

THE CITY OF EDMONTON

**PROJECT AGREEMENT
VALLEY LINE WEST LRT**

Schedule 5 – D&C Performance Requirements

Part 4: Transportation Structures and Building Structures

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PART 4: TRANSPORTATION STRUCTURES AND BUILDING STRUCTURES

SECTION 4-1 GENERAL DESIGN REQUIREMENTS

4-1.1 SCOPE

- A. Part 4 [*Transportation Structures and Building Structures*] sets out structural Design and Construction Requirements for all Transportation Structures and Building Structures unless otherwise specified.

4-1.2 GENERAL STRUCTURAL PERFORMANCE REQUIREMENTS

4-1.2.1 Safety

- A. Building Structures shall be designed to have a minimum reliability index consistent with that achieved by designs complying with the NBCAE.
- 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 this Schedule provided additional design requirements as noted in Section 4-1.3 [*Codes and Standards*] of this Schedule 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 activities, in accordance with the Operability and Maintainability Parameters, and throughout their Design Service Life as described in Section 1-2.9 [*Design Service Life*] of this Schedule.
 - 1. Elevated Guideways, Stations and Stops shall meet the life safety requirements of NFPA 130 and NBCAE, as applicable.
 - 2. Components of Transportation Structures within 1 m of the Dynamic Envelope specified in Section 1-2.1.8 [*LRV Accommodation*] of this Schedule shall be designed to not be a snagging hazard to Trackway vehicles in the event of the component being struck by a Trackway vehicle.
- D. The Construction shall not adversely impact the structural integrity or safety of other structures.
- E. Single load path structures and primary load carrying components with non-inspectable webs for Transportation Structures shall fail in a ductile manner and provide warning of failure prior to failure; for example, critical concrete components fail in bending rather than in shear.

4-1.2.2 Functionality

- A. The geometry and details of the Structures shall permit the safe operation, inspection and maintenance of the Infrastructure, including requirements during emergencies as described in the Operability and Maintainability Parameters.

4-1.2.3 Serviceability / Durability

- A. There shall be no noticeable or measurable deterioration of the performance or ability of a Structure to carry load and no deterioration detrimental to the appearance of a Structure over its Design Service Life.
 - 1. Transportation Structure components, such as 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 if permitted by the City, in its discretion. Prior to proceeding with designing a shorter than specified Design Service Life, submit to the City all documentation or evidence requested by the City to demonstrate that the component can be replaced and meet the Operability and Maintainability Parameters.

- B. Connections and interfaces between structural components shall be designed and detailed to accommodate any tolerances and deviations that could reasonably be expected to occur between the design and fabricated dimensions and elevations of the components being connected. The connections shall accommodate the tolerances and deviations without shimming, and in such a way that unanticipated stresses are not introduced into the structural components.

4-1.3 CODES AND STANDARDS

- A. Without limiting Section 1-1.7 [*Reference Documents*] of this Schedule and except as otherwise specified herein, Building Structures shall comply with the NBCAE.
- B. Without limiting Section 1-1.7 [*Reference Documents*] of this Schedule and except as otherwise specified herein, 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.
 - 2. The Canadian Highway Bridge Design Code Commentary, CAN/CSA S6.1 shall not be a compliance document for this Agreement.
- C. NBCAE and CAN/CSA S6 shall be supplemented by other codes where required in this Part 4 [*Transportation Structures and Building Structures*]
- D. The Design requirements in this Part 4 [*Transportation Structures and Building Structures*] may also be supplemented with additional Design requirements from other codes and standards not expressly listed in this Section 4-1.3D [*Codes and Standards*] if permitted by the City, in its discretion. Prior to proceeding with using such additional Design requirements from such codes and standards, submit to the City all documentation or evidence requested by the City to demonstrate that the reliability index criteria of Section 4-1.2.1 [*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 M55.1, Specification for Grouting of Post Tensioned Structures (PTI M55.1);
 - 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. AASHTO, LRFD Bridge Construction Specifications (AASHTO LRFD BCS);
 - 10. AASHTO, Standard Specifications for Highway Bridges (AASHTO SSHB);
 - 11. AWS D1.5 Bridge Welding Code (AWS D1.5);

12. PTI/ASBI M50.3 Guide Specification for Grouted Post-Tensioning (PTI/ASBI M50.3);
13. FHWA-NHI-05-039, Micropile Design and Construction Reference Manual;
14. FHWA-NHI-14-007, Soil Nail Walls Reference Manual;
15. FHWA-NHI-10-025, Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes.
16. Fib Bulletin No. 34, Model Code for Service Life Design (FIB 34);
17. NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail System (NFPA 130); and
18. TAC Geometric Design Guide for Canadian Roads (TAC)

4-1.4 DESIGN LOADS

- A. This Section 4-1.4 [*Design Loads*] sets out loads to be accounted for in the design of Structures, which are additional to those in CAN/CSA S6 and the NBCAE, as applicable.
- B. The loads given in this Section 4-1.4 [*Design Loads*] are listed as minimum loads. Valley Line LRT Stage 1 LRV loads shall be used if the Valley Line LRT Stage 1 LRV loading results in more unfavorable effects than from the Trackway vehicle live loads given in this Section 4-1.4 [*Design Loads*].

4-1.4.1 Trackway Vehicle Vertical Live Load

- A. Load Model
 1. Trackway vehicle vertical live loads shall be used as live loads, "**L**", in CAN/CSA S6 and NBCAE.
 2. The minimum Trackway vehicle vertical live load shall be the load presented in Figure 4-1.4.1-1 [*Trackway Vehicle Vertical Live Load*] unless it is demonstrated in the Accepted **Gerry Wright OMF Building Parametric Programming Report** defined in Section 8-2.6.2 [*Site Requirements*] of this Schedule or the Accepted **Lewis Farms Storage Facility Building Parametric Programming Report** defined in Section 8-3.6.3 [*Site Requirements*] of this Schedule, that a modified load model is appropriate to use for the design of Maintenance and Storage Facilities.

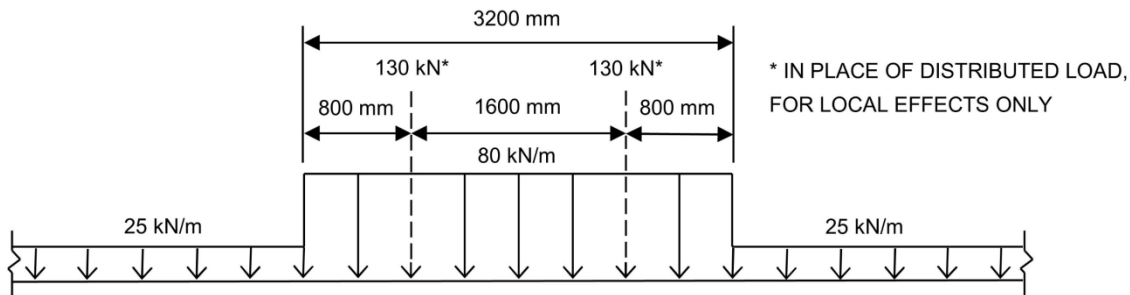


Figure 4-1.4.1-1: Trackway Vehicle Vertical Live Load

3. The load shown in Figure 4-1.4.1-1 [*Trackway 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 to maximize the load effects in the Transportation Structure.

B. Dynamic Load Allowance (DLA)

1. The Trackway 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, unless it is demonstrated in the Accepted **Gerry Wright OMF Building Parametric Programming Report** or the Accepted **Lewis Farms Storage Facility Building Parametric Programming Report**, that a modified DLA is appropriate to use in the design of Maintenance and Storage Facilities:
 - a. For global effects $DLA = \frac{2.16}{\sqrt{L_\phi - 0.2}} - 0.27$, but $0 \leq DLA \leq 1$, where L_ϕ is according to Table 6.2 in EC1 (in metres). If L_ϕ is not specified in Table 6.2 in EC1, L_ϕ 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 Trackway vehicle horizontal live loads.

C. Tracks to Be Loaded

1. Each Track shall be loaded simultaneously with the Trackway 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 Structure, in which case the loading of fewer Tracks shall be used.

D. Rolling or Lurching Load

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

4-1.4.2 Trackway Vehicle Horizontal Live Load

- A. Trackway vehicle horizontal live loads shall be used as live loads, "L", in CAN/CSA S6. Trackway vehicle vertical live load, Trackway vehicle horizontal live loads acting perpendicular to the Track centerline and Trackway 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 Structure resulting in the most unfavourable load effect; and
 2. 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 Trackway vehicle.
- C. For horizontal live loads acting parallel to the Track centreline:
 1. the load due to Trackway 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 Trackway vehicle; and
2. the load due to Trackway vehicle deceleration shall be applied uniformly at the top of the rails over a length of “ l ”, where “ l ” is the length of the Structure in metres to a maximum of 90 m, and be the greater of:
- a. $10l$ kN, or
 - b. the actual deceleration load of the Trackway vehicle.

4-1.4.3 Trackway Vehicle Wind Load

- A. The wind load on Trackway vehicles shall be used as a wind load “V” in CAN/CSA S6.
- B. The horizontal drag coefficient on the Trackway vehicles shall be a minimum of $C_h = 2.0$.

4-1.4.4 Trackway Vehicle Derailment Load

- A. The Trackway vehicle derailment load, including both vertical and horizontal loads, shall be used as a collision load, “H”, in CAN/CSA S6.
- B. The Trackway 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 Trackway vehicle derailment loads, applied concurrently to the supporting Structure, shall be as follows:
 - 1. The vertical load shall be:
 - a. the Trackway vehicle vertical live load with DLA = 1.0, positioned between the rail and the barrier to cause the maximum load effects in the Structure; and
 - b. a second Trackway vehicle vertical live load with DLA = 0.0, applied on the adjacent Track, if it increases the load effects in the Structure.
 - 2. The horizontal load (perpendicular to the Track centreline) shall be 10% of the Trackway 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 Structure. A rational method in accordance with Good Industry Practice shall be used to determine the wheel load distribution.

4-1.4.5 Roadway Traffic Live Load

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

4-1.4.6 Combined Roadway Traffic and Trackway Vehicle Load

- A. Structures that have a combined loading with Roadway vehicles and Trackway vehicles shall be analyzed with the combined loading of Roadway traffic live loads and Trackway vehicle live loads.
- B. The modification factor for multi-lane roadway traffic loading shall be in accordance with Table 3.6 of CAN/CSA S6.
 - 1. The modification factor for multi-lane loading shall only be applied to the Roadway traffic live loads and shall not be applied to the Trackway vehicle loads.

4-1.4.7 Building Structures Loads

4-1.4.7.1 Stops and Stations

- A. Publicly accessible areas of Misericordia Station, West Edmonton Mall Station and all Platforms shall be designed for a minimum live load of 4.8 kPa.
- B. Platforms shall be designed to accommodate loading from all Passenger Interface Equipment, including those supplied and installed by the City, as described in Section 5-2.6.11 [*Passenger Interface Equipment*] in this Schedule.

4-1.4.7.2 Maintenance and Storage Facilities

- A. The Maintenance and Storage Facilities shall be designed for structural live loads required to accommodate the functions and equipment in accordance with the Accepted Gerry Wright OMF Building Parametric Programming Report and the Accepted Lewis Farms Storage Facility Building Parametric Programming Report.

4-1.4.8 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 in accordance with Good Industry Practice that includes the stiffness of the Transportation Structure, rails, rail fastenings, the rail fastenings load response and accurate boundary conditions shall be used to account for the rail-structure interaction.
- C. The temperature differences between the rail temperature and the average temperature of a Transportation Structure girder 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. The temperature difference 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.
- 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.

4-1.4.9 Snow Loads on Transportation Structures

- A. Minimum snow loads on Transportation Structures shall be determined according to the NBCAE assuming a snow importance category of "Normal" 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 ULS 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 Trackway vehicles as specified in the Operability and Maintainability Parameters.
- C. If snow clearing in accordance with the Operability and Maintainability Parameters will increase the height of snow above that due to natural accumulation, snow loads shall be increased by a factor of 1.5 above the value determined according to the NBCAE.

- D. Transportation Structures with direct fixation track shall be designed for a minimum accumulation of 50 mm of snow above the top of rail.

4-1.4.10 Collision Loads

- A. The collision loads set out in this Section 4-1.4.10 [*Collision Loads*] shall be used as collision loads, "H", in CAN/CSA S6.
- B. Transportation Structure components located less than 10 m horizontally from the centreline of any Track shall be designed for a minimum collision load of 50% of the Trackway 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 0.00.
1. The collision load need not be applied to Protection Railings, barriers or to components that are protected from being struck by a Trackway vehicle.
- C. Transportation Structure substructures located above ground 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 ≥ 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 under-passing 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.

4-1.4.11 LRV Barrier Loads

- A. LRV barriers adjacent to a Trackway shall be designed to resist a horizontal collision load of 115 kN combined with a vertical collision 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 LRV barrier loads shall be used as live loads, "L", in CAN/CSA S6.

4-1.4.12 Seismic Loads

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

4-1.5 LIMIT STATES DESIGN

4-1.5.1 Introduction

- A. 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.
- B. Notwithstanding Section 4-1.5.1A [*Introduction*], limit states design of the Gerry Wright OMF Building B and Lewis Farms Storage Facility Building shall be in accordance with the requirements of Building Structures for all loads, including Trackway vehicle live loads.

4-1.5.2 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 4-1.5.2A [*Ultimate Limit State (ULS)*] of this Schedule, Transportation Structures erected using segmental concrete construction shall satisfy the load combination requirements in Section 5.12.5.3.4 [*Construction Load Combinations at Strength Limit States*] of AASHTO LRFD.

4-1.5.3 Serviceability Limit State (SLS)

4-1.5.3.1 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 5.12.5.3.3 [*Construction Load Combinations at the Service Limit State*] of AASHTO LRFD.

4-1.5.3.2 Live Load Deflections of Structures Carrying Trackway Vehicles

- A. The live load deflections of Transportation Structures carrying Trackway vehicles shall be determined based on SLS Combination 2 in CAN/CSA S6.
- B. The live load deflections of Transportation Structures carrying Trackway 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.

4-1.5.3.3 Vibrations

- A. For Transportation Structures carrying Trackway vehicles and/or pedestrians and having a fundamental vertical flexural frequency of less than 3.5 Hz, a vibration analysis report shall be submitted to the City 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 Trackway 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 a SUP or sidewalk.

4-1.5.4 Fatigue Limit State (FLS)

- A. For Transportation Structures carrying Trackway vehicles:
1. the FLS for steel load carrying members carrying Trackway vehicles 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 Trackway vehicle vertical live load and λ_1 is a correction factor accounting for the difference in fatigue damage caused by the Trackway vehicle vertical live load and the actual Trackway vehicles that pass over a Structure;

2. a rational analysis in accordance with Good Industry Practice shall be performed to determine λ_1 accounting for the anticipated actual Trackway vehicle loads and their frequency and the Design

Service Life of the Transportation Structure. The anticipated frequency of the Trackway vehicle loads shall be based on the Infrastructure operating at the Maximum Service Level based on the Operability and Maintainability Parameters; and

3. a fatigue report providing a summary of the methodology used to determine λ_1 and the recommended value of λ_1 shall be submitted to the City with the Final Design of each Transportation Structure supporting the Trackway. Values for λ_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. The specified number of design stress cycles, N_c shall be at least 150,000 per year.

B. For transportation structures carrying both Trackway vehicles and Roadway traffic, the FLS for steel load carrying members shall be satisfied considering that the Trackway vehicle and Roadway traffic loads occur simultaneously.

4-1.6 MATERIALS

A. This Section 4-1.6 *[Materials]* sets out minimum requirements for materials permitted for use in Structures.

4-1.6.1 Concrete

- A. Concrete classes shall conform to Table 4-1.6.1-1 *[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.
- E. All concrete classes except Class SCC shall have a slump no greater than 200 mm. Slumps higher than 100mm shall be obtained using superplasticizers.
- F. Class SCC concrete shall have a maximum spread diameter of 800 mm.
- G. The size of coarse aggregate and air content shall conform to CSA A23.1.
- H. The maximum practical size of coarse aggregate shall be used.
- I. The fly ash content for concrete not containing silica fume shall not exceed 30% by mass of cementing materials unless otherwise specified in Section 4-1.7 *[Durability]* of this Schedule.
- J. For Building Structures, where the concrete is not exposed to freeze thaw, sulfates or chlorides, air entrainment is not required.
- K. Dry cast concrete shall not be permitted.

Table 4-1.6.1-1 Concrete Classes

Class of Concrete	Minimum Specified Compressive Strength at 28 Days (MPa)	Max. Water/ Cementing Materials Ratio
B	25	0.45
C	35	0.40
HPC ^[1]	45	0.38
Pile	30 ^[2]	0.42
SCC	35	0.40

Notes:

1. Class HPC concrete shall contain silica fume. Additional requirements for concrete containing silica fume are set out in Section 4-1.6.2 [Additional Requirements for Concrete Containing Silica Fume] of this Schedule.
2. Pile Design strength shall not be greater than 30 MPa.

4-1.6.2 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 super plasticizing 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 (Procedure A), shall not exceed 10% of the mass of coarse aggregate.
- D. Minimum Type GU cement content (excluding supplementary cementing materials) shall be 335 kg/m³. Type HS cement shall not be used.
- 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 .

4-1.6.3 Concrete Reinforcement

- A. Concrete reinforcement shall be carbon steel, stainless steel or low carbon/chromium steel and shall conform to the following standards:
 - 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. Austenitic grades shall meet the requirements of ASTM A262, Practice E. Duplex grades shall meet the requirements of ASTM 1084, Method C by demonstrating no presence of detrimental phases. The UNS designations shall be UNS S31653, S31803, or S32304; and
 - 3. Low carbon/chromium reinforcing steel shall conform to ASTM A1035. The alloy type shall be CS with a minimum yield strength of 690 MPa, based on the 0.2% offset method.

4-1.6.4 Type 1c Concrete Sealer

- A. Type 1c concrete sealer shall be selected from the Alberta Transportation Products List.

4-1.6.5 Deformed Welded Wire Mesh

- A. Deformed welded wire mesh shall conform to ASTM A1064, Grade 70 ($f_y = 485$ MPa) with a minimum yield strength based on the 0.2% offset method. Welded wire mesh reinforcement shall be able to attain a minimum elongation of 4% at ultimate strength. Testing for elongation shall be in accordance with the Tension Test specified in ASTM A1064 with the following modifications:
 - 1. The minimum test gauge length shall be 100 mm;
 - 2. 100% of the tests shall be across the welds; and
 - 3. The extensometer shall not be removed until 4% elongation has been attained.

4-1.6.6 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.

4-1.6.7 Structural Steel

4-1.6.7.1 Transportation Structures

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

4-1.6.7.2 Building Structures

- A. Structural steel for Building Structures shall conform to the following requirements:
 - 1. steel for open web steel joists shall comply with CAN/CSA G40.20/G40.21, Grade 260W for chord sections and web material;
 - 2. W steel shapes shall comply with ASTM A992/A992M, Grade 50;
 - 3. square/rectangular HSS steel shapes shall comply with CAN/CSA G40.20/G40.21, Grade 350W, Class C;
 - 4. round HSS steel shapes shall comply with ASTM A500/A500M, Grade C;
 - 5. channel and angle steel shapes shall comply with CAN/CSA G40.20-13/G40.21, Grade 350W;
 - 6. other steel shapes and plates shall comply with CAN/CSA G40.21, Grade 300W; and
 - 7. cold-formed structural steel shall conform to the material standards in CAN/CSA S136 and comply with ASTM A653/A653M Grade 230.
- B. Galvanizing for steel shapes shall comply with ASTM A123/A123M, or CAN/CSA G164 for irregularly shaped articles, and shall have a minimum 600 g/m² coating.
- C. 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 and:
 - 1. roof and floor decks shall conform to CSSBI 10M and 12M, respectively, and shall be designed to act as diaphragms.

4-1.6.7.3 Structural Bolts and Anchor Rods

- A. Structural bolts shall conform to ASTM F3125 Grade A325/A325M heavy hex style except that bolts in contact with CAN/CSA G40.20/G40.21 Grade 350 AT or 350A steel shall conform to ASTM F3125 Grade A325, Type 3.
- B. Nuts shall be heavy hex style and shall conform to ASTM A563/A563M.
- C. Hardened washers shall conform to ASTM F436/F436M.
- D. Anchor rods shall conform to ASTM F1554 (Grade 36 or Grade 55 Weldable) or ASTM A193 Grade B7.
- E. Nuts and washers shall be of equal or greater strength than the bolts or anchor rods to which they attach.
- F. Bolts, nuts and washers shall be finished to match the members to which they attach.

4-1.6.8 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 shall not be permitted.
- B. Anchorages of ground anchors shall comply with the requirements of PTI DC35.1.

4-1.6.9 Micropiles

- A. Permanent steel casing/pipe (if required) shall:
 - 1. come in one section without splices or joints.
 - 2. meet the tensile requirements of ASTM A252, Grade 3, except the yield strength shall be a minimum of 345 MPa to 552 MPa.
- B. Steel bars shall be deformed bars with a yield strength of 520 MPa in accordance with ASTM A615.

4-1.6.10 Soil Nails

- A. Soil nail tendons shall be continuous, solid steel bars without splices or welds. Soil nail tendons shall be Grade 420 or 520 steel and shall meet the requirements of ASTM A615.

4-1.6.11 Structural Wood

- A. The use of structural wood in Structures shall only be permitted in Building Structures.
- B. Structural wood shall conform to the material standards in CAN/CSA O86.
- C. Structural wood shall be installed in such a manner that moisture is not trapped within the wood.
- D. Structural wood shall have the appropriate preservatives and treatments to provide protection from exposure.

4-1.6.12 Masonry

- A. The use of masonry material in Structures shall only be permitted in Building Structures, and for Transportation Structure veneers.
- B. Concrete block masonry shall conform to CAN/CSA S304.1.
- C. Masonry shall conform to CAN/CSA A371.
- D. Veneers used in Transportation Structures shall not be considered a protection system against chloride attack.

4-1.6.13 Grout

- A. Unless otherwise specified, grout in Transportation Structures shall be a non-shrink grout on the Alberta Transportation Products List.

4-1.7 DURABILITY

- A. This Section 4-1.7 [*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 1-2.9 [*Design Service Life*] of this Schedule.
- C. The Stray Current levels allowed by the Stray Current Program shall be accounted for when determining the Design Service Life of a Structure.

4-1.7.1 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. Concrete reinforcing in Splash Zone Surfaces for Building Structures and Transportation Structures shall be stainless steel in accordance with the requirements in Section 4-1.6.3 [*Concrete Reinforcement*] of this Schedule unless noted otherwise.
- C. Trackway slabs and Building Structure surfaces may be exempted from using stainless steel reinforcement by the City, if a report is prepared and submitted to the City justifying the selection of materials to be used in all concrete within 300 mm of any Splash Zone Surface, to achieve the minimum Design Service Life of the Structure.
 1. The analysis justifying the selection of materials to be used shall be a full probabilistic verification in accordance with fib-34, “*Model code for Service Life Design*”, using test data of the applicable concrete mix and the probabilistic distributions and values proposed in fib-34, with the exception of the following parameters in Table 4-1.7.1-1 [*fib-34 Full Probabilistic Method Parameters*] or by an alternate method acceptable to the City:

Table 4-1.7.1-2 fib-34 Full Probabilistic Method Parameters

Parameter	Variable	Value
Initial Chloride Content, C_0 (wt.-%/c)	μ	0.055%
	σ	0.028%
Critical Chloride Content, C_{crit} (wt.-%/c) For Carbon Steel	μ	0.20%
	σ	0.08%
	a	0.1%
	b	0.6%
Chloride content at depth Δx , $C_{s,\Delta x}$ (wt.-%/c)		
Exposure Class XD4	μ	4%
	σ	3%
Exposure Class XD3	μ	3%
	σ	2.25%
Exposure Class XD2	μ	2%
	σ	1.5%
Exposure Class XD1	μ	1%
	σ	0.75%

where the Exposure Classes are defined as follows:

- **Exposure Class XD4** means any surfaces with direct application of de-icing salts, including Roadway, Platform, WEM Transit Centre passenger loading area, Misericordia Station plaza, SUP and sidewalk surfaces, surfaces within 30 m of a Roadway crossing or 2 m of a pedestrian crossing, and interior surfaces of Building Structures within 2 m of an entrance adjacent to a surface receiving de-icing salts;
- **Exposure Class XD3** means any surfaces within less than 1.5 m of a surface with direct application of de-icing salts or surfaces buried less than 300 mm below a surface with direct application of de-icing salts;
- **Exposure Class XD2** means any surfaces within more than 1.5 m, but no more than 3 m, of a surface with direct application of de-icing salts, surfaces buried more than 300 mm, but less than

- 1 m, below a surface with direct application of de-icing salts, or surfaces buried less than 300 mm below surfaces within 1.5 m of a surface with direct application of de-icing salts; and
 - **Exposure Class XD1** means any surfaces exposed to splash within more than 3 m of a surface with direct application of de-icing salts, or surfaces buried more than 300 mm below surfaces within 1.5 m of a surface with direct application of de-icing salts.
2. The report shall define testing standards, procedures, and testing frequency during Construction to validate the assumptions used in the report.
- D. CAN/CSA G40.20/G40.21, Grade 350A and 350AT steel shall not be used within a Splash Zone Surface unless galvanized in accordance with Section 4-4.10.8.2 [*Galvanizing*] of this Schedule.
 - E. The fly ash content in concrete used as a Splash Zone Surface shall not exceed 25% and the cement content of the concrete shall be greater than 300 kg/m³.
 - F. Concrete within splash zones shall be resistant to chloride ion penetration according to CSA A23.2-23C.
 - G. All Building Structures steel within a Splash Zone Surface, excluding benches, leaning rails, waste receptacles, and waste and recycling receptacles, shall be galvanized or be stainless steel.
 - H. Metal components of benches, leaning rail, waste receptacles, and waste and recycling receptacles shall be aluminum, galvanized, or stainless steel.

4-1.7.2 Clear Concrete Cover

- A. The nominal concrete covers for Transportation Structures specified in Table 8.5 of CAN/CSA S6 shall be considered as minimum concrete covers with no negative tolerance on the nominal cover.
- B. For MSE wall panels, minimum cover to concrete reinforcement shall be 50 mm (excluding any additional thickness required for aesthetic surface treatment) on both front and back faces of the panels, and concrete reinforcement shall be electrically isolated from soil reinforcement attachment hardware.

4-1.7.3 Concrete Surfaces

- A. Concrete placement procedures shall be prepared for each concrete mix design to outline the procedures for concrete placement to minimize the probability of the concrete deficiencies noted in Section 4-4.5.20 [*Concrete Deficiencies*] of this Schedule.

4-1.7.4 Steel Surfaces

4-1.7.4.1 General

- A. All steel surfaces, except CAN/CSA G40.20/G40.21, Grade 350A and 350AT steel surfaces, shall be protected by hot-dip galvanizing or by metallizing.
 1. Galvanizing shall conform to ASTM A123/A123M and A385/A385M.
 2. Metallizing shall be a minimum of 180 microns thick and shall conform to AWS C2.23M, "Specification for the application of thermal spray coatings (metallizing) of aluminum, zinc, and their alloys and composites for the corrosion protection of steel".
- B. Paint based coating systems shall not be permitted unless otherwise specified.

4-1.7.4.2 Permanent Steel Piles

- A. Steel piles that are exposed above ground shall be hot dip galvanized to 1000 mm below ground.
- B. Steel piles shall be designed to account for long term section loss by providing additional sacrificial area, by hot dip galvanizing or by a combination of both.

4-1.7.5 Voids

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

4-1.7.6 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.

4-1.7.7 Micropile Corrosion Protection

- A. Micropile steel bars shall be encased in grout-filled, corrugated HDPE sheathing (encapsulation) for double corrosion protection in accordance with the requirements of FHWA-NHI-05-039.

4-1.7.8 Soil Nail Corrosion Protection

- A. All soil nails shall be provided with a Class A Corrosion Protection (encapsulation) in accordance with the requirements of FHWA-NHI-14-007.

4-1.7.9 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/ASBI M50.3.
- B. Post-tensioning tendons shall not be located within 300 mm of a Splash Zone Surface.

4-1.8 GEOMETRICS

- A. This Section 4-1.8 [*Geometrics*] sets out minimum geometric requirements for Transportation Structures.

4-1.8.1 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 or edge of shoulder of the under-passing Roadway shall be a minimum of 3.0 m unless otherwise specified in Section 4-3 [*Structure Specific Requirements*] of this Schedule.

4-1.8.2 Horizontal Clearances

- A. Transportation Structures carrying Trackway 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 functional requirements of the Operability and Maintainability Parameters.
- 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 TAC; and
 2. the offset distance required to meet the upper limit sight distance requirements as specified in TAC.
- C. The use of barriers to reduce clear zone dimensions shall not be permitted unless otherwise specified in Section 4-3 [*Structure Specific Requirements*] of this Schedule.

4-1.8.3 Vertical Clearances

- A. Transportation Structures carrying Trackway vehicles shall have adequate vertical clearances over the Tracks to accommodate the Dynamic Envelopes of the vehicles listed in Table 1-2.1.6 [*Dynamic Envelope Widths*].
- 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*] of this Schedule.
- 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*] of this Schedule.
- D. Vertical clearance signs shall be provided on all Transportation Structures at the locations of underpassing Roadways or SUP 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.

4-1.9 GEOTECHNICAL

4-1.9.1 General

- A. This Section 4-1.9 [*Geotechnical*] sets out general geotechnical requirements for Building Structures, Transportation Structures, Trackway, and Other Structures.
- B. The geotechnical designs required for Transportation Structures, Building Structures, Trackway, and Other Structures, including slope stability assessments and stabilization, shall be undertaken taking into account 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 term and long-term stability of all slopes, including the Groat Ravine slopes, the McKinnon Ravine slopes, the headslopes and sideslopes of the approach fills of new Transportation Structures, and the headslopes and sideslopes of the approach embankments of the Existing Anthony Henday Drive Bridge. 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 and Other Structures, the geotechnical investigations and evaluations shall be completed in accordance with the requirements of the NBCAE and the CFEM.
- E. The use of geotechnical resistance factors corresponding to “High Degree of Understanding” per Table 6.2 of CAN/CSA S6 in the design of Transportation Structures shall only be used when accepted by the City in its discretion.
- F. Detailed geotechnical reports documenting the geotechnical conditions and engineering recommendations to address Design and Construction Requirements shall be submitted to the City

as part of the Final Design of each Transportation Structure and Building Structure. The geotechnical assessments for Other Structures may be compiled in one or a series of reports, as may be deemed practical by the Designer.

- G. 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.
- H. For lineal structures such as retaining walls, Trackway, and Overhead Catenary System, the spacing between geotechnical boreholes shall not exceed 200 m.
- I. Geotechnical boreholes shall be drilled at all Building Structure and Other Structure locations. The number and depth of boreholes shall be consistent with the data requirements for the foundation designs.
- J. 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 mean 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.
- K. The competency and frost heave susceptibility of subgrade soils beneath grade-supported Infrastructure shall be evaluated as part of the Final Design of the Infrastructure. A competent subgrade is defined as having suitable load carrying characteristics and not susceptible to detrimental volume changes from moisture content fluctuations or frost heaving. The assessment of frost heave susceptibility shall be conducted in accordance with the criteria outlined in the CFEM. Mitigation measures (e.g. soil replacement, soil reinforcement, sub-drainage, insulation, grading, surface drainage, etc.) shall be implemented as required to improve subgrade conditions, prevent frost heave, and ensure no measurable deterioration in the performance of the Infrastructure over their Design Service Life. The results of the geotechnical assessment and the engineering recommendations to address Design and Construction Requirements shall be submitted to the City as part of the Final Design of the Infrastructure.

4-1.9.2 Foundations

- A. Foundations of Transportation Structures shall be designed in accordance with CAN/CSA S6 and the CFEM. Foundations for Building Structures and Other Structures shall be designed in accordance with the NBCAE and the CFEM.

4-1.9.3 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.

4-1.9.4 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 sideslopes, cut slopes, and retaining walls, shall be designed for a minimum factor of safety of 1.3 at the end of slope or wall construction and 1.5 in the long term upon dissipation of construction induced excess pore water pressures. Irrespective of the computed value of the factor of safety, the inclination of permanent, unreinforced cut or fill slopes shall not be steeper than 3H:1V, unless noted otherwise in Section 4-1.8 [*Geometrics*] or Section 4-3 [*Structure Specific Requirements*] of this Schedule.

- B. The design of retaining walls and Transportation Structure headslopes and approach fills shall account for global stability, bearing capacity (where applicable), long-term settlements, and lateral 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 considered in the design of the Transportation Structure and shall provide for acceptable structural performance and aesthetics of the approach fills and walls.
- C. The geotechnical investigations and design of reinforced soil slopes shall be undertaken in accordance with the requirements of FHWA-NHI-10-025 and the CFEM.

4-1.10 DRAINAGE

- A. This Section 4-1.10 [Drainage] sets out drainage requirements for structural components of Transportation Structures unless otherwise specified.
- B. Drainage of Transportation Structures shall be in accordance with this Section and Section 3-5 [*Stormwater Management*] of this Schedule.
- C. Drainage on Transportation Structures shall channel all water off 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.

4-1.10.1 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.
- B. The tops of all horizontal surfaces, (i.e. abutment seat, pier cap, curb, coping cap, retaining wall, and barrier top) shall have a minimum wash slope of 3%.
- C. Drip grooves shall be provided near the outside edges of all deck soffits and top flanges of concrete box girders or trough girders so as to prevent water running down the exposed girder faces.

4-1.10.2 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 the decks. Differential settlements and other movements between Transportation Structures and approach fills shall not compromise the collection of drainage.
- B. Discharge point(s) of Transportation Structure drainage shall be kept a minimum of 8 m away from the foundations of piers, abutments or other structure elements, and shall not 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.

4-1.10.3 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.

4-1.10.4 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 material behind the abutment/retaining wall is backfill, the drainage system shall include clean granular material with a maximum aggregate size of 25 mm and a maximum fines content (soil particles finer than 0.08 mm) of 5 percent, complete with perforated weeping drains daylighted or connected to a discharge point 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 to a discharge point 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. The bottom and sides of swales shall be lined with an impervious material to prevent infiltration of surface water into soil retained behind the walls. Swales and top of walls shall slope away from abutments. The swale shall be designed such that the greatest depth of drainage flow shall be located at the center of the swale. The backside of the retaining wall shall not be used as part of the swale.

4-1.10.4.1 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 daylighted or connected to a discharge point for Positive Drainage. The water level within the mechanically stabilized earth mass shall be assumed at the invert level of the weep drains or higher should the design warrant it in accordance to Good Industry Practice.
- 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 daylighted beyond the MSE mass. 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;

- 5. extended for the full width of the surface receiving de-icing salts plus a minimum of 2 m beyond it on either side, and a minimum of 500 mm beyond the ends of the reinforced soil zone; and
 - 6. All joints shall be shingled in the direction of drainage and welded or bonded to prevent leakage.
- D. For MSE wall abutments, the concrete walkway provided in front of the abutment for inspection purposes shall be underlain by the impermeable membrane.

4-1.10.4.2 Drainage of Soil Nail Walls

- A. Surface drainage shall be controlled and channeled away from the back of the soil nail wall facing and reinforced earth mass.
- B. A drainage system consisting of geocomposite drain strips, PVC connection pipes, soil nail wall footing drains, and weepholes shall be provided to collect and direct perched groundwater and/or infiltrated surface water away from the soil nail wall, and to prevent the buildup of water pressure behind the wall facing. The geocomposite strip drain shall have sufficient capacity to convey the anticipated water flow, and sufficient resistance to prevent collapse during construction and throughout the Design Service Life.

4-1.11 DUCT BANKS

- A. Duct bank accommodation requirements for Transportation Structures shall be in accordance with Section 6-1.6 [*Systems Duct Bank and Associated Infrastructure*] and Section 6-2.3.3.2 [*Traction Power Duct Bank*] of this Schedule.

4-1.12 INSPECTION ACCESS

- A. This Section 4-1.12 [*Inspection Access*] sets out general inspection access requirements for Transportation Structures including portions of the Elevated Guideway within Misericordia and West Edmonton Mall Stations 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 hands-on 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. The top of the abutment seat shall be a maximum of 1.2 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. The top of the abutment seat shall be a maximum of 1.5 m above the inspection walkway.
- E. A suitably flat area shall be provided at the base of all retaining walls over 2 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 or other substructure shall be accessible for inspections via access hatches in the abutment backwall.
- G. All 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; and
 - b. provided with access hatches that shall be lockable and operable by one person.
- H. Pathways shall be provided for maintenance and inspection of Elevated Guideway Piers in accordance with Section 2-14.6.5.3F [*Area Specific Requirements*] of this Schedule.

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

4-2.1.1 General

- A. Foundation requirements shall apply to Building Structures, Transportation Structures, and Other Structures unless noted otherwise.
- B. Driven piles shall not be permitted anywhere except for locations within:
1. the Alberta Transportation TUC;
 2. 200 m west of the TUC western boundary and 200 m south of Webber Greens Drive but shall be:
 - a. at least 100 m from the nearest residential or commercial property; and
 - b. greater than 20 m from any ATCO pipeline or facility; and
 3. the Gerry Wright OMF Site.
- C. The pile load carrying 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 analyses and verified using pile driving analyzer (PDA) 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 using non-destructive ultrasonic testing techniques as specified in Section 4-4.2.5.5 [*Steel Pile Spllices*] of this Schedule.
1. 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.
- G. The top of foundations for Transportation Structures, including footings and pile caps, shall be buried a minimum of 600 mm below finished grade.
- H. Combining shallow and deep foundations to support a single Transportation Structure or Building Structure shall not be permitted.
- I. The following Structures shall be supported on pile foundations:
1. the Gerry Wright OMF Building B superstructure and all Shop Tracks and slabs-on-grade within Gerry Wright OMF Building B;
 2. the Lewis Farms Storage Facility Building superstructure; and
 3. the Lewis Farms Stop Platform, including all structural elements.

- J. All Trackway slabs with Embedded Track for Gerry Wright OMF Stage 2, excluding the driveable apron areas as required in accordance with Section 3-1.1.5.6B [Yard Tracks] of this Schedule, shall be structurally supported on pile foundations.
- K. An instrumentation program shall be implemented to monitor the magnitude and rate of settlement of the Trackway and any structural fills placed to raise the site grade for Gerry Wright OMF Stage 2.
 - 1. The instrumentation program shall be extensive enough to provide a complete picture of fill and Trackway settlement over time.
 - 2. As a minimum, the instrumentation shall include twenty (20) settlement plates.
 - 3. The monitoring instruments shall be installed at critical locations/depths that allow the measuring of maximum values of settlement.
 - 4. The monitoring results shall be used to confirm compliance with the settlement criteria outlined in Section 3-1.1.5.1 [*General*] of this Schedule.
 - 5. Instrumentation monitoring shall be carried out as follows:
 - a. During Construction of Gerry Wright OMF Stage 2, once every two weeks or more frequently if deemed necessary by the Contractor's geotechnical engineer based on the monitoring results and Good Industry Practice.
 - b. After Phase 1 Construction Completion and until Construction Completion, every two months or more frequently if deemed necessary by the Contractor's geotechnical engineer based on monitoring results and Good Industry Practice; and
 - c. Submit monitoring results to the City within one week of the date of measurements.
- L. Helical piles are not permitted to support any portion of a Transportation Structure, Station or Maintenance and Storage Facility.

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 supported on piles at both ends 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. Headslopes for Transportation Structures spanning over Roadways shall be covered with concrete slope protection unless otherwise 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.

- G. Approach slabs shall be used at the end of abutments. The approach slabs shall be a minimum of 6 m long and settlements shall not cause rotations at the abutment the approach slab is supported on that cause deviations to the track profile greater than 15 mm measured over 9.4 m.
- H. Abutment designs shall account for the potential horizontal movement of embankments or retaining walls.

4-2.2.2 Integral Abutments

- A. Integral abutments, including both fully integral and semi-integral abutments, shall not be used for bridges with the following conditions:
 - 1. 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.
 - 2. Bridge abutments with a skew angle greater than 23 degrees.
- 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 are required and shall be parallel to the approach fill and cantilevered off the back of the abutment. Such wingwalls 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 to achieve the Design Service Life. The H-piles shall be embedded a minimum of 2 pile widths into the abutment seat.
 - a. For fully integral abutments without driven steel piles, W-shape or built-up steel sections may be used.
 - 5. Cycle control joints at the ends of the approach slabs shall be located at least 1.125 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 30 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 shall be founded on piles.
- B. 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.

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 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*] of this Schedule, 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 soil and shall be designed to discourage attempts to climb the wall.
- E. The top of retaining walls, including copings, shall have a consistent negative slope from its high point to the ends of the wall.
- F. 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.
- G. Dry cast concrete block walls or stacked masonry block walls are not permitted for retaining walls, except for the retaining wall along the west side of 170 Street south of 87 Avenue.

4-2.4.1.1 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.
- F. Mechanically stabilized earth walls are not permitted in locations where the wall is required to support a Structure.

4-2.4.1.2 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.

4-2.4.1.3 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.
- 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. For MSE walls with full height precast concrete panels, the total settlement shall be limited to a maximum of 50 mm, and the differential settlement shall not exceed 20 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. A repair/replacement procedure shall be submitted to the City with the applicable Final Design.

4-2.4.1.4 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.
- C. Copings shall have control joints perpendicular to the wall alignment. The spacing of the control joints shall not exceed 4 m. Longitudinal steel in the copings shall be discontinuous and have 50 mm cover measured from the centre of the control joint. The copings shall also have drip grooves in the soffit.
- D. Typical control joint details shall be in accordance with the Control Joint Detail in the Alberta Transportation Standard Drawing S1412-17.

4-2.4.1.5 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.

4-2.4.1.6 Obstructions within the Backfill

- A. Soil reinforcing shall accommodate any obstruction within the mechanically stabilized earth, including foundation piles and associated casings, and casings for future pile installations. For MSE wall systems that lend themselves to splaying of the soil reinforcement, the splay angle shall not exceed 15° 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.

4-2.4.1.7 Inspection Wires

- A. Galvanized steel inspection wires shall be provided in all steel reinforced MSE wall systems in addition to the soil reinforcement design requirements. One inspection wire shall be provided for each 25 m² 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 Products 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. Adhesively mounted survey targets will not be permitted.

4-2.4.2 Retaining Walls with Ground Anchors

- A. Ground anchors shall not extend laterally 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. PTI DC35.1; and
 - 2. CAN/CSA S6.
- 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 test setup, testing procedures and results of verification tests shall be reviewed and accepted by the Engineer of Record prior to the installation of production ground anchors.
- E. The minimum bond length of a ground anchor shall be 4.5 m.
- F. 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.
- G. 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.
- H. A ground anchor design report containing all design parameters required for load resistance calculations, installation procedures, procedures required for installation verification, results of verification and proof tests, and details on how the corrosion-protection system provides the necessary corrosion protection over the Design Service Life shall be submitted to the City with the applicable Final Design.
- I. Ground anchors shall be in accordance with Section 4-1.6.8 [*Ground Anchors*] of this Schedule.

4-2.4.3 Soil Nail Walls

- A. Soil nails shall not extend laterally beyond the boundary of the City Lands.
 - 1. Soil nail walls shall be designed in accordance with the requirements in FHWA-NHI-14-007.
- B. The pullout capacity of soil nails shall be verified by verification tests on sacrificial pre-production soil nails and proof tests on production soil nails, in accordance with the recommendations of FHWA-NHI-14-007. For permanent soil nails, a minimum of one verification test in each different soil condition (in terms of geologic origin, composition and strength) shall be performed at the location of each soil nailed structure. Proof tests shall be conducted on a minimum of 5 percent of production soil nails in each nail row with a minimum of one test per row. Verification tests shall not be counted towards the number of required proof tests.
- C. The test setup, testing procedures and results of verification tests shall be reviewed and accepted by the Engineer of Record prior to the installation of production soil nails.

- D. The factored design load, service design load, and test load of the soil nails shall be stated on the applicable Final Design.
- E. A soil nail wall design report containing all design parameters required for load resistance calculations, installation procedures, results of verification and proof tests, and procedures required for installation verification shall be submitted to the City with the applicable Final Design.
- F. Soil nail tendons shall be in accordance with 4-1.6.10 [*Soil Nails*] of this Schedule.

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, shrinkage, and foundation or embankment movements.
- 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.
 - 1. The concrete surrounding the grout pocket recess shall be cast monolithically with the supporting substructure element.
- 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.
 - 1. If there is an elastomer, the weld shall be a minimum of 40 mm away from the elastomer.
 - 2. Overhead welding shall not be permitted.
 - 3. Transverse sole plate ends not welded shall be sealed against moisture.
- G. Sole plates attached to concrete girders and base plates attached to concrete substructure shall be sealed against moisture.
- H. 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 5 mm. Future jacking locations shall be located on the permanent substructure and shall not require the installation of temporary supports, use of proprietary equipment, or require prolonged traffic closures. 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.

- I. Disk bearings shall not be used.
- J. The height of each bearing base plate shall be adjustable until after the superstructure is erected and installed on to the bearing.
- K. Uplift of bearings shall not be permitted at serviceability limit states.

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, material requirements for elastomers shall conform to AASHTO M251 Standard Specification for Plain and Laminated Elastomeric Bridge Bearings (AASHTO M251). Cured elastomeric compounds shall be low temperature Grade 5 and meet the minimum requirements listed in Table X1 of AASHTO M251 with a Shore A durometer hardness of 60. For fully integral abutments and piers, cured elastomeric compounds shall be Shore A durometer hardness of 50.
 - 3. Elastomeric bearing pads shall be designed for a maximum of 10 mm of horizontal deformation.
 - 4. Sliding surfaces shall allow for translation by sliding of a stainless steel surface against a mating PTFE element. PTFE shall be 4.8 mm thick unlubricated, unfilled 100% virgin polymer conforming to Section 18.8.2.5 (Unfilled PTFE Sheet) of the AASHTO LRFD Bridge Construction Specifications (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. PTFE sheets shall have the same plan dimensions as the elastomeric pad.
 - 5. Elastomeric bearing 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 and contain spherical reservoirs for lubricant pressed into its surface. The diameter of the reservoirs shall not exceed 8 mm measured at the surface of the PTFE, and the depth shall not be less than 2 mm nor more than half the thickness of the PTFE. The reservoirs shall be evenly distributed across the surface of the PTFE and shall occupy 20% to 30% of the surface.
 - 4. PTFE used as a mating surface for guides for lateral restraint shall not be dimpled or lubricated. All PTFE elements shall be fully bonded and recessed in a rigid backing material.

5. All PTFE surfaces except those that act as mating surfaces for guides for lateral restraint or that are subjected to a contact pressure of less than 5 MPa shall be permanently lubricated with silicone grease.
6. 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 values specified in Table 4-2.5.3-1 [Average Contact Pressure for Unfilled PTFE elements].

Table 4-2.5.3-2 Average Contact Pressure for Unfilled PTFE Elements

Limit State	Permanent Load (MPa)	All Loads (MPa)
SLS	25	35
ULS	40	55

7. 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 4-2.5.3-2 [Average Contact Pressure for Unfilled PTFE Elements].
8. Notwithstanding Section 11.6.3.6 of CAN/CSA S6, the average contact pressure for all loads on 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 at SLS and 55 MPa at ULS.
9. Notwithstanding Section 11.6.5.4 of CAN/CSA S6, the average stress in the elastomer at SLS loads shall not exceed 30 MPa. Notwithstanding Section 11.6.5.2 and 11.6.6.2.2 of CAN/CSA S6, cured elastomeric compounds shall be low temperature Grade 5 and meet the minimum requirements listed in Table X1 of AASHTO M251 and Shore A durometer hardness of 50.
10. 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.
11. 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 SLS and ULS conditions, plus a fabrication and construction tolerance allowance of 0.01 radians. The total rotational capacity shall not be less than $\pm 1^\circ$.
12. The coefficient of friction between stainless steel sliding surfaces and lubricated virgin PTFE shall be in accordance with Section 14.7.2.5 and Table 14.7.2.5-1 of the AASHTO LRFD BCS.
13. 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.
14. 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.
15. 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 accounted for.

16. The surfaces in contact with the elastomer shall not be metallized or galvanized and shall be lubricated with silicone grease.

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 pre-tensioning 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 greater than 250% of the strand area.
- B. Concrete girders that are adjoined in parallel (i.e. side-by-side) shall be steel reinforced through the shear interface between the girders for the entire girder length.

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.

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. 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.

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 shall 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 concrete reinforcement.
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. In accordance with AWS D1.5, Bridge Welding Code, the bottom of the bearing ends of bearing stiffeners shall be flush and square with the web and shall have a minimum of 75% of this area in contact with the flanges. The top shall be a “tight fit” and shall have a maximum gap of 1 mm. The bearing stiffeners shall be fillet welded to both the top and bottom flanges and to the web.
 - 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. If a stiffener is wider than the flange, the end of the stiffener shall be coped at 45 degrees from the flange edge.
 - 6. 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.

7. Gusset plates for attachment of horizontal bracing shall be bolted and not welded to girders.
8. 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.
9. 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 DECKS

4-2.7.1 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.
- B. Cast-in-place concrete decks shall meet the following requirements:
 1. deck slabs shall have a minimum thickness of 225 mm, unless otherwise specified, and shall have two mats of concrete reinforcement;
 2. deck slabs, supporting sidewalks or SUPs, shall have a minimum thickness of 175 mm; and
 3. stay in place deck soffit formwork shall not be permitted.

4-2.8 DECK JOINTS

4-2.8.1 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 and curbs shall have removable cover plates on the inside face and across the top except for the Stony Plain Road Bridge, where the cover plate shall also cover the outside face.
- 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.

4-2.8.1.1 Sealed deck joints

- A. Sealed deck joints shall include Strip Seal Deck Joints and Cover Plated V-Seal Deck Joints in accordance with the Alberta Transportation Standard Drawings listed in Table 4-2.8.1-1 [*Alberta Transportation Standard Drawings for Sealed Deck Joints*].
- 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. The maximum allowable gap for sealed deck joints shall be taken as the summation of the minimum 60 mm and the maximum permissible normal movement.
- C. The maximum permissible shear movement shall be based on the maximum absolute temperature difference between the temperature at the time of joint installation and the maximum or minimum design temperature, whichever is greater.
- D. For skew bridges, the longitudinal direction of bridge movement shall be resolved into its normal and shear components with respect to the joint axis. The governing movement limit is reached when either one of the component movement ranges exceeds the respective permissible values listed in Table 4-2.8.1-1 [*Alberta Transportation Standard Drawings for Sealed Deck Joints*]. The normal component gap shall be set at the time of concreting the joint extrusion, in accordance with the temperature setting chart provided on the standard drawings, but the shear component shall be zero at the time of seal installation. The temperature of seal installation is assumed to be 15°C for the standard design but shall be adjusted for the installation temperature.
- E. The Type I Strip Seal Deck Joint is the preferred deck joint and shall be used, unless Project Co can demonstrate to the satisfaction of the City that the Type I Strip Seal Deck Joint cannot be installed.
- F. Setting of deck joints may be based on the effective bridge temperature at the time of installation which may be assumed to be the mean shade air temperature taken over the previous 48 hours for concrete structure and 24 hours for steel structures.
- G. For multi-cell strip seal type deck joints on roadways with skew angles within the range of 20° to 45°, snow plow guard plates shall be installed (similar to what is shown in Alberta Transportation standard drawing S-1811-17) to prevent snow plow blades from dropping into the joint gap and catching the edge of the joint extrusion. Welded snow plow guard plates shall not be located directly under the expected vehicular wheel paths.
- H. Only neoprene seals shall be permitted.
- I. The construction joint for deck joint block-outs shall be located outside the width of the concrete paving lip and shall be within the extents of the deck waterproofing system.

Table 4-2.8.1-1 Alberta Transportation Standard Drawings for Sealed Deck Joints

Alberta Transportation Standard Drawing	Joint Type	Maximum Permissible Normal Movement	Maximum Permissible Shear Movement
S-1810-17 (Type I Strip Seal Deck Joint – Sheet 1)	Multi-cell strip seal	55 mm	13 mm
S-1811-17 (Type I Strip Seal Deck Joint – Sheet 2)			
S-1812-17 (Type I Strip Seal Deck Joint – Sheet 3)			
S-1800-17 (Cover Plated V-Seal Deck Joint – Sheet 1)	Cover-plated 102 mm V-Seal	30 mm	20 mm

S-1801-17 (Cover Plated V-Seal Deck Joint – Sheet 2)	Cover-plated 125 mm V-seal	55 mm	25 mm
S-1802-17 (Cover Plated V-Seal Deck Joint – Sheet 3)	Cover-plated 178 mm V-seal	90 mm	30 mm

4-2.9 BARRIERS

4-2.9.1 General

- A. Concrete barriers shall have crack control joints in accordance with the details provided in Alberta Transportations standard drawing S-1412-17 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.
- B. 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. The height of the base plates shall be adjustable until after the barrier alignment has been fixed.

4-2.9.2 LRV Barriers

- A. Transportation Structures carrying Trackway vehicles and with an elevation difference of 600 mm or more between grade and top of deck shall be provided with LRV barriers. The LRV barriers shall be sufficient to prevent Trackway vehicles from falling off of the Structure, including due to tipping.
- B. An LRV barrier may be considered to be sufficient to prevent a Trackway vehicle from falling off of a Structure provided it meets the following requirements:
 - 1. the LRV barrier satisfies the loading requirements specified in Section 4-1.4.11 [*LRV Barrier Loads*] of this Schedule; and
 - 2. the LRV barrier has sufficient height to prevent a Trackway vehicle from tipping over it. The height of the centre of gravity of the Trackway vehicle above the top of rail shall be based on the actual Stage 1 LRV 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. Unless otherwise specified Transportation Structure components located behind LRV barriers shall be set-back a minimum of 600 mm from the traffic face of the LRV barrier.

4-2.9.3 Pedestrian Barriers

- A. Pedestrian railing pickets shall be vertical and have a maximum clear spacing no greater than 100 mm.

4-2.9.4 Attachments Behind LRV 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 LRV barriers shall be set-back a minimum of 600 mm from the traffic face of the barrier.

4-2.10 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.

4-2.11 TRACKWAY SLABS

- A. Joints between at-grade Trackway slab segments shall allow for expansion and contraction to occur across the joint while preventing differential settlement across the joint.
 - 1. The joints shall be filled with a compressible material and sealed to prevent water ingress into the joint.
 - 2. Stainless steel dowels shall intersect the joint.
 - 3. Joints shall be no greater than 20 mm wide at the time of construction.
- B. An approach slab shall be provided under a Trackway slab to provide a smooth transition between a structurally supported Trackway slab to a ground supported Trackway slab or Ballasted Track.
 - 1. Approach slab shall be in accordance with Section 4-2.2.1.G [*Abutments*] of this Schedule.

4-2.12 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 elastic 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.

4-2.13 DIRECT FIXATION SUPPORT

- A. The Design Service Life of direct fixation supports (i.e. plinths), including the fatigue limit state of the shear mechanism between the plinth and deck or slab, shall be the same as the Design Service Life of the Transportation Structure supporting the direct fixation support.
- B. Track fasteners and anchorages shall not be directly anchored into a concrete deck.

4-2.14 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.

SECTION 4-3 STRUCTURE SPECIFIC REQUIREMENTS

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

4-3.1 87 AVENUE ELEVATED GUIDEWAY

4-3.1.1 Geometrics

4-3.1.1.1 Substructure Placement

- A. Piers and abutments shall be placed to meet the horizontal clearance requirements of Section 4-1.8.2 [*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.

4-3.1.1.2 Vertical Clearances

- A. The minimum vertical clearance of the 87 Avenue Elevated Guideway over 165 Street, 169 Street, 170 Street, 175 Street, 178 Street, and property access roads (i.e. West Edmonton Mall and Misericordia Hospital) shall be 5.5 m.
- B. The minimum vertical clearance of the 87 Avenue Elevated Guideway over the pedestrian crosswalks shall be 3.0 m.

4-3.1.2 Geotechnical

- A. Where the approach fills at the ends of the 87 Avenue Elevated Guideway exceed 1 m in height, the Trackway slabs shall be structurally supported on pile foundations.
- B. Settlement of substructures and approach fills of the 87 Avenue Elevated Guideway shall be evaluated using appropriate stress-strain analyses based on the results of site-specific geotechnical investigation and testing.
- C. Appropriate Design and Construction measures shall be implemented, as required, to limit differential settlement between Trackway slabs structurally supported on piles and Trackway slabs supported on approach fills of the 87 Avenue Elevated Guideway over the Design Service Life of the structure to a maximum of 10 mm. Settlements shall also not cause rotations that cause deviations to the track profile greater than 1/600 over 9.4 m. The settlement assessment and measures to control differential settlement to within the specified limit shall be included in a geotechnical report and submitted to the City as part of the Final Design of the 87 Avenue Elevated Guideway

4-3.1.3 87 Avenue Elevated Guideway Piles Close to Sewer Lines

- A. The design and construction of pile foundations supporting the 87 Avenue Elevated Guideway shall not have any adverse effects on the integrity or serviceability of existing sewer lines, including the following sewer lines deemed to be in close proximity to potential guideway pile locations:
1. 460 m length of 1200 mm to 1500 mm storm sewer draining east along 87 Avenue between 176 Street and 180 Street. The sewer line consists of precast concrete pipe, and the depth to crown varies between 4.5 m to 7.5 m. The sewer line may be in close proximity to piers P02 through P16 in accordance with the Preliminary Reference Design of the 87 Ave Elevated Guideway;
 2. a 2100 mm EYE sewer crossing 87 Avenue to the west of 172 Street. The sewer line consists of precast concrete pipe, and the depth to crown is about 9.2 m. The sewer line may be in close

proximity to pier P24 in accordance with the Preliminary Reference Design of the 87 Ave Elevated Guideway; and

3. a 1200 mm sanitary sewer near 165 Street. The sewer line consists of cast-in-place concrete oval section, and the depth to crown is about 26 m. The sewer line may be in close proximity to piers P38, P39 and P40 in accordance with the Preliminary Engineering design of the 87 Ave Elevated Guideway.
- B. For all locations where the minimum horizontal clear distance between an 87 Avenue Elevated Guideway pile and any portion of an existing sewer line is less than 4.0 m, Project Co shall, as a minimum:
1. physically locate the sewers through a drilling program or other method accepted by the City;
 2. drill a geotechnical test hole at the pile location to the full pile depth to characterize the geotechnical conditions prior to construction;
 - a. At completion, the test holes shall be fully grouted from bottom to top using cement slurry.
 3. provide full time monitoring during pile construction by a geotechnical engineer;
 - a. The geotechnical engineer shall maintain and provide a complete installation record for each pile installation, including descriptions and depths of the encountered soils and bedrock, groundwater level, size and depth of pile hole, length and diameter of temporary casing used (if used), condition/cleanliness of pile base, pile materials (concrete, rebar), etc.
 4. design and construct piles to maintain a minimum 1.5 m horizontal clear distance to any portion of an existing sewer line;
 5. design and construct pile bottom elevations to be at least 1.5 m below the lowest portion of an existing sewer line, taken at the cross-section intercepting the centre of the pile and being perpendicular to the applicable sewer line;
 - a. If belled piles are used, the top of the bell shall be at least 1.5 m below the lowest portion of an existing sewer line, taken at the cross-section intercepting the centre of the pile and being perpendicular to the applicable sewer line.
 6. install piles no more than 50 mm out of the horizontal positions shown on the applicable Final Design, in accordance with Section 4-4.2.6.3 [*Tolerances*];
 7. construct piles within a maximum verticality tolerance of 10 mm per vertical meter (1%); and
 8. stop drilling at a minimum clear depth of 2.0 m from the highest point of an existing sewer line, remove the drill, and use sonic caliper verticality testing equipment to confirm that the minimum horizontal clear distance to any portion of an existing sewer line will be at least 1.5 m:
 - a. resume pile drilling, at the reduced speed outlined in the **87 Avenue Elevated Guideway Sewer Lines Risk Mitigation Plan**, if adequate horizontal clearance is achieved; or
 - b. fill the hole and re-drill, if adequate horizontal clearance is not achieved.
- C. Submit, within 60 Business Days of the Effective Date, a plan (the "**87 Avenue Elevated Guideway Sewer Lines Risk Mitigation Plan**") outlining measures to mitigate the risks of pile construction damaging existing sewer lines, which shall include, as a minimum:
1. a description of the measures to be implemented to protect existing sewers from damage, based on the sewer location drilling program, the geotechnical information gathered from the

geotechnical test hole drilling, and the sewer condition assessment information provided by EPCOR Drainage;

2. any additional measures required near sewers identified by EPCOR Drainage to be in poor condition;
 3. measures to monitor vibrations during pile construction;
 4. the type of pile drilling equipment used, including means to report and control the verticality of the bore;
 5. measures to identify potentially problematic soil and/or groundwater conditions requiring, e.g., the use of temporary casings;
 6. measures to monitor geotechnical conditions during pile construction;
 7. reduced drilling speeds and applicable locations and depths;
 8. measures to monitor the pile drill bit as drilling progresses; and
 9. measures to confirm verticality is maintained during drilling.
- D. Submit, within 60 Business Days of the Effective Date, a plan (the “**87 Avenue Elevated Guideway Pile Construction Emergency Response Plan**”) that describes how Project Co will respond in the event pile construction damages an existing sewer line, which shall include, as a minimum:
1. immediate measures to be taken to minimize damage;
 2. immediate notification of the City and EPCOR Drainage;
 3. immediate evacuation of an area that is a minimum 50 m, measured perpendicular to the damaged sewer line alignment, by 300 m, measured parallel to the damaged sewer line alignment, centered on the damaged location;
 4. rescheduling of work activities to minimize delays to the overall project schedule, accounting for a maximum evacuation of the sewer line area of four (4) months; and
 5. methodology to complete pile construction following repair of the sewer line.

4-3.1.4 Infrastructure Requirements

- A. A dry fire standpipe system shall be provided determined in the Safety and Security Certification program, so as to ensure fire protection coverage along all parts of the 87 Avenue Elevated Guideway. This system shall:
1. be a single standpipe loop spanning across each affected 87 Avenue Elevated Guideway section, with an FDC provided at each end;
 2. consist of a DN150 galvanized carbon steel standpipe routed across the Elevated Guideway, 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.

4-3.2 STONY PLAIN ROAD BRIDGE

4-3.2.1 Existing Information

- A. Drawings for the Existing Stony Plain Road Bridge are included in the Disclosed Data.

4-3.2.2 Geometrics

4-3.2.2.1 General

- A. The Stony Plain Road Bridge shall be a single span structure with no piers. The span length shall be a minimum of 46 m.
- B. A minimum vertical clearance of 6 m shall be maintained over Groat Road.

4-3.2.2.2 Deck Cross Section

- A. The deck geometry shall at a minimum meet the curvature, lane widths, and cross slope of the Roadway and Track Final Design at the limits of the bridge.
- B. The Roadway lane width shall be in accordance with Section 3-2.11 [*Area Specific Requirements*] of this Schedule.

4-3.2.3 Durability

- A. For concrete within 300 mm of a Splash Zone Surface and for the following components, concrete shall be Class HPC:
 - 1. Decks, Trackway slabs, curbs, barriers, and sidewalks;
 - 2. Abutment roof slabs, approach slabs and sleeper slabs;
 - 3. Abutment diaphragms and upper 300 mm portions of abutment backwalls;
 - 4. Deck joint block outs; and
 - 5. MSE wall precast concrete fascia panels and cast-in-place copings.
- B. A Type 1c concrete sealer selected from the Alberta Transportation Products List shall be applied to all concrete surfaces with a Class 2, Class 5 or Class 6 finish.
 - 1. This shall include all concrete surfaces up to 600 mm below grade. Surfaces that are to receive a waterproofing membrane shall not have sealer applied.
 - 2. Sealer will not be required on the underside of the bridge deck between girders, however, the faces of the end diaphragms nearest the abutment backwalls, inside face of backwall and top surface of abutment seat, excluding bearing recess pockets, shall be sealed.
- C. The traffic lane surface material shall be an Asphalt Concrete Pavement (ACP) wearing surface. The ACP wearing surface shall be a minimum 80 mm thick.
- D. A waterproofing membrane shall be placed between the ACP wearing surface and the concrete deck surface in accordance with the standard details provided in Alberta Transportation Standard Drawings S1838-17, S1839-17, and S1840-17.

4-3.2.4 Sidewalk and SUP

- A. A sidewalk shall be constructed along the north side of Stony Plain Road with a minimum width of 4.2 m.
- B. A SUP shall be constructed along the south side of Stony Plain Road with a minimum width of 4.2 m.
- C. The sidewalk and SUP shall have a cross slope towards the roadway, and shall drain through 150 mm diameter drain holes at the base of the traffic separation barrier onto the roadway gutter.

4-3.2.5 Loading

- A. The sidewalk and SUP shall be designed to support the following loads:
 - 1. The maintenance vehicle load specified in CAN/CSA S6, Section 3.8.11;
 - 2. Pedestrian loads; and
 - 3. City of Edmonton maintenance vehicle ASPEN A-40 details of which are included in the Disclosed Data.

4-3.2.6 Geotechnical

- A. The stability of the east and west slopes of the Groat Ravine at the location of the Stony Plain Road Bridge shall be evaluated and appropriate stabilization measures implemented to ensure the integrity and serviceability of the completed Infrastructure over the required Design Service Life and that the Infrastructure operates in full compliance with the Project Requirements.
 - 1. The minimum bank areas requiring evaluation and improvement shall encompass the entire ravine slope from crest to toe in the east-west directions and for 10 m beyond either side of the Stony Plain Road Bridge in the north-south directions.
 - 2. The scope and extent of slope stabilization measures shall meet the minimum requirements described in this Section.
- B. The overall ground profile of the existing Groat Ravine slopes shall be preserved. Any profile changes associated with the headslopes of the Stony Plain Road Bridge shall not alter the overall ground profile of the existing Groat Ravine slopes.
- C. The stability of the east and west slopes of the Groat Ravine shall be evaluated using limit equilibrium and stress-strain analyses.
 - 1. The analyses shall address both shallow and deep-seated failure mechanisms and shall take into consideration the potential impacts of grading works (including construction of retaining walls), removal of vegetation cover, changes to natural drainage patterns, and rise in groundwater levels due to precipitation and/or known urban development on the slope stability.
 - 2. Slope stabilization measures shall be implemented to maintain a minimum long-term factor of safety (following the dissipation of construction induced pore water pressures) of 1.5 or the factor of safety of the existing slope prior to construction, whichever is greater.
- D. Horizontal drains and drainage wells shall not be relied upon, as part of any permanent slope stabilization measures, to achieve the target long-term slope factor of safety.
- E. The placement of additional fill onto the Groat Ravine slopes for temporary or permanent purposes shall be kept to a minimum and shall have no adverse effects on slope stability.

- F. Temporary Construction measures, Construction sequence and the erection of any components of the permanent Infrastructure shall not adversely affect the conditions of the Groat Ravine slopes and shall not result in any reduction in the slope factors of safety from the initial values prior to the commencement of Construction.
- G. A geotechnical report documenting the results of the slope stability assessment and demonstrating the slope stabilization measures needed to attain the target slope factor of safety taking into account the anticipated operations shall be submitted to the City as part of the Final Design of the Stony Plain Road Bridge.
- H. The requirements of the pre-construction condition survey of adjacent buildings described in Section 1-6 [*Pre-Construction Asset Condition Survey*] of this Schedule shall apply to the buildings around the Stony Plain Road Bridge.
- I. An instrumentation program shall be implemented to monitor excess pore water pressure and the vertical and lateral displacements of the Groat Ravine slopes, and the abutments and wingwalls of the Stony Plain Road Bridge during the Term.
1. As a minimum, the instrumentation shall include four vibrating wire piezometers (VWs), four shape arrays (SAAs), and six survey markers.
 2. The monitoring instruments shall be installed at critical locations/depths that allow the measuring of maximum values of settlement, lateral displacement, and pore water pressure.
 3. Monitoring of the VWs and SAAs shall be fully automated. All VWs and SAAs shall be connected to data logger(s) capable of transmitting the monitoring information wirelessly to a data management system with a web-based interface.
 4. During Construction, the monitoring results shall be used to provide early information regarding the impact of Construction on the slope stability and nearby structures and to adjust, in a timely manner, the Construction methodology to prevent degradation in the slope condition and damage to adjacent buildings, Structures, Infrastructure, or Utility Infrastructure.
 5. During the Construction Period, the data logger(s) shall be programmed to record measurements of the VWs and SAAs at maximum 3-hour intervals. Surveying of survey markers shall be performed weekly, or more frequently if deemed necessary by Project Co's geotechnical engineer based on the observed slope performance.
 6. After the Construction Period and until the end of the Term, the data logger(s) shall be programmed to record measurements of the VWs and SAAs at maximum 24-hour intervals. Surveying of survey markers shall be performed every three months, or more frequently if deemed necessary by Project Co's geotechnical engineer based on Good Industry Practice and observed slope performance.
 7. The results of slope monitoring shall be submitted to the City within one week of the date of measurements.
- J. After the Construction Period and until the end of the Term, the occurrence of an observed cumulative lateral displacement of 10 mm or a movement rate of 5 mm per year at any location within the slope areas specified in Section 4-3.2.6.A [*Geotechnical*] of this Schedule (including the abutments of the Stony Plain Road Bridge) shall require the implementation of a more comprehensive slope monitoring program, including additional instruments and increased monitoring frequency, and additional evaluations as follows.
1. A detailed review of the slope condition shall be undertaken by Project Co's geotechnical consultant.

2. The review shall include an assessment of the cause(s) of observed movements and the impact of the observed movements on the performance of the Stony Plain Road Bridge and the LRT Trackway, and the preparation of a plan of mitigation measures to arrest the slope movement should the magnitude of movement continue to increase.
- K. After the Construction Period and until the end of the Term, the occurrence of an observed cumulative lateral displacement of 20 mm, a movement rate of 10 mm per year, or where the rate of movement does not exhibit a diminishing trend over time at any location within the slope areas specified in Section 4-3.2.6.A [*Geotechnical*] of this Schedule (including the abutments of the Stony Plain Road Bridge) shall require the implementation of suitable mitigation measures to arrest the slope movement and prevent further degradation in the slope condition and damage to the abutments of the Stony Plain Road Bridge.
 - L. Any existing erosion features on the east and west slopes of the Groat Ravine within the limits specified in Section 4-3.2.6.A [*Geotechnical*] of this Schedule shall be repaired.
 1. Adequate protection measures shall be designed and implemented to prevent future erosion of the Groat Ravine slopes within the areas specified in Section 4-3.2.6.A [*Geotechnical*] of this Schedule.

4-3.2.7 Foundations

- A. The existing foundations shall be abandoned and not used in the design of the new structure.

4-3.2.8 Abutments

- A. The abutments shall be integral abutments and accommodate all structure design movements without the need of deck joints.
- B. The exposed abutment seat height shall be no greater than 1.2 m.
- C. Concrete slope protection is not required for the abutment headslopes unless it is required to satisfy the requirements in Section 4-3.2.6 [*Geotechnical*] of this Schedule.

4-3.2.9 Deck

- A. The deck shall be full depth cast-in-place concrete.

4-3.2.10 Barrier and Railing

- A. A TL-4 single slope concrete barrier with a steel bicycle railing shall separate the traffic lanes and pedestrian sidewalk.
 1. The extents of the separation barrier shall at minimum be equal to the extents of the pedestrian railing for the adjacent sidewalk or SUP.
- B. Notwithstanding the requirements in Section 2-4.5.3.3 B [*Collision Barriers*] of this Schedule, there shall be a steel bicycle railing installed on top of the concrete barrier.
 1. The distance from the top of steel rail to top of concrete shall be a minimum 0.37 m.
- C. The ends of the barrier shall have a smooth linear transition without any blunt edges that may be a snagging hazard for vehicles.
- D. A bicycle railing shall be installed along both outside edges of the bridge.

4-3.2.11 Drainage

- A. The bridge deck shall have a minimum longitudinal grade of 0.5% for deck drainage.
- B. The travel lanes shall have a minimum transverse grade of 2% away from the center of the bridge unless the bridge structure is super-elevated.
- C. The tops of the sidewalk and SUP shall slope 2% towards the roadway..
- D. Water shall be collected on the structure and discharged into the City drainage system.
 - 1. Water shall not be discharged onto Groat Road or the headslopes.

4-3.2.12 Trackway Slab

- A. The Trackway slab shall be constructed separately from the bridge deck and/or approach slabs but reinforced across the interface between the Trackway slab and deck and/or approach slabs.

4-3.2.13 Utility

- A. The duct bank shall not be anchored to the bridge girders.

4-3.2.14 Wildlife Crossing

- A. Provide Wildlife Crossing Benches at the Stony Plain Road Bridge in accordance with the following requirements:
 - 1. See Schedule 10 [*Environmental Requirements*] of this Schedule for functional dimensions.
 - 2. See Part 2 [*Sustainable Urban Integration*] of this Schedule for SUI and landscaping requirements.
 - 3. A Wildlife Crossing Bench shall be located at mid height of each abutment headslope.
 - 4. Each Wildlife Crossing Bench shall be constructed without adding additional earth fill to the existing headslopes.
 - 5. The horizontal surface of each Wildlife Crossing Bench shall consist of compacted clay with a minimum thickness of 300 mm.
 - 6. The stability of the headslope shall be evaluated and a retaining wall shall be constructed to support the headslope above the Wildlife Crossing Bench.
 - a. The scope and extent of any required slope stabilization measures shall meet the minimum requirements described in Section 4-1.9 [*Geotechnical*] of this Schedule.

4-3.2.15 Existing Sidewalk and Retaining Wall

- A. The existing retaining wall on the west side of Groat Road shall not be modified or disturbed.
- B. The existing sidewalk shall be expanded to cover the area that was previously occupied by the Existing Stony Plain Road Bridge piers.

4-3.3 ANTHONY HENDAY DRIVE LRT BRIDGE

4-3.3.1 Existing Information

- A. Drawings for the Existing Anthony Henday Drive Bridge and the existing retaining wall at the east side of the bridge are included in the Disclosed Data.

4-3.3.2 Geometrics

4-3.3.2.1 General

- A. The requirements of Alberta Transportation's Roadside Design Guide shall be met.
- B. Impacts to the existing roadside and median barrier systems on the Anthony Henday Drive, including ramps, shall be minimized.

4-3.3.2.2 Location

- A. The Anthony Henday Drive LRT Bridge shall be located on the south side of the Existing Anthony Henday Drive Bridge.

4-3.3.2.3 Clearances

- A. The minimum vertical clearance between Anthony Henday Drive (including northbound and southbound ramps onto Anthony Henday Drive) and the soffit of the bridge structure shall be 5.7 m or 0.2 m greater than the vertical clearance provided under adjacent structures over Anthony Henday Drive, whichever provides the larger vertical clearance.
 - 1. The minimum vertical clearance for cast-in-place slab or precast slab type structures, including single concrete trough girder structures shall be 6.0 m, unless the redundancy of the structure can be demonstrated through an engineering study that shall be submitted to the City as part of the Final Design of the Anthony Henday Drive LRT Bridge.
 - a. The engineering study shall confirm to the City's satisfaction, in its discretion, that in the event of a highway vehicle impact with the superstructure resulting in damage, the superstructure will continue to be capable of carrying service loads without risk of failure or collapse.
 - b. The extent of damage to be considered in the engineering study shall be dependent on the superstructure type chosen.
 - c. The study shall be independently checked in accordance with Section 6.9 [*Independent Checking*] in Schedule 4.
 - d. The study shall be authenticated by both the designer and checker in accordance with APEGA requirements.
 - 2. The vertical clearance of the bridge shall be posted. The method of determining the vertical clearance posting is as follows:
 - a. measure the minimum as-constructed vertical clearance between the roadway surface and lower bottom edge of the girder/structure within the roadway width (including shoulders) to the nearest centimetre (e.g. 5.37 m); then
 - b. subtract one decimetre for tolerance (e.g. 5.27 m); then
 - c. round down to the nearest decimetre (e.g. 5.20 m).

- d. The minimum allowable posted vertical clearance shall be 5.50 m, or 0.2 m less than the design minimum vertical clearance.
- B. The horizontal clear distance between the new bridge structure and the Existing Anthony Henday Drive Bridge structure shall be a minimum 10.0 m.
- C. The following horizontal clearance limits measured from the base of the edge of the EPCOR transmission power line tower:
 - 1. any permanent Structure shall be set back a minimum of 17 m; and
 - 2. the toe of earth fills shall be set back a minimum of 25 m.
- D. The minimum horizontal clearance provided by the Anthony Henday Drive LRT Bridge over Anthony Henday Drive shall meet or exceed the horizontal clearance (retaining wall to retaining wall) provided by the Existing Anthony Henday Drive Bridge.

4-3.3.2.4 Placement

- A. A pier may only be placed between the Anthony Henday Drive northbound and southbound lanes. The pier shall be in line with the Existing Anthony Henday Drive Bridge pier.
- B. The abutments of the Anthony Henday Drive LRT Bridge shall be located such that the exposed face of the abutment seats are in line with the exposed face of the Existing Anthony Henday Drive Bridge abutment seats.

4-3.3.2.5 Egress

- A. The superstructure shall provide sufficient width for egress to be on both the north and south side of the tracks.
- B. Egress shall be provided for along the entire length of the bridge that is confined by barriers.

4-3.3.3 Barriers

- A. Impacts to existing roadside and median barrier systems shall be minimized.
- B. New barrier systems along Anthony Henday Drive, if required, shall meet the requirements of Alberta Transportation's Roadside Design Guide.

4-3.3.4 Retaining Walls

- A. Retaining walls that are permanently required in the Final Design shall be designed as permanent walls.
- B. Temporary retaining walls that are to remain in place shall be buried a minimum of 600 mm below the final grade surface.

4-3.3.4.1 New Permanent Walls

- A. Permanent retaining walls that adjoin the existing retaining wall shall be designed to geometrically and aesthetically match the existing wall alignment such that the wall is continuous.
- B. The existing retaining wall shall be cut at an existing control joint location.

4-3.3.5 Geotechnical

4-3.3.5.1 General

- A. Where the approach fills at the ends of the Anthony Henday Drive LRT Bridge exceed 1 m in height, the Trackway shall be structurally supported on approach spans that are founded on piles.
- B. Piles shall be founded into competent bedrock.
- C. Settlement of substructures and approach fills of the Anthony Henday Drive LRT Bridge shall be evaluated using appropriate stress-strain analyses based on the results of site-specific geotechnical investigation and testing.
 - 1. Appropriate design and construction measures shall be implemented, as required, to limit differential settlement between substructures and approach fills to a maximum of 10 mm over the Design Service Life of the bridge (specified in Section 1-2.9 [*Design Service Life*] of this Schedule).
 - 2. The settlement assessment and recommended measures to control differential settlement to within the specified limit shall be included in a geotechnical report and submitted to the City as part of the Final Design of the Anthony Henday Drive LRT Bridge.
- D. Temporary Works, Construction sequence and the erection of any components of the Anthony Henday Drive LRT Bridge and associated Structures and Infrastructure shall not adversely affect the stability of substructures or approach embankments of the Existing Anthony Henday Drive Bridge.
 - 1. Appropriate measures shall be implemented such that the factors of safety of the headslopes, sideslopes and retaining walls of the Existing Anthony Henday Drive Bridge are not less than the initial values prior to the commencement of Construction.
 - 2. Construction-induced vertical and lateral displacements of the substructures, wing walls, and approach slabs of the Existing Anthony Henday Drive Bridge shall not exceed 5 mm in each direction, and shall not adversely affect the integrity or serviceability of the Existing Anthony Henday Drive Bridge and the 87 Avenue traffic lanes and sidewalks.
 - 3. Construction-induced vertical and lateral displacements of the approach embankments of the Existing Anthony Henday Drive Bridge shall not exceed 20 mm in each direction, and shall not adversely affect the integrity of serviceability of the Existing Anthony Henday Drive Bridge and the 87 Avenue traffic lanes and sidewalks.
- E. A geotechnical report demonstrating the temporary and permanent stabilization measures that will be implemented to maintain the stability and minimize the vertical and lateral displacements of substructures and approach embankments of the Existing Anthony Henday Drive Bridge shall be submitted to the City as part of the Final Design of the Anthony Henday Drive LRT Bridge.
- F. An instrumentation program to monitor the magnitude and rate of settlement and lateral displacement of the abutments and approach embankments of the Existing Anthony Henday Drive Bridge during the Construction Period shall be implemented.
 - 1. As a minimum, the instrumentation shall include four settlement plates, six survey markers, and three shape arrays (SAAs).
 - 2. The monitoring instruments shall be installed at critical locations/depths that allow the measuring of maximum values of settlement and lateral displacement.

3. Monitoring of the SAAs shall be fully automated. All SAAs shall be connected to a data logger capable of transmitting the monitoring information wirelessly to a data management system with a web-based interface.
 4. During the Construction Period, the data logger shall be programmed to record measurements of the SAAs at maximum 3-hour intervals. Surveying of settlement plates and survey markers shall be performed weekly, or more frequently if deemed necessary by Project Co's geotechnical engineer based on the observed response of substructures and approach embankments of the Existing Anthony Henday Drive Bridge.
 5. The monitoring results shall be submitted to the City within one week of the date of measurements.
 6. The monitoring results shall be used to provide early information regarding the impact of Construction on the stability of substructures and approach embankments of the Existing Anthony Henday Drive Bridge and to adjust, in a timely manner, the Construction methodology to prevent any damage to the Existing Anthony Henday Drive Bridge and its approach embankments.
- G. A pre-construction condition survey of the Existing Anthony Henday Drive Bridge and approach embankments shall be conducted in accordance with the requirements outlined in Section 1-6 [*Pre-Construction Asset Condition Survey*] of this Schedule.

4-3.3.5.2 Micropiles

- A. The use of micropiles shall not be permitted except for the area under the EPCOR powerlines bound by a 15 m horizontal offset on both sides of the utility centerline.

4-3.3.6 Approach Spans

- A. Approach spans are spans between the main bridge spans over Anthony Henday Drive and the point where the Trackway slab is cast directly on ground material.
- B. The approach spans shall be a minimum 8 m long and shall be cast-in-place concrete slab or precast concrete slab girders.
- C. The void beneath the approach spans and between pile supports shall be permanently enclosed.
 1. Access shall be provided for inspection purposes but shall not be accessible by the public.
- D. Approach spans shall not be post tensioned.

4-3.3.7 Drainage

- A. Water shall be collected on the Anthony Henday Drive LRT Bridge and discharged at the end of the approach spans into a concrete drain trough.
 1. Water shall not be discharged onto the Anthony Henday Drive roadway, Anthony Henday Drive median, and the existing Anthony Henday Drive Bridge, including retaining walls or the Structure headslopes.
- B. The concrete drain trough shall collect drainage from the bridge and direct it to the base of the side slopes without causing potential erosion of the slope material.
- C. Drainage between 87 Avenue Roadway and Trackway shall be directed longitudinally away from Anthony Henday Drive

4-3.3.8 Lighting

- A. Lighting requirement for Anthony Henday Drive, including ramps, under and adjacent to the Anthony Henday Drive LRT Bridge shall be in accordance with Alberta Transportation's Highway Lighting Guide and Design Bulletins #35 and #88.
- B. Any conduits required for wiring to under-bridge lighting systems shall be cast within the bridge piers and pier caps and shall not be routed through abutment ends.
- C. The conduit system shall be concealed and shall comprise rigid PVC conduit having a minimum trade size of 41 mm, together with industry-standard junction boxes and fittings.
 - 1. The system shall provide a continuous concrete-proof and weatherproof conduit arrangement from below ground to the top surface of each pier cap.
- D. Conduit shall be installed as follows:
 - 1. Conduits shall enter the bridge structure a minimum 1000 mm below finished ground elevation at the exterior of the pier as necessary and shall bend up to connect with a PVC junction box to be recessed on the exterior surface of the pier shaft 1000 mm above the finished ground elevation. Minimum clear inside dimensions of this PVC junction box shall be 150 mm x 150 mm x 150 mm.
 - a. The junction box may be larger if necessary, for the proper connection and bonding of bridge wiring to incoming supply cables.
 - b. The PVC junction box is to be set flush with the surface of the pier shaft and shall be fit with a gasketed weatherproof securable cover.
 - 2. A riser conduit shall extend up to a weatherproof PVC access junction box secreted in the top surface of the pier cap.
 - a. The junction box shall be sized for the number of luminaire conduits and wires to be accommodated at that point.
 - b. For bridge structures where a concrete pier diaphragm precludes placement of an access junction box in the top of the pier cap, it may, subject to the City's acceptance, be placed unobtrusively in the face of the pier cap near its top edge.
 - c. For structures with integral pier cap/diaphragms, the riser conduit shall extend into the pier cap/diaphragm and up to the weatherproof PVC access junction box secreted in the side surface of the pier cap/diaphragm.
 - 3. Additional weatherproof access junction boxes may be installed in the pier cap as required by the width of the bridge and the number of luminaires to be serviced.
 - a. These additional access junction boxes shall be supplied by a rigid PVC conduit not less than 27 mm trade size cast horizontally within the pier cap/diaphragm.
 - 4. Rigid conduits exiting the access junction boxes to service under-bridge luminaires shall be the minimum diameter required for the number and sizes of wires employed and the availability of attached support points, but not less than 16 mm trade size.
 - 5. All wiring to under-bridge luminaires shall be RW90 of appropriate number and gauge to comply with voltage drop limitations.

- a. A continuous ground wire shall be provided in all under-bridge lighting conduits to ensure the whole system is properly bonded.
- 6. Prior to the wiring being installed, all conduits shall be proven to be free and clear of obstructions.
- E. Under bridge lighting fixtures or any other lighting fixture shall include the ROAM Smart Node sensor and shall be connected to the existing ROAM Smart Node sensor system.

4-3.4 MACKINNON RAVINE PEDESTRIAN BRIDGE

4-3.4.1 Existing Information

- A. Drawings for the MacKinnon Ravine Pedestrian Bridge are included in the Disclosed Data.

4-3.4.1.2 General

- A. The first span from the north end of the MacKinnon Ravine Bridge shall be modified as required to provide a smooth transition from the bridge to the sidewalk.
- B. The bridge shall be independently supported from the MacKinnon Ravine Retaining Wall such that both structures are unaffected from their respective potential movement.

4-3.5 MACKINNON RAVINE RETAINING WALL

4-3.5.1 Geotechnical

- A. Earth fills for the widening of Stony Plain Road onto the north slope of the MacKinnon Ravine to accommodate the Infrastructure shall be supported with a retaining wall.
- B. The stability of the north slope of the MacKinnon Ravine at the location of the MacKinnon Ravine Retaining Wall shall be evaluated and stabilization measures implemented to ensure the integrity and serviceability of the completed Infrastructure over the required Design Service Life and that the Infrastructure operates in full compliance with the Project Requirements.
 - 1. The minimum bank area requiring evaluation and assessment shall encompass the entire ravine slope from crest to toe in the north-south direction and for the full length of the MacKinnon Ravine Retaining Wall in the east-west direction.
 - 2. The scope and extent of any required slope stabilization measures shall meet the minimum requirements described in Section 4-1.9 [*Geotechnical*] of this Schedule.
- C. The stability of the north slope of the MacKinnon Ravine shall be evaluated using limit equilibrium and stress-strain analyses.
 - 1. The analyses shall address both shallow and deep-seated failure mechanisms and shall account for the potential impacts of grading works, removal of vegetation cover, changes to natural drainage patterns, and rise in groundwater levels due to precipitation and seasonal effects on the slope stability.
 - 2. Slope stabilization measures shall be implemented as required to maintain a minimum long-term factor of safety (following the dissipation of construction induced pore water pressures) of 1.5 or the factor of safety of the existing slope prior to construction, whichever is greater.
- D. The minimum separation distance between the south edge of the Trackway slab and the face of the MacKinnon Ravine Retaining Wall shall be established such that the long term factor of safety of slip surfaces daylighting north of the southern edge of the Trackway slab is greater than 1.5, but shall not be less than 3 m.

- E. Horizontal drains and drainage wells shall not be relied upon, as part of any permanent slope stabilization measures, to achieve the target long-term slope factor of safety.
- F. The placement of additional fill onto the MacKinnon Ravine slopes for temporary or permanent purposes shall be kept to a minimum and shall have no adverse effects on slope stability.
 - 1. Temporary Works, Construction sequence and the erection of any components of the permanent Infrastructure shall not adversely affect the stability of the MacKinnon Ravine slopes and shall not result in any reduction in the slope factors of safety from the initial values prior to the commencement of Construction.
- G. Geotechnical report(s) demonstrating the slope stabilization measures needed to attain the target slope factors of safety for both temporary and permanent conditions taking into account the anticipated operations in accordance with the Operability and Maintainability Parameters, shall be submitted to the City as part of the Final Design of the MacKinnon Ravine Retaining Wall.
- H. An instrumentation program shall be implemented to monitor excess pore water pressure and the vertical and lateral displacements of the McKinnon Ravine north slope during the Construction Period.
 - 1. As a minimum, the instrumentation shall include two vibrating wire piezometers (VWs), two shape arrays (SAAs) and survey markers.
 - 2. The monitoring instruments shall be installed at critical locations/depths that allow the measuring of maximum values of settlement, lateral displacement, and pore water pressure.
 - 3. Monitoring of the VWs and SAAs shall be fully automated. All VWs and SAAs shall be connected to a data logger capable of transmitting the monitoring information wirelessly to a data management system with a web-based interface.
 - 4. During the Construction Period, the data logger shall be programmed to record measurements of the VWs and SAAs at maximum 3-hour intervals. Surveying of survey markers shall be performed weekly, or more frequently if deemed necessary by Project Co's geotechnical engineer based on the observed slope performance.
 - 5. The monitoring results shall be used to provide early information regarding the impact of Construction on the slope stability and to adjust, in a timely manner, the Construction methodology to prevent degradation in the slope condition and damage to adjacent buildings, Structures, Infrastructure, or Utility Infrastructure.
 - 6. The results of slope monitoring shall be submitted to the City within one week of the date of measurements.

SECTION 4-4– STRUCTURES CONSTRUCTION REQUIREMENTS

4-4.1 BACKFILL

4-4.1.1 General

- A. This Section 4-4.1 [Backfilling] sets out the requirements for construction of backfills associated with or forming part of a Structure, including minimum requirements for fill material, placement, compaction, and testing.
- B. Supply, placement, compaction and testing of fill materials shall conform to the requirements of the Valley Line West LRT Roadways Design and Construction Standards, unless stated otherwise in this Section 4-4.1 [Backfilling].

4-4.1.2 Materials

- A. Aggregate materials shall conform to the requirements in Tables 2.1.1, 2.1.2, and 2.1.3 of the Valley Line West LRT Roadways Design and Construction Standards Section 2.1 – Aggregates.
- B. In-situ fill material from excavations or imported fill from borrow sources shall be reviewed and approved by the Engineer of Record for the intended use.
- C. Fill materials shall be unfrozen, and free from ice, rocks larger than 75 mm, cinders, ashes, sods, refuse, Hazardous Substances or other deleterious materials.

4-4.1.3 Stockpiling

- A. Stockpile fill materials in designated areas. Protect fill materials from contamination.
- B. Stockpile granular materials in controlled manner to minimize segregation.
- C. Provide temporary erosion and sedimentation control measures to prevent soil erosion and discharge of soil-bearing runoff water or airborne dust to water bodies and adjacent properties and walkways, in accordance with Applicable Law.

4-4.1.4 Base/Subgrade Preparation

- A. Remove and dispose of all materials at the base of excavation / subgrade that are deemed unsuitable as specified in Valley Line West LRT Roadways Design and Construction Standards Section 02310 – Grading, including but not limited to peat, roots, stumps, topsoil, frozen soil, frost susceptible material, garbage, construction debris or any other material deemed unsuitable by the Field Review Monitor. The requirements specified in Section 15 [Contamination, Hazardous Substances, and Waste] and Section 18 [Stockpiles and Imported Fill] of Schedule 10 [Environmental Performance Requirements] apply to conducting this work.
- B. Proof Rolling of the base/subgrade shall be conducted in accordance with the Valley Line West LRT Roadways Design and Construction Standards Section 02345 – Proof Rolling, with the following amendments.
 - 1. There shall not be any discernable rutting or deflection during proof roll. Rutting and deflection requirements shall conform to the following requirements:
 - a. Clay Material: rutting or deflection of finished surface shall not exceed 10 mm.
 - b. Aggregate Material: rutting or deflection of finished surface shall not exceed 5 mm.

2. Rutting and/or deflection in excess of limits above shall be considered a failure and shall require the base/subgrade to be reworked and compacted to meet density and performance requirements.
3. After remedial work is performed, additional proof rolls shall be performed to ensure the material conforms to the limits above.

4-4.1.5 Fill Placement and Compaction

- A. Required compaction densities shall be specified as percentages of maximum dry densities obtained from standard proctor laboratory tests in accordance with ASTM D698 (Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort).
- B. Prior to placing any fill, the excavation base shall be scarified to a minimum depth of 150 mm and compacted to a minimum of 95 percent of the standard proctor maximum dry density, as determined by ASTM D698.
- C. Place backfill material in uniform lifts not exceeding 150 mm compacted thickness up to the grades indicated on the Final Design. Compact each lift before placing the subsequent lift.
- D. Compact each lift to the minimum requirements specified in the Valley Line West LRT Roadways Design and Construction Standards, or to higher densities as specified by the Engineer of Record based on Good Industry Practice. Under no circumstances shall the compacted field density be less than 98 percent of the standard proctor maximum dry density.
- E. Backfill material shall be compacted at moisture contents within ± 2 percent of the optimum moisture content, as determined from standard proctor laboratory tests in accordance with ASTM D698.
- F. Backfilling shall not be permitted when the average air temperature is expected to be below 0°C. The air temperature shall be the temperature reported by Environment Canada.
- G. The attained degree of compaction shall be verified via field density tests at a minimum frequency of one test for each 1000 m² of compacted lift, with a minimum of one test per lift per day. Field density tests shall be conducted in accordance with the requirements of ASTM D2922 test method.
- H. A minimum of one laboratory standard proctor test (ASTM D698) shall be conducted per 500 m³ of backfill material to be placed on site.

4-4.2 PILING

4-4.2.1 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 and OCS foundations, including minimum requirements for quality, supply, placement, curing, and testing of the piles.

4-4.2.2 Materials

4-4.2.2.1 Steel

- A. Mill certificates for steel piles shall be obtained prior to pile installation and shall meet the requirements in Section 4-4.10.3.4 [*Mill Certificates*] of this Schedule.

4-4.2.2.2 Concrete

- A. Pile Concrete shall comply with the requirements of Section 4-4.5 [*Cast-In-Place Concrete*] of this Schedule.

4-4.2.2.3 Concrete Reinforcement

- A. Concrete reinforcement shall comply with the requirements of Section 4-4.9 [*Concrete Reinforcement*] of this Schedule.

4-4.2.3 Galvanizing

- A. Galvanizing of steel piling, when required in the Final Design, 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 and tested for adhesion.
- 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.

4-4.2.4 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.

4-4.2.5 Driven Steel Piles

4-4.2.5.1 Equipment

- A. Pile driving equipment shall be sized such that piles can be driven to the specified load 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 (PDA) 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.
 - 5. Pile driving equipment shall use fixed leads. The use of hanging leads shall not be permitted.
- 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.

4-4.2.5.2 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.
- E. At the completion of each driven pile within a foundation element, a control elevation shall be established on the pile to determine if heave has occurred after all piles for the foundation element have been driven.
 1. Piles that heave shall be re-driven to the depth and capacity required.

4-4.2.5.3 Pile Driving Plan

- A. A pile driving plan shall be submitted to the City prior to commencement of pile installation work. The pile driving plan shall include, as a minimum, the following items:
 1. Specifications, setup and configuration of pile driving equipment, including:
 - a. Hammer Data, including the hammer type, manufacturer, model number, serial number, maximum rated energy and range of operating energy, stroke at maximum rated energy, range of operating stroke, ram weight and modifications;
 - b. Details of onboard equipment capable of energy monitoring;
 - c. Striker plate data, including the weight, diameter, thickness and composition;
 - d. Hammer cushion data, including the manufacturer, area thickness per plate, number of plates, total thickness and composition;
 - e. Helmet data, including weight and composition; and
 - f. Pile cushion data, including material, area, thickness per sheet, number of sheets and total thickness of cushion.
 2. Driving methods, procedure and driving sequence.
 3. Details and drawings of driving frames.
 4. Pile driving tools and accessories.
 5. Pile lengths, splicing details, and anticipated splicing locations.
 6. List of welders and proof of certification.
 7. Welding procedures.

- 8. Environmental plan that includes seepage water management strategy for open ended pipe piles.
 - 9. Cold weather protection methods.
 - 10. PDA testing procedures, contact information, and qualifications of independent testing agency.
- B. If during the course of Construction the required pile set criteria and tip elevations are not achieved, a revised pile driving plan shall be submitted to the City before any further pile driving continues.

4-4.2.5.4 Pile Driving

- A. Steel driving frames shall be used for driven pile installations.
- B. Piles shall be driven to the tip elevations and the load capacities specified on the applicable Final Design.
 - 1. Where practical driving refusal is encountered, the pile(s) may be terminated at a shallower elevation determined by the Engineer of Record that achieves the required pile stability and the specified minimum axial and lateral load capacities.
 - 2. If the required capacity at the design tip elevation is not achieved, restrike tests may be performed after an appropriate waiting time of at least one week to confirm the pile capacity.
 - a. Alternatively, the pile may be driven further to a deeper elevation and then assessed again to confirm that the required capacity is achieved.
- C. 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 the Engineer of Record for the given pile section and length, piling equipment, soil conditions, and required pile load capacity.
 - 1. The driving termination criteria shall be determined using wave equation analyses and verified using pile driving analyzer (PDA) 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.
- D. Access to all foundation piles shall be maintained until all PDA tests have been completed.
- E. 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.
- F. 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.
- G. Piles shall be cut off level at the required elevations shown on the applicable Final Design.
- H. The soil plug inside of an open-ended pipe pile shall not be disturbed and the remaining space shall be filled with Pile Concrete.
- I. When concrete infill of open-ended pipe piles is required for structural resistance, the following shall apply.

1. The removal of the soil plug inside the pipe pile shall be terminated a minimum of 2 m above the pile toe. For example, a native soil plug of a minimum height of 2 m shall be maintained at the toe of the pipe piles.
 2. All loose material and all material adhering to the inside walls of the piles shall be removed.
- J. Open pipe piles shall be covered until concrete is placed.
- K. Driving of any type of piles within 3 m of a pipe pile that contains concrete shall not be undertaken until the concrete has been placed and cured for a minimum of 3 days.

4-4.2.5.5 Steel Pile Splices

- A. Full strength pile splices shall be used unless otherwise specified 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 4-4.2.3 [*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.
- 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.

4-4.2.5.6 Defective Piles

- A. A pile damaged by driving or driven out of proper location shall be considered a 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. The top of the deficient pile shall be cut to a minimum of 300 mm below the design cut off elevation.
- 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.

4-4.2.6 Drilled Cast-in-place Concrete Piles

4-4.2.6.1 Drilling Pile Holes

- A. Only rotary type equipment shall be used. Hydraulic oscillating equipment will be permitted for the installation of temporary or permanent casings. Continuous flight auger equipment shall not be permitted.

- B. 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.
- C. The drilling of pile holes shall not proceed if adjacent piles may be damaged due to the effects of vibration or other reasons.
- D. 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.
 - 3. If a "dry" pile hole cannot be achieved, the pile shall be filled with concrete by tremie methods.
- E. Removal of temporary casing shall not damage the Pile Concrete.
 - 1. Temporary casing, if used in drilling operations, shall be removed from the hole as the Pile Concrete is being placed and before initial set of the concrete.
 - 2. The bottom of the casing shall be maintained below the top of the concrete during casing withdrawal and concrete placing operations.
 - 3. Separation of the concrete during casing withdrawal shall be avoided. Hammering or vibrating the casing to facilitate withdrawal operations shall not be permitted.
- F. Drilled pile holes shall extend to the elevations shown on the applicable Final Design.
 - 1. Pile reinforcement and Pile Concrete shall not be placed until the pile hole is deemed acceptable by the Field Review Monitor.
 - 2. The presence of any gas shall be determined and appropriate means and equipment shall be employed to ensure a safe work site.

4-4.2.6.2 Inspection and Testing

- A. The bottom of the excavated pile hole shall be inspected with a down the hole video camera equipped with visual measurement scale to determine the depth of any loose sediments at the base.
 - 1. The camera shall be capable of capturing a still image or record a video at a minimum resolution of 1080p.
 - 2. The walls and bottoms of the pile holes shall be cleaned to remove all loose and extraneous material.
 - 3. The bottom of the pile shall be clearly visible to determine the cleanliness of the hole.
- B. The inspection device/camera shall be capable of verifying the cleanliness of the base in all expected piling conditions, including under water or drilling fluid.

4-4.2.6.3 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.

4-4.2.6.4 Concrete Reinforcement Placement

- A. Concrete reinforcement 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 concrete reinforcement to ensure the concrete reinforcement is kept centered in the concrete when placing Pile Concrete.

4-4.2.6.5 Concrete Placement

- A. Under no circumstances shall the pile holes be left open for periods longer than 2 hours.
- B. If delay in placement of concrete reinforcement 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 the Engineer of Record.
- C. Forms shall be used to maintain the specified dimensions of the portions of concrete piles above ground level.
- D. If a dry pile hole cannot be achieved in accordance with the requirements of Section 4-4.2.6 [*Drilled Cast-in-place Concrete Piles*] of this Schedule, Pile Concrete shall be placed in accordance with the requirements of Section 4-4.5.13.3 [*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 4-4.5.13.3 [*Concrete Placed Under Water*] of this Schedule.

The concrete below ground specified in this section is exempt from the requirements of Section 4-4.5.16 [*Concreting in Cold Weather*] of this Schedule.

When the temperature of the ground against which Pile Concrete is placed is below 0 degrees Celsius the concrete shall be protected from heat loss as follows.

- 2. The pile hole diameter shall be oversized by 100 mm to below the design frost depth.
- 3. 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 in accordance with Section 4-4.5.18 [*Curing Concrete*] of this Schedule for a minimum period of seven days.
- 4. If the top of the pile extends above the ground surface it shall be protected in accordance with Section 4-4.5.16 [*Concreting in Cold Weather*] of this Schedule.
- 5. Raising the temperature of concrete reinforcement which concrete will be placed against to a temperature of between 5 and 20 degrees Celsius before placing any concrete.

4-4.2.7 Pile Capacity Testing

4-4.2.7.1 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.

1. Osterberg tests shall conform to ASTM D1143 Standard Test Method for Piles under Static Axial Load using the Quick Load Test Method for Individual Piles.
 2. Statnamic tests shall conform to ASTM D7383 Standard Test Methods for Axial Compressive Force Pulse (Rapid) Testing of Deep Foundations.
- C. If higher geotechnical resistance factors are to be used in the design of a Structure, they shall be justified as follows:
1. a minimum of one pile load test shall be performed for each Structure;
 2. for Structures longer than 500 m, a minimum of one pile load test shall be performed for each 500 m long segment of the Structure; and
 3. the frequency of testing shall be increased as necessary to account for changing soil conditions, pile sections and types and construction methods.

4-4.2.7.2 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 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, the greater of 2 piles or 15% 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 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 initial driving and upon re-strike when re-striking is required.

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 the Engineer of Record.
 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, and such report shall be submitted to the City promptly thereafter.
- G. The PDA testing agency shall complete a final testing report, complying with ASTM D4945, within seven Business Days of PDA testing, and such report shall be submitted to the City promptly thereafter. 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 determine the requirements for modification of pile driving procedures or equipment, and for pile acceptance.

4-4.3 MICROPILES

4-4.3.1 General

- A. This Section 4-4.3 [*Micropiles*] sets out the Construction requirements for micropiles forming part of a Structure, including minimum requirements for supply, installation, grouting and testing.

4-4.3.2 Engineering Data

4-4.3.2.1 Related Project Construction Requirements

- A. Section 4-4.5 [*Cast-In-Place Concrete*] of this Schedule.
- B. Section 4-4.9 [*Concrete Reinforcement*] of this Schedule.

C. Section 4-4.10 [*Structural Steel*] of this Schedule.

4-4.3.2.2 Shop Drawings

- A. Shop drawings showing fabrication and installation details of the micropiles shall be submitted to the City. The shop drawings shall include the following:
1. batter, length, and diameter of micropile;
 2. type, length and size of the micropile steel bar;
 3. type, length, diameter, wall thickness, and elevation of permanent steel casing (if applicable);
 4. required ultimate geotechnical resistance of micropile;
 5. anchorage connection details to the Structure footing(s);
 6. corrosion protection system for the reinforcing bar, couplers and anchorage components;
 7. type and spacing of reinforcing bar centralizers and spacers; and
 8. grout mix design and grout placement procedures, including post-grouting details (if applicable).

4-4.3.2.3 Mill Certificates

- A. Mill certificates for the micropile steel components (e.g. steel bars, couplers, casings, plates), including the ultimate strength, yield strength, load/elongation curves, and composition, shall be provided to the City.
- B. Manufacturer certificates of compliance for the micropile centralizers and spacers shall be provided to the City.
- C. Mill test reports originating from a mill outside of Canada or the United States of America shall meet the requirements of Section 4-4.10.3.4 [*Mill Certificates*] of this Schedule.

4-4.3.3 Materials

- A. Materials for micropiles shall comply with Section 4-1.6.9 [*Micropiles*] and Section 4-1.7.7 [*Micropile Corrosion Protection*] and FHWA-NHI-05-039.
- B. Reinforcing bar encapsulation (for double corrosion protection) shall be shop fabricated using high-density, corrugated polyethylene tubing conforming to the requirements of ASTM D3350 with a nominal wall thickness of 0.8 mm. The inside annulus between the reinforcing bar and the encapsulating tube shall be a minimum of 5 mm and be fully grouted with non-shrink grout.
- C. Steel bar couplers shall develop 120 percent of the specified tensile yield strength of the bar as certified by the manufacturer.
- D. Centralizers and spacers shall be fabricated from Schedule 40 PVC pipe or tube, steel, or material non-detrimental to the steel bar. The use of wood shall not be permitted.
- E. Permanent steel casing, if used, shall conform to the requirements of API, Grade N80.
- F. Micropile grout shall be neat cement or sand/cement mixture with a minimum 3-day compressive strength of 21 MPa and a minimum 28-day compressive strength of 35 MPa in accordance with ASTM C109.

- G. Admixtures, if used, shall meet the requirements of ASTM C494, and shall be compatible with the grout. The use of accelerators shall not be permitted. Expansive admixtures may only be used for filling anchorage covers.

4-4.3.4 Installation

4-4.3.4.1 General

- A. The entity performing any micropiling shall be experienced in the construction and load testing of micropiles and have successfully constructed at least 5 projects in the last 5 years involving construction totaling at least 500 micropiles of similar capacity to those required in the Final Design.
- B. Micropile materials, including steel bars, anchorage components, cement and admixtures, shall be handled, stored and installed in such a manner as to avoid damage, corrosion or contamination with dirt or deleterious substances, in accordance with the requirements of FHWA-NHI-05-039.
- C. The use of drilling fluids (such as bentonite slurry) to advance micropile holes shall not be permitted.

4-4.3.4.2 Installation Tolerances

- A. Micropiles shall be installed at the locations, elevations, and orientations shown on the applicable Final Design.
- B. The centers of micropiles shall not deviate from the horizontal locations shown on the applicable Final Design by more than 50 mm in any direction.
- C. Micropiles shall not deviate by more than 15 mm per metre from the vertical or from the batter shown on the applicable Final Design.
- D. Micropile reinforcing bars shall be placed within 20 mm of the center of the drilled hole.
- E. The cut-off elevations of micropiles shall be within plus or minus 25 mm of the elevations shown on the applicable Final Design.
- F. Micropiles that do not satisfy the specified tolerances shall be replaced.

4-4.3.4.3 Drilling

- A. The micropile drill hole shall be open along its full length prior to placing the reinforcing bar and the grout. Where the reinforcing bar cannot be installed to the design depth easily, the micropile hole shall be re-drilled and adequately supported to facilitate bar insertion.

4-4.3.4.4 Grouting

- A. Grouting of micropiles shall comply with FHWA-NHI-05-039
- B. Grouting of the drill hole after the installation of the steel bar shall be completed within two hours of completion of drilling and shall be done in one continuous operation. Cold joints in the grout column shall not be permitted.
- C. The grout shall be free of lumps and undispersed cement.
- D. Admixtures, if used, shall be mixed in accordance with the manufacturer's recommendations.
- E. The compressive strength of micropile grout shall be tested in accordance with ASTM C109 at a frequency of no less than one test for every 5 cubic meters of grout placed. Irrespective of the volume

of grout placed, a minimum of one test shall be performed on a set of grout cubes from each grout plant on each day of operation.

- F. 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.
 - 2. The grout shall be placed within one hour of mixing.
- G. A positive displacement grout pump shall be used.
 - 1. The pump shall be equipped with a pressure gauge to monitor grout pressure. A second pressure gauge shall be placed at the point of injection at the micropile top.
 - 2. The pressure gauges shall be capable of measuring pressures of a least 1.0 MPa or twice the actual grout pressures required, whichever is greater.

4-4.3.4.5 Installation Records

- A. An installation record shall be prepared for each micropile and shall include:
 - 1. a unique reference number for each micropile;
 - 2. the date of installation and weather conditions;
 - 3. soil and groundwater conditions encountered during drilling;
 - 4. the as-built location, and batter of micropile;
 - 5. final cut-off and tip elevations;
 - 6. the as-built length and diameter of micropile;
 - 7. grade, size, and length of the steel bar;
 - 8. top and tip elevations, grade, diameter, wall thickness, and length of permanent steel casing (if applicable); and
 - 9. quantity of grout, grout pressure and, if applicable, details of post-grouting stages (number of stages, date/time of each stage, grout volume and pressure, etc.).

4-4.3.5 Load Testing

- A. The load carrying capacity and overall performance of micropiles, including creep behavior, shall be evaluated for acceptance using verification tests on sacrificial pre-production micropiles and proof tests on production micropiles, in accordance with the recommendations of FHWA-NHI-05-039.
- B. A minimum of one verification test shall be performed in each anticipated major soil/rock strata at the location of each Structure. For lineal structures, a minimum of one verification test shall be performed for each 500 m long segment of the Structure. The diameter, embedment depth, and equipment and installation procedures for the verification test micropiles shall be identical to those specified for the production micropiles. The test setup, testing procedures and results of verification tests shall be reviewed and accepted by the Engineer of Record prior to the installation of production micropiles. Verification test micropiles shall be sacrificial and shall not be incorporated as production micropiles.
- C. Proof tests shall be carried out on a minimum of 5% of the production micropiles, with at least one proof test per each Structure foundation. The frequency of proof tests shall be increased where

variable subsurface soil conditions are anticipated or where proof tests on production micropiles in the same structure failed to meet the test acceptance criteria.

- D. Verification test micropiles shall be loaded incrementally in accordance with the loading schedule in Table 7.1 of FHWA-NHI-05-039. Proof test micropiles shall be loaded incrementally in accordance with the loading schedule in Table 7.2 of FHWA-NHI-05-039. The micropile movements shall be recorded at each load increment. For the purposes of testing, the "Design Load" in Tables 7.1 and 7.2 of FHWA-NHI-05-039 shall be taken as the governing Serviceability Limit State (SLS) load detailed on the applicable Final Design.
- E. The travel of testing equipment (e.g. jack ram, dial gauges, transducers, etc.) shall be sufficient to allow the test to be completed without resetting the equipment.
- F. Measurements of applied loads during verification and proof tests shall be recorded using load cell and jack pressure gauge calibrated within 6 months prior to testing. The load cell shall be properly aligned with the axis of the micropile and jack.
- G. Acceptance criteria for verification and proof tests shall be in accordance with the requirements of FHWA-NHI-05-039. The following additional criteria shall also be met for both tests:
 - 1. the axial movement at the top of the test micropile when subjected to compression or tension load equal to 1.6 times the "Design Load" shall not exceed 25 mm.
 - 2. the axial movement at the top of the test micropile at 1.0 times the "Design Load" shall meet the design criteria for the Structure as determined by the Engineer of Record.
 - 3. the creep rate throughout the creep load hold period shall be constant or decreasing.
- H. Micropiles not meeting the acceptance criteria shall necessitate modification of the design, the construction procedure, or both. These modifications may include installing replacement micropiles, incorporating the micropiles at a reduced load capacity of not more than 50 percent of the maximum load attained during testing, postgrouting, modifying the installation methods, increasing the bond length, or changing the micropile type. Any modifications shall require additional verification and proof testing.

4-4.4 GROUND ANCHORS

4-4.4.1 General

- A. This Section 4-4.4 [*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.

4-4.4.2 Engineering Data

4-4.4.2.1 Shop Drawings

- A. Shop drawings showing fabrication and installation details of the ground anchors shall be 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.

4-4.4.2.2 Mill Certificates

- A. Mill certificates for the tendons, including load/elongation curves, shall be provided to the City.
- B. Mill certificates for the anchorages shall be provided to the City.
- C. Mill test reports originating from a mill outside of Canada or the United States of America shall meet the requirements of Section 4-4.10.3.4 [*Mill Certificates*] of this Schedule.

4-4.4.3 Materials

- A. Material for ground anchors shall comply with PTI DC35.1, and Section 4-2.4.2 [*Retaining Walls with Ground Anchors*] and Section 4-1.7.6 [*Ground Anchor Corrosion Protection*] of this Schedule.
- B. Admixtures, if used, shall meet the requirements of ASTM C494 and PTI M55.1, and shall be compatible with the grout, any admixtures, and tendon components. The use of accelerators shall not be permitted. Expansive admixtures may only be used for filling sealed encapsulations, trumpets, anchorage covers

4-4.4.4 Installation

4-4.4.4.1 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.

4-4.4.4.2 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.

4-4.4.4.3 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.

4-4.4.4.4 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. A minimum of one pre-production test shall be performed in each anticipated major soil/rock strata at the location of each Structure. Pre-production tests shall satisfy the minimum requirements of the performance test. The test setup, testing procedures and results of pre-production tests shall be reviewed and accepted by the Engineer of Record prior to the installation of production ground anchors.
- C. 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.
- D. 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.
- E. 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.
- F. 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.

4-4.4.5 Ground Anchor Installation Records

- A. A ground anchor installation record shall be provided to the City for each ground anchor installed and shall include:
 1. a unique reference number for each ground anchor;
 2. the date of installation and weather conditions;
 3. the Field Review Monitor's name;
 4. the as-built 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.

4-4.4.6 Basis for Rejection

- A. A Corrective Action Plan shall be submitted to the City in the event of any of the following circumstances:
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.

4-4.5 CAST-IN-PLACE CONCRETE

4-4.5.1 General

- A. This Section 4-4.5 [*Cast-In-Place Concrete*] sets out the requirements for all cast-in-place concrete, which includes cementitious products such as grout and concrete patching materials, 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 4-4.8 [*Concrete Segmental Construction*] of this Schedule.
 2. Concrete elements that are cast-in-place but not in its final location shall meet the following additional requirements:
 - a. Sections 4-4.6.10 [*Dimensional Tolerances*], 4-4.6.14 [*Handling and Storage*], 4-4.6.15 [*Erection of Precast Concrete Units*] of this Schedule; and
 - b. Shall be fabricated in a production facility that is certified by the Canadian Precast Concrete Quality Assurance (CPCQA) Certification Program.

4-4.5.2 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:

- C. Materials originating from outside Canada or the United States of America intended for use in the production of concrete shall be tested to the required standard by a laboratory in Canada certified to CSA A283.

4-4.5.2.1 Portland Cement

- A. Portland cement shall comply with CAN/CSA A3001. General use (Normal), Type GU, shall be used unless otherwise specified herein.
 - 1. 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.

4-4.5.2.2 Water

- A. Water for mixing concrete, concrete patching materials, 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.

4-4.5.2.3 Aggregates

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

4-4.5.2.4 Admixtures

- A. Admixtures shall meet the following requirements.
 - 1. Admixtures shall be compatible with all mix constituents.
 - 2. Water reducing admixtures and superplastizing admixtures shall comply with ASTM C494.
 - 3. Air entraining admixtures shall comply with ASTM C260.
 - 4. Hydration stabilizing admixtures shall comply with ASTM C494 for Type B and/or Type D water reducing and retarding admixtures.
 - a. Hydration stabilizing admixtures are only permitted as follows:
 - i. when haul times are reasonably expected to exceed the times specified in Section 4-4.5.7 [*Time of Placing*] of this Schedule;
 - ii. where hydration stabilization is required due to mass concrete placement considerations; and
 - iii. where Project Co has prepared and submitted to the City a report justifying the use of such admixtures.
 - 5. Calcium chloride, air-reducing admixtures or accelerating admixtures are not permitted.
 - 6. Anti-washout admixtures shall conform to the US Army Corps of Engineers CRD-C 661.
- B. Admixtures not noted above shall not be permitted without the prior written consent of the City, in its discretion.

4-4.5.2.5 Silica Fume

- A. Silica fume shall comply with CAN/CSA A3001 for a Type SF supplementary cementing material, with a minimum SiO₂ content of 85%, a maximum loss on ignition of 10% and maximum SO₃ content of 1%.
- B. A compatible superplasticizing admixture shall be used together with the silica fume.

4-4.5.2.6 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.

4-4.5.2.7 Fly Ash

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

4-4.5.2.8 Grout

- A. Grout and concrete patching materials shall be packaged in waterproof containers with the production date and shelf life of the material shown.

4-4.5.3 Storage of Materials

- A. All constituent materials for cast-in-place concrete shall be stored separately 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 them from moisture.
 - 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 level and firm.
 - 3. If aggregates are placed directly on the ground, aggregates within 150 mm of the ground level shall not be used and this material shall remain undisturbed to avoid contaminating the aggregate being used.
 - 4. Aggregates shall be handled in a manner that prevents segregation.

4-4.5.4 Concrete Mix Design and Aggregate Tests

4-4.5.4.1 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 to the City a concrete mix design review letter, together with applicable material quality compliance test reports, for each class of concrete to the City before first placement of such concrete.
 - 1. The mix design review letters shall include the following items:
 - a. Evaluation and summary of all mix constituents;
 - b. Material test reports;
 - c. Mix proportion quantities;
 - d. Trial batch results (if applicable);
 - e. Mass concrete design considerations (if applicable); and
 - f. Portable batch plant batching procedures (if applicable).
 - 2. Each concrete mix design review letter, 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.
 - 3. Where concrete will be placed by concrete pump, the concrete mix shall be specifically designed for pumping.
 - 4. Where concrete will be placed under water, the concrete mix shall be specifically designed for placing concrete under water.
 - a. An excess of 15% above the cement quantity required by the equivalent conventionally placed concrete mix design shall be provided.
 - b. 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 4-4.5.4.1.
- D. Unless otherwise noted, submission of a concrete mix design review letter is not required for prebagged grouts and concrete patching materials provided they are mixed in strict accordance with the manufacturer’s recommendations.

4-4.5.4.2 Aggregate Tests

- A. A break in production of a particular class of concrete shall not constitute the need for additional testing if the following items are submitted to the City:
- a. Aggregate sieve analysis;
 - b. Organic impurities in sands for concrete;
 - c. Petrographic examination of aggregates; and
 - d. Letter of evaluation prepared by the professional signatory of the mix design review letter indicating that the material initially tested is still representative.
- 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). Clauses 4.2.3.3.2 (a) and (b) of CAN/CSA A23.1-14 shall not apply.
 2. Testing in accordance with CSA A23.3-2A and 5A shall not have more than 3.0% passing an 80 μm sieve.
- 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 24 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. In the absence of test data, the aggregate shall be considered highly reactive.
- D. Petrographic analysis on the coarse and fine aggregates shall be performed in accordance with CAN/CSA A23.2-15A by experienced personnel employed by a CAN/CSA A283 certified laboratory. The petrographic analysis report shall be signed and sealed by either a Professional Engineer, a Professional Geologist, or a Geological Engineer.
1. The (weighted) petrographic number of the coarse aggregates shall not exceed 130, and the ironstone content shall not exceed 0.8%.
 2. Ironstone content in fine aggregate (material retained on the 2.5 mm sieve) shall not exceed 1.5% by total dry mass of fine aggregate for all classes of concrete in Table 4-1.6.1-1 [*Concrete Classes*] except Pile Concrete.
- E. Material test reports shall be current according to the required frequency of analysis in Table 4-4.5.4-1 [*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 to the City.

Table 4-4.5.4-1 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, A23.2-13A (Procedure A), A23.2-23A, A23.2-24A, A23.2-29A	180
Potential expansivity of aggregates	CAN/CSA A23.2-14A	24 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 4-4.5.4-1 [*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 or coarse aggregates.

4-4.5.4.3 Trial Batches

- A. Prior to first placement of each different mix design of cast-in-place concrete containing silica fume or hydration stabilizing admixtures, or of Class SCC concrete, 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 35 days prior to placement of concrete at Site.
 2. Each trial batch shall be a minimum of 3 m³ 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. slump retention after 50 minutes shall be at least 50% of that measured at 15 minutes;
 - c. at 70 minutes after batching, samples shall be cast to determine compressive strength at 7 and 28 days;
 - d. rapid chloride ion penetration, and hardened air void spacing analysis shall be carried out in accordance with the requirements of Section 4-1.6.2 [*Additional Requirements for Concrete Containing Silica Fume*] of this Schedule;

- e. shrinkage of the trial batch concrete shall be measured in accordance with CAN/CSA A23.2-21C; and
 - f. trial batch concrete shall be placed into a 4.5 m x 4.5 m x 0.15 m thick form on grade to assess the mix's workability and finishability.
4. For concrete containing hydration stabilizing admixtures:
- a. The time of initial and final set shall be determined;
 - b. workability including slump and air content shall be assessed in accordance with ASTM C403 at 15 minutes after batching, quarter points of the design hydration stabilization period and at the design period;
 - c. hardened air void spacing analysis shall be carried out in accordance with the requirements of Section 4-1.6.2 [*Additional Requirements for Concrete Containing Silica Fume*] of this Schedule;
 - d. samples shall be cast to determine compressive strength at 3, 7, and 28 days; and
 - e. trial batch(es) containing silica fume shall also meet the requirements of Section 4-1.6.2 [*Additional Requirements for Concrete Containing Silica Fume*] of this Schedule for rapid chloride ion penetration.
5. Trial batches for Class SCC concrete:
- a. fresh concrete shall be tested in accordance with the tests identified in Table 4-4.5.4-2 [*Fresh Class SCC Concrete Parameters*].
 - b. hardened 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.
6. For Class SCC Concrete mixes:
- a. the requirements of CSA A23.1, Table 22 shall be met;
 - b. the Maximum Hardened Visual Stability Index (HVS_I), determined in accordance with ASTM C1611 shall be 1;
 - c. hardened air void analysis shall be carried out in accordance with the requirements of Section 4-1.6.2 [*Additional Requirements for Concrete Containing Silica Fume*]; and
 - d. A full scale mock up using a form with characteristics similar to that which will be used on site shall be cast to verify the self-consolidating characteristics and to show that the mix will result in a homogenous structure without segregation.

Table 4-4.5.4-3 Fresh Class SCC Concrete Parameters

Parameter	Minimum Requirement	Maximum Requirement
Slump Flow (CSA A23.2-19C) Flow	500 mm	800 mm
t-50 cm Time	2 sec	7 s
VIS Index	0	1

J-ring (CSA A23.2-20C)	-	Difference between slump flow and J-ring slump flow < 25 mm
L-box (MTO LS-440)	$h_2/h_1=0.8$	$h_2/h_1=1.0$
Column Separation (ASTM C1610)	-	Static Segregation $\leq 10\%$

7. 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 4-4.5.7 [*Time of Placing*] of this Schedule or that required by structural or mass concrete pour 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.

4-4.5.5 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.

4-4.5.6 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 volumetric 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 in accordance with 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.
- D. Grout and concrete patching materials shall be mixed in strict accordance with the manufacturer's recommendations stated on the published product data sheet.

4-4.5.6.1 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 batch.
 - 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 wet prior to use.

4-4.5.7 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.

4-4.5.8 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 minimize re-handling and facilitate placing of the concrete without damage to the Structure or the concrete.

4-4.5.9 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.
 - 1. For concrete elements with a minimum dimension greater than 1.0 m with a thermal control plan submitted to the City for mass concrete pour, the temperature of concrete shall be between 5 degrees Celsius and 25 degrees Celsius at discharge.

4-4.5.10 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 unless noted otherwise.
 - 2. Sampling may occur at the truck's chute for the following concrete placement:
 - a. For concrete placed under water by tremie methods, sampling may occur at the pump's hopper.
 - 3. The properties of concrete tested at the end of the truck's chute shall be verified prior to concrete placement by comparing air and slump test results at the truck chute and at the end of the pump hose.
- C. Slump tests shall comply with CAN/CSA A23.2-5C and shall be carried out on all concrete batches.
- D. Air content and density tests shall comply with CAN/CSA A23.2-4C and A23.2-6C and shall be carried out on all concrete batches
 - 1. ACI or CCIL/CSA 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. 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. Any concrete batch confirmed to be unacceptable by slump, air content or temperature testing shall be rejected.
- F. Any concrete from a rejected batch already placed in the Structure shall be rejected and immediately removed.
- G. The test cylinders shall be cast as specified in Section 4-4.5.10.1 [*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.
- H. 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 4-4.5.10.1 [*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.

- I. Grout cubes shall be tested in compression in accordance with CAN/CSA A23.2-1B by experienced ACI or CSA certified testers. A set of compressive strength cubes shall be taken to represent each day's production or 0.25 m³, whichever is more frequent.

4-4.5.10.1 Test Cylinders

- A. Making and curing concrete test cylinders shall be carried out in accordance with CAN/CSA A23.2-3C, except that the time for cylinders to reach the testing laboratory shall be between 20 and 48 hours.
 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 shall not be permitted.
- D. Test cylinders shall be tested in compression in accordance with CAN/CSA A23.2-9C by an independent CSA 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 4-4.5.10.2 [*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 per structure element 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.

4-4.5.10.2 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 cores 100 mm in diameter x 200 mm in length 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; and
 - 3. cores shall be sampled and tested by an independent CSA A283 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 to the City 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 strengths indicated by the cylinder tests shall govern.

4-4.5.11 Falsework and Formwork

4-4.5.11.1 General

- A. All formwork shall be of sufficient strength and rigidity to ensure that the concrete when the formwork is removed 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. 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.
 - 3. Formwork shall be positioned against hardened concrete to avoid form lines and discontinuities at construction joints.
- B. All formwork material shall be compatible with meeting the surface finish requirements of Section 4-4.5.21 [*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 shop drawings shall be prepared, signed and sealed by a Professional Engineer.

4-4.5.11.2 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.

4-4.5.11.3 Forms for Exposed Surfaces

- A. Forms for exposed surfaces shall meet the requirements of Section 4-4.5.11.1 [*General*] of this Schedule as well as the following requirements.
 - 1. All non-steel forms for exposed surfaces shall be as new material, made of coated formply consisting of Douglas Fir substrate with resin-impregnated paper overlay and factory treated chemically active release agent.
 - 2. Forms proposed for reuse shall be free of holes or patched holes in plywood or form liner surfaces, bulging, delamination, damage, or other imperfections that affect the trueness of the formed concrete surfaces.
 - 3. Forms shall be full sized sheets, as practical.
 - 4. 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.
 - 5. The top edges of exposed surfaces shall have chamfers formed by chamfer strips that establish a true line for screeding.
 - 6. 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 except for curbs, barriers and medians where the entire plastic sleeve shall be removed.
 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 Products List in the Vertical/Overhead (OH-V) category and placed in accordance with the manufacturer's published product data sheet.
 5. For fibre reinforced polymer rods, the rods shall be removed a distance of 75 mm back from the face of the concrete and filled with an approved concrete patching material from Alberta Transportation Products List in the Vertical/Overhead (OH-V) category and placed in accordance with the manufacturer's published product data sheet.
- C. Form ties on exposed surfaces shall be regularly spaced and shall not leave holes larger than 40 mm in diameter on the concrete surface.
- D. Form hangers or ties for exposed surfaces of decks and sidewalks, including underside surfaces, shall be removable threaded type.
- E. 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.

4-4.5.11.4 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. Polyurethane sealant or approved equivalent materials 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 girder surfaces wet but not "running wet" and shall be repeated when the girders are completely dry.

4-4.5.11.5 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.
3. There shall be no trace of staining after the specified concrete finishing is completed.

4-4.5.12 Handling and Placing Concrete

4-4.5.12.1 General

- A. Concrete shall be placed while fresh and before it has reached its initial set.
 1. All the necessary equipment for any 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 shall not be permitted.
- C. The method of concrete placement shall not have a negative impact on the concrete properties.
 1. Concrete shall be placed to not cause segregation of the materials or displacement of the reinforcement.
 2. When placing operations, involve the free drop of concrete by more than 1 m, it shall be deposited by metal pipes or equivalent.
 3. Concrete placing operations shall be carried out in a manner that minimizes the accumulation of concrete or concrete paste on concrete reinforcement that is not currently being cast into concrete.
 4. After initial set of the concrete, the forms shall not be jarred, or strain placed on the ends of projecting concrete reinforcement or have additional concrete worked into it.
 5. 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.
 6. When concrete placing is discontinued, all accumulations of concrete or concrete paste deposited on the projecting concrete reinforcement and the form surfaces shall be removed before the concrete or concrete paste sets. Care shall be exercised not to injure or break the concrete-steel bond at and near the surface of the concrete, while cleaning the concrete reinforcement.
- 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.
- E. Grout and concrete patching materials shall be placed in strict accordance with the manufacturer's recommendations stated on the published product data sheet.

4-4.5.12.2 Consolidation

- A. Concrete, during and immediately after depositing, shall be thoroughly consolidated by internal mechanical vibration.
- 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 be of sufficient duration and intensity to thoroughly compact the concrete but shall not be continued so as to cause segregation. 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 or stepped into. No additional concrete shall be added after consolidation.

4-4.5.12.3 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.

4-4.5.13 Placing Pile Concrete

4-4.5.13.1 General

- A. The placement of type "Pile" concrete under water will only be permitted in the event that Project Co has demonstrated that all reasonable attempts at obtaining a dry hole have failed.

4-4.5.13.2 Concrete Placed in the Dry

- A. Pile Concrete shall be placed in accordance with the requirements of Section 4-4.5.12.1 [*General*] and Section 4-4.5.12.3 [*Pumping*] of this Schedule.
 - 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.
- B. Concrete in the upper 3 m of the piles shall be consolidated in accordance with Section 4-4.5.12.2 [*Consolidation*] of this Schedule.

4-4.5.13.3 Concrete Placed Under Water

- A. Placement of Pile Concrete under water shall be in accordance with Section 4-4.5.17 [*Depositing Concrete Under Water*] of this Schedule.
- B. All Pile Concrete placed under water shall be inspected by CSL in accordance with ASTM D6760 to check the structural integrity of the drilled piles.
- C. CSL testing shall be completed within 3 to 7 days after concrete placement.
- D. 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 with regular internal diameter and free from defects, obstructions and joints, to permit inspection by CSL in order to test for voids or other abnormalities in the concrete. A minimum of three 50 mm inside diameter tubes shall be supplied and securely installed in each drilled pile with a minimum diameter of 750 mm or one tube for every 0.3 m of pile diameter. 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 installed a minimum of 40 mm away from vertical bars.
 - 3. Tubes shall be water tight, free from corrosion, have clean internal and roughened external faces to ensure a good bond with the concrete. Tubes may be extended with watertight mechanical couplings and all coupling locations shall be recorded.
 - 4. 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.
 - 5. Tubes shall be secured to the interior of the reinforcement stirrups a minimum of every 1.0 m along the length of the pile.
 - 6. Tubes shall be installed parallel to each other and equidistant around the circumference of the pile.

7. The tubes shall be installed in a manner that allows the CSL probes to pass through the entire length of the tubes without binding.
- E. The installation of reinforcement shall not damage the CSL tubes.
 - F. CSL tubes shall be filled with water with a minimum temperature of 4°C prior to concrete placement.
 - G. A 50 mm diameter core hole shall be drilled if the testing equipment cannot pass through the entire length of the CSL tube or if tube debonding has occurred.
 - H. CSL measurements shall be made at depth intervals of 50 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 Products List with the same strength and durability as the Pile Concrete.
 - I. 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.

4-4.5.13.4 Qualification

- A. Submit to the City the name of a proposed testing agency which has a minimum of three years experience in CSL testing and a Professional Engineer on staff to supervise the testing and interpretation of results prior to carrying out the CSL testing, interpreting the results and preparing a report. 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.
- B. The CSL testing report shall include test summaries, results, analyses, and an opinion of the Pile Concrete's integrity and suitability for the intended use.

4-4.5.13.5 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 4-4.5.13.5-1 [*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 unless otherwise accepted by the City, in its discretion.

Table 4-4.5.13.5-1: 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 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

4-4.5.14 Placing Deck, Deck Overlay, Slab and Floor Concrete

4-4.5.14.1 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/m²/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 degrees 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.
- D. All concrete reinforcement projecting from deck surfaces (barriers, curbs, medians, and adjacent deck pour stages) shall be covered during deck concrete placement, consolidation, screeding, and testing operations such that it is not contaminated with concrete or concrete paste.

4-4.5.14.2 Placing/Finishing Machines

- A. Except for abutment roof slabs and approach slabs placing/finishing machines shall be used to finish all Stony Plain Road Bridge deck, deck overlay concrete, and any other span where the top surface is the final exposed surface.
 - 1. Screeding shall be by the following concrete placing/finishing machines or equivalents:
 - a. Allen Models: 4836 B, 6036 B, 6048 B;
 - b. Gomaco Model C450 or C750; or
 - c. Terex Bidwell Models: 2450, 3600, 4800.
 - 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 parallel to the concrete surface, between 250 mm and 600 mm above the concrete surface, and shall provide an unobstructed working surface that is wide enough to permit diverse uses concurrently, and rigid enough that dynamic deflections are negligible. Work bridges shall include specialized work platforms to facilitate concrete finishing in front of curbs, barriers or medians.
- B. The finishing machine and guide rails and guide rail supports 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 guide rail 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 4-4.5.12.2 [*Consolidation*] of this Schedule even when placing/finishing machines are used.

4-4.5.14.3 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 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 screed.

4-4.5.14.4 Bull Floating/Surface Texturing

- A. The concrete surface produced behind the screed 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 who have completed the ACI Concrete Flatwork Finisher Certification Program or are under the direct supervision of a certified journeyman concrete finisher shall be employed to carry out bull floating and surface texturing.
- B. The screeded 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.

4-4.5.15 Construction Joints

4-4.5.15.1 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. Construction joints shall have concrete reinforcement that intersects the adjoining surfaces.
- C. The surface of the construction joints shall be thoroughly cleaned to remove laitance, damaged concrete and loose and foreign material. The concrete surface shall then be blown clean with compressed air 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.
- D. Construction joints shall be made only where indicated on the applicable Final Design, unless otherwise accepted by the Engineer of Record.
- E. The face edges of all joints that are exposed to view shall be formed true to line and elevation with a pour strip that is removed before proceeding with subsequent concrete placement.
- F. Construction joints shall be located to allow a minimum of 60 mm concrete cover on reinforcing running parallel to the joint.
- G. The placing of concrete shall be carried out continuously from construction joint to construction joint.

4-4.5.16 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 4-4.5.18 [*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 4-4.5.9 [*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, concrete reinforcement, 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, concrete reinforcement, previously placed concrete, substrate surfaces, 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 15 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 17 days, 14 days wet curing and 3 days of air drying), including:
 - a. enclosing the concrete in such a way that the concrete and air temperature within the enclosure are maintained above 10 degrees Celsius; and
 - b. Changes and fluctuations to the temperature of the concrete shall not change at a rate exceeding 10 degrees Celsius per day to that of the surrounding air.
 5. Provisions for maintaining a wet cure on all concrete surfaces for a minimum of 7 days with Sika UltraCure D.O.T curing blankets or an approved equivalent.
 6. The use of salamanders, coke stoves, oil or gas burners and similar spot heaters that have an open flame or intense heat is prohibited.
 7. 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.
 8. 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.
 9. 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:
 10. 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.
11. 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 4-4.5.18 [*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.

4-4.5.17 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 line and/or a tremie system. 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. A tremie system shall consist of a concrete pump line and/or a hopper connected to a rigid tube. If constructed in sections, the rigid tube shall have flanged couplings fitted with gaskets.
 - 3. The use of non-rigid lines will not be permitted.
 - 4. The discharge end of the concrete pump line and/or tremie system shall be temporarily closed to prevent water from entering the line and lowered to the bottom of the form or pile hole. The tremie tube shall be kept full to the bottom of the hopper, and water shall be kept out of the line at all times.
 - 5. 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.
 - 6. Pumping shall then proceed with the end of the discharge line being continually buried no less than 1 m 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.
 - 7. 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.
 - 8. The surface of the concrete shall be kept as horizontal as is practicable at all times.
- B. Concrete shall not be placed in water which is below 4 degrees Celsius or flowing at the point of discharge.
- C. Concrete shall not be placed under water unless permitted by the City, in its discretion.

- D. Dewatering shall not be permitted while concrete placement is in progress. Dewatering may proceed when the concrete seal is sufficiently hard and strong such that dewatering will not damage 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 damage the remaining concrete.

4-4.5.18 Curing Concrete

4-4.5.18.1 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 at an average ambient temperature of at least 10°C 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.
 - 2. Sika UltraCure DOT curing blankets or an approved equivalent may be used in lieu of using filter fabric.
- C. All flat surfaces such as decks, deck surfaces, slabs and slab surfaces, for concrete not containing silica fume shall be wet cured for a minimum of 7 days.
- D. The temperature of the centre of in-situ concrete shall not fall below 10 degrees Celsius or exceed 70 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 1.0 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 and until 24 hours after the maximum temperature has occurred. 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.
- E. The requirements of Table 20 of CAN/CSA A23.1 shall apply.
- F. "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.

- G. Prepare and submit the procedure for the wet cure of concrete before any concrete 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.

4-4.5.18.2 Curing Requirements for Concrete Containing Silica Fume

- A. The requirements of Section 4-4.5.18.1 [*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 14 days 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 3 days of air drying at a minimum temperature of 15 degrees Celsius 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 hours after concrete placement and every 8 hours thereafter for the remainder of the specified cure period and until 24 hours after the maximum temperature has occurred.
 - 1. Two thermocouples, one in the centre and one at the surface of the concrete, shall be supplied and installed for every 100 m² of deck.
- E. Curb and barrier formwork shall be removed such that the concrete is not damaged by removal operations, but no later than 72 hours after concrete placement. Wet curing of the concrete surfaces exposed after formwork removal, shall commence immediately after formwork is removed.

4-4.5.19 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, except for the surfaces of the Stony Plain Road Bridge roadway lanes, SUP, and

sidewalk which shall not have a gap greater than 3 mm. 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 (3 mm for the Stony Plain Road Bridge) but not higher than 10 mm above the correct surface shall be ground down;
 - b. any areas lower than 5 mm (3 mm for the Stony Plain Road Bridge) 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 4-4.5.19.
- 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 1.2 m long straight edge placed anywhere in any direction on the surface, there shall not be any gap greater than 3 mm between the bottom of the straight edge and the concrete surface. The gap for formwork misalignment of all other components shall not be greater than 5 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 4-4.8.3 [*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.

4-4.5.20 Concrete Deficiencies

- A. Concrete Deficiencies such as honeycombs, cavities and related defects shall be repaired as required to restore the concrete to its initial intended condition as determined by the City acting reasonably.
1. Concrete Deficiencies are those areas that are greater than 30 mm in depth or 0.05 m² in area. Defects less than 30 mm in depth or 0.05 m² in area shall be repaired in accordance with Section 4-4.5.21.3 [*Class 1A Modified Ordinary Surface Finish*]
 2. Concrete Deficiency repair procedures shall be developed, signed and sealed by a Professional Engineer and submitted to the City prior to the commencement of the repair.
 3. As a minimum, the repair procedure for concrete 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 Products 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 concrete reinforcement.
 5. Repair areas shall be roughened to remove all loose material and laitance. Exposed concrete reinforcement 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 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 as determined by the City acting reasonably.
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. All repair procedures shall be developed, signed and sealed by a Professional Engineer and submitted to the City prior to the commencement of the repair.
 3. Cracks with widths equal or greater than 0.2 mm may be repaired using the following procedure:
 - a. Clean and dry cracks with oil-free compressed air.
 - b. Seal cracks with an approved gravity flow concrete crack filler from Alberta Transportation Products List in accordance with the manufacturer's recommendations. The crack filler shall maximize the penetration by taking into consideration the ambient temperature, substrate temperature, viscosity and pot life of the material.
 - c. The crack filler shall have a viscosity less than 105 centipoises.
 - d. Epoxy injection is required for cracks that extend the full depth of the deck slab, barriers, curbs, and other concrete members or extend partial depth of decks that are cast to grade. The epoxy resin shall meet the requirements of ASTM C881 Type IV, Grade 1, Class B or C and have a viscosity less than 500 cP.
- C. Deficiencies in girders constructed using segmental concrete construction shall be assessed in accordance with Section 4-4.6.11.2 [*Precast Concrete Girder and Girder Segment Deficiencies*] of this Schedule.

4-4.5.21 Concrete Surface

4-4.5.21.1 General

- A. Prior to concrete surface finishing, all surfaces shall conform to the requirements of Section 4-4.5.20 [*Concrete 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. Wood or magnesium tools shall be used for finishing concrete. Finishing aids are not permitted during any concrete finishing operations.
- D. For all finishing operations, concrete shall not be disturbed (ex. stepped into) once the final screed has been completed.
- E. 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.
- F. 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 for which other finishes are not specified in the Project Requirements; and
 - b. top surfaces of abutment seats, retaining walls and pier caps.
2. Class 1A Modified Ordinary Surface Finish:
 - a. Trackway slab plinth surfaces located 200 m away from any Stop or Station Platform end.
3. Class 2 Rubbed Surface Finish:
 - a. all exposed formed concrete surfaces except for the underside of decks between girders.
4. Class 3 Bonded Concrete Surface Finish:
 - a. none specified.
5. Class 4 Floated Surface Finish:
 - a. top surfaces which are to receive waterproofing membranes and wearing surfaces.
6. 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);
 - c. sidewalks; and
 - d. concrete slope protection.
7. 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.

4-4.5.21.2 Class 1 Ordinary Surface Finish

A. Unformed Surfaces

1. Immediately following concrete placement and consolidation, the concrete shall be screeded to conform to the required surface elevations, and then floated to ensure that the surface is 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, shall be thoroughly chipped out, cleaned, and filled with a patching product.

- a. The patching product shall be on the Alberta Transportation 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 projections shall be removed immediately after removal of the forms.

4-4.5.21.3 Class 1A Modified Ordinary Surface Finish

- A. Surface finish shall be as specified in 4-4.5.21.2 [*Class 1 Ordinary Surface Finish*] of this Schedule, with the following additional requirements:
 1. Prior to finishing, all lines that do not meet tolerance requirements or surface irregularities shall be corrected by grinding. Parging or surface patching to correct irregularities shall not be permitted.
 2. Bug holes and surfaces larger than 19 mm in any direction shall be repaired.
 3. All holes greater than 9 mm on the face of the chamfer or holes greater than 9 mm that could retain water shall be repaired.

4-4.5.21.4 Class 2 Rubbed Surface Finish

- A. The finish shall have a smooth, uniform and closed texture and shall be uniform in color and texture. 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 shall not be permitted.
 2. All concrete fins and irregular projections shall be removed from all surfaces immediately following the removal of the forms.
 3. All surfaces shall be thoroughly exposed by brush abrasive blasting.
 4. sack rub materials shall be wet cured for a minimum of 72 hours. Patching materials shall be wet cured in accordance with the manufacturer's published instructions, but for a minimum of 24 hours. Curing compounds are not permitted.
 5. Patching material used shall be from the Alberta Transportation Products List and shall be wet cured in accordance with the manufacturer's requirements and for a minimum of 24 hours.
 6. The cavities produced by form ties, air bubbles and all other holes, honeycomb areas, broken corners or edges and any other such Deficiencies, shall be thoroughly exposed by diamond grinding wheels or similar tools. Surface voids greater than 19 mm diameter but less than 0.05 m² area or 30 mm or deeper shall be filled with a non-shrink patching product on the Alberta Transportation Products List.
 7. 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.
 8. 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.

4-4.5.21.5 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 Products 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.

4-4.5.21.6 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.

4-4.5.21.7 Class 5 Floated Surface Finish, Broomed Texture

- A. The concrete surface shall be finished 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. A bronze edging tool shall be used at all edges and control joints.
- D. Sidewalk and median joints shall be installed at the same locations as curb joint, barrier joint and control joint locations to a minimum depth of 1/4 of the slab thickness.
- E. Where indicated on the applicable Final Design, sidewalk surfaces shall be laid out in blocks using a grooving tool.

4-4.5.21.8 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 uniform over the entire concrete surface with 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 troweled smooth and the surface left closed.

4-4.5.21.9 Surface Finish under Bearings

- A. Air voids created in concrete surfaces of grout pad recesses shall be filled with an approved concrete patching material listed on the Alberta Transportation Products List in the Normal Horizontal (NH) category and placed in accordance with the manufacturer's published product data sheet.
 - 1. The concrete patching material shall reach a compressive strength equal to or greater than the substrate concrete, prior to the installation of bearings and girder erection.
- B. Concrete, including air void patches, on which bearing plates, pads or shims are to be placed shall be finished or ground to a smooth and even surface.
- C. When checked with a straight edge placed anywhere in any direction on the concrete surface, there shall not be any gap greater than 1 mm between the bottom of the straight edge and the finished concrete surface.
 - 1. The straight edge shall at a minimum be equal to the longest dimension of the bearing surface area.

4-4.5.21.10 Surface Finish under Baseplates

- A. Concrete surfaces of grout pad recesses shall be bush hammered to a depth of 3 mm including all air voids prior to the installation of bridgerail post or other baseplates.
 - 1. Bush hammering shall not occur within 25 mm of anchor rods.
 - 2. Anchor rods shall be protected from any damage during the work.

4-4.5.22 Type 1c Concrete Sealer

- A. The sealer shall be applied in accordance with the manufacturer's recommendation but the application rate shall be increased by 30% from that indicated on the Alberta Transportation Product List.
- B. The substrate of the concrete surface shall be a minimum of 5°C.
- C. The concrete shall be cured for at least 28 days prior to the application of the concrete sealer.
- D. The concrete surface shall be dry, air blasted to remove all dust and debris prior to the application of the concrete sealer.
- E. Concrete sealer shall be applied using a minimum of 2 coats.
- F. Asphalt concrete pavement surfaces and other elements shall be adequately protected from overspray and runoff during the concrete sealer application.

4-4.6 PRECAST CONCRETE

4-4.6.1 General

- A. This Section 4-4.6 [*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 4-4.6 [*Precast Concrete*] of this Schedule. Requirements for post-tensioning are given in Section 4-4.7 [*Post-Tensioning*] of this Schedule.
 3. Additional requirements for precast concrete segmental construction are given in Section 4-4.8 [*Concrete Segmental Construction*] of this Schedule.

4-4.6.2 Supply and Fabrication Standards

- A. The precast concrete fabricator shall be fully certified by the Canadian Precast Concrete Quality Assurance (CPCQA) 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 and the PCI Quality Control Manual MNL-116, with the most stringent of the requirements governing.
- C. The fabrication of precast concrete units shall be done in an environmentally controlled permanent building capable of supplying and manufacturing products in a well-organized and continuous operation. The building temperature shall be maintained between 15 °C and 30 °C and prevent contamination and/or deterioration of materials.

4-4.6.3 Engineering Data

4-4.6.3.1 Shop Drawings

- A. Shop drawings showing all fabrication details of each precast concrete unit shall be prepared prior to fabrication and submitted to the City. As a minimum, the following information shall be included in a submission:
1. Properties of all materials used;
 2. Dimensional information of all precast concrete units;
 3. Concrete reinforcement;
 4. Prestressing strand;
 5. Steel diaphragms;
 6. Miscellaneous steel;
 7. Blockouts and voids;
 8. Stressing system;
 9. Anchorage and hold down devices;
 10. Void support system; and

11. Screed rail details.

4-4.6.3.2 Stressing Calculations

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

4-4.6.3.3 Stressing Steel and Jack Calibration 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. All prestressing strand load/elongation curves shall be legible and in English.
- B. Where mill test reports originate outside of Canada or the United States of America, they shall meet the requirements of Section 4-4.10.3.4 [*Mill Certificates*]. Jack calibration certificates shall be provided with stressing calculation design notes and independent check notes.

4-4.6.3.4 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 to the City 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 shall specify the upper slump limit for the superplasticized concrete at which the mix is stable without any segregation. The slump of the concrete used in the production shall be 10 mm below the upper limit identified in the mix design.
 - 3. 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.
 - 4. 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.
 - 5. The minimum air content shall be in accordance with CSA A23.1 Table 4 based on the maximum aggregate size used and the maximum air void spacing factor shall be 0.23 mm.
 - 6. The concrete mix design information shall include one microscopic air-void analysis performed by an independent CSA A283 certified testing laboratory to determine the spacing factor of the hardened concrete. If adjustments to the mix design are necessary, the air void analysis shall be repeated.

7. The test sample used for the microscopic air-void analysis shall be made from a trial concrete batch, vibrated into a cylinder mould to represent the level of vibration of the production concrete in the forms.
 - a. The trial concrete batch should be performed a minimum of 28 days prior to the placement of concrete.
- C. Only the Accepted 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 the use of such modifications.

4-4.6.4 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.

4-4.6.4.1 Portland Cement

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

4-4.6.4.2 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.

4-4.6.4.3 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.
 2. Silica fume shall have a minimum SiO₂ content of 85%, maximum loss on ignition of 10%, and no more than 1% SO₃ content.

4-4.6.4.4 Aggregates

- A. Fine and coarse aggregates shall be normal weight and comply with CAN/CSA A23.1 and Section 4-4.5.4.2 [*Aggregate Tests*] of this Schedule.
 1. The maximum coarse aggregate size shall be 14 mm.

4-4.6.4.5 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.
- F. No admixtures outside of the above requirements shall be permitted without the prior written consent of the City, in its discretion.

4-4.6.4.6 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.
- B. Concrete longitudinal cold joints that intersect a draped duct shall be avoided. Should there be a longitudinal cold joint, there shall be a minimum of 35 mm between the exposed duct and the previously poured concrete surface around the perimeter of the duct.

4-4.6.4.7 Galvanizing

- A. Factors contributing to galvanization-induced cracking shall be minimized. 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. Cleaning and pickling procedure of high strength ASTM A193 Grade B7 anchor rods shall be modified as follows:
 1. Brush blast to remove mill scale and oil after threading ends;
 2. Flash pickle up to 5 minutes; and
 3. Quick dry prior to hot-dip galvanizing (not stored in flux or acid rinse).
- C. 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 mm² 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. Galvanized material shall be stacked or bundled and stored to prevent wet storage stain in accordance with the American Hot Dip Galvanizers Association (AHDGA) publication "Wet Storage Stain". Any evidence of wet storage stain shall be removed.
- E. Galvanized contact surfaces of bolted connections shall be hand wire brushed to a Class A slip coefficient surface condition. Slip coefficients surface conditions shall meet the requirements of Table 10.9 of CSA S6.

4-4.6.4.8 Epoxy Bonding Agents

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

4-4.6.5 Fabrication

4-4.6.5.1 Forms

- A. Precast concrete units shall be fabricated 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 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.

4-4.6.5.2 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 or damaged wire shall be removed and replaced. All stressing strands shall be checked for wire breaks and damage before placement of concrete. Stressing strand damage includes nicks, gouges, and indentations.
- 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. At the completion of tensioning, the two control measurements, force and elongation, shall meet the verification requirements of Subsection 5.2.2 of the PCI Quality Control Manual MNL-116.
 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.

4-4.6.5.3 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.

4-4.6.5.4 Lifting Hooks

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

4-4.6.5.5 Identification of Precast Concrete Units

- A. The fabricator's name, year of manufacture, unit serial number and design loading shall be cast into the bottom of the precast concrete units in 50 mm letters approximately 1.0 m from the precast concrete unit end.

4-4.6.5.6 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.

4-4.6.5.7 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.

4-4.6.5.8 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.

4-4.6.6 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, concrete reinforcement, 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.

4-4.6.7 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, in accordance with CAN/CSA A23.2-3C; and
 2. a calibrated weigh scales.

4-4.6.7.1 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 m³ 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.

4-4.6.7.2 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.

4-4.6.7.3 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 consented to 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.

4-4.6.8 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.

4-4.6.9 Curing

4-4.6.9.1 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.

4-4.6.9.2 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 95% 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.

4-4.6.9.3 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 in accordance with Section 4-4.6.9.2 [*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 Products List and at an ambient temperature of between 15 degrees Celsius to 25 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.

4-4.6.10 Dimensional Tolerances

- A. Precast concrete unit surfaces shall meet the requirements of Section 4-4.5.19B [*Dimensional Tolerances*] of this Schedule.

4-4.6.10.1 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 dimensions in Table 4-4.6.10-1 [*Dimensional Tolerances of Precast Concrete Girders*]:

Table 4-4.6.10-2 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.

4-4.6.10.2 Dimensional Tolerances of Precast Concrete Girder Segments

- A. Dimensional Tolerances for precast concrete segmental construction shall be in accordance with Section 4-4.8.3 [*Dimensional Tolerances*] of this Schedule.

4-4.6.10.3 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 4-4.6.10-3 [*Dimensional Tolerances of Precast Concrete Full Depth and Partial Depth Deck Panels*]:

Table 4-4.6.10-4 Dimensional Tolerances of Precast Concrete Full Depth and Partial Depth Deck Panels

Length ¹	$\pm 5 \text{ mm}$
Width ²	$\pm 5 \text{ mm}$
Thickness	+ 5 mm, - 3mm

Maximum difference in plan view diagonal dimensions (squareness) of rectangular panels	10 mm
Location of concrete reinforcement projecting out of units	+5, - 0 mm

¹ As measured perpendicular to the girder lines.

² 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.

4-4.6.10.4 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.

4-4.6.11 Concrete Deficiencies

4-4.6.11.1 General

- A. Concrete Deficiencies such as cracks, honeycombs, spalls or other defects shall be repaired as required to restore the concrete to its initial intended condition as determined by the City acting reasonably.
- B. Repairs to all concrete Deficiencies shall be carried out in accordance with this Section 4-4.6.11 [*Concrete 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 shall be done in a sheltered environment and repairs shall not be performed in freezing or windy conditions or in direct sunlight.

4-4.6.11.2 Precast Concrete Girder and Girder Segment Deficiencies

- A. In this Section 4-4.6.11.2, 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 consented by the City in its discretion , but without alleviating or otherwise modifying any of Project Co’s responsibility or liability in respect of such cracks, 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 consent pursuant to Section 4-4.6.11.2.B.1 [*Precast Concrete Girder and Girder Segment 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. The epoxy resin shall meet the requirements of ASTM C881 Type IV, Grade 1, Class B or C and have a viscosity less than 500 cP.
- C. Honeycombs and Spalls
1. The following conditions of honeycomb or spall shall result in rejection of the girder or girder segment unless otherwise consented by the City in its discretion, but without alleviating or otherwise modifying any of Project Co’s responsibility or liability in respect of such conditions, 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 0.05 m² in area.
 2. Subject to the City’s consent pursuant to Section 4-4.6.11.2.C.1 [*Precast Concrete Girder and Girder Segment Deficiencies*], all repairs for honeycombs and spalls shall be made using a cementitious material.

4-4.6.11.3 Precast Concrete Panel Deficiencies

- A. A panel having any one of the following 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 concrete reinforcement;
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.

4-4.6.12 Concrete Finish

4-4.6.12.1 General

- A. Prior to concrete surface finishing, all surfaces shall conform to the requirements of Section 4-4.6.11 [*Concrete 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 4-4.5.21.1 [*General*] of this Schedule. Based on this classification, the finish shall meet the requirements set out in this Section 4-4.6.12 [*Concrete Finish*] of this Schedule.
- 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.

4-4.6.12.2 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.

4-4.6.12.3 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.

4-4.6.12.4 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 Products 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.

4-4.6.12.5 Class 4 Floated Surface Finish

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

4-4.6.12.6 Class 5 Floated Surface Finish, Broomed Texture

- A. The concrete surface shall be floated and troweled 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 to 3 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.

4-4.6.12.7 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.

4-4.6.13 Type 1c Concrete Sealer

- A. The sealer shall be applied in accordance with the manufacturer's recommendations but the application rate shall be increased by 30% from that indicated on the Alberta Transportation Product List.
 1. The substrate of the concrete surface shall be a minimum of 5°C.
 2. Before applying the sealer, the concrete shall be cured for at least 14 days. Patches shall be cured for at least 2 days.
 3. The concrete surface shall be dry, free of form oil, and air blasted to remove all dust and debris prior to the application of the concrete sealer.
 4. Concrete sealer shall be applied using a minimum of 2 coats.
- B. Sealer shall not be applied in areas of the girders that will have field concrete cast against them.

4-4.6.14 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 permitted.
 5. Precast concrete panels shall be protected from salt spray during shipping.

6. Precast concrete panels shall be stored flat.

4-4.6.14.1 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 into the Structure shall not be permitted unless accepted by the City in accordance with 4-4.6.11 [*Concrete Deficiencies*] of this Schedule.

4-4.6.15 Erection of Precast Concrete Units

4-4.6.15.1 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.

4-4.6.15.2 Transportation, Handling and Storing Materials

- A. Girders with webs shall be transported with girder webs in the vertical position.
- B. Girders with webs may be transported in other positions provided:
 1. A Professional Engineer prepares a signed and sealed transportation assessment report and provides a written statement that the transportation method will not damage the elements.
 2. Upon arrival at the Site and prior to erection, the elements shall be checked for correct tolerances, material cleanliness and presence of damage.
 3. An adequate flat storage area shall be provided for the inspection
 4. A detailed inspection report shall be submitted within three days of the inspection.
- C. Precast concrete elements shall be protected from dirt, road salts, slush or other contaminants during transportation, handling and storage.

1. Precast concrete elements that become contaminated shall be cleaned prior to erection or installation.
- D. Any precast concrete girder damaged during transportation, handling, storing or erection shall be immediately reported to the City.
1. An engineering assessment report and repair procedure prepared, signed and sealed by a Professional Engineer experienced in the evaluation and inspection of damaged concrete members shall be submitted to the City.
 2. An independent inspection and assessment performed on the damaged member by a Precast/Prestressed Concrete Institute (PCI) level 2 certified inspector.
- E. Stored material shall be placed on timber blocking and kept clean, free from dirt, grease and any other foreign matter, and store in a properly drained area.
- F. Handling and lifting devices shall not mark, damage, or distort members.
- G. Precast concrete girders shall be shored and stored in the vertical position.

4-4.6.15.3 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.

4-4.6.15.4 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:
 - a. 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;
 - b. Location, elevation, and grade of support bearings;

- c. Theoretical top of girder elevations at bearing and splice locations; and
 - d. Vertical, horizontal, and longitudinal position adjustment mechanisms;
8. An as constructed survey of substructure elements, including:
- a. Location and elevation of all bearing grout pad recesses including anchor rod voids;
 - b. Shim height required at each bearing location; and
 - c. Longitudinal and transverse measurements between centreline of bearings of all substructure elements.
9. Superstructure layout plan, including:
- a. Installation details of reference lines and markings of substructure and bearing components used to determine final bearing and girder positions; and
 - b. Theoretical top of girder elevations at substructure bearing locations.
10. Details of lifting of girders or girder segments, showing forces at lifting hooks;
11. Post-tensioning procedures, including prestressing strand specifications, jack dimensions, pressures, forces and elongations, and grouting;
12. Grout pad construction;
13. Complete details of blocking for bearings where necessary to constrain movements due to horizontal forces and/or gravity effects; and
14. 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 is in accordance with the epoxy manufacturer's requirements.

4-4.6.15.5 Girder Adjustments

- A. Girder position, bearing location and bearing elevation shall be adjusted to achieve as closely as possible the lines and grades shown on the applicable Final Design.
- B. Minimize differential camber (girder to girder) and the sweep of the girders by jacking, loading of girders, or winching.
 - 1. Once the girder position has been achieved, temporary attachments shall be installed to maintain the position.
 - 2. Maximum dimensional deviation in mm of erected precast concrete girders from that as detailed on the Final Design shall not exceed the following:
 - a. Sweep (NU Girders): 1 mm/m;
 - b. Sweep (Other Precast Concrete Units): deviation from true, $20 \text{ mm} \times \text{length (m)} \div 50$

- C. All cracks shall be inspected, and locations shall be mapped if force is required to bring girders into alignment.

4-4.6.15.6 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 ± 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.

4-4.6.15.7 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 Products 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.

4-4.6.15.8 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; and
 - 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.

4-4.6.15.9 Lifting Hooks and Lifting Holes

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

4-4.7 POST-TENSIONING

4-4.7.1 General

- A. This Section 4-4.7 [*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.

4-4.7.2 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).

4-4.7.3 Qualification

- A. The site supervisor responsible for the post tensioning and grouting operations shall be at the site whenever post-tensioning operations are being performed.
- B. The site supervisor of post tensioning and grouting operations shall be certified to PTI Level 2 Bonded PT Field Specialist.
- C. The foreman for each installation and stressing crew shall be certified to PTI Level 2 Bonded PT Field Specialist.
- D. The foreman for each grouting crew shall be certified to PTI Level 2 Bonded PT Field Specialist.
- E. At least 25% of the members of each crew shall be certified in PTI Level 1 Bonded – Field Installation.

4-4.7.4 Engineering Data

- A. Shop drawings providing a complete description and details of the post-tensioning system to be used shall be 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 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.

4-4.7.5 Materials

4-4.7.5.1 Prestressing Strand

- A. Stressing strand shall conform to the requirements of Section 4-4.6.5.2 [*Stressing Strand*] of this Schedule.
- B. Grouting operations shall be completed within 20 calendar days of the installation of the stressing steel, unless otherwise accepted by the City.
- C. 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.
- D. 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.

4-4.7.5.2 Anchorages

- 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.

4-4.7.5.3 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 ± 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 1000 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 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.

4-4.7.5.4 Concrete

- A. Concrete shall be supplied in accordance with Section 4-4.5 [*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.

4-4.7.5.5 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 in accordance with 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. A Schupack pressure bleed test in accordance to ASTM C1741 and PTI M55.1-12 acceptance criteria can be carried out in lieu of the wick induced bleed test.
- 4. 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.
- 5. Mud Balance Test
 - a. For each tendon, a mud balance 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".

4-4.7.6 Equipment

4-4.7.6.1 Stressing

- A. Stressing shall conform to the requirements of Section 4-4.6.5.2 [*Stressing Strand*] of this Schedule.
- B. Hydraulic jacks and pumps with sufficient capacity shall be used for tensioning of strands 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.

4-4.7.6.2 Grouting

- A. The grout shall be mixed using a high speed shear mixer that is capable of continuous mechanical mixing and producing grout that is free of lumps and undispersed cement.
 - 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.

4-4.7.7 Construction

4-4.7.7.1 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.

4-4.7.7.2 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.

4-4.7.7.3 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.

4-4.7.7.4 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 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 oil free 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 mud balance 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.

4-4.8 CONCRETE SEGMENTAL CONSTRUCTION

4-4.8.1 General

- A. This Section 4-4.8 [*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 4-4.5 [*Cast-In-Place Concrete*], Section 4-4.6 [*Precast Concrete Units*] and Section 4-4.7 [*Post-Tensioning*] of this Schedule.

4-4.8.2 Submittals

- A. Shop drawings, calculations and manuals which include, but are not necessarily limited to, the items listed in this Section 4-4.8 [*Concrete Segmental Construction*] shall be submitted to the City 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 and submitted to the City in advance of use. Any such submissions will be subject to a 30 Business Day Review Period.

4-4.8.2.1 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 concrete reinforcement, post-tensioning ducts, post-tensioning hardware, 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.

4-4.8.2.2 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, 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, 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.

4-4.8.2.3 Design Calculations for Construction Procedures

- A. Calculations signed and sealed by a Professional Engineer shall be submitted to the City 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.

4-4.8.2.4 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.

4-4.8.2.5 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 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.

4-4.8.3 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 4-4.8.3 [*Dimensional Tolerances of Concrete Segments*]:

Table 4-4.8.3 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

4-4.8.3.1 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.

4-4.8.4 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.

4-4.9 CONCRETE REINFORCEMENT

4-4.9.1 General

- A. This Section 4-4.9 [*Concrete Reinforcement*] sets out the requirements for all concrete reinforcement 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.

4-4.9.2 Engineering Data

- A. Shop drawings showing concrete reinforcement details shall be prepared prior to fabrication of concrete reinforcement.
- B. Mill test reports shall be prepared for each lot of concrete reinforcement delivered to site prior to the placement of any concrete reinforcement.
- C. Mill test reports shall be provided in English and at a minimum include:
 - 1. Heat number;
 - 2. Date;
 - 3. Location of product;
 - 4. Compliance with production standards;
 - 5. Chemical analysis;
 - 6. Mechanical properties;
 - 7. Pickling process details for stainless reinforcing steel; and
 - 8. Authentication by the manufacturer.
- D. Mill test reports originating from a mill outside of Canada or the United States of America shall meet the requirements of Section 4-4.10.3.4 [*Mill Certificates*] of this Schedule.
- E. 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 A1084, Method C by demonstrating no presence of detrimental phases.

4-4.9.3 Fabrication

- A. Concrete reinforcement 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. Stainless steel fabrication facilities shall be exclusive to the fabrication of stainless reinforcing steel or in a facility that provides a permanent fixed physical barrier which fully isolates the stainless steel fabrication process.
 - 1. Fabrication shall occur only on equipment dedicated solely to fabrication of stainless reinforcing steel.
 - 2. All machinery points that come into contact with stainless reinforcing steel bars shall consist of hardened steel to a minimum of 35 Rockwell, stainless steel, or nylon.

3. All racking shall be protected with hardened steel to a minimum of 35 Rockwell, stainless steel, nylon or wood.
- E. All concrete reinforcement requiring bends shall be cold bent at the fabrication facility, unless otherwise approved by the Engineer of Record and accepted by the City.
 1. Heating of concrete reinforcement to facilitate bending shall not be permitted.
 - F. Concrete reinforcement shall be cut by shearing or with fluid-cooled saws.
 1. Torch cutting shall not be permitted.
 - G. Concrete reinforcement shall be fabricated without laminations or burrs.
 - H. Stainless reinforcing steel shall be pickled to remove all mill scale and surface oxidation.
 - I. Stainless reinforcing steel shall be shot blasted and pickled at the production mill to remove all mill scale and surface oxidation.

4-4.9.4 Shipping, Handling and Storage

- A. All necessary precautions shall be taken to prevent damage to the concrete reinforcement during shipping, handling and storage.
 1. Concrete reinforcement of differing material types shall be stored separately.
 2. All concrete reinforcement 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 concrete reinforcement shall not exceed 120 days unless protected with polyethylene sheeting or equivalent protective material.
 4. Concrete reinforcement shall be covered and protected at all times during transportation.
 5. Bundles shall be handled with spreaders and non-metallic slings.
 6. Lifting of stainless steel reinforcing shall be completed with nylon strapping dedicated to stainless reinforcing steel.
 7. Fork trucks used in the handling of coil or straight stainless reinforcing steel shall have their forks covered with hardened steel to a minimum of 35 Rockwell, stainless steel, or nylon.
 8. Stainless reinforcing steel bundles shall be tied with plastic strapping or stainless steel tie wire and not with carbon steel or epoxy coated carbon steel strapping.
 9. Polyethylene wrap shall be used to fully cover all stainless reinforcing steel bars and bundles for shipping.
 10. Stainless reinforcing steel shall be covered with a tarp at all times during shipping with tarps dedicated for stainless reinforcing bars.
- B. Concrete reinforcement tags identifying the material type shall be clearly visible and shall be maintained in-place until installation of the material.

4-4.9.5 Placing and Fastening

- A. Concrete reinforcement incorporated into the work shall be free from loose rust, scale, dirt, paint, oil, concrete, concrete paste, or other foreign materials.
- B. Concrete reinforcement shall be accurately 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 bar 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 4-1.6.3 [*Concrete Reinforcement*] of this Schedule.
- D. Concrete reinforcement 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. Bundled concrete reinforcement of two or more bars is not permitted.
- F. Specified distances of concrete reinforcement from forms shall be maintained by supports, spacers, or other means.
 - 1. Concrete reinforcement supports shall be either plastic or precast concrete. Brick or mortar supports shall not be permitted.
 - 2. Supports shall be staggered and configured to facilitate full concrete consolidation.
 - 3. 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. The precast concrete supports shall be placed in a configuration that minimizes the geometric size of the precast concrete support and does not adversely affect concrete placement and consolidation processes.
 - 4. Plastic bolster slab supports shall be Aztec Strong Back Slab I Beam Bolster- PSBB manufactured by Dayton Superior or equivalent.
 - 5. Bolster slab supports of length not exceeding 100 mm shall be used for exposed faces of curbs, medians and barriers.
 - 6. Precast concrete supports shall be Total Bond Concrete Supports manufactured by Con Sys Inc or equivalent.
- G. Welding of concrete reinforcement shall not be permitted.
- H. Field bending of concrete reinforcement, shall not be permitted, unless otherwise approved by the Engineer of Record and accepted by the City.
- I. Concrete reinforcement showing signs of damage shall be replaced.

4-4.9.6 Concrete Reinforcement Tolerances for Cast-In-Place Concrete

- A. Concrete reinforcement for cast-in-place concrete shall be placed in conformance with the following tolerances:
 - 1. Location, where the smallest dimension of the element is:
 - a. 200 mm or less: ± 8 mm;
 - b. Larger than 200 mm but less than 600 mm: ± 10 mm; or
 - c. 600 mm or larger: ± 20 mm;
 - 2. Lateral spacing: ± 30 mm;
 - 3. Longitudinal location of bends and ends of bars: ± 50 mm;
 - 4. Longitudinal location of bends and ends of bars at discontinuous ends: ± 20 mm; and
 - 5. The clear distance between reinforcement shall not be less than 1.5 times the nominal diameter of the reinforcement, 1.5 times the maximum coarse aggregate size, or 40 mm.

4-4.9.7 Splicing

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

4-4.9.8 Repair of Stainless Reinforcing Steel

- A. Individual stainless steel reinforcing bars exhibiting any Deficiencies including any of the following Deficiencies shall be repaired or replaced:
 - 1. Any location of contamination from grinding or cutting slag;
 - 2. Any location of iron contamination greater than 100 mm in length;
 - 3. More than 10 discrete points of iron contamination on bar deformations within any 1 m of bar length; and
 - 4. More than 20 discrete points of iron contamination on bar deformations per bar; or
 - 5. More than 5 discrete points of iron contamination that are not located on bar deformations per bar.
- B. Discrete points of contamination are defined as areas of contamination less than or equal to 5 mm². If any area of contamination is larger than 5 mm², the area shall be divided by 5 to determine the number of discrete points.
- C. Bars exhibiting excessive staining shall have the contaminants identified by energy dispersive x-ray analysis (EDXA).
- D. 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.

4-4.10 STRUCTURAL STEEL

4-4.10.1 General

- A. This Section 4-4.10 [*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 4-4.10.12 [*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, fasteners, splice plates, deck drains, anchor rods, dowels, deck joint assemblies, buffer angles, connector angles, anchor bolt sleeves, curb, barrier and median cover plates, trough plates, pier nose plates, pier bracing, bridge rails and miscellaneous steel components and associated materials.

4-4.10.2 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) in accordance with CAN/CSA W47.1 in the following divisions:
1. fabrication of steel girders, girder components, welded steel trusses or other primary load carrying members – Division 1;
 2. all other Structure components – Division 1 or 2; and
 3. field welding/repairs – Division 1 or 2.
- B. 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.
- C. The fabrication of structural steel tubing shall comply with the American Welding Society (AWS) Structural Welding Code D1.1.
- D. Fabricators of steel girders, girder components, welded steel trusses, and other primary load carrying members shall be certified by the Canadian Institute of Steel Construction as meeting the quality compliance requirements in the category of steel bridges.

4-4.10.3 Engineering Data

4-4.10.3.1 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.
- B. Sizes of hardware, shear stud connectors, and any other material shown on the shop drawings shall be in the actual units (imperial or metric) of the material being supplied.

4-4.10.3.2 Welding Procedures

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

4-4.10.3.3 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 fabrication and assembly of all the component parts, as well as shop assembly, identification of witness points, and details for surface preparation and coating.

4-4.10.3.4 Mill Certificates

- A. Mill certificates are required for all structural steel elements described in Section 4-4.10.1A.1 of this Schedule.
- B. Mill certificate data and results of impact tests shall be obtained prior to shipment of material from the mill.
- C. Mill certificates shall be obtained for all material before fabrication commences.
- D. Mill certificates shall be in English.
- E. Mill test reports originating outside of Canada or the United States of America shall be verified by testing the material to the specified material standards, including boron content, by a laboratory that is certified in Canada in accordance with Schedule 9, Section 6.3 [*Accreditation Standards*].
 1. Samples for testing shall be collected by personnel employed by the certified laboratory
 2. A verification letter shall be prepared by the certified laboratory that includes at a minimum, the applicable mill test reports, testing standards, date of verification testing, and declaration of material compliance.
 3. The verification letter shall be signed by an authorized officer of the certified laboratory.
 4. The boron content shall not exceed 0.0008%.

4-4.10.4 Materials

4-4.10.4.1 Structural Steel

- A. Structural steel shall conform to the standard specified on the applicable Final Design.
 1. Interpretation of equivalent steels shall be in accordance with Appendix "A" of CAN/CSA G40.21 (1976 only).
- B. 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%.
3. Repair of steel plates or rolled shapes by welding at the producing mill shall not be permitted.

4-4.10.4.2 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. Rotational capacity testing and reporting shall be performed in accordance with ASTM F3125.

4-4.10.4.3 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.

4-4.10.5 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.

4-4.10.5.1 Submerged Arc Welding (SAW)

- A. The submerged arc welding process is permitted for all flat and horizontal position welds.
- B. All flange and web groove welds shall be welded by a semi or fully automatic submerged arc welding process.
- C. All web to flange welds and all longitudinal stiffener to web welds shall be made by a fully semi-automatic submerged arc welding process.
- D. All fluxes shall conform to the diffusible hydrogen requirements of AWS D1.5 filler metal hydrogen designator H8 or lower.

4-4.10.5.2 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, bridge bearings, pier nose plates and buffer angles.
- B. SMAW electrodes shall conform to the diffusible hydrogen requirements of AWS D1.5 filler metal hydrogen designator H4.

4-4.10.5.3 Metal Core Arc Welding (MCAW) and Fluxed Core Welding

- 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, bridge bearings, hand rails, bridgerails and buffer angles.
- B. Field application of the metal core arc welding process shall not be permitted.
- C. All electrodes shall conform to the diffusible hydrogen requirements of AWS D1.5 filler metal hydrogen designator H4.

4-4.10.5.4 Cleaning Prior to Welding

- A. Weld areas shall be clean, free of mill scale, dirt, grease and other contaminants prior to welding.
- B. For multi-pass welds, previously deposited weld slag shall also be thoroughly cleaned prior to depositing subsequent passes.

4-4.10.5.5 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.

4-4.10.5.6 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 thickness and shape shall replicate the joint detail being welded.
 - 3. 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.
 - 4. Tabs shall be removed by flame cutting after welding.

4-4.10.5.7 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.

4-4.10.5.8 Welding at Stiffener Ends

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

4-4.10.5.9 Preheat and Interpass Temperatures

- A. Preheat and interpass temperature requirements shall be performed and maintained in accordance with AWS D1.5, except for the following:
 - 1. All welds on girder flanges and post to base plate groove welds shall be preheated to a minimum temperature of 100°C unless a higher temperature is required by AWS D1.5 for the flange thickness.
 - 2. All post to base plate fillet welds shall be preheated to a minimum temperature of 60°C.
 - 3. 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.

4-4.10.5.10 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.

4-4.10.5.11 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.
 - 3. The repair procedure shall also include MPI and hardness testing of the affected area. Hardness of the repaired area shall conform to the requirements of Section 4-4.10.9.6 [*Hardness Tests*] of this Schedule.

4-4.10.5.12 Grinding of Welds

- A. Flange groove welds shall be ground flush or to a slope not exceeding 1 in 10 on both sides.
- B. Web butt joints and post to baseplate groove welds that meet the profile requirements of AWS D1.5 shall not require grinding.
- C. Fillet welds shall be continuous with uniform size and profile.
 - 1. Fillet welds not conforming to an acceptable profile as defined in AWS D1.5 shall be ground to the proper profile without substantial removal of the base metal.
 - 2. Grinding shall be smooth and parallel to the line of stress.
 - 3. Caution shall be exercised to prevent over grinding. Over grinding that results in reduced thickness of the base metal or size of the weld shall not be permitted.

4-4.10.5.13 Plug and Slot Welds

- A. Plug welds or slot welds shall not be permitted.

4-4.10.5.14 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 any flange groove weld.

- B. Shear stud connectors and bolt holes shall not be placed within 50 mm of any flange groove weld.
- C. 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 any web groove welds.

4-4.10.5.15 Field Welding

- A. Structural field welds are welds that are required to maintain the integrity of the Structure.
- B. Field welding of primary load carrying members shall not be permitted, unless otherwise specified.
- C. All material to be field welded shall be prepared in the shop.
- D. 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 4-4.10.5 [*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.
- E. 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 4-4.10.5 [*Welding*] of this Schedule;
 - 4. when the air temperature is below 5° 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
 - 5. 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.

4-4.10.6 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. Fabrication shall be performed in a fully enclosed area which is heated to at least 10° Celsius.
- C. 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.

4-4.10.6.1 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 permitted.
- 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.

4-4.10.6.2 Flame Cut Edges

- A. The flame cut edges of flanges shall have a maximum Brinell hardness as stated by Section 4-4.10.9.6 [*Hardness Tests*] of this Schedule.
 - 1. The surface roughness of the flame cut edge shall not be greater than ANSI B46.1 500 µin. (12.5 µm) and be such as to allow Brinell hardness testing without spot grinding.
 - 2. Brinell hardness tests shall be performed at random 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, signs of lamination, or any other discontinuity detected on plate cut edges for tension members 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 and repair procedure shall be prepared, signed and sealed by a Professional Engineer indicating whether or not the material is suitable for fabrication.

4-4.10.6.3 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.

4-4.10.6.4 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.

4-4.10.6.5 Shop Assembly

- A. General
 - 1. Primary load carrying members including box girders shall be preassembled in accordance with AASHTO LRFD BCS,
- B. Plate Girders
 - 1. The preassembly of plate girders shall only require two sections to be assembled at one time.
 - 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 in accordance with Section 4-4.10.3.3 [*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.
- C. Box Girders
 - 1. The shop assembly of box girders shall be the same as for plate girders with the additional requirements specified in this section.
 - 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.

4-4.10.6.6 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.

4-4.10.6.7 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 to ensure a proper faying surface.
 1. Splice plates shall be securely ship-bolted to the girders.
- C. At field splice locations, the gap between adjacent girder ends shall be 10 mm \pm 5 mm.

4-4.10.6.8 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. Diaphragm bracing members for curved girder bridges are considered primary structural members and therefore punching of full size holes shall not be permitted.
- D. All holes in girder splices and structural members shall be circular and perpendicular to the member. Cutting of slotted holes shall be done by plasma arc cutting. Holes shall be deburred inside and outside and free of nicks and gouges.

4-4.10.6.9 Flame Straightening and Heat Curving

- A. Flame straightening and heat curving 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.

4-4.10.6.10 Stress Relieving

- A. When stress relieving is specified in the applicable Final Design, it shall be performed in accordance with AWS D1.5.

4-4.10.6.11 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.

4-4.10.6.12 Barrier

- A. All barrier rail splices shall be completed using properly fitted backing bars.
- B. All barrier rail splices shall be ground smooth and 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.

4-4.10.7 Dimensional Tolerances

4-4.10.7.1 General

- A. The normal tolerance for structural steel fabrication and fitting between whole groups shall be ± 3 mm unless otherwise specified.
- B. The dimensional tolerances for structural members shall comply with AWS D1.5, Section 3.5, unless otherwise specified.
 - 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.

4-4.10.7.2 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 ± 3 mm of the theoretical camber line or a specified amount from the line.

4-4.10.7.3 Combined Warpage and Tilt

- A. Combined warpage and tilt of flanges at any cross section of welded I-shape 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.

4-4.10.7.4 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.

4-4.10.7.5 Splices

- A. The tolerance for girder depth or box girder geometry shall be as specified by AWS D1.5, except that the difference between similar dimensions of adjoining sections being spliced shall not exceed ± 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.
- C. At field splice locations, the gap between adjacent girder ends shall be $10 \text{ mm} \pm 5 \text{ mm}$.
- D. Filler plates will be required when the difference between two adjacent sections is greater than 2 mm.

4-4.10.7.6 Stiffeners

- A. The bearing ends of bearing and jacking 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.

4-4.10.7.7 Bearing to Bearing Dimension

- A. The bearing to bearing distance is a set dimension and therefore has no tolerance.

4-4.10.7.8 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.

4-4.10.7.9 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 ± 6 mm.
 2. Horizontal sweep or variations in gap setting shall not be greater than ± 3 mm.
 3. Deck joint assemblies shall be assembled for inspection in a relaxed condition with erection angles removed.

4-4.10.7.10 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.

4-4.10.7.11 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 ± 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.

4-4.10.8 Surface Preparation and Coating

4-4.10.8.1 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.

4-4.10.8.2 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.
 - 3. Factors contributing to galvanization-induced cracking shall be minimized.
- 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 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 repair area is less than 100 mm^2 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.
- D. The cleaning and pickling procedure of high strength ASTM A194/A193 Grade B7 anchor rods shall be modified as follows prior to hot-dip galvanizing:
1. Brush blast to remove mill scale and oil after threading ends;
 2. Flash pickle up to 5 minutes; and
 3. Quick dry prior to hot-dip galvanizing (not stored in flux or acid rinse).

4-4.10.8.3 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 of the coating shall be in accordance with the coating manufacturer's recommendations.
 3. The adhesion of the fully cured coating shall be tested in accordance with 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.

4-4.10.8.4 Prime Coating

- A. At bearing locations, a prime coat shall be applied to the underside of bottom flanges in contact with the bearing sole plate. The primer shall extend the full width of the flange and 15 mm beyond the projected contact surface of the bearing sole plate in the longitudinal direction.
- B. At all deck joint locations, a complete SF2, SF3 or SF4 approved bridge coating system from the Alberta Transportation Products List shall be applied to the bottom flange surfaces (underside, top and edges), with the exception that the faying surface of the underside of the bottom flange in contact with the bearing sole plate shall only receive the prime coat.
1. The coating system shall extend longitudinally from the girder end to a distance 100 mm beyond the bearing sole plate or 100 mm beyond the jacking stiffener, whichever is greater
 2. The selected SF2, SF3, or SF4 coating system shall be applied to the full height of the bridge webs (both sides of web and including any applicable bearing/jacking stiffeners) and to the underside of the top flanges. The longitudinal extent of this coating shall be the same as described in Section 4-10.8.4.B.1 of this Schedule.
 3. Faying surfaces of bolted connections shall only receive the prime coat.
- C. Any portions of the girder that will be encased in cast-in-place concrete shall be left in bare steel condition with no prime coat applied.
- D. 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".

4-4.10.9 Inspection and Testing

4-4.10.9.1 General

- A. Inspection and testing shall be carried out as required in this Section 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 E10.
- 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.

4-4.10.9.2 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 groove welds, all stiffener butt welds and all diaphragm groove welds, and any groove welded attachments to flange plates;
 - 2. a minimum of 25% of all other flange groove welds randomly selected for each Transportation Structure;
 - 3. 100% of all web groove welds; and
 - 4. additional testing shall be carried out if required to ensure the quality of welds.
- B. In addition to radiographic inspection, for steel members with a thickness of 65 mm or greater, 25% of the welds shall be supplemented by ultrasonic inspection.
- C. Deficiencies discovered shall be repaired and the suspect area re-inspected.

4-4.10.9.3 Radiographic Inspection of Members Other than Girders

- A. Unless otherwise specified, radiographic inspection of groove 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. In addition to radiographic inspection, for steel members with a thickness of 65 mm or greater, 25% of the welds shall be supplemented by ultrasonic inspection.
- C. 25% of post to base plate welds shall be inspected by ultrasonic or radiographic inspection.
- D. Deficiencies discovered shall be repaired and the suspect area re-inspected.

4-4.10.9.4 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. The tests shall be in 1.5 m lengths including a 1.5 m length at each end of the web to flange weld;
 2. 20% of the web to stiffener welds;
 3. 100% of the stiffener and diaphragm connector plate to flange welds;
 4. 100% of the bearing sole plate to flange welds;
 5. 20% of the diaphragm connector plate welds to web;
 6. 100% of all manual (SMAW) welds; and
 7. 25% of all fillet welds for all other components.
- B. Deficiencies discovered shall be repaired and the suspect area re-inspected.

4-4.10.9.5 Dye Penetrant Inspection

- A. Dye penetrant inspection shall be performed at the ends of the weld metal of all flange groove welds after the removal of run-off tabs.
- B. Dye penetrant inspection shall be done for all flange plate edges regardless of whether or not the plates are cut before or after welding.
- C. Deficiencies discovered shall be repaired and the suspect area re-inspected.

4-4.10.9.6 Hardness Tests

- A. Hardness tests shall be performed on the flame cut edges of girder flanges prior to assembly.
1. If grinding is required to obtain a reliable hardness reading, the full length of the plate edge shall be ground.
- B. A minimum of three readings for each cut edge of the plate (at each end and mid-point along the length of the edge) shall be taken.
- C. Unless otherwise specified, the hardness of the flame cut edges shall not exceed the following maximum Brinell hardness's:
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.

- D. Remedial work to the edges which exceed the specified hardness shall be performed and the edges re-inspected prior to assembly.

4-4.10.9.7 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.
 3. All remaining studs shall be tested by striking with a hammer. A dull sound indicates incomplete fusion and a bend test will then be required for a potentially defective stud.

4-4.10.9.8 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 and shall be corrected and retested.
 1. Leaking, defective or torn strip seals shall be replaced.

4-4.10.10 Structural Steel Erection

4-4.10.10.1 General

- A. Structural steel shall be erected in a manner that does not damage or adversely affect the steel. The erection procedure shall maintain girder stability; location; and horizontal, vertical and longitudinal alignment at all times.
- B. Drilling of additional holes and any other modifications including field welding shall not be permitted.
- C. Lifting forces shall be vertical.
- D. Lifting devices shall not be welded to girders or require the removal of any stud shear connectors.
- E. Steel girders shall be erected with cranes.
- F. 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.

4-4.10.10.2 Transporting Materials

- A. Girders and beams shall be transported and stored with webs in the vertical position, unless otherwise specified.
- B. Structural steel shall be protected from dirt, road salts, slush or other contaminants during transportation, handling, and storage. All girders shall be cleaned of all loose or foreign material prior to erection or installation.
- C. Girders and beams may be transported in other positions provided:
 1. A Professional Engineer prepares a signed and sealed transportation assessment report and provides a written statement that the transportation method will not damage the elements. The assessment shall account for all static and dynamic forces and associated stresses 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 for correct tolerances, material cleanliness and presence of damage.
 3. An adequate flat storage area shall be provided for the inspection.
- D. Any element damaged during transportation, handling, storage or erection shall be immediately reported to the City.
1. An engineering assessment report and repair procedure prepared, signed and sealed by a Professional Engineer experienced in the evaluation and inspection of damaged concrete members shall be submitted to the City.
 2. An independent inspection and assessment shall be performed on the damaged elements by a Level III certified welding inspector in accordance with CSA 178.2 accredited with W47.1.
- E. All elements shall be lifted and handled using devices that do not mark, mar, damage or distort the elements and assemblies in any way.
- F. Galvanized material shall be stacked or bundled and stored to prevent wet storage stain in accordance with the American Hot Dip Galvanizers Association (AHDGA) publication "Wet Storage Stain".
1. Galvanized steel exhibiting heavy wet stain shall have affected areas repaired according to ASTM A780 prior to installation.

4-4.10.10.3 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 such temporary supporting structure.
1. Drawings for temporary supporting structures and berms shall be prepared, signed and sealed by a Professional Engineer.

4-4.10.10.4 Erection of Structural Steel Girders

- A. A detailed erection procedure for the erection of structural steel girders and other primary load carrying members shall be provided to the City in advance of the scheduled start of erection. The erection procedure shall include all drawings and documents necessary to describe the following:
1. Access to the work, including temporary access berms and/or work bridges;
 2. Details of Temporary Work, including:
 - a. Drawings and methods to be used to ensure the required position and stability of the girders or girder segments prior to placing concrete;
 - b. Location, elevation, and grade of support bearings;
 - c. Theoretical top of girder elevations at bearing and splice locations; and
 - d. Vertical, horizontal, and longitudinal position adjustment mechanisms;
 3. An as constructed survey of substructure elements, including:
 - a. Location and elevation of all bearing grout pad recesses including anchor rod voids;

- b. Shim height required at each bearing location; and
 - c. Longitudinal and transverse measurements between centreline of bearings of all substructure elements;
4. Superstructure layout plan, including:
 - a. Installation details of reference lines and markings of substructure and bearing components used to determine final bearing and girder positions;
 5. Theoretical top of girder elevations at substructure bearing locations;
 6. Type and capacity of cranes and other equipment required for handling and erecting of girders;
 7. Sequence of operation including positions of cranes, trucks with structural steel girders and Transportation Accommodation;
 8. Position of cranes relative to substructure elements such as abutment backwalls, with details of load distribution of wheels and outriggers;
 9. Lifting devices and lifting points;
 10. Girder stabilization details, methods of maintaining girder location and alignment, and details of blocking for girder and bearings;
 11. Diaphragm and bracing installation schedule and sequence;
 12. Bolt tightening sequence;
 13. Grout pad construction; and
 14. 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 at all times.

4-4.10.10.5 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.

4-4.10.10.6 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.

4-4.10.10.7 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 50% 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 and be distinguishable from the final bolts. Cylindrical erection pins shall be sized to accurately fit the holes.
5. Should adjustments in elevation of the girder or primary load carrying member splices become necessary to allow free rotation of the joint, only enough pins or bolts to allow rotation shall be removed.

4-4.10.10.8 Grout Pads

- A. Grout pads shall comply with Sections 4-4.12.10.3 [*Grout Pads*] and 4-4.12.10.4 [*Grouting in Cold Weather*] of this Schedule.

4-4.10.11 High-Tensile-Strength Bolted Connections

4-4.10.11.1 General

- A. All girders and primary load carrying members 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 as required by the Final Design. The Final Design shall indicate what type of surface preparation has been assumed.
 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. The smooth side of the hardened washer shall be placed against the structural steel.
 1. Surfaces of bolted parts in contact with the bolt head and nut shall be parallel.
 2. For sloped surfaces sloping more than 1:20, ASTM F436 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. Re-lubrication of bolts before installation is permitted.

4-4.10.11.2 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 4-4.10.11.2 [*Bolt Tension*], “snug tight” shall mean the tightness attained by a few impacts of an impact wrench or the full effort of a person 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 rotational 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.
- G. The Field Review Monitor shall witness the tightening of 10% of all bolts at the following times:
 - 1. The marking of the nuts after they are snug tight; and
 - 2. After they have been tightened by the turn of nut method.

4-4.10.11.3 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.

4-4.10.11.4 Misfits

- A. The correction of minor misfits involving reaming, cold cutting and chipping for secondary members may be permitted by the City, in its discretion.
 - 1. If such field corrections are required, a repair procedure signed and sealed by a Professional Engineer shall be prepared and submitted to the City prior to the corrections being carried out.

4-4.10.11.5 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.
- C. Reaming of primary members shall not be permitted.

4-4.10.12 Structural Steel for Building Structures

4-4.10.12.1 General

- A. This Section 4-4.10.12 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.

4-4.10.12.2 Standards

- A. Structural steel shall comply with the applicable requirements of the following standards:
 - 1. ASTM F3125/F3125M – High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength;
 - 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.

4-4.10.12.3 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.
 - 5. CISC – Guide for Specifying Architecturally Exposed Structural Steel.
- F. Shop drawings, procedures and calculations shall be submitted to the City.

4-4.10.12.4 Materials

- A. Welding materials shall comply with CAN/CSA W48 and W59.
- B. Galvanizing shall be touched up with a minimum of 2 coats of zinc rich primer for interior exposures.

4-4.10.12.5 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.
- 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.

4-4.10.12.6 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 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.

4-4.10.12.7 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 CAN/CSA S136 and 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.

4-4.11 ASPHALT CONCRETE PAVEMENT (ACP)

4-4.11.1 General

- A. ACP shall be installed on the bridge deck, roof slabs and approach slabs for the Stony Plain Road Bridge.
 - 1. Asphalt concrete pavement shall be mix type 10 mm – High Traffic (10mm-HT) as specified in the Valley Line West LRT Roadways Design and Construction Standards.
 - 2. Use of reclaimed asphalt pavement on Transportation Structures shall not be permitted.
- B. 10mm-HT aggregate shall be provided to the gradation band shown on *Table 4-4.11.1-1: 10mm-HT Gradation Band*.

Table 4-4.11.1-1: 10mm-HT Gradation Band

Designation	1
Class	10.0
Application	10mm-HT
Sieve Size (µm)	% Passing by Mass
12 500	100
10 000	97-100
8 000	70-94
6 300	45-85
5 000	32-75
2 500	23-55
1 250	16-45
630	11-36
315	8-26
160	5-15
80	3-8

- C. The asphalt mix design shall be provided to the City 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 4-4.11.1-2 [Requirements for 10mm-HT Mix Design].

Table 4-4.11.1-2 Requirements for 10mm-HT Mix Design

Parameter	Requirement
Number of Gyration	
Gyrations N_{design}	100
Gyrations $N_{maximum}$	160
Density at $N_{maximum}$ (% G_{mm})	98.0 max
Bailey CA-CUW	60 to 85 max Fine Graded Or >95 to 105 max Coarse Graded
Air Voids, % of total mix (virgin mix)	4.0 ± 0.4%
VMA, %	13 min
Voids Filled, %	70 - 80
Tensile Strength Ratio, % (AASHTO T283) ¹	80 min
Minimum Film Thickness ² , 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, with optional freeze thaw, 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.

4-4.11.1.2 ACP Mixing Plant

- A. The ACP mixing plant used for the preparation of ACP shall conform to the Valley Line LRT 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 ± 10 degrees Celsius of the specified mixing temperature.

4-4.11.1.3 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.

4-4.11.1.4 Pavers

- A. Pavers shall be self-propelled and operated to maintain the lines and grades shown on the applicable Final Design.

4-4.11.1.5 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.

4-4.11.2 Placement of ACP

4-4.11.2.1 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.

4-4.11.2.2 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/m².
 - 1. The ambient air temperature at the time of application shall be 5 degrees Celsius or higher.

4-4.11.3 Spreading and Compaction

4-4.11.3.1 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.

4-4.11.3.2 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.

4-4.11.3.3 Compaction

- A. ACP percent compaction shall be expressed in percent of Maximum Theoretical Density (MTD). The MTD used for determining ACP compaction shall be as follows:
 1. MTD determined on field sampled ACP mixture, or if not available then; and
 2. MTD 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, 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. The average maximum density readings from the five control strip test locations will be the Control Density of the lift.

1. ACP density measurements shall be taken for all remaining mats of the lift using nuclear testing equipment.
 2. Following compaction of the lift, density readings shall be taken and recorded at a minimum frequency of one per 10 m of bridge length or 20 m of approach road transitions for each mat placed. The average of the readings taken by the nuclear gauge shall be considered the Average Mat Density.
- E. The ACP shall be compacted to the densities specified in Section 4-4.11.4 [*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 consent of the City, in its discretion.
- 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 shall not be permitted.

4-4.11.4 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 shall not be permitted.
- G. The allowable temperature range for compaction of the ACP lifts on the deck waterproofing membrane shall comply with Table 4-4.11.4-1 [*Compaction Temperature Range of ACP Lifts*]:

Table 4-4.11.4-1 Compaction Temperature Range of ACP Lifts

ASPHALT GRADE	COMPACTION TEMPERATURE RANGE	
	FIRST LIFT	SECOND LIFT
PG58-28 (A)	MAX. 105 degrees Celsius	128 – 138 degrees Celsius

- H. The minimum average density of the first ACP lift shall be 95% of MTD with no individual test less than 93% of MTD.
- I. The minimum average density of the second lift shall be 97% of MTD with no individual density less than 95% of MTD.

4-4.12 BEARINGS

4-4.12.1 General

- A. This Section 4-4.12 [*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.

4-4.12.2 Engineering Data

4-4.12.2.1 Shop Drawings

- A. Shop drawings meeting the requirements of Section 4-4.10.3.1 [*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.

4-4.12.2.2 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.

4-4.12.2.3 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.

- B. Mill test reports originating from a mill outside of Canada or the United States of America shall meet the requirements of Section 4-4.10.3.4 [*Mill Certificates*] of this Schedule.

4-4.12.3 Materials

4-4.12.3.1 Elastomer

- A. Except for fully integral abutments and piers, cured elastomeric compounds shall be low temperature AASHTO Grade 5 and shall meet the physical and low temperature brittleness requirements listed in Table X1 and Section 8.8.4 of AASHTO M251.
- B. Cured 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 X1 and Section 8.8.4 of AASHTO M251.
- C. Cured elastomeric compounds shall also meet the requirements of ASTM D2240 for low temperature crystallinity increase in hardness at an exposure of -25°Celsius for 168 hours.

4-4.12.3.2 Lubricant

- A. Lubricant for bearings shall be silicone grease, effective to -40° Celsius, and shall comply with U.S. Department of Defense MIL-S-8660C.

4-4.12.3.3 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.

4-4.12.4 Base Plate Corrosion Protection

- A. Bearing base plate corrosion protection requirements shall be in accordance with Section 4-4.10.8.3 [*Base Plate Corrosion Protection*] of this Schedule.

4-4.12.5 Welding

4-4.12.5.1 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.
- C. All electrodes, electrode/flux combinations, and electrode/shielding gas combinations shall be CSA certified.
- D. Field welding of sole plates to girders by fluxed core welding is permitted.

4-4.12.5.2 Submerged Arc Welding (SAW)

- A. The submerged arc welding process is permitted for all flat and horizontal position welds.
- B. All welds shall be welded by a semi or fully automatic submerged arc welding process.

- C. All fluxes shall conform to the diffusible hydrogen requirements of AWS D1.5 filler metal hydrogen designator H8 or lower.

4-4.12.5.3 Shielded Metal Arc Welding (SMAW)

- A. SMAW electrodes shall conform to the diffusible hydrogen requirements of AWS D1.5 filler metal hydrogen designator H4.

4-4.12.5.4 Metal Core Arc Welding (MCAW) and Fluxed Core Welding

- A. Field application of the metal core arc welding process shall not be permitted.
- B. All electrodes shall conform to the diffusible hydrogen requirements of AWS D1.5 filler metal hydrogen designator H4.

4-4.12.5.5 Cleaning Prior to Welding

- A. Weld areas shall be clean, free of mill scale, dirt, grease, and other contaminants prior to welding.
- B. For multi-pass welds, previously deposited weld metal shall also be thoroughly cleaned prior to depositing subsequent passes.

4-4.12.5.6 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 to a maximum of 15 times the weld size and shall be subject to the same quality requirements as the final welds.
- B. Cracked tack welds shall be completely removed prior to welding over.
- C. Tack welds shall be sufficiently ground out prior to final weld in order to obtain a uniform weld bead.

4-4.12.5.7 Run-off Tabs

- A. Run-off tabs shall be used at the ends of all welds that terminate at the edge of a member.
- B. The thickness and shape of the tabs shall replicate the joint detail being welded and shall be a minimum of 100 mm long unless greater length is required for satisfactory work.
- C. They shall be tack welded only to that portion of the material that will not remain a part of the structure, or where the tack will be welded over and fused into the final joint.
- D. After welding, the tabs are to be removed by flame cutting, not by breaking off.

4-4.12.5.8 Grinding of Welds

- A. Welds that are sufficiently smooth with a neat appearance and uniform profile will not require grinding.
 - 1. Welds not conforming to an acceptable profile shall be ground to the proper profile without damaging or substantial removal of the base metal.
- B. Grinding shall be smooth and parallel to the line of stress. Caution shall be exercised to prevent over grinding.
 - 1. Over grinding that results in reduced thickness of the base metal or size of the weld shall not be permitted.

2. Acceptability of the welds without grinding will be determined by the City, in its discretion.

4-4.12.5.9 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.
 3. The repair procedure shall include MPI and hardness testing of the affected area. Hardness of the repaired area shall conform to the requirements of Section 4-4.10.9.6 [*Hardness Tests*] of this Schedule.

4-4.12.5.10 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.

4-4.12.5.11 Plug and Slot Welds

- A. Plug welds or slot welds shall not be permitted.

4-4.12.6 Fabrication

4-4.12.6.1 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) in accordance with 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.

4-4.12.6.2 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.

4-4.12.6.3 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 a uniform 3 mm nominal 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 in accordance with Section 4-4.12.6.5 [*Machining*] of this Schedule.

4-4.12.6.4 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.

4-4.12.6.5 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 and sliding laminated elastomeric bearings shall be machined to a surface finish of 6.4 µm and a flatness tolerance of 0.001 x bearing dimension.

4-4.12.6.6 Identification

- A. Each bearing shall be marked with the fabricator's name, date of manufacture and unique identification number.
 - 1. The characters shall not be less than 10 mm in height.

4-4.12.6.7 Galvanizing

- A. The fabricator shall provide a smooth finish on all edges and surfaces, and remove all weld spatters, and all welding flux residue from the steel components prior to galvanizing.
- B. Unless otherwise specified, metal components, except weathering steel (CAN/CSA G40.20/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 or metallized in accordance with ASTM A780, Method A3.
- C. The cleaning and pickling procedure of high strength ASTM A193 Grade B7 anchor rods shall be modified prior to hot-dip galvanizing:
 - 1. Brush blast to remove mill scale and oil after threading ends;
 - 2. Flash pickle up to 5 minutes; and
 - 3. Quick dry prior to hot-dip galvanizing (not stored in flux or acid rinse).
- D. For pot bearings, the pot and piston plates, except surfaces in contact with elastomer, shall be metallized in accordance with ASTM A780, Method A3 with the thickness of metallizing not less than 180 µm.
- E. 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 mm² 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.
- F. The galvanized contact surfaces of bolted connections shall be hand wire brushed to a Class A slip coefficient surface condition.
 - 1. Slip coefficient surface conditions shall meet the requirements of CAN/CSA S6 Table 10.9.
- G. Galvanized material shall be stacked or bundled and stored to prevent wet storage stain in accordance with the American Hot Dip Galvanizers Association (AHDGA) publication "Wet Storage Stain".
 - 1. Any evidence of wet storage stain shall be removed to the satisfaction of the City.

4-4.12.7 Base Plate Corrosion Protection

- A. The bottom surface of each base plate 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 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.

- B. The fully cured coating shall be tested for adhesion in accordance with ASTM D3359 “Standard Test Methods for Measuring Adhesion by Tape Test”.
 - 1. The selected method of testing shall depend on the dry film thickness of the coating.
 - 2. The coating manufacturer’s product data sheets shall be provided to the City prior to the application of the coating.
 - 3. Adhesion test result shall meet a minimum of “4B” classification (maximum allowable flaking of 5%).

4-4.12.8 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 pot 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 ± 3 mm;
 - b. overall bearing height ± 3 mm; and
 - c. machined surface dimensions ± 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.

4-4.12.9 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 to the City.
- C. 25% of all fillet and partial penetration welds shall be magnetic particle inspected in accordance with ASTM E-709.
- D. Elastomeric Bearings
 - 1. Testing of elastomeric compounds shall be completed in accordance with Section 8 of AASHTO M251. Material shall conform to the specified requirements of Table X1.
 - 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.
 - b. The dimensional tolerances for each bearing shall be checked.
 - c. The hardness of elastomer shall be tested.
 - d. A minimum of two sample laminated bearings shall be cut and tested for shear modulus.

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.

E. 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 in accordance with the long-term proof load test requirements.

4-4.12.9.1 Fabrication Outside of Canada

- A. All components fabricated outside of Canada shall be shipped to a shop located in Canada that is certified by CWB in accordance with CSA W47.1 to Division 1 or 2 for re-inspection and testing.
- B. The components shall be in a condition that facilitates all re-inspection and testing requirements.
- C. The re-inspection and testing at the Canadian shop shall be completed in accordance with Section 4-4.12.9 [*Inspection and Testing*] of this Schedule.
- D. The component shall also be inspected by a CSA 178.2 Level III certified welding inspector accredited with W47.1 to inspect the following items:
 1. All components to ensure that they were undamaged during transportation; and
 2. 100% of all fillet and partial penetration welds using magnetic particle inspection in accordance with ASTM E709.
- E. Components shall not be shipped from the Canadian shop until all requirements have been met and mill certificates have been provided to the City.

4-4.12.10 Installation

4-4.12.10.1 General

- A. Bearings shall be installed in a manner that does not damage them or affect their performance.
- B. Bearings shall be adjustable in accordance with the requirements in Section 4-2.5 [*Bearings*] of this Schedule.
- C. A bearing installation procedure shall be prepared prior to installation.

4-4.12.10.2 Bearing and Anchorage

- A. Bearing base plates shall not be placed upon surfaces which are improperly finished, deformed or irregular.
- B. Foreign materials on concrete surfaces, such as oils, grease or other contaminants shall be removed by sandblasting prior to installation of anchor rods.

- C. 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.
- D. The tops of bearing sole plates shall be within a tolerance of ± 3 mm of the correct elevation prior to girder erection.
- E. 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.
- F. Galvanizing or metallizing damaged during bearing installation shall be repaired in accordance with the requirements of ASTM A780, Method A3.

4-4.12.10.3 Grout Pads

- A. Grout pads shall be constructed using a flowable non-shrink grout from the Alberta Transportation Products List.
 - 1. Dry-pack methods of constructing grout pads shall not be 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. Curing shall be a minimum 3 day wet cure.
- D. A set of compressive strength cubes shall be taken to represent each day's grout production or each 0.25 m³ 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.

4-4.12.10.4 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°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° Celsius.
 - 2. The temperature of the grout during placing shall be between 10° Celsius and 25° Celsius.
 - 3. The grout pads shall be enclosed and kept at 15° Celsius to 25° Celsius for a minimum of five days.
 - 4. The enclosure shall meet the requirements of Section 4-4.5.16 [*Concreting in Cold Weather*] 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 prior to fabrication and submitted to the City. As a minimum, the shop drawings shall show the following:
1. MSE wall design criteria and material lists;
 2. Precast concrete fascia panel reinforcing, connection and hardware details;
 3. MSE wall layout plans and elevations complete with dimensions, elevations and typical wall cross-sections;
 4. MSE wall backfill properties;
 5. all MSE wall component and connection details; and
 6. 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 4-4.5 [*Cast-In-Place Concrete*] and Section 4-4.6 [*Precast Concrete*] of this Schedule as applicable.

4-4.13.3.2 Concrete Reinforcement

- A. Concrete reinforcement shall comply with Section 4-4.9 [*Concrete Reinforcement*] of this Schedule.

4-4.13.3.3 Soil Reinforcing

- A. Steel soil reinforcing, including inspection wires, shall comply with ASTM A1064.
- B. Steel soil reinforcement consisting of steel strip reinforcement shall meet the requirements of ASTM A572.
- C. Safeguarding measures to prevent embrittlement and testing to detect embrittlement shall be completed in accordance with ASTM A143 for all lots of steel reinforcement, connections and associated hardware.
- D. Galvanizing of steel soil reinforcing shall comply with ASTM A123/A123M, and ASTM F2329.
1. All damage to galvanizing shall be repaired in accordance with ASTM A780, Method A3 "Metallizing" unless the repair area is less than 100 mm² in which case the repairs may comply

with ASTM A780 Method A1 "Repair Using Zine-Based Alloy". The thickness of the coating of both methods shall be 180 µm, and the repair tested for adhesion.

- E. Galvanized material shall be stacked or bundled and stored to prevent wet storage stain in accordance with the American Hot Dip Galvanizers Association (AHDGA) publication "Wet Storage Stain".
- F. 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. Site specific studies and testing shall be carried out to determine the strength reduction factors for geosynthetic reinforcements used in MSE wall construction to account for short-term and long-term degradation due to installation damage (RF_{ID}), creep (RF_{CR}), and chemical and biological factors (RF_D) throughout the Design Service Life. The studies and testing shall be performed by a third party, independent agency accredited by the Standards Council of Canada (SCC).
- G. Geosynthetic soil reinforcing materials shall meet the requirements of the following tests:
 - 1. ASTM D7737-11 "Standard Test Method for Individual Geogrid Junction Strength";
 - 2. ASTM D5262 – 07(2012) "Standard Test Method for Evaluating the Unconfined Tension Creep and Creep Rupture Behavior of Geosynthetics"
 - 3. ASTM D6706 – 01(2013) "Standard Test Method for Measuring Geosynthetic Pullout Resistance in Soil"
 - 4. GG 2-87 "Standard Test Method for Geogrid Rib Junction Strength";
 - 5. GG4-05 "Standard Practice for Determination of the Long Term Creep Design Strengths of Geogrids".
 - 6. GG4(a) Revised 2012, Standard Practice for Determination of the Long-Term Design Strength of Stiff Geogrids; and
 - 7. GG4(b) Revised 2012, Standard Practice for Determination of the Long-Term Design Strength of Flexible Geogrids.
- H. Geosynthetic soil reinforcing materials shall contain stabilizers or inhibitors to prevent degradation of properties due to ultraviolet light exposure.
- I. The ultimate tensile strength (T) of the specific soil reinforcing products used in MSE wall construction shall be determined by an independent agency such as the Highway Innovative Technology Evaluation Centre (HITEC) or the AASHTO National Transportation Product Evaluation Program (NTPEP)
 - 1. Product lines shall have been tested within the last 3 years.
- J. Material test reports shall be submitted for all geosynthetic soil reinforcement and impermeable geomembrane.
- K. Mill test reports shall be submitted for all steel fabricated components, steel soil reinforcement connections, and associated hardware and as a minimum, shall include the following items:
 - 1. Heat number;

2. Date;
3. Location of production;
4. Compliance with production standards;
5. Chemical Analysis;
6. Mechanical Properties; and
7. Galvanizing processes.

L. Mill test reports originating from a mill outside of Canada or the United States of America shall meet the requirements of Section 4-4.10.3.4 [*Mill Certificates*] of this Schedule.

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
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. Laboratory density testing shall be completed on backfill source(s) in accordance with ASTM D698.

- C. 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 migration of fine soil particles between the zones.
- D. MSE wall backfill material containing steel soil reinforcing shall comply with Table 4-4.13.3-2 [*Electrochemical Parameters for MSE Wall Steel Soil Reinforcing*]:

Table 4-4.13.3-2 Electrochemical Parameters 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
Magnesium Sulphate Soundness	Loss less than 30% after four cycles	D5240	T 104
Sulphates	≤ 200 ppm	G516	T 290
Organic Content	≤ 1.0%	D2974	N/A

- E. 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

- F. 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

Non-Woven Geotextile Filter Fabric		
Specifications and Physical Properties	Test Method (ASTM)	
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

Impervious Geomembrane		
Specifications and Physical Properties		Test Method (ASTM)
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 Type 1c Concrete Sealer

- A. Type 1c sealer shall be applied to exposed concrete surfaces.

4-4.13.5 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.

4-4.13.6 MSE Wall Panel Production

- A. The fabrication of precast concrete MSE wall panels shall comply with Section 4-4.6 [*Precast Concrete*] of this Schedule.

4-4.13.7 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 in accordance with the requirements of Table 4-4.13.7-1 [*Sampling and Testing of Backfill Properties During Construction*]:

Table 4-4.13.7-1 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

4-4.13.8 Construction

4-4.13.8.1 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.
 - 2. The representative of the MSE wall supplier shall document any deviations from shop drawings, recommended construction procedures and accepted industry practice, and shall record the mitigation measures implemented to correct such deviations.
 - 3. The MSE wall supplier representative shall sign off the final construction details.

4-4.13.8.2 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 the Engineer of Record.
- 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.

4-4.13.8.3 Backfill

- A. Backfill shall be placed in conformance with Section 4-4.1 [*Backfill*] of this Schedule and 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 such that soil reinforcement is fully supported over its length.

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 in lifts not exceeding 150 mm in thickness of loose material.
- D. Backfill shall not be placed on frozen substrate.
- E. Overlapping geosynthetic reinforcement layers shall be separated by a minimum 75 mm of compacted backfill.
- F. A control strip density shall be established on the first backfill lift and every 900 mm (vertically) of backfill placed thereafter for every 45 metres of wall or part thereof and not less than once per day. The control strip density shall be re-established where the gradation or source of aggregate change, or when different compaction equipment is used.
1. The control strip density shall be measured in accordance with Alberta Transportation Test Method ATT-58A, Density Test Control Strip Method.
 2. All backfill lifts shall be compacted to a minimum of 98% of the control strip density and shall be measured in accordance with Alberta Transportation Test Method ATT-11, Density Test In-Place Nuclear Method.
- G. 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 to direct potential run-off away from the wall face.
 4. Surface runoff from adjacent areas into the MSE wall construction site shall not be permitted.
- H. Sieve analysis shall be completed on backfill being placed at the beginning and end of each day for each zone of backfill containing soil reinforcing.

4-4.13.8.4 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.

4-4.13.8.5 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 DECK WATERPROOFING MEMBRANE SYSTEM

4-4.14.1 General

- A. This Section 4-4.14 [*Deck Waterproofing Membrane System*] sets out the requirements for all deck waterproofing membrane and asphalt concrete pavement (ACP) forming part of the Stony Plain Road Bridge, including minimum requirements for quality, supply, handing 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 Drawings* S-1838, S-1839 and S-1440 (Standard Water Proofing System for Deck and Abutments.).

4-4.14.2 Engineering Data

- A. Documentation showing that the deck waterproofing membrane materials comply with the requirements of Section 4-4.14.3 [*Materials*] of this Schedule shall be obtained prior to the installation of the deck waterproofing membrane.
- B. An asphalt mix design for the Stony Plain Road Bridge, with applicable material quality compliance test reports for each type of ACP, shall be submitted before first placement of such ACP.

4-4.14.3 Materials

4-4.14.3.1 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.

4-4.14.3.2 Deck Waterproofing Membrane Tack Coat

- A. The tack coat shall be a primer type meeting the requirements of CAN/CGSB-37-GP-9MA.

4-4.14.3.3 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.

4-4.14.3.4 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.

4-4.14.3.5 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.

4-4.14.3.6 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.

4-4.14.3.7 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.

4-4.14.3.8 ACP

- 1. ACP materials shall comply with Section 4-4.11 [*Asphalt Concrete Pavement (ACP)*] of this Schedule and the Valley Line LRT Roadways Design and Construction Standards unless otherwise specified in this Section 4-4.14 [*Deck Waterproofing Membrane System*] of this Schedule.

4-4.14.4 Equipment

4-4.14.4.1 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 4-4.14 [*Deck Waterproofing Membrane System*] of this Schedule.

4-4.14.4.2 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 $\pm 2^\circ$ Celsius to measure the temperature of the melted compound and oil.
 - 3. A separate calibrated thermometer with an accuracy of $\pm 2^\circ$ Celsius shall be available on-site to verify material temperatures.

4-4.14.5 Inspection and Testing

4-4.14.5.1 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.

4-4.14.5.2 ACP

- A. Inspection and testing of ACP shall comply with the Valley Line LRT Roadways Design and Construction Standards unless otherwise specified in this Section 4-4.14 [*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 4-4.14 [*Deck Waterproofing Membrane System*] of this Schedule.

4-4.14.6 Installation of Deck Waterproofing Membrane

4-4.14.6.1 General

- A. Installation of the deck waterproofing membrane shall only be carried out when the air and concrete surface temperatures are 5° 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 4-4.14 [*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.

4-4.14.6.2 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 shall not be 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.

4-4.14.6.3 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. All concrete surfaces shall have less than 6% moisture prior to application of the tack coat.
 - 1. Testing shall be completed using a Hygrometer or Protimeter.

- D. 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.
- E. 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, shall not be permitted.
 - 3. Tack coat material shall be applied at an approximate rate of 0.25 L/m².
- F. Waterproofing equipment or material shall not be permitted on the tack coat until it has fully cured and is completely tack-free.

4-4.14.6.4 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 4-4.14.6.5 [*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.

4-4.14.6.5 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.

4-4.14.6.6 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.

4-4.14.6.7 Application of Protection Board

- A. The asphalt membrane thickness shall be checked and documented to confirm conformance to the requirements of Section 4-4.14.6.5 [*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.

4-4.15 SOIL NAILS

4-4.15.1 General

- A. This Section 4-4.15 [Soil Nails] sets out the requirements for permanent soil nails and other related structural components resisting lateral earth load/surcharge load and forming part of a Structure, including minimum requirements for supply, installation, grouting and testing.

4-4.15.2 Engineering Data

4-4.15.2.1 Related Project Construction Requirements

- A. Section 4-4.5 [Cast-In-Place Concrete] of this Schedule.
- B. Section 4-4.9 [Concrete Reinforcement] of this Schedule.
- C. Section 4-4.16 [Shotcrete] of this Schedule.

4-4.15.2.2 Shop Drawings

- A. Shop drawings showing fabrication and installation details of the soil nails shall be submitted to the City. The shop drawings shall include the following:
 - 1. inclination, length, diameter, and vertical and horizontal spacing of soil nails;
 - 2. type, length and size of the soil nail steel bar;
 - 3. design pullout resistance per unit length of soil nail;
 - 4. tendon anchorage details, including all components of soil nail head;
 - 5. corrosion protection system for the tendons and soil nail head components;
 - 6. the type and spacing of tendon centralizers and spacers; and
 - 7. grout mix design and grout placement procedures.

4-4.15.2.3 Mill Certificates

- A. Mill certificates for the soil nail tendons and couplers, including the ultimate strength, yield strength, load/elongation curves, and composition, shall be provided to the City.
- B. Mill certificates for the soil nail head components shall be provided to the City.
- C. Manufacturer certificates of compliance for the soil nail centralizers shall be provided to the City.
- D. Mill test reports originating from a mill outside of Canada or the United States of America shall meet the requirements of Section 4-4.10.3.4 [*Mill Certificates*] of this Schedule.

4-4.15.3 Materials

- A. Materials for soil nails shall comply with Section 4-2.4.3 [*Soil Nail Walls*] and Section 4-1.7.8 [*Soil Nail Corrosion Protection*] of this Schedule, and FHWA-NHI-14-007.
- B. Tendon couplers shall develop 120 percent of the specified tensile yield strength of the tendon as certified by the manufacturer.
- C. Steel hardware of soil nail heads shall be hot-dip galvanized per ASTM A153 / A153M.

- D. Centralizers and spacers shall be fabricated from Schedule 40 PVC pipe or tube, steel, or material non-detrimental to the steel bar. The use of wood shall not be permitted.
- E. Soil nail grout shall be neat cement or sand/cement mixture with a minimum 3-day compressive strength of 21 MPa and a minimum 28-day compressive strength of 30 MPa in accordance with ASTM C109.
- F. Admixtures, if used, shall meet the requirements of ASTM C494, and shall be compatible with the grout and the steel bar components. The use of accelerators or expansive admixtures shall not be permitted.

4-4.15.4 Installation

4-4.15.4.1 General

- A. The entity performing any soil nailing shall be experienced in the construction and load testing of soil nails and have successfully constructed at least 5 projects in the last 5 years involving construction totaling at least 1000 soil nails of similar capacity to those required in the Final Design.
- B. Soil nail tendons, including all components of soil nail head, shall be handled, stored and installed in such a manner as to avoid damage, corrosion or contamination with dirt or deleterious substances, in accordance with the requirements of FHWA-NHI-14-007.
- C. The use of drilling fluids (such as bentonite slurry) to advance the soil nail holes shall not be permitted.

4-4.15.4.2 Installation Tolerances

- A. Soil nail head location shall not deviate from the design location by more than 150 mm in any direction.
- B. Soil nail inclination shall be within plus or minus 3 degrees from the design inclination.
- C. Installation tolerances are applicable to individual soil nails, and not to the average of multiple soil nails in an area.
- D. Soil nail tendon shall be placed within 25 mm of the center of the drill hole.
- E. Soil nails that do not satisfy the specified tolerances shall be replaced.
- F. The soil nail head assembly shall be installed perpendicular to the tendons, without bending or kinking of the tendons.

4-4.15.4.3 Grouting

- A. Grouting of soil nails shall comply with FHWA-NHI-14-007.
- B. Grouting of drill holes after installation of the soil nail tendons shall be completed within two hours of completion of drilling and shall be done in one continuous operation. Cold joints in the grout column are not allowed except at the top of the bond length of production soil nails that will be proof tested.
- C. The grout shall be free of lumps and undispersed cement.
- D. Admixtures, if used, shall be mixed in accordance with the manufacturer's recommendations.
- E. Soil nail grout shall be tested in accordance with ASTM C109 at a frequency of no less than one test for every 4 cubic meters of grout placed. Irrespective of the volume of grout placed, a minimum of one test shall be performed on a set of grout cubes from each grout plant on each day of operation.

4-4.16 SHOTCRETE

4-4.16.1 General

- A. This Section 4-4.16 [*Shotcrete*] sets out the requirements for shotcrete for soil nail walls including minimum requirements for quality, sampling and testing, placing, curing and finishing shotcrete.

4-4.16.2 Materials

4-4.16.2.1 Shotcrete

- A. Only wet mix shotcrete mix-designs will be permitted.
- B. A shotcrete mix design review letter, together with applicable material quality compliance test reports, shall be submitted to the City.
- C. The mix design review letter shall include the following items:
1. An evaluation and summary of all mix constituents;
 2. Material test reports;
 3. Mix proportion quantities by mass or volumes;
 4. Cement type;
 5. Aggregate source, grading, and test reports;
 6. Water source(s); and
 7. Trial batch test results confirming the proposed mixture design is capable of meeting the specified performance requirements in Table 4-4.16.2.1 [*Concrete Classes*].

Table 4-4.16.2.1 Concrete Classes

Test Description	Test Method	Age (Days)	Specified Requirement
Maximum water/cementitious materials ratio			0.45
Air content – as shot	CSA A23.2-4C		4 +/- 1%
Slump at discharge into pump	CSA A23.2-5C		60 +/- 20 mm
Minimum compressive strength	CSA A23.2-14C	7 28	20 MPa 30 MPa
Maximum Boiled Absorption	CSA A23.2-11C	7	8%

Maximum Volume of Permeable Voids	CSA A23.2-11C	7	17%
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4-4.16.2.2 Portland Cement

- A. Portland cement shall comply with CAN/CSA A3001. General use (Normal), Type GU, shall be used unless otherwise specified herein.
 - 1. 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.

4-4.16.2.3 Fly Ash

- A. Fly ash, if required, shall conform to the requirements of CSA A3001 Type F with a calcium oxide content not exceeding 12%.
- B. A minimum pozzolanic activity index (PAI) of 75% at 28 days is required.

4-4.16.2.4 Silica Fume

- A. Silica fume, if required, shall conform to the requirements of CSA A3001 Type SF in a ratio of 6% to 8% of the mass of the cement.

4-4.16.2.5 Admixtures

- A. Air entraining admixtures shall conform to the requirements of ASTM C260.
- B. Chemical admixtures such as water reducers, high-range water reducers (superplasticizers), and retarders, shall conform to the requirements of ASTM C1141.
- C. Admixture containing chlorides shall not be used.
- D. All admixtures and set accelerators shall be sourced from a single manufacturer. The manufacturer shall state compatibility between admixtures.

4-4.16.2.6 Aggregates

- A. Fine and coarse aggregates shall comply with CAN/CSA A23.1.
- B. The relative density and absorption of fine and coarse aggregates shall be determined in accordance with CSA A23.2-6A and CSA A23.2-12A.
- C. The water absorption of the combined aggregate shall not exceed 2%.

Use nominal 10 mm maximum size coarse aggregate combined with a concrete sand to provide a blend that conforms to

Table 4-4.16.2.6 [*Composite Gradation Envelope*]

Table 4-4.16.2.6 Composite Gradation Envelope

Sieve Size (mm)	Total Passing each sieve % by mass
14	100
10	90-100
5	70-85
2.5	50-70
1.25	35-55
0.630	20-35
0.315	8-20
0.160	2-10

4-4.16.2.7 Reinforcement

- A. Concrete reinforcement shall comply with Section 4-4.9 [*Concrete Reinforcement*] of this Schedule.
- B. Mill test reports shall be submitted for all steel reinforcement, including welded wire mesh.
- C. Mill test reports originating from a mill outside of Canada or the United States of America shall meet the requirements of Section 4-4.10.3.4 [*Mill Certificates*] of this Schedule.

4-4.16.2.8 Supply and Equipment

- A. Wet-mix shotcrete shall be batched, mixed, and supplied in accordance with the following:
 - 1. Central mixing with transit mixture delivery
 - a. Aggregate, cement, and silica fume shall be mass batched in a central mixer in accordance with the requirements of CSA A23.1-04.
 - b. Water and chemical admixtures shall be batched to the accuracy specified in CSA A23.1-04. Transit mixers shall be free of excessive accumulations of hardened shotcrete or concrete in the drum or on the blades.
 - c. Blades shall be free of excessive wear.
 - d. Transit mixture delivery shall conform to the requirements of CSA A23.1-04. All shotcrete shall be shot within 60 minutes after addition of mixture water to the batch. Shotcrete loads shall be of such batch size that this requirement is met. This time limit may be extended, subject to

acceptance by the Engineer of Record, if proper use is made of set retarding or hydration controlling admixtures to maintain workability without retempering with water.

2. Transit mixing and delivery

- a. The same requirements as central mixing except that all mix constituents shall be added directly to the transit mixer instead of the central mixer.
- b. Transit mixers shall be filled to not more than 70% of their rated capacity, to enable efficient mixing action.

4-4.16.2.9 Shotcrete Placing Equipment

- A. The shotcrete placing equipment shall be capable of delivering a steady stream of uniformly mixed material to the discharge nozzle at the proper velocity and rate of discharge.
- B. The use of positive displacement pumps equipped with hydraulic or mechanically powered pistons (for example, similar to conventional concrete piston pumps), with compressed air added at the discharge nozzle, is the preferred type of wet-mix shotcrete delivery system.
- C. Pneumatic feed guns, rotary type feed guns (similar to dry-mix guns) and peristaltic squeeze-type pumps shall only be used if Project Co can demonstrate that they can produce shotcrete meeting the project requirements.
- D. The air ring at the nozzle shall be carefully monitored for any signs of blockage of individual air holes. If non-uniform discharge of shotcrete becomes apparent, shooting shall be stopped, and the air ring cleaned or other appropriate corrective actions taken.
- E. The delivery equipment shall be thoroughly cleaned at the end of each shift. Any build-up of coatings in the delivery hose and nozzle shall be removed. The air ring and nozzle shall be regularly inspected and cleaned and replaced if required.

4-4.16.2.10 Auxiliary Shotcrete Equipment

- A. Clean, dry, compressed air capable of maintaining sufficient nozzle velocity for all parts of the Work and simultaneous operation of a blowpipe shall be supplied.
- B. The air supply system shall contain a moisture and oil trap to prevent contamination of the shotcrete.
- C. It is Project Co's responsibility to supply auxiliary shotcrete equipment such as material delivery hoses, blowpipes, and couplings as required to complete the Work.

4-4.16.2.11 Nozzleman Qualification

- A. The nozzle operator shall be an ACI-certified Shotcrete Nozzleman for vertical applications for the shotcrete process type used.
- B. The names of the nozzle operators and proof of their qualifications shall be provided to the City.

4-4.16.2.12 Alignment Control and Cover

- A. Implement alignment control to establish control over line and grade and ensure that the minimum specified shotcrete thickness and cover to concrete reinforcement are maintained. Verify that reinforcing bars are fixed to provide specified cover before application of any shotcrete.

- B. Provide alignment control by means of devices such as shooting wires, guide strips, depth gauges, or forms. Depth gauges shall be installed at 1.8 m spacing longitudinally and transversely with no less than two gauges per increment of surface area to receive shotcrete.
- C. When ground wires (also called guide wires or shooting wires) are used, they shall consist of a high-strength steel wire kept taut during shotcreting. Ground wires shall be removed after completion of shotcreting and screeding operations.
- D. Guide strips and forms shall be of such dimensions and installation configuration that they do not impede the ability of the nozzle men to produce uniform, dense, properly consolidated shotcrete. In particular, installations that are conducive to the entrapment of rebound or formation of shadows and voids shall not be used.

4-4.16.2.13 Preconstruction Trial

- A. Project Co. shall carry out a preconstruction trial to prequalify the nozzle men proposed for use on the project. Nozzle men who have not been prequalified shall not be permitted to apply shotcrete on the project. The preconstruction trial shall use the same materials, shotcrete mixture, and equipment proposed for use on the project and approximate actual working conditions, configuration, reinforcement, and shooting position, as near as possible.
- B. Nozzle men shall prequalify by shooting mock-ups of the reinforced structural wall element. Five cores shall be taken from each mock-up for core grading from locations as determined by the Engineer of Record. Cores shall be evaluated by the Engineer of Record to check the quality of shotcrete placement. Cores shall show adequate consolidation and be free of excessive voids around concrete reinforcement, shadows, sags, sloughing, or delamination.
- C. Project Co shall prepare and cure test panels according to ASTM C1140. Test panels shall have a minimum length and width of 600 mm and 150 mm deep. The test panels shall be made from wood and sealed plywood and have 45-degree sloped edges to permit rebound to escape and facilitate demoulding. The reinforcement shall equal the densest configuration expected in the shotcrete batch.
- D. Test panels shall be cured in the field, close to the location where shot, for two days before being transported in the form to a testing laboratory. The test panels shall be cured under wet burlap covered with plastic sheet under temperature conditions similar to that experienced by the wall. The panels shall be protected from disturbance or damage.
- E. Test panels and cores extracted from the test panels shall be moist cured at 23 °C and in accordance to AASHTO M201 until the time of compressive strength testing. Alternatively, the test panels and core samples shall be covered and tightly wrapped with material conforming to ASTM C171.
- F. After 14 days, but no later than 28 days after shooting, perform and report concrete quality tests including density, boiling absorption and volume of permeable voids. At least three samples shall be tested from each non-reinforced test panel. Samples may consist of cores, pieces of cores or test panels that are without observable cracks, fissures, or shattered edges.
- G. Three core samples shall be drilled, 75 mm in diameter, from each test panel at least 40 hours prior to both the 7 day and 28-day compressive strength tests. The cores shall be collected and tested in accordance with ASTM C1140. Before compressive strength testing, saw or tool the ends of the cores to eliminate projections and to achieve perpendicularity to the longitudinal axis. Compressive strength tests of the three cores in accordance with CSA A23.2-9C shall be carried out at 28 days.
- H. If the preconstruction test specimens fail to meet the project requirements, the materials, mix design and application shall be adjusted and a new test panel shall be shot. No work shall commence until the preconstruction requirements have been met.

- I. If the source or quality of the materials or the mix proportions change, new shotcrete trials shall be completed prior to using the shotcrete new mix design for production.
- J. Project Co shall submit results from all shotcrete trials, including the following information:
 - 1. Test panel and core identification including panel number, shooting orientation, mix proportions and nozzle operator;
 - 2. Date and time of test panel application including dimensions, size and spacing of reinforcement, and type of curing;
 - 3. Date and time specimen was tested;
 - 4. Curing time for each specimen;
 - 5. Strength of each core specimen;
 - 6. Dimensions of each core specimen and sketch of each failed core specimen; and
 - 7. Measured strain at failure of each core specimen.

4-4.16.2.14 Construction Testing

- A. Project Co shall submit a Construction Testing Plan to the City before beginning shotcrete construction.
- B. One construction test panel shall be shot for each 50 m³ of shotcrete production, or for each day of shotcrete production, whichever is more frequent. The panel shall be shot in the same orientation as the work being done.
- C. Construction test panels shall be produced, stored, handled, cured, and tested in the same manner prescribed for preconstruction test panels.
- D. All results from production tests shall be provided to the City.

4-4.16.2.15 Shotcrete Application and Finishing

- A. All shotcrete work shall follow good industry practice as defined in ACI 506.
- B. Concrete reinforcement shall be supported so it is not displaced during the application of shotcrete.
- C. Shotcrete shall not be applied to frozen surfaces. Project Co shall dampen surfaces and confirm that the soil is free of surface water prior to shotcrete application.
- D. Shotcrete application shall be in layers no greater than 75 mm unless Project Co can demonstrate that a thicker application can be achieved without sloughing or sagging. When applying more than one layer of shotcrete, trim with a cutting rod, or brush with a stiff bristle broom to remove all loose material, overspray, laitance, or other material detrimental to bonding of the next layer of shotcrete. Each shotcrete layer shall be allowed to stiffen sufficiently before applying next layer of shotcrete. If shotcrete has set and hardened, high-pressure clean water (34.4 MPa) shall be used to blast the surface. The surface shall then be soaked for 2 to 24 hours and excess water shall be blown away immediately prior to placing the next layer of shotcrete to provide a saturated surface dry condition.
- E. Project Co shall use a shooting technique that provides full encapsulation of all concrete reinforcement and embedments. All voids, shadows, sags, and/or other defects shall be cut out from the applied shotcrete while it still plastic and re-shot.

- F. The shotcrete shall be trimmed with a cutting rod or other suitable device to the specified line and grade. The shotcrete shall be finished to a sandy texture acceptable to the Engineer of Record. Project Co shall protect all fixtures and adjacent concrete surfaces from build-up of rebound, overspray and shotcrete trimmings, and promptly remove any excess shotcrete applied outside of the specified areas to be shot.
- G. Construction joints shall have a 45 degree tapered edge. Square construction joints shall not be permitted. The shotcrete shall be cut while plastic with a trowel or other suitable tool to form construction joints. The shotcrete shall be green cut with a 34.4 MPa water pressure jet the following day, if necessary, to remove loose material. Feather-edge construction joints shall not be permitted.
- H. The general requirements for hot and cold weather concreting detailed in CSA A23-1 shall apply to the shotcrete Work. Shotcrete application shall be terminated if the ambient temperature rises above 30°C, unless Project Co adopts special hot weather shotcreting procedures acceptable to the Engineer of Record.
- I. Shotcrete shall not be applied during high winds or heavy rainfall. The shotcrete mix temperature shall be maintained between 10°C and 30°C.
- J. During periods of cold weather, shotcreting may only proceed if the substrate to which the shotcrete is applied is above 5°C for a minimum of 24 hours prior to application.
- K. For shotcreting of the final excavation face, the application of the shotcrete shall not be delayed by more than 8 hours without acceptance from the Engineer of Record.

4-4.16.2.16 Shotcrete Facing Tolerances

- A. The shotcrete facing shall meet the tolerances listed in Table 4-4.16.2.16 [*Shotcrete Facing Tolerances*].

Table 4-4.16.2.16 Shotcrete Facing Tolerances

Item	Tolerance
Horizontal location of welded wire mesh, reinforcing bars, and headed studs	10 mm
Thickness of shotcrete	15 mm
Planeness of finish face surface, gap under 3 m straightedge	15 mm
Nail head bearing plate deviation from parallel to wall face	5 degrees

4-4.16.2.17 Shotcrete Surface Finish

- A. A smoothing layer a minimum of 25 mm thick shall be applied to create a smooth surface for the installation of the frost protection insulation.
- B. The shotcrete shall not have any irregularities that exceed a ratio of 5 units of length to 1 unit of depth, and its minimum radius shall be 200 mm.
- C. The final surface shall be free from structural steel, fixings, and any other sharp edges or pointed forms.

4-4.16.2.18 Curing

- A. Shotcrete shall be moist cured using fogging, wetting or maintenance of a minimum 95% relative humidity in the area surrounding the shotcrete, for a minimum of 7 days. Moist curing shall be accomplished using one or more of the following procedures:
 - 1. Wrap the elements in wet burlap covered with a plastic sheet or a presaturated plastic coated nonwoven synthetic fiber; or
 - 2. Install sprinklers, soaker hoses, or other devices to keep the shotcrete continuously wet for the specified period.
- B. The use of intermittent wetting procedures that will allow the shotcrete to undergo cycles of wetting and drying during the curing process shall not be permitted.
- C. If the prevailing ambient conditions (relative humidity, wind speed and air temperature) are such that the shotcrete develops plastic shrinkage and/or early drying shrinkage-cracking, terminate shotcrete application.
- D. Corrective measures such as the installation of wind barriers or fogging devices to protect the work shall be implemented before restarting shotcrete application. Do not proceed with shotcrete application if the rate of evaporation at the shotcrete surface exceeds 1.0 kg/m².hr as detailed in CSA A23.1-04, Appendix D.
- E. After application of the shotcrete, the air temperature at the shotcrete surfaces shall be maintained at 10° Celsius or greater for at least four days after the application of shotcrete. The means of maintaining the air temperature shall be acceptable to the Engineer of Record. The use of unvented heaters that give rise to carbonation are prohibited.

4-4.17 EXISTING STONY PLAIN ROAD BRIDGE

4-4.17.1 General

- A. Deconstruction of the Existing Stony Plain Road shall be carried out in accordance with Schedule 10.
- B. Bridge structure removal shall be to an elevation of 0.6 m below existing ground for piers and 1.0 m below existing ground for bridge abutments and all other bridge elements.

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