 4-4.16.8.1 **General**

- A. The ACP mixture shall be placed only upon a dry, frost free substrate on which the tack coat has cured, and when the ambient air temperature is 5 degrees Celsius or higher.
- B. Prior to delivery of the ACP mixture, the protection board surface shall be cleaned of all loose or foreign material.
- C. The ACP mixture shall be spread and compacted during daylight hours only, unless artificial light is provided.
- D. During spreading and compaction operations, care shall be taken at all times to ensure that:
  1. the ACP mixture is not wasted over the sides of the Structure or onto adjacent surfaces;
  2. the deck waterproofing membrane, curbs, barriers, medians and drains are not damaged; and

3. the Structure including guide posts, guardrails, signs, power conduits or any other roadside installations is not damaged.

E. Immediate repairs shall be made to any damage resulting from Construction activities.

#### 4-4.16.8.2 Spreading

- A. The ACP mixture shall be spread at a temperature sufficient for the specified compaction and finishing of the ACP.
- B. The manner of placing the ACP shall ensure safe accommodation of traffic, quality control and drainage.
- C. The longitudinal and transverse edges of the ACP in each traffic lane shall be straight in alignment, uniform, and of the same thickness as the adjoining ACP lift.
  1. The exposed edges of ACP lifts shall be protected throughout Construction.
- D. Each ACP lift shall be placed, finished and compacted for its full width, and then allowed to cool down to 50 degrees Celsius or colder prior to commencing the subsequent lift.
- E. In the placing of successive ACP lifts, the individual ACP mixture spreads shall be aligned in a manner such that the longitudinal joints in successive lifts do not coincide.
  1. The lateral distance between the longitudinal joints in successive ACP lifts shall be not less than 0.30 m.
  2. The longitudinal joints of the final lift of ACP shall not be located within the wheel path areas.
- F. All longitudinal and transverse joints in the ACP shall be of the vertical butt joint type, well bonded and sealed, and shall be finished to provide a continuous, smooth profile across the joints.
- G. The surfaces of all ACP lifts shall not exhibit evidence of segregation.

#### 4-4.16.8.3 Compaction

- A. ACP percent compaction shall be expressed in percent of Marshall Standard Density. The Marshall Standard Density used for determining ACP compaction shall be as follows:
  1. Marshall Densities determined on field sampled ACP mixture, or if not available then;
  2. Marshall Design Density as reported in the accepted mix design.
- B. The compaction process shall be monitored using a control strip method. Control strips shall be established on each lift of ACP placed.
- C. The control strip lift shall be compacted using at least the following equipment:
  1. One steel roller weighing not less than 10 t; and
  2. One self-propelled pneumatic roller, ballasted to its maximum capacity, weighing not less than 10 t.
- D. Once the ACP mixture has been spread by the paver and the initial pass of the breakdown roller has been done, moisture and density measurements for determining the control density

will commence at five locations within the control strip area, and will continue following repeated passes of the compaction equipment until the apparent maximum density is attained.

1. ACP density measurements shall be taken using nuclear testing equipment.
- E. The ACP shall be compacted to the densities specified in Section 4-4.16.9 [ACP Paving] of this Schedule.
- F. When the compaction methods and procedures are not achieving the desired compaction, in the opinion of the City, cores of the top lift of ACP shall be taken. The number of cores shall be determined by the City. The cores shall be tested by Project Co and the results provided to the City as soon as they become available.
1. Coring of the ACP shall be carried out using methods which will not damage the asphalt membrane or protection board.
  2. Core holes shall be completely de-watered and dried. A generous application of liquid asphalt shall be applied to the bottom and sides of the core hole and allowed to cure. ACP mixture shall then be tamped in lifts into the core hole until flush with the surface of the surrounding ACP.
  3. Coring shall not be undertaken without the acceptance of the City.
- G. In order to maintain the crown of the deck surface, the compaction equipment shall not be operated on or across the crown.
- H. Compaction procedures and equipment shall be such that displacement of the ACP mixture does not occur.
- I. Roller wheels on compaction equipment shall be kept slightly moistened by water or oil to prevent picking up the ACP mixture, but an excess of either water or oil is not permitted.

#### 4-4.16.9 **ACP Paving**

- A. The completed ACP wearing surface and all intermediate lifts shall be smooth and true to the lines and grades show on the applicable Final Design.
1. The finished surface of any lift shall have a uniform closed texture and shall be free of signs of poor workmanship.
- B. The ACP wearing surface shall be placed and compacted in two nominal 40 mm thick lifts.
- C. The first lift of ACP shall be spread by the asphalt paver in the direction of the laps in the protection board.
- D. To avoid damaging the deck waterproofing membrane, the paver shall not exceed the placing rate or push the delivery trucks.
- E. Equipment shall perform all turning movements off the deck.
- F. Dumping of the ACP mixture onto the protection board ahead of the paver is not permitted.
- G. The allowable temperature range for compaction of the ACP lifts on the deck waterproofing membrane shall comply with Table 4-4.16.9-1 [Compaction Temperature Range of ACP Lifts]:

Table 4-4.16.9-1 Compaction Temperature Range of ACP Lifts

ASPHALT GRADE	COMPACTION TEMPERATURE RANGE	
	FIRST LIFT	SECOND LIFT
150 - 200 (A)	MAX. 105 degrees Celsius	128 – 138 degrees Celsius
200 - 300 (A)	MAX. 105 degrees Celsius	123 – 133 degrees Celsius

- H. The minimum average Marshall Density of the first ACP lift shall be 95% with no individual test less than 93%.
- I. The minimum average Marshall Density of the second lift shall be 97% with no individual density less than 95%.

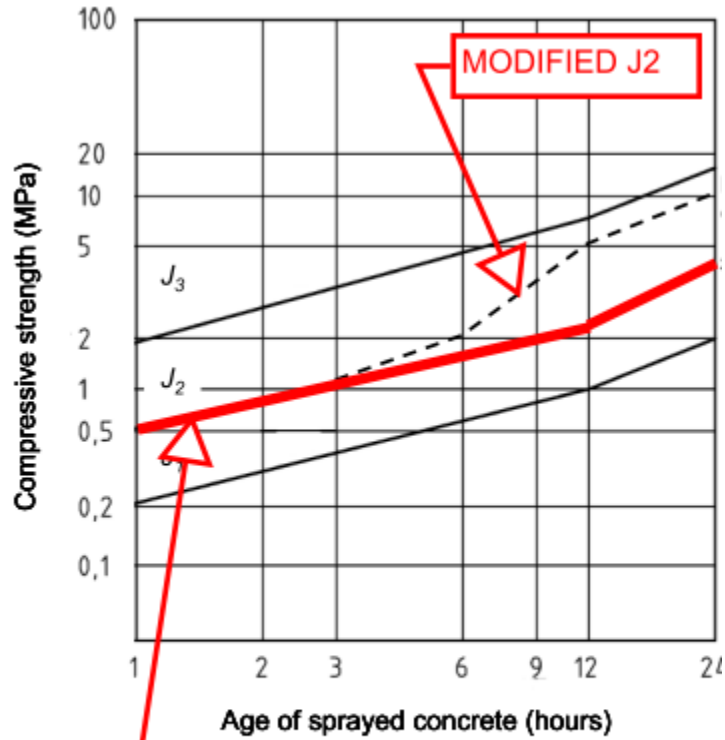
**4-4.17 SHOTCRETE FOR FINAL TUNNEL LINING**

**4-4.17.1 General**

- A. This Section 4-4.17 [*Shotcrete for Final Tunnel Lining*] sets out the requirements for Shotcrete forming the final tunnel lining for the Mined Tunnel, and is applicable solely where a two-pass lining system with a waterproofing layer is utilized. A Shotcrete final tunnel lining is not permitted where a one-pass lining system is used. This specification shall be read in conjunction with Section 4-4.4 [*Cast-in-Place Concrete*].

**4-4.17.2 Performance Requirements**

- A. Shotcrete shall be capable of being applied by a robotic manipulator in a series of up to 100mm thick continuous passes to form a homogeneous layer of the final thickness as specified in the Mined Tunnel Final Designs.
- B. The applied Shotcrete shall exhibit no sagging and shall ensure full encasement of reinforcement, lattice girders, and inserts where installed.
- C. Early age strength development shall comply with Figure 4-4.17.2 [*Early Age Strength Development for Final Tunnel Lining Shotcrete*].
- D. Project Co shall determine the Shotcrete compressive strength at 1, 7, 28, 56 and 90 days. The maximum cylinder compressive strength at 28 and 90 days when using fibres shall be limited to a value that appropriately controls the brittleness of the Shotcrete and prevents underperformance of the fibres.



FINAL LINING SHOTCRETE CURVE FOR EARLY AGE STRENGTH

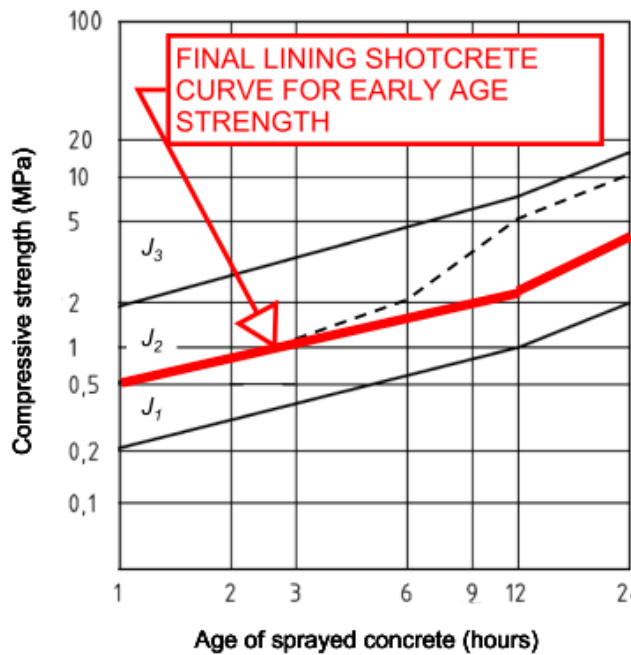


Figure 4-4.17.2 – Early Age Strength Development for Final Tunnel Lining Shotcrete

#### 4-4.17.3 **Materials for Shotcrete Final Tunnel Lining**

- A. All constituent materials for the final tunnel lining Shotcrete shall be selected to provide Shotcrete with sufficient durability to meet the Design Service Life requirements of the Structure and sufficient strength to meet structural strength requirements.
- B. All constituent materials shall be obtained only from sources that demonstrate the capability of producing the materials required by the Project Requirements at a consistent quality. Each constituent material shall be supplied from a single source.
- C. The sources of the different types of constituent materials shall not be changed during the course of Construction except through the obtaining of satisfactory results in physical and chemical tests.
- D. The Shotcrete trials shall be repeated if the source or quality of any of the materials is changed or if the mix proportions are to be changed during the course of the work.
- E. Only the Wet Method of Shotcrete shall be allowed on site.

##### 4-4.17.3.1 **Cement and Cementitious Additives**

- A. Cement shall comply with the requirements of Section 4-4.4.2.1 [*Portland Cement*], and with the requirements of this Section 4-4.17.3.1 [*Cement and Cementitious Additives*].
- B. Cement shall comply with the following additional requirements:
  - 1. fineness not less than 350m<sup>2</sup>/ kg and C<sub>3</sub>A content not less than 5% unless proved by Shotcrete trials that the setting time, early strength gain and 90 day strength of the Shotcrete for the Final Design are compliant with the requirements of the Mined Tunnel Final Design and of this Section 4-4.17 [*Shotcrete for Final Tunnel Lining*]; and
  - 2. compressive strength testing of mortar prisms shall conform to ASTM C349.
- C. Fly ash (PFA – Pulverized fuel ash) shall comply with CAN/CSA A3001, for Type “F” fly ash with calcium oxide content (CaO) not exceeding 12%.
- D. Fly ash may be included in the Shotcrete mix provided the target performance with regard to setting and early strength development can be achieved.
- E. The content of SO<sub>3</sub> shall not exceed 4.8% by weight of total binder content.
- F. Different brands or types of cement shall be stored separately and shall not be mixed together for use in the work.
- G. Cement and cementitious additives that demonstrate comparatively lower variation in chemistry and physical properties between production runs and with favorable setting performances with the set accelerator, shall be chosen for the Shotcrete.

##### 4-4.17.3.2 **Silica Fume**

- A. Silica fume shall be in the form of water-based slurry. It shall comply with CAN/CSA A3001 for Type SF and the following requirements:
  - 1. the content of SiO<sub>2</sub> by weight of dry mass shall be not less than 85%;
  - 2. the silica fume shall not contain more than 0.4% elemental silica (by weight of dry mass) or any deleterious materials such as quartz, rust, and/ or cellulose fibres;

3. the specific surface area shall not be less than 15,000 m<sup>2</sup>/kg;
  4. the carbon content shall not exceed 2% and the total alkali content as Na<sub>2</sub>O equivalent shall not exceed 2%;
  5. SO<sub>3</sub> content (by weight of dry mass) shall be less than 2%;
  6. pH shall be 5.5 ± 1.0;
  7. the relative density shall be between 1.3 and 1.4;
  8. the activity index shall be at least 100% after 28 days; and
  9. the loss on ignition (L.O.I) shall be less than 4%.
- B. The compatibility of silica fume and admixtures shall be established by carrying out appropriate testing in compliance with Section 4-4.17.4 [Testing].
- C. The optimum content of silica fume shall be determined during Shotcrete trials.

#### 4-4.17.3.3 **Water**

- A. Water for mixing concrete, patching products, concrete finishing materials or mortar shall comply with CAN/CSA A23.1 and shall be free from harmful amounts of alkali, organic materials and other deleterious substances.
1. Slurry water, treated wash water or water from shallow, stagnant or marshy sources shall not be used.

#### 4-4.17.3.4 **Aggregates**

- A. Aggregates shall comply with the requirements of CAN/CSA A23.1.
- B. The nominal particle size of the coarse aggregate shall be a maximum of 10mm.
- C. Fine and coarse aggregates shall be clean. The combined aggregate grading for the respective Shotcrete materials shall remain within the limits shown in Figure 4-4.17.3.4 [Target Aggregate Grading Envelope for Shotcrete]. The following Shotcrete aggregate requirements are:
1. Structural Shotcrete - Grading Envelope between limits A and B;
  2. Shotcreted Regulating Layer - Grading Envelope between limits B and C. The maximum particle size of the aggregate used for the Regulating Layer shall be limited as required to meet the requirements of the waterproofing membrane manufacturer.
- D. The drying shrinkage of aggregates from natural sources in concrete shall not exceed 0.075%.

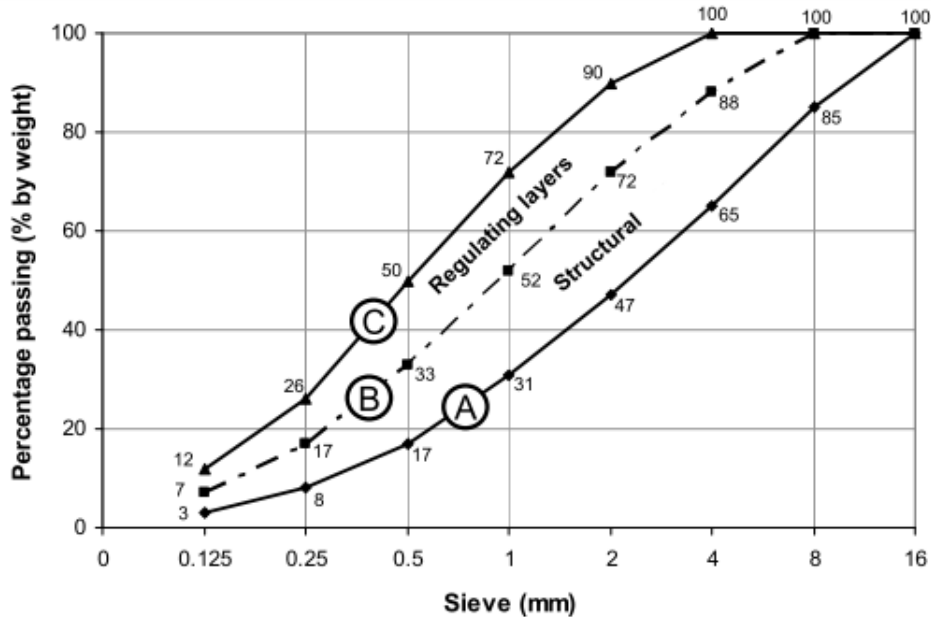


Figure 4-4.17.3.4: Target Aggregate Grading Envelope for Shotcrete

#### 4-4.17.3.5 Admixtures

- A. Admixtures shall be compatible with all mix constituents.
- B. Prepare and submit proposals for admixtures to the mix as part of the Shotcrete concrete mix design. The performance of the mix shall be demonstrated by Shotcrete trials prior to that mix being used in the work.
- C. Admixtures shall be free of chlorides such that the percentage of chlorides shall not exceed 0.1% by weight.
- D. Plasticisers (water reducing admixtures) and superplasticisers shall comply with ASTM C494.
- E. Plasticisers and superplasticisers may be used to reduce the quantity of the mixing water and to improve the workability and pumpability of the Shotcrete. The effects and optimum dosages of the plasticiser shall be determined by Shotcrete trials.
- F. Compatibility of plasticisers and superplasticisers with the cement, cementitious additives, admixtures and set accelerators shall be verified by observation and Shotcrete trials.
- G. Hydration control admixtures (hydration stabilization admixtures) may be used to enhance the logistical requirements of the work. The effects and optimum dosages of hydration control admixtures shall be determined by Shotcrete trials, both in terms of maintaining workability over the required wet concrete mix storage time, and the early age strength development of the Shotcrete. Hydration control admixtures shall be used in accordance with the manufacturer's instructions.
- H. All admixtures and set accelerators shall be sourced from one manufacturer.

#### 4-4.17.3.6 Set Accelerators

- A. Only liquid alkali-free set accelerators (pH 2.5 to 8.0 and having an alkali content less than 1% by weight  $\text{Na}_2\text{O}$  equivalent) shall be used. Sodium silicate (waterglass) and potassium or sodium aluminate based accelerators shall not be used.



- B. Only the minimum quantity of set accelerator necessary shall be permitted in normal Shotcrete operations. This quantity shall be determined by Shotcrete trials. The maximum allowable dosage of set accelerator shall be 8% by weight of the cementitious material content.
- C. Testing of set accelerators with regard to acceleration of setting, early strength and long term compressive strength of the Shotcrete shall be determined by Shotcrete trials.

#### 4-4.17.3.7 **Fibres**

- A. Structural steel fibres shall meet the following requirements:
  - 1. steel fibres shall comply with ASTM A820/A820M, Type 1 or 2;
  - 2. minimum tensile strength for the steel fibres shall be 800MPa;
  - 3. minimum steel fibre content shall be 30kg per cubic meter for steel fibre reinforced Shotcrete;
  - 4. dosage of structural fibres shall be determined to meet the requirements for flexural strengths; and
  - 5. structural fibres shall have an aspect ratio in the range of 30 to 150 for lengths of three times the maximum aggregate size. Steel fibre length shall not exceed 0.7 of the internal diameter of the delivery hoses, unless Shotcrete trials demonstrate reliable, blockage-free pumping and spraying.
- B. Microsynthetic fibres shall be used where required for fire protection.
  - 1. Microsynthetic fibres shall be included to achieve anti-spalling fire resistance properties when exposed to the Design Fire Event. Dosages and type to be determined by Project Co in accordance with Section 4-5.15 [*Fire Resistance*].

#### 4-4.17.4 **Testing**

##### 4-4.17.4.1 **Shotcrete Trials.**

- A. General
  - 1. Shotcrete trials shall only be undertaken by trained and certified nozzlemen who are certified through records of training in accordance with ACI Certification program CP-60 and can demonstrate at least five years of successful experience on the similar Project.
  - 2. The Shotcrete trials shall employ equipment of identical type to that to be used in the work and constituent materials shall be the same as those to be used in the work.
  - 3. The Shotcrete trials shall be repeated if the source or quality of any of the materials or the mix proportions are changed.
  - 4. All Shotcrete trial test results shall be submitted at least nine weeks before the actual application of Shotcrete to ensure that the required Shotcrete mixes are developed and all site trials testing completed satisfactorily before construction of the final tunnel lining begins.
  - 5. The tests and frequency of tests shall be in accordance with Table 4-4.17.5B [*Shotcrete Test Requirements for Shotcrete Trials*] unless otherwise modified in agreement with the City, in its discretion.
  - 6. Beams for flexural tests to ASTM Standards shall be sprayed, not cast.

7. Materials approval associated with residual flexural strength requirements will be based on the results of 12 beams.
  8. Cores for compressive strength testing shall be taken from the mix from which the beams for flexural strength testing are sprayed.
  9. The fibre content of the sprayed mix and the sprayed fibre content of the mix shall be established and recorded.
  10. For the Shotcrete trials the nozzleman who will be carrying out the main spraying shall prepare a sufficient number of test panels as per ASTM C1140, except that the panels shall have a minimum width and length of 1000 mm. The Shotcrete in the panels shall adhere well to the backform, be properly compacted and exhibit no sagging. The panels shall be sprayed with the same equipment and technique as will be used for the actual work.
  11. The test panels shall be arranged in a manner to simulate Shotcrete application to both the Mined Tunnel side wall (vertical wall) and to the tunnel crown (overhead, at least 45° hanging).
  12. The time at which each Shotcrete panel is completed shall be recorded. The panels shall not be moved for 18h after spraying and shall be stored without disturbance at a temperature of +20°C (±5°C), covered by polythene sheet and shall not be exposed to direct sunlight until the time of coring.
  13. The chosen method for forming radial joints (for example the connection between top heading and bench linings) between concrete sprayed at different times shall be trialed during the Shotcrete trials to examine the behaviour and integrity of the joints. The time between applications of the different parts of the joints shall be representative of the worst case construction sequence expected during the work. The joint shall be investigated by drilling at least two 100mm cores through the joint.
  14. The surface finishes required by Section 4-4.17.5F [*Shotcrete Surface*] shall be trialed during the Shotcrete trials to examine the behaviour, workability and integrity of the fresh Shotcrete surface. The surface integrity during the Shotcrete trials shall be investigated by drilling 100 mm deep cores through 2 consecutive Shotcrete layers.
- B. Results of Shotcrete Trials – Compressive Strength
1. Cores for 1, 28 and 90 days compressive strength tests shall be obtained from the panels
  2. No sets of cores to be tested at any given age shall come from the same panel. Sets of cores to be tested at different ages may come from the same panel. For each test at least one spare specimen shall be provided. The testing requirements shall be: compressive strength in the spray direction after 1, 28 and 90 days on each set of cores.
  3. Compressive strength between one and twelve hours shall be measured using a penetration or driving bolt or other calibrated method in accordance with Good Industry Practice.
- C. Results of Shotcrete Trials – Other Properties
1. Control values for porosity and minimum density shall be established based on the core samples.

2. Aggregate and fibre rebound shall be measured during the spraying of all test panels. Efforts shall be made to minimise the wastage of materials and maximise the sustainability of the Shotcrete lining.
3. The depth of water penetration into the concrete (permeability) shall be measured on samples of concrete in accordance with ACI 506.4 following appropriate procedures described in EN 12390-8. At least three samples shall be cored. No sample shall display a depth of penetration greater than 35mm. The mean depth of water penetration shall not exceed 25mm.
4. Target workability values and methods of measuring workability shall be determined by Project Co during the Shotcrete trials. The workability shall be measured over a time duration to match the intended work plan.
5. Fibre reinforced Shotcrete shall limit crack widths in the final lining to 0.3mm at twenty eight and ninety days by the addition of steel fibres.
6. Fibre quantity and distribution shall be randomly checked by taking sets of three 10 litre samples. The average fibre content from the set of three samples shall reflect the design fibre content and no individual sample shall have a fibre content less than 80% of the design fibre content.
7. The Shotcrete shall have a maximum drying shrinkage tested in accordance with ASTM C341 (Standard Practice for Length Change of Cast, Drilled or Sawed Specimens of Hydraulic Cement, Mortar or Concrete) including an initial period of seven days curing in water.
8. Satisfactory freeze-thaw durability shall be substantiated by proper air-entrainment and shall be in accordance with CSA A23.1. Preconstruction testing shall be conducted during the Shotcrete trials. If appropriate air-entrainment is not substantiated, the freeze-thaw resistance shall be proved on at least 3 samples in accordance with ASTM C666/C666M.
9. If Project Co proposes to employ hydration control admixtures to "stabilise" the mix, Project Co shall prepare and submit data to confirm that the long term properties of the concrete at 28, 56 and 90 days are unaffected by the hydration control process and that the early age strength development is to the curve specified in Section 4-4.17.2 [*Performance Requirements*].

#### D. Production Testing of Shotcrete

1. Production testing of Shotcrete shall generally be performed using the same test methods and procedures defined in Section 4-4.17.4 A to C [*Shotcrete Trials*].
2. Tests shall be carried out on a routine basis on cores or other samples taken from final Shotcrete placed in the work. The locations of the cores shall be determined to give an even distribution around the entire lining including at longitudinal joints (i.e. samples from crown, axis and invert). Locations of sampling shall be recorded.
3. Test panels sprayed in-situ in the section of tunnel under construction may also be used instead of taking samples from the lining.
4. Project Co shall keep a record of all tests on Shotcrete, which shall be kept on site and shall identify the tests with the section of work to which they relate.
5. The tests shall be in accordance with the requirements of the codes, standards, acts and reference documents referenced in Section 4-5.4B [*Codes, Standards, Acts and*

*Reference Documents*] unless otherwise accepted by the City. The tests and frequency of the tests shall be in accordance with Table 4-4.17.5A [*Shotcrete Test Requirements During Construction*]. Depending on the compliance of test results, circumstances of application and importance of construction, the frequency of production tests may be reduced or increased at the City's discretion.

6. Final tunnel lining cores shall stop at least 50mm from the waterproofing layer. All cores shall be visually inspected to verify that the Shotcrete is dense and homogeneous without segregation of aggregate or other visible imperfections. At least 20%, but no more than 35% of cores shall be taken through joints to allow inspection of workmanship and ensure compaction and completeness.

#### E. Hammer Testing of Shotcrete Final Tunnel Lining

1. All Shotcrete final tunnel linings shall be tested for voids. The area of testing shall be 45 degrees either side of the tunnel crown (the highest internal point). Initially a width of 1.5 metres shall be tested at 10m spacing along the tunnel. This frequency may be increased or reduced with the agreement of the City, acting in its discretion, depending on the results obtained. The finished surface shall be struck with a hammer. The operator shall listen to the ring or sound that the Shotcrete imparts. A hollow sound is indicative of lack of bond between layers of Shotcrete. Hollow sounding areas shall be marked and recorded. At the same time as the testing, cracking in the crown area shall also be recorded. Before the testing is carried out several hammer weights shall be tried to determine the best weight for the lining thickness and Shotcrete mix being tested. It is anticipated that the hammer weight will be between 0.5kg. and 2.0kg. This testing shall be carried out within 3 weeks of placing the lining.

If voids are found, drilling, removal and/ or patching may be necessary. Void repair procedures shall be developed, signed and sealed by a Professional Engineer prior to the commencement of the repair. These procedures shall be agreed with the City prior to any remedial works commencing

#### 4-4.17.5 Handling and Placing Concrete

##### A. Profile and thickness control

1. The minimum thickness and profile for Shotcrete linings shall be in accordance with the applicable Final Design and their respective tolerances shall be as follows:
  - a. The thickness of the Final Lining shall not be less than its theoretical thickness at any point; and
  - b. The internal profile shall not depart from the design profile by more than 50 mm or by the value of the construction tolerances determined in accordance with Section 4-4.17.5.B.1 [*Tolerances*] whichever is more stringent.
2. Excavation profile, Shotcrete thickness and sprayed profile shall be controlled by remote surveying techniques, (either as standalone systems or built into the excavator and robotic spraying equipment) and shall satisfy the specified tolerances of this Section 4-4.17.5 [*Handling and Placing Concrete*].

##### B. Tolerances

1. It is Project Co's responsibility to determine the minimum excavation profile and tolerances by adding allowances to the theoretical excavation line in the radial direction so that the requirements of Section 4-5.3 [*Mined Tunnel Methods and Configuration*] are met.

2. In addition, at the interface with mechanical, structural or architectural components (if any) concrete surfaces shall be finished to meet any additional tolerances required by the components.
3. Any sections of the lining that are out of the defined tolerances shall be trimmed back or filled accordingly. Prior to any trimming taking place a method statement (included any required additional monitoring) and risk assessment shall be submitted to the City.

#### C. Survey Control

1. Project Co shall:
  - a. Perform tunnel horizontal traverses as closed loops and adjusted by the least squares method or similar method of adjustment.
  - b. Perform tunnel vertical traverses as closed loops and adjusted by distributing the error of closure equally through the turning points.
2. Project Co shall verify for each advance or sprayed section that the required control of tunnel excavation, lining thickness and profile control is achieved to a measuring accuracy of  $\pm 3\text{mm}$ . The excavated ground profile and finished tunnel linings shall be readily compared to the design profiles. Survey points shall be at a maximum grid spacing of 1000mm.

#### D. Construction Joints

1. The excavation and cleaning of construction joints shall be carried out such that a clean, perpendicular joint is formed free from deleterious materials (such as rebound, soil and waterproofing material). The operation shall be mechanised wherever possible to avoid work with handheld tools. The cleaned joint should include protruding steel fibres.
2. Project Co shall address the following issues in detail in a method statement:
  - a. Lapping of reinforcement at joints.
  - b. Trimming and cleaning of previously placed Shotcrete to achieve a perpendicular joint face prior to application of a subsequent shotcreted lining.
  - c. Methods used to trim shotcreted lining shall reduce to a minimum or eliminate macro and micro cracking damage to the tunnel lining.
3. The final tunnel lining shall be installed in bays over the full arc of the tunnel. The bay length shall be determined by Project Co. Joints in layers in the final tunnel lining shall be staggered by at least 300mm.

#### E. Shotcrete Application

1. No rebound material is to be covered with Shotcrete. To facilitate this and depending on ground conditions and the excavation cycle, the Shotcrete shall preferably be applied from the footing towards the crown. The rebound material shall be removed from the tunnel and shall not be used in the work. At joint locations, any rebound shall be removed from the previously installed lining prior to cleaning the joint and spraying the adjoining lining.
2. Each layer of Shotcrete shall be built up by making several passes of the nozzle over the working area. The Shotcrete shall emerge from the nozzle in a steady uninterrupted flow. Should the flow become intermittent for any cause the nozzleman shall direct it away from the work until it again becomes constant.

3. Where a layer of Shotcrete is to be covered by succeeding layers, it shall first be allowed to set and loose material and rebound shall be removed. The surface shall be finally cleaned and wetted using air and water jetting.
4. The temperature of the mix before placing shall not be below 15°C and shall not exceed 30°C unless special measures are taken. Spraying shall not be undertaken when ambient temperature is below 5°C unless special measures are taken to provide protection against frost until the Shotcrete has developed a compressive strength of at least 5MPa.
5. Freshly applied overhead Shotcrete should be considered as a Hazard. Until the Shotcrete hardens, the potential of breakouts of Shotcrete placed in the roof of the tunnel exists. Therefore the Shotcreted area shall be a personnel exclusion zone.
6. The final tunnel lining shall be installed in any area within 3 weeks of the installation of the waterproofing system in this area
7. At the junction between plain Shotcrete with mesh and fibre reinforced Shotcrete there shall not be a zone of unreinforced plain Shotcrete.

F. Shotcrete Surface

1. The surfaces of Shotcrete final tunnel linings shall be such that when checked with a 1.2 m long straight edge placed anywhere in the longitudinal direction on the surface there shall not be any gap greater than 3 mm (not including the required chord offset on curved sections of the tunnel horizontal alignment) between the straight edge and the concrete surface. The Shotcrete surface shall consist of a dense and uniform concrete without rebound inclusions, segregation or discernible weakness of bond between layers.
2. All Shotcrete final tunnel linings containing structural steel fibres shall have a minimum 50mm Regulating Layer applied to cover the protruding structural steel fibres. This layer does not need to form part of the structural thickness of the final tunnel lining.
3. Shotcrete surfaces shall be trowelled smooth in accordance with the tolerances specified in Sections 4-4.17.5F1 and 4-4.17.5A [*Shotcrete Surface*].
4. Project Co shall ensure the surface finish of the Shotcrete is protected from damage and that the durability of the surface due to screeding or trowelling is not reduced. A Shotcrete mix appropriate for screeding and trowelling shall be evaluated during the Shotcrete trials.

G. Spraying onto Waterproofing Membranes

The application of Shotcrete linings to the inside of waterproofing membranes shall be in accordance with the recommendations of the membrane manufacturer.

H. Curing of Shotcrete Linings

1. Shotcrete linings shall be cured in accordance with ACI 506.2 unless otherwise accepted by the City. Details of Project Cos curing methods shall be submitted to the City with the Shotcrete concrete mix design at least nine weeks before the actual application of Shotcrete.
2. Internal curing compounds added to the wet Shotcrete concrete mix during batching shall be evaluated by Shotcrete trials in accordance with Section 4-4.17.4 [*Testing*] of this Schedule.

Performance criteria	Rate of sampling	Times of Testing
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Early age compressive strength	1 set every third advance	1 hour 3 hours 6 hours 12 hours
Compressive strength - cores	1 set per 50m <sup>3</sup> except 1 set per 20m <sup>3</sup> for 1 day tests.	1 day 28 days 90 days
Fibre Content	2 cores /50m <sup>3</sup> /workface	Taken from set of cores for compressive strength testing/50 m <sup>3</sup> /workface (mean value of 6 cores)
Fibre Content and compressive strength of Shotcrete for beam tests	Set of 2 cores/50c.m. (with flexural strength tests)	1 month with flexural strength testing. 28 & 90 days
Density	As per compressive – strength cores	As per compressive – strength cores
Workability	Each batch	After batching and prior to spraying
Estimated fibre and aggregate rebound	1 test every 2 months	During spraying
Water permeability	1 set/month	28 days
Flexural strength (Set of 3 beam tests)	1 set/month (each batch)	28 and 90 days
Concrete drying shrinkage	1 set/month	28 and 90 days
Modulus of elasticity	1 set of 3 cores for each age	1st 50m of tunnel: 1 day 28 days 90 days
SC Final Liner Thickness	1 set	Each advance/bay
Finished profile	1 set	Each advance/bay

Table 4-4.17.5A - Shotcrete Test Requirements During Construction

Performance criteria	Minimum number of tests per mix (at each stage)	Times of Testing
Early age compressive strength	6	1 hour 3 hours 6 hours 12 hours
Compressive strength - cores	6	1 day 28 days 90 days
Fibre content	6	
Density	As per compressive – strength cores	As per compressive – strength cores
Workability	Each batch	After batching and prior to spraying
Estimated fibre and aggregate rebound	12	During spraying

Water permeability	6	28 days
Flexural strength	12 in sets of 3	28 and 90 days
Concrete drying shrinkage	6	28 and 90 days
Modulus of elasticity	6	1 day 28 days 90 days
Surface Finishes (trowelling, screeding if applicable)	6	** After spraying and initial set of Shotcrete

\*Fibre content and compressive strength of the batch used to spray the beams shall be recorded.

\*\*Time of testing shall coincide with planned time of screeding and trowelling during the work. Identical equipment and methodology as utilized during the work shall be used.

Table 4-4.17.5B - Shotcrete Test Requirements for Shotcrete Trials



## **SECTION 4-5 MINED TUNNEL DESIGN AND CONSTRUCTION REQUIREMENTS**

### **4-5.1 QUALIFICATIONS**

- A. The qualifications and experience of the Mined Tunnel contractor and key personnel shall comply with the following requirements:
1. Mined Tunnel Contractor: Shall have completed a minimum of three similar tunneling projects within the last 10 years. A similar project is defined as a mined tunnel of similar length, diameter and lining methods driven in an urban environment with similar conditions of geology, and groundwater using equipment similar to that used for this Project.
  2. Mined Tunnel Project Manager. Shall have at least ten years of recent experience in managing underground construction work including five years' experience with the excavation and tunnel lining methods used for the Project.
    - a. Duties of the Mined Tunnel Project Manager shall include the following:
      - i. Contractor's designated representative on-Site with overall managerial responsibility for the execution of the Mined Tunnel Construction;
      - ii. responsibility for the safety, quality, conformance to Project Requirements and timely completion of the Construction;
      - iii. attending meetings with the City;
      - iv. Preparation, submission, review, and modifying/updating of procedures, work plans, shop drawings, etc; and
      - v. Coordination with the Mined Tunnel Project Engineers, Mined Tunnel Superintendents, and the City.
  3. Mined Tunnel Project Engineer. Shall have a minimum 10 years of experience in underground construction, including five years' experience with the excavation and tunnel lining methods used for the Project.
    - a. Duties of the Mined Tunnel Project Engineer shall include the following:
      - i. Supervisory responsibility for no more than one Mined Tunnel excavation face and associated works at any given time;
      - ii. Responsibility for supervising the execution of the Mined Tunnel excavation, including installation of initial and final supports, grouting, and other elements of the tunnel works, appurtenant structures and surface facilities;
      - iii. Responsibility for the safety, quality and timely completion of the Construction;
      - iv. Being available at all times during Mined Tunnel excavation activities;
      - v. Informing Mined Tunnel Superintendent of issues relating to safety, productivity, ground conditions, and other factors. Ensuring remedial measures are determined and implemented promptly;

- vi. Reviewing daily instrumentation measurement readings during excavation;
  - vii. If the Sequential Excavation Method is utilized, submitting weekly reports on geologic conditions as encountered during excavation for the City's use including records of daily discussions. The weekly report shall include documentation of the geologic mapping of the tunnel face. Each excavation heading shall be mapped at least twice per day. Prepare final report on geologic conditions encountered, ground control measures taken, and problems encountered after completion of the sequential excavation work;
  - viii. If a Tunnel Boring Machine is utilized, ensuring the correct operation of the Tunnel Boring Machine, including the guidance system and alignment control, monitoring of the Tunnel Boring Machine performance and ensuring the correct installation of the precast concrete tunnel lining, optimal orientation of the segmental rings, and minimizing damage to the precast concrete tunnel lining;
  - ix. Recordkeeping;
  - x. Implementing procedures and work plans to meet the Project Requirements and implementing remedial measures when specified limits are approached or exceeded or when ground loss, instability or water inflow occurs, or appears likely to occur;
  - xi. Coordination with the Mined Tunnel Superintendent; and
  - xii. Participation in all pertinent coordination meetings with the City.
4. Mined Tunnel Superintendents. Shall have successfully completed at least two similar tunneling projects within the last 10 years.
- a. Duties of the Mined Tunnel Superintendents, which may be carried out by different persons on different shifts, shall include the following:
    - i. Overall supervisory responsibility for planning, coordinating and reviewing all Mined Tunnel excavations, installation of tunnel lining, grouting, monitoring data and protection of building structures, surface facilities and subsurface Utility Infrastructure, and elements of the Mined Tunnel;
    - ii. Responsibility for the safety, quality, conformance with Project Requirements, timely completion and keeping of accurate records of the Construction as required in the Project Agreement;
    - iii. Attending meetings with the City if required;
    - iv. Implementation of procedures, work plans and shop drawings and overseeing remedial measures when specified limits are approached or exceeded;
    - v. Being present in the Mined Tunnel throughout each shift, leading tunnelling activities; and
    - vi. Coordination with the Mined Tunnel Project Engineers, other Mined Tunnel Superintendents, and the City.

5. Mined Tunnel Contractor equipment operators, mechanics and crews shall be certified through records of training that the staff are prepared and equipped to operate equipment and/or install all support measures and linings required for the Mined Tunnel.
6. Mined Tunnel Surveyor. Shall be a licensed Professional Land Surveyor registered in the Province of Alberta, with a minimum of ten years of experience in underground construction. Responsibilities shall include the accurate measurement of areas, volumes and setting out points and the collection and reporting of all data.
7. Mined Tunnel Instrumentation Specialist. Shall be a licensed Professional Engineer or Professional Land Surveyor registered in the Province of Alberta with a minimum of five years of experience in tunneling and installation of instruments of the type required by the Project. Responsibilities shall include installation of all instrumentation, monitoring of all instruments, collection of all data, identification of Action Levels and submission of all data in accordance with the Building and Utility Settlement Study Report. Specialist shall be on site during installation of any instrumentation to supervise and direct the installation technicians. The Mined Tunnel Instrumentation Specialist shall not be an employee of Project Co.
8. Excavation Equipment Manufacturer. Shall demonstrate at least five years successful experience in the manufacture or reconditioning of Mined Tunnel excavation equipment of similar type, capability and complexity as required for the Project.
9. Waterproofing Manufacturer. Shall provide a list of similar tunnel projects for which the material was successfully used and reference letters from the owners of a minimum of three projects on the list indicating satisfactory water tightness performance on their projects
10. Waterproofing Installer: Shall demonstrate at least five years of experience in successful installation of the selected membrane waterproofing, and be approved by the Waterproofing Manufacturer to install the waterproofing system
11. Waterproofing Supervisor: Shall demonstrate a minimum of five years of supervisory experience in applying and testing the proposed waterproofing membrane in similar tunnels under similar conditions. The Waterproofing Supervisor shall be certified by the Waterproofing Manufacturer as an applicator.

#### **4-5.2 DESCRIPTION**

- A. This Section 4-5 [*Mined Tunnel Design and Construction Requirements*] sets out requirements for the Design and Construction of the Mined Tunnel and appurtenant structures, including cross-passages and sumps, including requirements for the following:
  1. Mined Tunnel methods and configuration
  2. applicable codes, standards, and manuals
  3. loads and load combinations
  4. ground improvement;
  5. protection of existing lands and infrastructure;
  6. instrumentation and monitoring
  7. excavation and initial ground support;

8. waterproofing;
  9. final tunnel linings
  10. tunnel systems
- B. Cut and Cover Tunnels shall comply with Section 4-1 [*General Design Requirements*], Section 4-2 [*Structural Component Requirements*], Section 4-3 [*Structure Specific Requirements*] and Section 4-4 [*Structures Construction Requirements*] of this Schedule.

#### **4-5.3 MINED TUNNEL METHODS AND CONFIGURATION**

- A. Where a TBM is employed: (i) it shall be capable of operating and maintaining face stability at all times under all Project ground and groundwater conditions; (ii) provide all backup equipment and systems necessary for safe and sustained operation from TBM mobilization through TBM retrieval and disassembly. TBM(s) and all backup equipment and systems shall be new or factory refurbished by the original manufacturer to a like-new condition, and designed specifically to meet the requirements for the Project.
- B. Prepare and submit contingency plans to the City before commencing the Mined Tunnel excavation, which define: (i) Corrective Actions to be utilized for each Instrument Response Level associated with surface settlement and groundwater monitoring; (ii) remedial measures to correct deviations from design line and grade; (iii) corrective measures to be implemented for high groundwater or Utility Infrastructure inflows; (iv) actions to be implemented if a fire event occurs and a TBM is employed; and (v) corrective measures to be implemented if power to the TBM or support system is interrupted. The Review Period shall be 40 Business Days.
- C. The design, construction methodology, construction extent and configuration of the Mined Tunnel shall take into account all factors impacting the design, construction, maintenance and use of the Mined Tunnel over its Design Service Life, including geology, hazardous gas, cross-section, excavation stability, minimization of ground movements, protection of existing lands and infrastructure, avoidance of Hazards and mitigation of risks to workers and other Persons.
- D. The Mined Tunnel shall be a single-bore or twin-bore configuration meeting the requirements of NFPA 130.
- E. Mined Tunnel initial support convergence, final lining deformations and construction tolerances shall be accounted for in the determination of the required Mined Tunnel cross-section.
- F. The Mined Tunnel cross-section shall be sized such that all Operational Systems, fire life safety systems and other Infrastructure, including emergency egress pathways, cross passages, signage, ductwork, standpipes, drainage, lighting and tunnel ventilation, do not intrude into the Dynamic Envelope.
- G. The Mined Tunnel shall be an “undrained” or “closed tunnel”, as defined in the FHWA Technical Manual for the Design and Construction of Highway Tunnels – Civil Elements.

#### **4-5.4 CODES, STANDARDS, ACTS AND REFERENCE DOCUMENTS**

- A. The Mined Tunnel shall be considered a Transportation Structure. The initial support and final lining of the Mined Tunnel and appurtenant structures shall be designed and constructed in accordance with the requirements of Section 4-1.3 [*General Structural Performance Requirements*] of this Schedule unless otherwise specified in this Section 4-5 [*Mined Tunnel Design and Construction Requirements*].

- B. In addition to the requirements of Section 4-5.4A [*Codes, Standards, Acts and Reference Documents*] of this Schedule the Mined Tunnel Design and Construction shall also comply with the following codes, standards and reference documents:
1. ACI publications:
    - a. ACI 211.1, Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete.
    - b. ACI 506R, Guide to Shotcrete.
    - c. ACI 506.1, State-of-the-Art Report on fibre reinforced Shotcrete.
    - d. ACI 506.2, Specification for Shotcrete.
    - e. ACI 506.4R-94, Guide for the Evaluation of Shotcrete.
    - f. ACI CP-60, ACI Certification Program for Shotcrete Nozzleman
  2. ASTM Standards:
    - a. ASTM A820, Standard Specification for Steel Fibres for Fibre-Reinforced Concrete.
    - b. ASTM C3, Standard Method of Making and Curing Concrete Test Specimens in the field.
    - c. ASTM C39, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.
    - d. ASTM C78, Standard Test Method of Flexural Strength of Concrete.
    - e. ASTM C94, Standard Specification for Ready Mix Concrete.
    - f. ASTM C192, Standard Method of Making and Curing Concrete Test Specimens in the Laboratory.
    - g. ASTM C266, Standard Test Method for Time of Setting Hydraulic Cement by Gillmore Needles.
    - h. ASTM C341, Standard Practice for Preparation and Conditioning of Cast, Drilled or Sawed Specimens of Hydraulic-Cement Mortar and Concrete,
    - i. ASTM C349, Standard Test Method for Compressive Strength of Hydraulic-Cement Mortars.
    - j. ASTM C494/C494M, Standard Specification for Admixtures for Concrete.
    - k. ASTM C666/C666M, Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing.
    - l. ASTM C1077, Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation.
    - m. ASTM C1116, Standard Specification for Fibre-Reinforced Concrete.
    - n. ASTM C1140, Standard Practice for Preparing and Testing Specimens from Shotcrete Test Panels.

- o. ASTM C1141, Standard Specification for Admixtures for Shotcrete.
  - p. ASTM C1240, Standard Specification for Use of Silica Fume for Use as a Mineral Adjuvant in Hydraulic-Cement Concrete, Mortar, and Grout.
  - q. ASTM C1550, Standard Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel).
  - r. ASTM C 1116-[02], Standard Specification for Fibre-Reinforced Concrete and Shotcrete.
  - s. ASTM E329, Standard Specification for Agencies Engaged in Construction Inspection and/or Testing
3. FHWA Technical Manual for the Design and Construction of Highway Tunnels – Civil Elements
  4. New and O'Reilly (1982), "Settlements Above Tunnels in the United Kingdom – their Magnitude and Prediction"
  5. New and O'Reilly (1991), "Tunnelling Induced Ground Movements; Predicting their Magnitude and Effects"
  6. NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems
- C. Design of protection requirements and any repairs to building structures shall comply with the Alberta Building Code

#### 4-5.5 LOADS AND LOAD COMBINATIONS

- A. Initial support and final lining shall be designed for all ground load conditions during Construction and on the completed Mined Tunnel respectively. All loads, including the potential for unsymmetrical vertical loads or unbalanced horizontal loads due to variations in ground conditions or properties shall be accounted for in the Design.
- B. The Mined Tunnel shall be designed to support the most adverse combinations of all applicable loads over its Design Service Life including the following:

	Load Type	Design Requirement
	<b>Permanent Loads</b>	
1.	Structural Dead Loads (D) - (DC/DW)	(a) Structural dead loads shall be divided into structural components (DC) and non-structural components (DW) comprising wearing surfaces, Utility Infrastructure, and finishes. (b) The dead loads of all structural and non-structural components, shall be based on unit weights and computed volumes of materials.
2	Earth Loads (E)	(a) Horizontal earth loads (EH); (b) Vertical earth loads (EV);
3	Hydrostatic Loads (EW)	(a) Hydrostatic pressure shall be applied to initial support systems as

		appropriate. The Mined Tunnel final lining shall be designed for normal low and high groundwater elevations, as well as a 100-year ground water elevation.
4	Surcharge Loads (U)	Surcharge loads from adjacent building foundations shall be applied where applicable. Regardless of surcharge loads from adjacent building foundations a minimum of 20 kPa shall be applied to surfaces where no surcharge loads or less than a 20 kPa surcharge load from adjacent building foundations is applied, except that the minimum 20 kPa surcharge load shall not be applied in locations where it acts favourably.
<b>Transient Loads</b>		
5.	Highway Live Loads (LL)	Where any type of motorized vehicle can gain access to a surface above the Mined Tunnel, the Mined Tunnel shall be designed to support highway traffic loading in accordance with Section 4-1.5 [Design Loads] of this Schedule.
6.	Pedestrian Loads (LP)	Pedestrian loads, applied: (i) at the ground surface over the Mined Tunnel; and (ii) within the Mined Tunnel, in accordance with CAN/CSA-S6.
7.	Train Loads (LR)	Train loads shall include loads from On-Track Vehicles. All relevant loads shall be in accordance with Section 4-1.5 [Design Loads] of this Schedule.
8.	Centrifugal Force (CE)	The effects of centrifugal forces due to On-Track Vehicles shall be considered as defined in Section 4-1.5 [Design Loads] of this Schedule.
9.	Thermal and Shrinkage Loads (K)	Thermal and shrinkage loads shall be calculated in accordance with CAN/CSA S6.
10.	Construction Loads (ST)	Construction loading due to equipment and materials located over, adjacent to, or within the Mined Tunnel.
<b>Extreme Loads</b>		
11.	Derailment Loads (H)	Derailment loads shall be applied as defined in Section 4-1.5 [Design Loads] of this Schedule.

#### 4-5.5.1 Load Combinations and Load Factors

- A. Most adverse load combinations and load factors for the Mined Tunnel shall be as provided in Table 4-5.5.1 [Load Factors and Load Combination].

Load Type	Permanent						Transient						Extreme
Load Designation	DC	DW	EH	EV	EW	U	LL	LP	LR	CE	K	ST	H
<b>Service Limit State (SLS)</b>													

I Uplift (FS>1.1) <sup>Note 1</sup>	0.9	0.9	0.9	0.9	1.0								
II Construction <sup>Notes 2, 4-6</sup>	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0			1.0	
III In-Service <sup>Notes 3-6</sup>	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0		
<b>Ultimate Limit State (ULS)</b>													
IV Construction <sup>Notes 2,4-6</sup>	aDC	aDW	aEH	aEV	aEW	aU	aLL	aLP	aLR	aCE	aK	aST	
V In-Service <sup>Note 3-6</sup>	aDC	aDW	aEH	aEV	aEW	aU	aLL	aLP	aLR	aCE	aK		
VI Derailment <sup>Note 2,</sup>	aDC	aDW	aEH	aEV	1.0	aU	bLL	bLP	bLR	bCE			1.35

Load Designation	a factor		b factor	
	Max.	Min.	Max.	Min.
DC	1.25	0.90	-	-
DW	1.50	0.65	-	-
EH	1.50	0.75	-	-
EV	1.50	0.75	-	-
EW	1.25	0.85	-	-
U	1.50	0.00	-	-
LL	1.50	0.00	1.00	0.00
LP	1.50	0.00	1.00	0.00
LR	1.50	0.00	1.00	0.00
CE	1.50	0.00	1.00	0.00
ST	1.00	0.00	-	-
K	1.25	0.00	-	-

Table 4-5.5.1–Load Factors and Load Combination

Notes:

1. The design shall address EW at normal high and low groundwater levels for the construction condition, and up to the 100-year groundwater elevation for the in-service condition.
2. The design shall address EW at normal high and low groundwater levels and up to the 100 year groundwater elevation



3. The design shall address every relevant permutation of transient loads identified within Table 4-5.5.1 [*Load Factors and Load Combinations*] in a way to achieve the most adverse combinations of all applicable loads.
4. The design shall address load conditions which result in maximum vertical loading in combination with minimum horizontal loading and vice versa.
5. The design shall address unbalanced loads from left to right with maximum vertical and horizontal loading on the left and minimum vertical and horizontal loading on the right and vice versa.
6. The design shall address load combinations with EW at normal high and low groundwater levels, and both with and without transient loads

#### 4-5.6 GROUND IMPROVEMENT

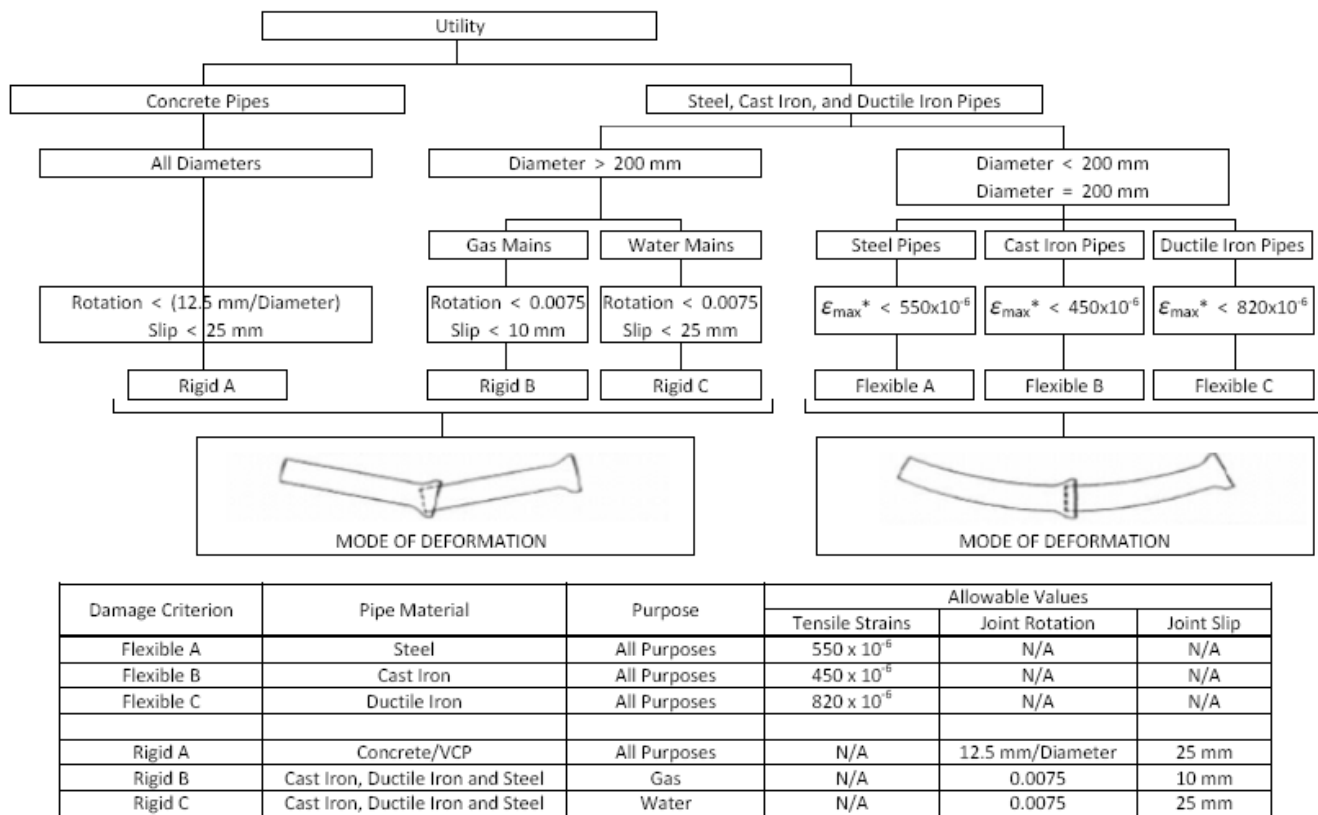
- A. Perform ground improvement as required to improve the strength and stiffness of the native soils, surrounding the Mined Tunnel, to reduce the permeability of these soils, to limit deformations around excavations, to prevent any damage and to keep movement of adjacent structures and Utility Infrastructure within maximum settlement and distortion limits as defined in Section 4-5.7.1 [*General Requirements*] of this Schedule.
- B. Extents, types and requirements of ground improvement shall be indicated in the Mined Tunnel Final Design

#### 4-5.7 PROTECTION OF EXISTING LANDS AND INFRASTRUCTURE

##### 4-5.7.1 General Requirements

- A. The Zone of Influence around the Mined Tunnel shall be determined in accordance with the methods described by New and O'Reilly (1982), in their paper entitled "Settlements Above Tunnels in the United Kingdom – their Magnitude and Prediction" and by New and O'Reilly (1991) in "Tunnelling Induced Ground Movements; Predicting their Magnitude and Effects" taking into account the method of Mined Tunnel Construction and the configuration of the Mined Tunnel (the "**Zone of Influence**"). The Zone of Influence of the Mined Tunnel shall include the width of the predicted settlement trough associated with the Mined Tunnel. A buffer zone shall extend a minimum of 10 metres beyond the Zone of Influence in all plan dimensions (the "**Buffer Zone**")
- B. The Design and Construction, including Construction of the Quarters Tunnel and Tunnel Approaches and any ground improvement, shall not result in settlements or distortions causing damage and shall not exceed the following maximum values:
  1. Building structures and surface facilities shall not settle/heave or exceed a maximum angular distortion more than the most stringent of either: i) those proved by appropriate calculations; or ii) the best practice values with ranges defined in FHWA (Technical for the Design and Construction of Highway Tunnels) which in any case shall not exceed more than 12.5 mm and 1:600 respectively; or
  2. Subsurface Utility Infrastructure shall not experience values of rotation, slip or tensile strain in excess of the most stringent of either: i) those proved by appropriate calculations which shall be presented by Project Co; ii) the maximum values presented in Figure 4-5.7.1 [*Maximum Limits for Utility Infrastructure Movements*]; or iii) the maximum values specified by the applicable Utility Company. With respect to Figure 4-5.7.1 [*Maximum*

Limits for Utility Infrastructure Movements], where Utility Infrastructure is comprised of polyvinyl chloride (PVC) pipe, the limiting tensile strain shall be deemed to be  $700 \times 10^{-5}$ .



\* Maximum Tensile Strain

Developed From: "Prediction and Effects of Ground Movements Caused by Tunneling In Soft Ground Beneath Urban Areas," by Mott MacDonald for CIRA, Sept. 1992

Figure 4-5.7.1– Maximum Limits for Utility Infrastructure Movements

#### 4-5.7.2 Building and Utility Settlement Study

- A. Perform a Building and Utility Settlement Study for the Quarters Tunnel and Tunnel Approaches during the design phase of the Project. The Building and Utility Settlement Study Report shall be prepared and submitted to the City prior to the start of construction of the Quarters Tunnel and Tunnel Approaches. The Review Period shall be 60 Business Days.
- B. The Building and Utility Settlement Study Report shall:
  1. identify the Zone of Influence and the Buffer Zone;
  2. identify each building structure, surface facility and subsurface Utility Infrastructure within the Zone of Influence, and those within the Buffer Zone;
  3. estimate the movement and distortion of, and impacts to, each building structure, surface facility and subsurface Utility Infrastructure within the Zone of Influence and the Buffer Zone resulting from the Construction.
  4. identify each building structure, surface facility and subsurface Utility Infrastructure where movements or distortions caused by the Construction are initially estimated to be in

excess of the maximum values or are predicted to result in damage. For each such building structure, surface facility and subsurface Utility Infrastructure, set out the measures to be implemented to prevent damage to the building structure, surface facility and subsurface Utility Infrastructure.

5. identify the need, extent and locations of surface-based and Mined Tunnel-based instrumentation and monitoring equipment.

#### 4-5.7.3 **Pre-construction Condition Survey**

- A. Prior to disturbing any area of the Lands within the Zone of Influence and the Buffer Zone, a preconstruction condition survey shall be carried out for all building structures, surface facilities and subsurface Utility Infrastructure within the Zone of Influence and the Buffer Zone. The pre-construction condition survey shall be comprised of notes, digital photographs and digital video sufficient to accurately and appropriately document the preconstruction condition of each building structure, surface facility and subsurface Utility Infrastructure within the Zone of Influence and the Buffer Zone. All defects shall be noted and recorded.
- B. The City will assist Project Co in obtaining access to the building structures, surface facilities and subsurface Utility Infrastructure within the Zone of Influence and the Buffer Zone identified as forming part of the pre-construction condition survey.
  1. Project Co shall prepare and submit the list of the building structures, surface facilities and subsurface Utility Infrastructure within the Zone of Influence and the Buffer Zone at least 8 months prior to disturbing any area of the Lands within the Zone of Influence and the Buffer Zone
  2. Project Co shall allow at least 2 months to complete the pre-construction condition survey. If access to building structures, surface facilities and subsurface Utility Infrastructure within the Zone of Influence and the Buffer Zone cannot be obtained, the survey shall be limited to the visible exterior of the relevant element.
- C. Prior to disturbing any area of the Lands within the Zone of Influence and the Buffer Zone, at least one photograph every 15 meters shall be taken over the extent of the Zone of Influence and Buffer Zone showing the areas and documenting the preconstruction condition of surface facilities including fences, walls, pavements, sidewalks, landscaping, hardscaping, artwork, and any other improvements.
- D. A preconstruction condition survey report, comprising all notes and copies of digital photos and videos along with a log describing the address, date, and viewing orientation of each photo and video segment shall be submitted to the City prior to disturbing any area of the Lands within the Zone of Influence and the Buffer Zone.

#### 4-5.7.4 **Post-construction Condition Survey**

- A. Upon completion of all Construction activities related to the Quarters Tunnel and Tunnel Approaches perform a post-construction condition survey. The survey shall document the post-construction condition of all areas included as part of the pre-construction condition survey.
- B. The City will assist Project Co in obtaining access to the building structures, surface facilities and subsurface Utility Infrastructure within the Zone of Influence and the Buffer Zone identified as forming part of the post-construction condition surveys.
  1. Project Co shall provide to the City at least 6 months' notice to assist Project Co in obtaining access.

2. Project Co shall allow at least 2 months to complete post-construction condition surveys. If access to building structures, surface facilities and subsurface Utility Infrastructure within the Zone of Influence and the Buffer Zone cannot be obtained, the survey shall be limited to the visible exterior of the relevant element.
- C. The post-construction condition survey shall be comprised of notes, digital photographs and digital video sufficient to accurately and appropriately document the post-construction condition of each building structure, surface facility and subsurface Utility Infrastructure included in the pre-construction survey. All defects shall be noted and recorded.
  - D. The post-construction condition survey report, comprising all notes and copies of digital photo and videos along with a log describing the address, date, and viewing orientation of each photo and video segment shall be submitted to the City within 20 Business Days of completing the post-construction condition surveys. The report shall highlight any damage identified since the submittal of the pre-construction condition survey report.

#### **4-5.8 INSTRUMENTATION AND MONITORING**

- A. Design, install and monitor a comprehensive system of instrumentation to monitor the impact of the Construction, on building structures, subsurface Utility Infrastructure, and surface facilities within the Zone of Influence and the Buffer Zone of the Quarters Tunnel and Tunnel Approaches. The system of instrumentation shall comply with the following:
  1. All instruments and required appurtenances including casing, cabling, readout units or wireless transmission devices shall be new.
  2. Instruments shall be supplied from a manufacturer with at least five years' experience in the manufacture of instruments of the type used for the Project.
  3. Equipment shall be calibrated by the manufacturer before shipment. Installed instruments shall be re-calibrated at intervals as recommended by the manufacturer. Submit all calibration and re-calibration certificates for each instrument within 5 Business Days of installation of the instrument or in the case of re-calibration within 5 Business Days of re-calibration.
  4. All instruments shall be clearly identified with permanent easily readable letters and numbers.
  5. Instruments within unpaved areas shall be protected by a steel casing with removable cap. Instruments within paved areas shall be provided with traffic rated covers. All covers and casings shall be of appropriate size with respect to the use of instruments. All covers and casings shall be marked to be unambiguously distinguishable.
  6. Instruments shall function within the Project conditions of environment, climate and temperature.
  7. All building structures and surface facilities within the Zone of Influence and Buffer Zone shall be monitored with instruments as described herein.
  8. All subsurface Utility Infrastructure that meet the following criteria and are within the Zone of Influence or Buffer Zone shall be monitored:
    - a. Wet Utility Infrastructure greater than or equal to 300 mm in diameter;
    - b. All gas mains and high pressure lines;

- c. All Utility Infrastructure greater than or equal to 1 m in diameter; and
  - d. Any Utility Infrastructure identified as being at risk of damage in the Building and Utility Settlement Study Report.
9. The City will assist Project Co in obtaining access to install instruments and take subsequent readings on building structures, surface facilities and subsurface Utility Infrastructure within the Zone of Influence and Buffer Zone.
  10. In addition to the requirements of Section 4-5.8.A.8 [*Instrumentation and Monitoring*] of this Schedule all subsurface Utility Infrastructure within the Zone of Influence or Buffer Zone, for which monitoring is requested by the appropriate Utility Company shall be monitored even if they don't comply with the requirements of Section 4-5.8.A.8 [*Instrumentation and Monitoring*] of this Schedule.
  11. Monitoring of subsurface Utility Infrastructure shall include CCTV video inspection of gravity sewer and drainage systems, acoustic leak detection of pressurized systems, visual inspection of portions of subsurface electrical vaults and video inspection and mandrel proofing of electrical and fiber optics ducts in addition to monitoring Utility Monitoring Points as required by Section 4-5.8.M [*Surface Based Instrumentation*] of this Schedule.
- B. The locations of all instrumentation and monitoring equipment shall be identified on the applicable Final Design, along with an instrumentation schedule showing:
1. quantities of all instruments and monitoring equipment;
  2. instrument identification number;
  3. instrument type;
  4. instrument manufacturer;
  5. instrument installation and reading requirements;
  6. Instrument Response Levels and monitoring frequency; and
  7. contingency plans for arresting movements or distortions trending towards maximum limits.
- C. All Instrumentation and monitoring work shall be overseen by a Mined Tunnel Instrumentation Specialist. The Mined Tunnel Instrumentation Specialist shall be on site during installation of any instrumentation to supervise and direct installation technicians.
- D. The Mined Tunnel Instrumentation Specialist shall take baseline readings of all instruments prior to commencement of Quarters Tunnel and Tunnel Approaches Construction activities. Baseline readings shall comprise daily readings of all instruments taken for a period of at least one week. Readings of each instrument shall be taken at least 24 hours apart.
- E. Instruments shall be monitored from the start of Quarters Tunnel and Tunnel Approaches Construction activities until the Completion of the Quarters Tunnel and Tunnel Approaches, with the exception that any instrument that continues to show increasing or trending movement shall continue to be monitored until such time as the movement has been stabilized.
- F. Project Co shall develop Instrument Response Levels such that movements of building structures, surface facilities and subsurface Utility Infrastructure do not exceed maximum

values as defined in Section 4-5.7 [*Protection of Existing Lands and Infrastructure*] of this Schedule. Instrument Response Levels shall comprise an Action Level and a Maximum Level, as defined below.

1. Action Levels of settlement or distortion are levels at which corrective measures are required, including procedural modifications that shall permit Quarters Tunnel and Tunnel Approaches construction to continue without reaching the specified Maximum Level. Frequency of instrument readings shall be increased per Table 4-5.8 [*Instrumentation Monitoring Frequency*] until five consecutive working days of readings below the Action Level are observed on all such affected devices and until the interpolated curve from consecutive readings demonstrates an unambiguous tendency to converge
  2. Maximum Levels of settlement or distortion are levels at which no further settlement or distortion is permitted. When instruments indicate movement equal to the Maximum Level is reached, the excavation shall be stabilized, Project Co shall immediately report to the City and follow all remedial measures necessary to prevent further settlement or distortion including the actions in the contingency plan. The frequency of instrument readings shall be increased per Table 4-5.8 [*Instrumentation Monitoring Frequency*] until five consecutive working days of readings below the Action Level are observed on all such affected devices and until the continuous readings demonstrate an unambiguous tendency to converge.
  3. All measured values shall be relative to the baseline readings.
- G. For multiple Quarters Tunnel/Tunnel Approaches drives and multiple excavation stages, baselines shall not be reset after each Quarters Tunnel/Tunnel Approaches drive and excavation stage and shall remain the same for the duration of the Quarters Tunnel/Tunnel Approaches construction.
- H. Except for monitoring wells, minimum instrumentation monitoring frequencies shall be in accordance with Table 4-5.8 [*Instrumentation Monitoring Frequency*].

Table 4-5.8– Instrumentation Monitoring Frequency

Instrument Type	Monitoring Frequency, Where Instrument Located Within 30 m of Active Excavation or Tunnel Face	Monitoring Frequency, Where Instrument Located Beyond 30 m of Active Excavation or Tunnel Face
Extensometer, Inclinometer, Tape Extensometer or Convergence Monitoring	Hourly	Weekly/Monthly <sup>(1)</sup> if measurements are below Action Levels  Hourly if measurements reach Action Levels
Convergence Monitoring	Each shift, but at least once a day, if measurements are below Action Levels  At minimum three times a day, but at least two times per shift with the interval between readings no longer than 4 hours where measurements reach Action Levels but are below Maximum	Weekly if measurements are below Action Levels and the tendency of readings demonstrate convergence (asymptotic behaviour toward a limit value)  Each shift, but at least once a day, where measurements reach Action Levels but are below Maximum Levels or where the tendency of readings demonstrate divergence (no asymptotic behaviour



	Levels or where the tendency of readings demonstrate divergence (no asymptotic behaviour toward a limit value)  Every 2 hours if measurements reach Maximum Levels	toward a limit value)  Every 2 hours if measurements reach Maximum Levels
All Other Instruments	Daily if measurements are below Action Levels  Twice daily where measurements reach Action Levels but are below Maximum Levels  Hourly if measurements reach Maximum Levels	Weekly/Monthly <sup>(1)</sup> if measurements are below Action Levels  Twice daily where measurements reach Action Levels but are below Maximum Levels  Hourly if measurements reach Maximum Levels

NOTE: (1) Weekly until movement substantially stops (less than 0.5mm movement relative to the previous reading) and monthly thereafter.

- I. Damaged or malfunctioning instruments shall be replaced or repaired within 48 hours.
- J. Quarters Tunnel and Tunnel Approaches Construction shall be suspended and the excavation stabilized if monitoring data is not available within the timeframes specified in Table 4-5.8 [Instrumentation Monitoring Frequency], and shall not be recommenced until data becomes available.
- K. Provide an integrated system that automatically collects data from extensometer, inclinometer and convergence monitoring (data loggers) and places it into a secure database using a data management system (DMS). The DMS shall also include all data from all manually read instruments and optical surveys. The DMS shall have the following capabilities:
  - 1. Data collected by data loggers shall be available for reporting within one hour of the reading.
  - 2. Data collected manually shall be available for reporting within one day of the reading.
  - 3. The DMS shall automatically alert Project Co and the City by email and text message within five minutes of any instrumentation readings reaching the Action Level or Maximum Level or of malfunction or loss of the instrument. The message shall include the instrument identification number; date and time of reading, malfunction or loss of instrument; the value of the reading, in appropriate SI units, and Instrument Response Level exceeded in appropriate SI units, or the details of the malfunction. All alerts shall be retained in the database for subsequent reporting.
  - 4. The DMS shall include a secure, web based user interface, featuring password protected access and different user levels that can be operated from any browser to allow a complete review of monitoring data. The interface shall:
    - a. Provide the monitoring point locations with respect to the Construction, building structures, subsurface Utility Infrastructure, and surface facilities;
    - b. Allow users to select and review individual instruments and monitoring points;
    - c. Display current and historical data for each instrument;

- d. Permit data review in either raw form or in corresponding SI units;
  - e. Display a summary report of the current active alerts from all active instruments together with the current level for each instrument. All readings that exceed the Action Level shall be displayed in orange. All readings that exceed Maximum Levels shall be displayed in red;
  - f. Permit authorized users to input comments to each reading that is editable by authorized users;
  - g. Provide reports, either formatted to a printable screen resolution, or output as a printable version of the report; and
  - h. Support export of data and reports to other software applications.
- L. The DMS shall be available to designated City Persons at all times without payment, using a secure on line Internet based system, acceptable to the City acting reasonably. Periodic training shall be provided to the City in the use of the DMS.
- M. Surface-based Instrumentation:
1. Pavement Monitoring Points (PMPs) and PMP Arrays
    - a. PMPs shall be a surveyor's nail embedded into the pavement. Where no pavement exists, PMPs shall be a hardwood stake with a P-K nail as a reference point.
    - b. Install and monitor PMP Arrays on the ground surface above the Mined Tunnel at a maximum 15 metre spacing. Each PMP Array shall include at least five (5) PMPs. PMP Arrays shall be spaced evenly along the ground surface above the Mined Tunnel, unless there are areas of particular concern that are identified in the Building and Utility Settlement Study Report. In such cases the maximum PMP Array spacing shall be locally reduced and/or more PMP's provided per array. Within each PMP Array, each PMP shall be evenly spaced to cover the Zone of Influence to the extent practicable.
    - c. PMPs will suffer from frost heave and such behavior shall be properly perceived and interpreted.
  2. Soil Deformation Monitoring Points (SDMPs)
    - a. SDMPs shall be 25 millimetre diameter steel pipes attached to a base plate installed at 2.5m depth (i.e. below frost) of the native soils. A PCV sleeve shall be installed around the pipe to further protect the pipe against frost heave. The SDMP read point shall comprise a stainless steel bolt or ball tack welded to the SDMP.
    - b. Install and monitor SDMPs on the ground surface above the Mined Tunnel at a maximum 15 metre spacing. SDMPs shall be spaced evenly along the ground surface above the Mined Tunnel, unless there are areas of particular concern that are identified in the Building and Utility Settlement Study Report. In such cases the maximum SDMP spacing shall be locally reduced based on Good Industry Practice.
  3. Building Monitoring Points (BMPs)
    - a. Install and monitor a minimum of one set of at least three optical survey prisms (OSP) on at least two sides of each building structure within the Zone of Influence



and the Buffer Zone. At least one side shall be perpendicular to the Mined Tunnel alignment, the other one shall be parallel to the Mined Tunnel alignment.

- b. Install and monitor a minimum of two settlement monitoring points on two sides of each building structure within the Zone of Influence and the Buffer Zone. At least one side shall be perpendicular to the Mined Tunnel alignment, the other one shall be parallel to the Mined Tunnel alignment. Monitoring points shall be bolts and shall be installed directly on structural columns and walls. Optical survey prisms, as defined in Section 4-5.8 M 3 a [*Surface-based Instrumentation*], may be used in lieu of settlement monitoring points provided they can provide data on the building's differential settlement along all sides of the building and the monitoring bolts carrying the optical survey prisms (targets) are installed directly on structural columns and walls.
4. Utility Monitoring Points (UMPs)
    - a. UMP's shall be provided for subsurface Utility Infrastructure as defined in Section 4-5.8 A.8 and A.10 [*Instrumentation and Monitoring*] of this Schedule.
    - b. UMP's shall comprise a pipe riser centralized monitoring bar. Installation of UMPs shall not damage the Utility Infrastructure.
  5. Inclinometers
    - a. Install and monitor inclinometer arrays at a maximum of 50 metre centers along the Mined Tunnel alignment. Inclinometer arrays shall comprise a minimum of two inclinometers and shall be provided in pairs;
    - b. Inclinometer measurement requirements:
      - i. Resolution: 0.0001 feet per 2 feet
      - ii. Accuracy: within 0.025 feet per 100 feet
      - iii. Range: within 35 degrees from vertical
  6. Extensometers (MPBX)
    - a. Install and monitor multiple point borehole extensometers at a maximum of 100 metre centers along the Mined Tunnel alignment.
    - b. Extensometer range for each extensometer's anchor point (gauge) shall be 50 millimetres for heave measurements and 150 millimetres for settlement measurements. Extensometers shall be readable to 0.25 mm precision and 0.25 mm accuracy.
    - c. The deepest extensometer anchor point (gauge) shall be installed no less than 1m and no more than 1.8m above the external tunnel crown (extrados of the SEM initial lining or extrados of the segmental lining).
  7. Piezometers
    - a. Install and monitor piezometers along the Mined Tunnel alignment at a maximum of 50 metre centers.
    - b. Piezometer measurement requirements:

- i. Resolution: within 0.025 percent of Full Scale.
- ii. Accuracy: within 0.1 percent of Full Scale.
- iii. Range: 1.5 times Mined Tunnel depth below ground water.

8. Monitoring Wells

- a. Install and monitor monitoring wells to be able to comprehensively identify the groundwater elevation along the Mined Tunnel alignment, but not more than at 100 metre centers along the Mined Tunnel alignment.
- b. Monitoring of groundwater elevations shall commence at least 12 months prior to Mined Tunnel Construction. Readings shall be taken on a monthly basis at a minimum.

N. Tunnel-based Instrumentation – Shotcrete Initial Support

1. Install, maintain and monitor one of the following tunnel-based instrumentation systems:

a. Convergence Monitoring

- i. Install, maintain and monitor convergence bolt arrays (monitoring cross section) in the initial Shotcrete lining of the Mined Tunnel at a maximum of 15m centres in a plane perpendicular to the tunnel axis. The convergence bolts shall accommodate the attachment of the optical survey prisms (targets). Where the Building and Utility Settlement Study Report identifies areas of risk, the maximum spacing of the convergence bolt arrays (monitoring cross sections) shall be reduced based on Good Industry Practice. Each convergence bolt array (monitoring cross section) shall include at least five (5) convergence bolts – at least three (3) of which shall be situated within the top heading and at least two (2) within the bench of the tunnel excavation. One convergence bolt shall be situated at the crown of the Mined Tunnel.
- ii. Where an intermediate wall is constructed within the Mined Tunnel cross-section as part of the initial support, at least two (2) convergence bolts with optical survey prisms (targets) shall be installed in the wall, at approximately one-third and two-thirds of the height of the wall.
- iii. The accuracy of the convergence monitoring shall be measured to an accuracy of +/- 2mm.

b. Tape Extensometers

- i. Monitoring bolts shall be installed in the initial Shotcrete lining at a maximum of 15 m centres. The monitoring bolts shall accommodate the attachment of a tape survey target or optical survey prism. A roof levelling point shall be installed in the crown of the Mined Tunnel, comprising a monitoring bolt with a suspension plate to accommodate roof deformation readings.
- ii. Where an intermediate wall is constructed within the Mined Tunnel cross-section as part of the initial support, at least two (2) monitoring bolts shall be installed in the wall, at approximately one-third and two-thirds of the height of the wall.
- iii. The absolute displacement of the monitoring bolts and roof levelling points shall be measured to an accuracy of 0.25 mm.

O. Tunnel-based Instrumentation – TBM - Precast Concrete Segmental Lining

1. Convergence Monitoring or Tape Extensometers

- a. Mined Tunnel lining convergence shall be measured by means of optical survey (convergence bolts with optical targets) or digital tape extensometers, capable of providing repeatable measurements to an accuracy of maximum +/- 2 mm for optical survey or ±0.25 mm for digital tape extensometers.
- b. Install a minimum of four monitoring bolts on every fifth completed segment ring for the first 50 metres of the Mined Tunnel. Install monitoring bolts thereafter at every 20th ring. Additional monitoring bolts shall be installed at the complete rings immediately adjacent to any cross passageway break in and break out openings.
- c. Measurements shall be taken as soon as possible after annular backfill grout is placed behind the segment ring. Additional readings shall be taken daily for seven days after segment installation and monthly thereafter until no changes in diameter are found or for three months, whichever is later.
- d. Additional measurements shall be taken as required during any subsequent secondary grouting.

P. Removal and Disposal of Instrumentation

1. Remove and dispose of all instrumentation when no longer required.
2. Building structure surfaces directly affected by installation of instruments shall be restored to their original condition.
3. Boreholes shall be abandoned and pavement repaired to their original condition.

**4-5.9 EXCAVATION AND INITIAL SUPPORT**

- A. Drilling of probe holes ahead of Mined Tunnel excavation is required to sample the ground for zones of weakness or groundwater. A minimum of two, continuously drilled probe holes shall be maintained a minimum of 10 metres in advance of the excavated face of the Mined Tunnel. The drilling tools and methodology used shall be in accordance with anticipated ground conditions and shall not decrease the stability or soil properties ahead of the face.
- B. In addition to the requirements of Section 4-5.9A [*Excavation and Initial Support*] of this Schedule at least one continuously drilled probe hole shall be drilled every 5 metres along the whole Mined Tunnel length to a minimum depth of 1.5 times the Mined Tunnel diameter below the designed invert level.
- C. All infiltration and construction water into, and from, the Quarters Tunnel shall be collected, treated and disposed of in accordance with Applicable Law.
- D. Mined Tunnel Structures constructed by SEM shall utilize a two-pass lining system consisting of both initial support and a final lining. Mined Tunnel Structures constructed by TBM shall utilize either a single-pass lining system, comprising a precast concrete bolted gasketed segmental lining or a two pass lining consisting of initial support and a final lining.
- E. Where a 2 pass lining system is used, the initial support shall:
  1. maintain the integrity of all existing lands and infrastructure, including building structures, surface facilities, and subsurface Utility Infrastructure during Construction;

2. limit ground movements and infrastructure deformations to maximum values as defined in Section 4-5.7 [*Protection Of Existing Lands And Infrastructure*] of this Schedule; and
  3. support all applicable ground, groundwater, construction and temporary loads during Mined Tunnel excavation and until installation of the final lining.
- F. No load sharing is permitted between the initial support and final lining.
- G. Blasting and use of explosives are strictly prohibited to minimize vibration and dynamic impact on existing infrastructure and to minimize risk of potential slope stability.

#### **4-5.10 MATERIALS**

##### **4-5.10.1 Concrete**

- A. Concrete used for the Quarters Tunnel and Tunnel Approaches shall be designed for the environmental conditions, including temperature, and for the prevention of the deleterious effects of erosion, groundwater attack, acid attack and sulfate attack as applicable.
- B. Concrete construction and testing shall comply with Section 4-4.4 [*Cast-In-Place Concrete*] or 4-4.5 [*Precast Concrete*] of this Schedule as applicable.

##### **4-5.10.2 Shotcrete**

- A. Shotcrete used for the Mined Tunnel shall be designed for the environmental conditions—including temperature, and for the prevention of the deleterious effects of erosion, groundwater attack, acid attack and sulfate attack as applicable.
- B. Shotcrete shall comply with relevant ASTM and ACI codes.
- C. Shotcrete for Initial Lining
  1. Shotcrete for Initial Lining shall comply with the requirements of Sections 4-4.17.3B, 4-4.17.3C and 4-4.17.3D, as well as the requirements of Sections 4-4.17.3.1 through 4-4.17.3.7 within Section 4-4.17 [*Shotcrete for Final Tunnel Lining*]. Shotcrete for Initial Lining shall meet the minimum compressive strength requirements of the J2 or modified J2 curve in Figure 4-4.17.2 [*Early Age Strength Development for Final Tunnel Lining Shotcrete*] for early age strength development or Good Industry Practice.
  2. Establish and execute a program of field test panel trials for vertical and overhead shotcreting positions to demonstrate the capability of equipment, workmanship, and materials under field conditions at least 30 days before actual application of Shotcrete in construction work. Field testing protocols shall be described as part of the Quality Management System. Field trial work shall be performed in the presence of the City.
- D. Shotcrete for Final Lining
  1. Shotcrete for Final Lining shall comply with the requirements of Section 4-4.17 [*Shotcrete for Final Tunnel Lining*].

##### **4-5.10.3 Reinforcing Steel**

- A. Reinforcing steel shall comply with Section 4-4.8 [*Reinforcing Steel*] of this Schedule.
- B. Welded Wire Fabric shall conform to ASTM A1064.
- C. Steel Fiber Reinforcement

1. Steel fibers shall conform to the requirements of Section 4-4.17.3.7 *[Fibres]*.
- D. Lattice Girders
1. Lattice girders shall consist of at least three primary retaining bars and stiffening elements.
- E. Spiling
1. Bar spiles shall consist of deformed reinforcing steel conforming to CAN/CSA G30.18
  2. Structural channels shall conform to CAN/CSA G40.21.
  3. Pipe spiles shall conform to ASTM A53/A53M.
- F. Canopy Pipes
1. Canopy pipes shall be black steel in accordance with ASTM A53.
- 4-5.10.4 **Structural Steel**
- A. Structural steel shall conform to Section 4-4.9 *[Structural Steel]* of this Schedule.
- 4-5.10.5 **Waterproofing System**
- A. Where a 2-pass lining system is used, provide a waterproof membrane located between the initial support and the final lining to protect the full perimeter of the Mined Tunnel.
- B. The membrane waterproofing shall:
1. Be durable and not suffer any physical or mechanical degradation when exposed to the environmental conditions of the Quarters Tunnel and soils and groundwater.
  2. Be safe to apply, non-toxic and non-combustible in compliance with NFPA 130.
- 4-5.11 FINAL TUNNEL LINING**
- A. Material requirements for final tunnel linings shall comply with Section 4-5.10 *[Shotcrete]* of this Schedule and the following:
- B. Final linings shall provide a durable, water-tight, structurally sound lining meeting the requirements of Section 4-5.12.3 *[Infiltration]* of this Schedule.
- C. The final lining of the Mined Tunnel if a two-pass lining system is used shall be applied either utilizing cast-in-place reinforced concrete or Shotcrete. Where a 1-pass TBM lining system is used, it shall be comprised of bolted and gasketed segmental pre-cast concrete linings. Segmental pre-cast concrete linings shall meet the following criteria:
1. Tapered rings shall be used as the sole means for negotiating curves and correcting alignment.
  2. Radial joints in adjacent rings shall be staggered so that there are no cruciform joints; and
  3. Fabrication and erection tolerances shall be selected to assure that the groundwater inflow criteria of Section 4-5.12.3 *[Infiltration]* of this Schedule are met.

- D. Where a 1-pass TBM lining system is used, requirements for casting, curing, tail void grouting, handling, installation, TBM-induced loads and repair procedures shall be determined. Quality control procedures shall be developed to assure consistent casting dimensions and quality throughout fabrication.

#### **4-5.12 SERVICEABILITY**

##### **4-5.12.1 Durability**

- A. Perform an investigation and chemical testing of soil and groundwater in the vicinity of the Quarters Tunnel for materials and chemicals potentially harmful to waterproofing and final lining materials, such that a rational assessment of the environment can be made. Types of cement and aggregate and the type and quality of concrete shall be suitable for the Quarters Tunnel and the environmental conditions of the Quarters Tunnel. Test locations, results and interpretation thereof shall be included in a report (the “**Service Life Prediction Report**”) which shall be submitted to the City prior to the start of Construction for the Quarters Tunnel.
- B. The Design Service Life of the Quarters Tunnel and appurtenant structures, such as cross-passages and sumps shall be at least 100 years and shall be confirmed by the Service Life Prediction Report
- C. All final linings in the Quarters Tunnel and appurtenant structures shall comply with CAN/CSA S6, including Section 8.11 (Durability).

##### **4-5.12.2 Fire Resistance**

- A. All materials and components used in the Quarters Tunnel and Tunnel Approaches shall comply with NFPA 130, including Section 6.3 - Construction Materials.
- B. Final linings in the Quarters Tunnel shall retain their structural integrity during and after, a Design Fire Event, as defined in Section 4-5.15 [*Design Fire Specification*] of this Schedule. There shall be no explosive spalling of concrete during or after a Design Fire Event.
- C. Project Co shall demonstrate the integrity of the Quarters Tunnel final lining following exposure to a Design Fire Event by thorough analysis, taking into account degradation in material properties due to temperature. Analysis shall be included as part of the applicable Final Design of the Quarters Tunnel.

##### **4-5.12.3 Infiltration**

- A. Infiltration into the Quarters Tunnel, as measured at the source of the infiltration, after final lining has been installed and over the Design Service Life of the Quarters Tunnel, shall not exceed:
  - 1. 0.05 liters/per square metre per day over any 100 meter length of the Quarters Tunnel;
  - 2. 0.1 liters/per square metre per day over any 10 meter length of the Quarters Tunnel; and
  - 3. one drip per minute at any location.
- B. Without limiting Section 4-5.12.3.A [*Infiltration*] of this Schedule:
  - 1. there shall be no water infiltration permitted at any location where water has the potential to cause damage to, or malfunction of any component/equipment forming part of the System; and

2. no water infiltration shall cause entry of soil particles into the Quarters Tunnel.
- C. No infiltration of water containing greater than 10,000mg/L total dissolved salts shall be permitted.

#### 4-5.12.4 **Crack Control**

- A. All final linings in the Quarters Tunnel and appurtenant structures shall comply with CAN/CSA S6, including Section 8.12 – Control of Cracking

#### 4-5.12.5 **Deformation**

- A. Total long-term deformations of the final linings in the Quarters Tunnel and appurtenant structures shall be limited such that they do not adversely impact the integrity of the Quarters Tunnel or interfere with the safe operation of the System.

### **4-5.13 SUBMITTALS**

- A. The Final Design for the Mined Tunnel shall include the following:
  1. Mined Tunnel Geotechnical Data Report containing the following information:
    - a. Purpose, scope, survey control, report organization and limitations;
    - b. Descriptions of the geologic setting, background information on previous investigations and local geology;
    - c. Comprehensive descriptions of the site exploration program(s);
    - d. Logs of all borings, trenches, and other site investigations;
    - e. Descriptions and discussions of all field and laboratory test programs; and
    - f. Results of all field and laboratory testing.
  2. Mined Tunnel Geotechnical Recommendations Report based on the Mined Tunnel Geotechnical Data Report containing the following information:
    - a. Purpose, scope, survey control, report organization and limitations;
    - b. Project Requirements;
    - c. Summary of both the field and the laboratory investigations;
    - d. Site conditions including geologic settings, geotechnical (subsurface) profile, properties for soil and rock and groundwater conditions;
    - e. Design recommendations;
    - f. Construction considerations.
  3. Building and Utility Settlement Study Report containing the information described in Section 4-5.7.2 [*Building and Utility Settlement Study*] of this Schedule including identification of instrumentation manufacturers, instrument types, installation and reading requirements, monitoring frequencies and mitigations for trending movements.
  4. Service Life Prediction Report containing the following information.

- a. Purpose, scope, report organization and limitations;
  - b. Project Requirements;
  - c. Environmental, loading and any other relevant conditions the Mined Tunnel could be subjected to and which could detrimentally affect its Design Service Life;
  - d. Deterioration mechanisms the Mined Tunnel could be subjected to over its Design Service Life;
  - e. Protective measures to mitigate the identified deterioration mechanisms and the rationale for their assumed effectiveness;
  - f. Design recommendations; and
  - g. Construction considerations.
5. Contingency plan comprising:
- a. Corrective Actions to be utilized for each Instrument Response Level associated with surface settlement and groundwater monitoring;
  - b. remedial measures to correct for deviations from design line and grade;
  - c. corrective measures to be implemented for high groundwater or Utility Infrastructure inflows;
  - d. corrective measures to be implemented if commercial electric power to the TBM or support system is interrupted, if applicable; and
  - e. actions to be implemented if a fire event occurs.
6. Full package of Mined Tunnel construction specifications as required to supplement Section 4-4 [*Structures Construction Requirements*].
7. Risk-register identifying major risks and mitigations for the design and construction of the Mined Tunnel. At a minimum, include measures to address:
- a. Unanticipated loose and unstable soils;
  - b. Face instability;
  - c. Unanticipated groundwater inflows;
  - d. Abandoned coal mine workings/voids;
  - e. Hazardous gas;
  - f. Contaminated soil;
  - g. Lining deformations in excess of allowable limits;
  - h. Surface/building deformations beyond specified allowable limits; and
  - i. Out-of-tolerance work.
8. Quarters Tunnel Systems Report including:



- a. A description of the design and installation of the tunnel ventilation system;
- b. An analysis of the performance of the tunnel ventilation system design under normal and congested operational conditions;
- c. An analysis of the performance of the tunnel ventilation system under emergency conditions due to fire;
- d. A demonstration that the tunnel ventilation system design provides compliance with the Project Requirements; and
- e. Pertinent drawings and schemes.

#### **4-5.14 TUNNEL SYSTEMS**

##### **4-5.14.1 Codes, Standards and Reference Documents**

- A. The systems in, and supporting, the Quarters Tunnel and Tunnel Approaches shall comply with the following codes, standards and reference documents.

##### **4-5.14.1.1 Codes**

- A. Alberta Occupational Health & Safety (OHS) Code
- B. National Research Council of Canada (NRCC)
- C. Alberta Fire Code (AFC)
- D. Alberta Building Code (ABC)

##### **4-5.14.1.2 Standards and Manuals**

- A. National Fire Protection Association (NFPA) 14, Standard for Installation of Standpipe and Hose Systems
- B. Canadian Electrical Code
- C. NFPA 101, Life Safety Code
- D. NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems,
- E. American National Standards Institution (ANSI) / Air Movement and Control Association (AMCA) 250-12, Laboratory Methods of Testing Jet Tunnel Fans for Performance
- F. AMCA Standard 210, Laboratory Methods of Testing Fans for Rating Purposes
- G. AMCA Standard 300, Test Code for Sound Rating Air Moving Devices
- H. AMCA Standard 301, Methods for Calculating Fan Sound Ratings from Laboratory Test Data
- I. ASHRAE Handbook 2011

##### **4-5.14.2 General Requirements**

- A. In all fire related matters, The City of Edmonton shall be the authority having jurisdiction (AHJ). All measures proposed shall be subject to the acceptance of the City.

- B. All systems in the Quarters Tunnel and Tunnel Approaches shall comply with the following additional requirements:
1. Tunnel Ventilation System - Operation
    - a. Normal Operations
      - i. During normal operations, ventilation of the Quarters Tunnel shall not allow the thermal environment within the Passenger space of the LRVs to exceed 30°C while the Train is moving through the tunnel. In order to minimize energy consumption, the ventilation system shall be designed to make maximum usage of available natural ventilation e.g. the piston effect arising from Train movement through the Quarters Tunnel.
    - b. Congested Operations
      - i. Comfort conditions, as defined in the ASHRAE Handbook 2011 Chapter 11, shall be maintained on board a stopped Train for at least one hour with a maximum Quarters Tunnel air temperature of 40°C.
    - c. Emergency Operations
      - i. In emergency operations, the ventilation system shall provide a tenable means of egress from the Quarters Tunnel and Tunnel Approaches in compliance with NFPA 130.
    - d. Control
      - i. The tunnel ventilation system shall be controlled from the OCC via a NFPA 130 tunnel ventilation SCADA system
      - ii. The tunnel ventilation SCADA system shall include a schematic display of the tunnel ventilation system indicating all of the ventilation elements to be activated and their mode of operation. The tunnel ventilation SCADA system shall provide a means of detection of noxious or flammable gases. The tunnel ventilation SCADA system shall be able to activate the tunnel ventilation system to dilute and disperse such gases when concentrations reach threshold levels set by the Alberta OHS Code 2009 Part 4. Local controls shall be provided at each Quarters Tunnel portal and sited such that they are accessible by emergency responders. The local controls shall be permitted to override the OCC in all modes in the event that the OCC becomes inoperative or in the event that operation of the tunnel ventilation system is specifically redirected to another site.
    - e. Noise
      - i. Refer to Section 1-2.1.3 [*Noise Control*] of this Schedule for details on noise requirements.
    - f. Emergency Ventilation
      - i. Emergency ventilation shall comply with NFPA 130, Chapter 7.
    - g. System Reversibility

- i. The tunnel ventilation system shall be reversible, with a minimum of 95% of the forward direction capacity when operating in reverse direction mode.
  - h. Ventilation System Redundancy
    - i. The tunnel ventilation system shall have sufficient redundancy such that the required ventilation capacity is maintained with any one fan removed. The electrical power supply to the tunnel ventilation system and tunnel ventilation SCADA system shall be designed such that no single failure of any part of either system can compromise the operation or capacity of the tunnel ventilation system.
  - i. Smoke Dispersion
    - i. A smoke dispersion analysis shall be performed to confirm that smoke discharged from the Quarters Tunnel and Tunnel Approaches will not be drawn into entrances or air intakes of building structures.
  - j. Portal Wind Condition
    - i. The tunnel ventilation system shall provide the required ventilation capacity in emergency mode with an adverse portal wind condition of 4.1 m/s (15 km/h) as measured at either portal.
2. Tunnel Ventilation System – Fans
- a. The tunnel ventilation system fans shall employ either jet fans or axial-flow fans.
  - b. Where employed, jet fans shall:
    - i. be of the vane-axial type;
    - ii. be reversible with at least 95% of the forward direction capacity when operating in reverse direction mode;
    - iii. shall comply (including fan motors) with NFPA 130; and
    - iv. have a power curve that does not exceed 100 percent of the motor rating at any point. The brake horsepower for reverse (supply) flow shall not exceed the brake horsepower for (exhaust) flow.
3. Where employed, axial-flow fans shall:
- i. be of the axial-flow type, with internally mounted, directly driven motor;
  - ii. be reversible with at least 95% of the forward direction capacity when operating in reverse direction mode;
  - iii. have adjustable-pitch blades or have a variable frequency drive fitted to permit changes in fan-operating characteristics;
  - iv. have a total efficiency of not less than 60 percent in the forward (exhaust) flow mode; and
  - v. shall comply (including fan motors) with NFPA 130.

#### **4-5.15 DESIGN FIRE SPECIFICATION**

- A. The Design Fire Event for the Quarters Tunnel and Tunnel Approaches shall be equal to the largest fire size for the Train.
- B. Project Co shall propose the methodology for assessment of the design fire size and shall submit the proposed methodology to the City prior to assessing the design fire size. The acceptability of the proposed methodology shall be assessed by comparison with Good Industry Practice for the specification of fixed guideway transit tunnel design fire events.
- C. The Design Fire Event and associated fire emergency scenarios shall be selected by Project Co and submitted to the City prior to development of the fire safety design.

#### **4-5.16 SYSTEMS DESIGN SERVICE LIFE**

- A. Refer to Schedule 5 [D&C Performance Requirements], Part 1 [*General*] of this Schedule for the Design Service Life requirements for the Quarters Tunnels and Tunnel Approaches.

#### **4-5.17 THERMAL REQUIREMENTS**

##### **4-5.17.1.1 Operational Continuity**

- A. The tunnel ventilation system shall maintain ambient conditions so as to allow reliable operation of the LRVs in the Quarters Tunnel under all environmental operating conditions.

##### **4-5.17.1.2 Maintenance**

- A. As a minimum, the tunnel environment shall satisfy all applicable requirements of the OHS Code 2009 Part 26.

#### **4-5.18 DRAINAGE REQUIREMENTS**

- A. Refer to Section 3-4 [*Stormwater Management*] of this Schedule for requirements.

#### **4-5.19 FIREFIGHTING SYSTEM REQUIREMENTS**

- A. A firefighting system that complies with NFPA 130 shall be provided in the Quarters Tunnel and Tunnel Approaches.

##### **4-5.19.1 Supply pressure and flow rate**

- A. Supply pressure and flow rate shall conform to ABC Section 3.2.5.7.

##### **4-5.19.2 Standpipes**

- A. Standpipes shall comply with ABC Section 3.2.5.8 and Section 3.2.5.9 and shall be painted with red primer and two (2) coats of red top coat paint.

##### **4-5.19.3 Hose connections**

- A. Hose connections shall comply with ABC Section 3.2.5.10.

##### **4-5.19.4 Fire department connections**

- A. Fire department connections shall comply with NFPA-14 Sections 6.4 and 7.12.

**4-5.19.5 Piping Support and protection requirements**

- A. Support and protection of fire protection systems shall comply with ABC Section 9.10.20.5 and NFPA-14 Sections 6.1 and 6.2.

**4-5.19.6 Hose connection spacing**

- A. Hose connections shall be spaced such that full coverage of the Quarters Tunnel and Tunnel Approaches is provided based on standard Edmonton Fire Rescue Services hose lengths.

**4-5.19.7 Hydrant connection type**

- A. Hydrant connection type shall comply with ABC Section 6.8.1.

**4-5.19.8 Commissioning requirements**

- A. A Commissioning Plan shall be developed to ensure that the tunnel systems and equipment satisfy the functional requirements and performance specifications. The Commissioning Plan shall be developed in accordance with Schedule 4 *[Design & Construction Protocols]*.