Region of Waterloo

Stage 1 Light Rail Transit Project

Design and Construction Performance Output Specifications

Article 15

Structures

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ARTICLE 15 STRUCTURES

15.1 General

(a) This chapter establishes the basic structural engineering criteria to be used in the design of the new and existing structures for the Light Rail Transit (LRT) system. The criteria were based on the requirements for passenger comfort and safety, vehicle performance, stability and accepted engineering practice.

(b) The design and construction of the following structures include, but are not limited to, the work described below:

#	Structure Name	Expected Scope of Work
1	Northfield Bridge (existing)	Evaluation, modification, or strengthening as needed
2	Weber Street Overhead CNR (existing)	Crash walls to be provided
3	Old Albert St. Culvert Extension (existing)	Evaluation, modification, widening, strengthening or replacement as needed
4	Bridge over Laurel Creek	Removal and replacement of existing structure
5	Culvert at Erb and Caroline Street (existing)	Evaluation, modification, widening, strengthening or replacement as needed
6	Culvert at Caroline Street (existing)	Evaluation, modification, widening, strengthening or replacement as needed
7	Culvert at King Street and Willis Way (existing)	Evaluation, modification, widening, strengthening or replacement as needed
8	Grade Separation at King Street	New structure under CN
9	Borden Avenue Bridge (existing)	Evaluation, modification, widening, strengthening or replacement as needed
10	Ottawa Street (existing)	Evaluation, modifications, widening, strengthening or replacement as needed
11	Bridge over Schneider creek (new)	Removal of old railroad bridge and construction of 2 new structures: LRT Structure and Railroad Structure
12	Montgomery creek structure (existing)	Evaluation, modifications, widening, strengthening or replacement as needed

The above mentioned structures and their scope of work are provided herein only as a guideline. It is the Project Co's responsibility to identify all new and existing structures needed to be constructed, replaced, widened, modified, strengthened or rehabilitated for the LRT project.

(c) Public Infrastructure Work (PIW)" is defined as work elements that Project Co has design, construction, testing and acceptance responsibilities but has no responsibility for ongoing maintenance after PIW is accepted for beneficial use by the Authority Having Jurisdiction. Project Co shall be responsible for the maintenance and up keep of all Public Infrastructure Work (PIW) performed by Project Co within the Project Agreement and on behalf of the Region, respective City, railroad, and public agency having jurisdiction and ownership rights of the plant until acceptance and beneficial use of the PIW on or before the commencement of Light Rail Transit revenue operation by Project Co; or until the Region, respective City, railroad, and agency having jurisdiction and ownership rights takes control of the plant in accordance with the Project Agreement “Possession and Use” requirements. This does not include Project Co’s responsibility for control of all maintenance and up keep of the LRT guideway infrastructure.

15.2 Design Codes and Standards

(a) The Design and Construction of structures shall be in accordance with the criteria included in this Article and the following codes and standards. If there is any conflict between the criteria contained in this Article and any Reference Documents, the following shall apply in descending order of precedence for Design of Structures:

(i) The criteria included in this Article;

(ii) The applicable codes used for the structural design shall include but no be limited to the following:

A. Structures subjected to LRT loading: Canadian Highway Bridge Design Code CAN/CSA-S6-06reprinted March 2013.

B. Structures subjected to railway loading: CN – Engineering Specifications for Industrial Tracks & AREMA – American Railway Engineering of Maintenance-of Way Association, Manual for Railway Engineering 2012.

C. Other structures: Ontario Building Code (OBC) 2006 & National Building Code (NBC) 2005.

(iii) Ontario Provincial Specifications for Roads and Public Works, OPS Municipal and Provincial Common;

(iv) Region of Waterloo Standard Specifications;

(v) Ministry of Transportation, Ontario, Bridge Design Manuals, latest edition:

A. Structural Manual, MTO;

B. Ontario Structure Inspection Manual, MTO;

C. Concrete Culvert Design and Detailing Manual, MTO;

D. Structural Rehabilitation Manual, MTO;

E. Structural Planning Guidelines 2005;

F. Structural Financial Analysis Manual, MTO;

G. Structural Steel Coating Manual, MTO;

H. Aesthetic Guidelines for Bridges, MTO;

I. Guidelines for prefabricated Bridges, MTO;

J. Drainage Management Manual, MTO;

K. Sign Support Manual, MTO.

L. All other applicable Bridge Standards and Manuals, MTO

(vi) CAN/CSA-A23.3-04 (R2010) - Design of Concrete Structures;

(vii) CAN/CSA-S16-09 - Design of Steel Structures;

(viii) TCRT Report 57 – Track Design Handbook for Light Rail Transit, Transportation Research Board;

(ix) ACI 358.1R-92: Analysis and Design of Reinforced Concrete Guideway Structures, American Concrete Institute;

(b) Structures subjected to various types of loadings shall be designed in accordance with all relevant code requirements.

15.3 Design Loads

The loads and forces defined the following Subsection shall apply to all structures or parts of structures designed for LRT facilities.

(a) Permanent Load

(i) Dead Load (D)

A. For structures above ground level, the dead load shall consist of the weight of the basic structure and the weight of secondary elements permanently supported by the structure.

B. All underground structures shall be designed for the actual cover depth or for any planned increase of the cover depth.

C. Dead load shall include miscellaneous loads of any system or facility that shall apply a permanent load on the structure. The dead load shall include the weight of utilities or other permanent loads that are planned for future installation.

D. The design unit weight of earth, both above and below the groundwater table, shall not be less than 21 kN/m^3. In calculations with regard to dead weight resisting flotation of the structure, the actual unit weight of backfill placed over the structure shall be used. In those cases where full hydrostatic pressure below the groundwater table is used as a design load, a submerged design unit weight shall be used for the earth below the groundwater table.

E. The following unit weights shall be used for various materials when encountered throughout the Project

Concrete, plain or reinforced	24.5 kN/m^3
Steel, or cast steel	78.5 kN/m^3
Cast iron	72.8 kN/m^3
Aluminum alloys	28 kN/m^3
Glass	25.6 kN/m^3
Timber	9.6 kN/m^3
Ballast, crushed stone	19.2 kN/m^3
Bituminous Pavement	24 kN/m^3
Stone masonry	27.2 kN/m^3
Stay in place forms	6.7 kN/m^3
Track (rail and fastening)	3 kN/m

(ii) Earth Pressure (E)

A. Structures that retain earth shall be designed for lateral pressure due to earth abutting against the structure, loads due surcharges and hydrostatic force as per the relevant code. The calculation of the earth pressure shall consider the minimum and maximum earth pressure loads factors.

(b) Transitory Loads

(i) Transitory loads shall include any live loads, such as transit vehicles and their load effects, weight of equipment and persons or other moving objects. Transitory loads shall include also environmental loads such as snow, ice, wind, thermal loads, thermal gradient effects and soil deformations.

(ii) Live Load (L)

A. Where appropriate at stations, buildings, and walkways, floor and roof live loads shall be in accordance with OBC.

B. Roadway Vehicle Load

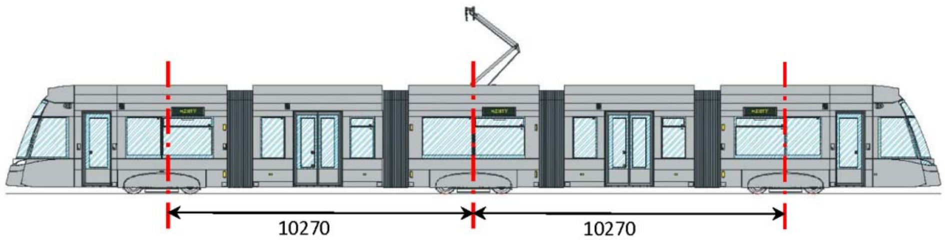
1. Roadway live loads on all LRT structures shall be based on the CL-W-ONT Loading (CL-W-ONT Truck or CL-625-ONT Lane Load), as specified in Section 3 of the current CAN/CSA-S6-06. Structures carrying roadway traffic or any combinations of roadway traffic and LRT shall be designed as per the loading requirements of LRT loadings and CL-W-Ont loadings. Reduction factor for multilane loading of CL-W-Ont shall be applied as per CAN/CSA-S6-06. Only roadway width dedicated for truck load should be considered in determining the number of design lanes.

C. Railway Train Load

1. Railway live loads on all LRT structures shall be based on the Owner of the Railway Authority requirements. Structures carrying railway traffic or any combinations of railway traffic and LRT shall be designed as per the loading requirements of LRT loadings and Railway Authority Loading requirements.

D. LRT Vehicle Load

1. The vehicle design loading used for the structures design is shown in Figure 15.3-1. The axle and car spacing shall be as indicted in the figure. Structures carrying more than one track shall include as many cars as can be accommodated on the span or spans under consideration. Reduction factor for multi-lane loading shall not be applied for LRT load.



Axle Loads (kg)	Total car	Motor Bogie	Trailer bogie	Motor Bogie
W1 Maximum allowable	49500	8800	8800	8800
W5 Maximum allowable	70000	11800	11800	11800

Note: This weight table does not correspond to the actual car weight estimate but reflects the maximum allowable weight.

Figure 15.3.1: Vehicle Design Loading

E. A fatigue damage assessment shall be performed for all structural elements which are subjected to stress fluctuations. The fatigue damage shall be assessed over the required service life of the structure.

(iii) Dynamic Load Allowance (DLA)

A. For LRT vehicle, minimum dynamic load allowance of 30% shall be used for all structural components of new and existing structures.

B. For all other vehicular loads, DLA shall be in accordance with the relevant codes.

C. The dynamic load allowance for loads on buried structures shall be multiplied by the factor $(1-0.5 D_E)$, but not less than 0.1, where D_E is the depth of earth cover between the riding surface and the highest point of a structure in meter.

(iv) Centrifugal Force (CF)

A. On horizontal curves, a LRT vehicle experiences a horizontal radial force, referred to as centrifugal force (CF). The centrifugal force shall be applied horizontally at the centre of gravity of the crush loaded vehicle and at a right angle to the direction of travel. The location of center of gravity of the vehicle must be verified with the Region's vehicle supplier.. The force shall be applied simultaneously to all loaded tracks and has a magnitude of:

$$CF = \frac{L.V^2}{R.g}$$

Where:

CF= the centrifugal force (kN)

V = the maximum velocity of the vehicle (m/s)

R = the radius of the horizontal curve (m)

g= the acceleration of gravity (9.81 m/s^2)

L= the total vehicle load without considering the dynamic load allowance (kN)

The design speed shall be that shown on the Basic Project Agreement Drawings, Series CP4.

B. For all other vehicular loads, the centrifugal force shall be in accordance with the relevant codes.

(v) Rolling Force (RF)

A. LRT vehicles will rock or shift in the lateral direction due to wind forces, rail profile variances and equipments configurations. Due to the rolling force, a vertical load equal to 10 percent of the LRT loading shall be applied downwards on one rail and upwards on the other rail for all tracks and wheels considered in the design.

(vi) Longitudinal Forces due to Braking and Traction (LF)

A. A force equal to 15 percent of the LRT crush loading per track (without DLA) shall be applied longitudinally at the centre of gravity of the crush loaded vehicles on all tracks.

B. For double-track structures, four longitudinal loading cases shall be considered:

1. Single track loaded - Longitudinal force acting, applicable forces on supporting structure.

2. Both tracks loaded - One train accelerating, one decelerating; maximum longitudinal forces acting, and applicable forces on supporting structure.

3. Both tracks loaded - Both trains accelerating or decelerating; longitudinal forces acting in opposite directions, applicable forces on supporting structure.

C. The distribution of the longitudinal forces to adjacent components of trackway structures shall be investigated and considered in the design. The longitudinal forces may be applied in either direction.

(vii) Hunting Force (HF)

A. The hunting force is caused by the lateral interaction of the vehicle and the trackway due to the oscillation of the vehicle back and forth between rails. For the structural design, hunting force shall be applied at the top of rail head at the lead axle of the train only. The force shall be applied to one track only of any tangent dual-track structure. On horizontal curves the more critical of hunting force or centrifugal force shall be applied. The magnitude of hunting force considered in the design shall be:

1. In areas of continuously welded rails

Non-steerable bogie 0.08 L

Steerable bogie 0.06 L

In areas of discontinuities 0.125 L

Where L is the vehicle live load (excluding dynamic load allowance)

(viii) Wind Load on Structure (w):

A. The forces and loads given herein are based on a wind velocity in accordance with the applicable design code. The wind pressure considered in the design of Transit structures shall be based on a return period of 50 years.

(ix) Wind Load on Live Load (WL):

A. The horizontal wind load shall be applied on the entire or part of the exposed area of the live load to produce the critical response on the structure.

(x) Temperature Load (T)

A. The structures shall be designed to withstand the anticipated temperature differential effects and thermal gradient effects as per the applicable design code.

(c) Exceptional Loads

(i) Seismic Loads (EQ)

A. Transit Structures shall be designed for earthquake loads in accordance with the provisions of the applicable design code. The importance categories of Transit structures are considered to be “emergency-route bridges”.

(ii) Vehicle Collision Loads

A. Piers or other trackway support elements, including any existing structures, such as columns, walls, and other supports, located less than 10 m from the edge of road pavement, shall be designed to withstand the collision force as per applicable a horizontal static force of 1400 kN, unless protected with suitable barriers. This force shall be applied on the support element at an angle of 10 degrees from the direction of the road traffic and at a height of 1.2 m above ground level. This condition occurs with the dead load of the structure, but need not be applied concurrently with other loadings.

(iii) Derailment Loads

A. LRT structures shall be designed and constructed such that in the event of a derailment, the damage to structure shall be minimal. Significant damage for major part, overturning or collapse of the structure shall not be allowed.

B. The LRT bridge structures shall be designed for a derailment load caused by a misdirected LRT vehicle oriented with its longitudinal axis parallel to the track, but transversely positioned a minimum of 0.5 metres to a maximum of 0.9 metres from the centerline of the track.

C. The derailment load shall consist of standard vehicles with a modified impact factor. A derailment impact equal to 100 percent of the axle load shall be applied to any two adjacent axles at a time, with a normal impact factor applied to the remaining axles. The 100 percent impact axles shall be selected to produce the critical loading condition for the structure.

D. When checking any component of a superstructure or substructure that supports two or more tracks, only one train on one track shall be considered to have derailed, with the other track being unloaded and/or loaded with a stationary train.

E. Horizontal derailment load on adjacent structures, alongside or above the LRT tracks and located within a distance of 10 m to the centerline of a LRT track, shall be considered in the design unless the structural element is protected from the derailment force. The magnitude of the derailment load considered in the design shall be 1400 kN. The force shall be applied horizontally 1.20 m above the ground at the adjacent structure, and at 10° to the direction of travel.

F. Derailment forces shall be applied both vertically and horizontally to the structure and considered in the superstructure and substructure designs.

G. For existing bridge structures adjacent to the LRT tracks and located within a distance of 10 m to the centerline of a LRT track, suitable measures shall be provided to protect the structures against horizontal derailment force or reduce the potential of transit vehicle derailment.

(iv) Emergency Braking

A. The LRT bridge structures shall be designed for a longitudinal emergency braking force of 30% of the crush vehicle load (without DLA). The load shall be applied at the center of gravity of the LRT vehicle.

(d) Miscellaneous load

(i) Other loads and forces shall be considered, including ice pressure loads, flooding loads, stream current loads, shrinkage and thermal forces, rail-structure and soil-structure interaction loads, as per the applicable design codes or standards. Other loads or forces on structures shall be as follows:

A. Structures subjected to LRT, highway loading, Structural Culverts, retaining walls: CAN/CSA-S6-06

B. Structures subjected to railway loading: CN requirements and AREMA

C. Other structures: Building Codes OBC and NBC

(e) Loads during Construction

(i) Prior to commencement of the work, Project Co shall submit the proposed method and sequence of construction for review. The submittals shall also include plans and design calculations, signed and sealed by a Professional Engineer licensed in the Province of Ontario, for all temporary construction structures used for shoring, bracing, and support, and shall demonstrate the structural adequacy of partially completed structures to safely support the proposed loadings during construction in accordance with the design criteria.

(ii) Live loads during construction should include the weights of workers and all equipment used during the process of erection.

15.4 Design Service Life

(a) Abutment walls shall have a durability to ensure a minimum design life of 100 years

(b) Retaining walls shall have a durability to ensure a minimum design life of 100 years

(c) New structures and components shall be designed to have a durability that will ensure a minimum design service life of 75 years without significant repairs, rehabilitation or replacement.

(d) Time dependant design calculations, including corrosion, fatigue, shrinkage and creep shall use a service life of 100 years.

15.5 LRT Ancillary Structures

(a) Overhead Catenary Power Supply Pole Structure

(i) The electric traction system for the light rail vehicles will be powered by an overhead catenary current collector system. Poles will be installed at a certain spacing to support the overhead power supply. The Overhead Catenary Power Supply, OCS, poles shall clear the dynamic envelope of the LRT without being too far from the centerline. The poles and their foundations shall be designed to sustain loads due to wind; wires wind span, tension force in the wires, differential strain in the wires, vertical loads and others. Project Co shall propose a detailed approach used to determine the following for the pole structures and support foundations:

A. The Limit State design wind pressure on all components;

B. The pole locations, expected span length and maximum span-ground clearance limitation;

C. The structural model and method used to design the pole foundations;

D. The performance and strength design criteria considered in the design of the pole-foundation system.

(ii) The foundation analysis and design shall include soil-structure interaction to ensure the desired performance of the poles under applied loads and soil deformations.

(b) Track Slab Structure

(i) Non-ballasted track concepts are commonly used for light train transit system. In stage 1 of this project, slab track structures will be used in several locations along the transit corridor and where the light rail shares the slab track pavement with automobiles. The contactor shall recommend the type of slab track structures used for this project. Project Co shall also describe in details the method used for the analysis and design of slab track structures to achieve the required strength and durability of the structures.

(ii) All structure deformations including settlement and soil heaving shall be considered in the design of the slab track and their effects on the trackwork to ensure the ride quality for the LRT system. The integral structural system shall be fully analyzed under the actual dynamic train loads and deformation applied by the supporting structure. Project Co shall take all necessary steps to eliminate or minimize the soil heave effect on the slab track.

(c) Crash wall

(i) Structural elements adjacent to any railway track and with a clear distance of 7600 mm or less from the centerline of the railroad track shall have a cross-sectional area equal or greater than crash wall or protected by a reinforced concrete crash wall. The crash wall shall be in accordance with AREMA 2012

(ii) For structures adjacent to light rail transit and within a horizontal distance of 7600 mm from the centerline of the railroad track, crash wall with the same configuration shall be used. Otherwise, the structure shall be designed considering the derailment force defined in previous section.

(iii) The minimum crash wall height is required to be either 1800 mm or 3600 mm above the top of rail, depending upon the centerline distance between the nearest track and each pier as per AREMA 2012.

(d) Retaining walls

(i) In addition to all other applicable codes and regulations, the following apply to new and existing retaining walls:

A. The design earth pressure and the structural design shall be performed by CHBDC, and as augmented by geotechnical requirements the Articles outlined herein and the Project Agreement.

B. Reinforced soil slopes steeper than 45 degrees shall be considered as retaining walls. The following are the retaining wall system and abutment walls types that are not acceptable:

1. Steel sheet pile walls that are visible;

2. Walls with wire facings that are within splash zone or subjected to surface run off containing any de-icing materials;

C. The entire footprint of the retaining walls shall be within the project ROW.

D. The tops of the walls shall be finished in straight-line segments;

E. Walls required to retain bridge embankments adjacent to bridge foundations shall be designed as abutment walls;

F. New retaining walls shall be provided with adequate drainage. Existing walls shall be retrofitted to ensure that they have proper drainage.

G. If the existing walls configurations or loading conditions are changed, then the walls shall be designed to meet the design criteria for new walls.

H. The aesthetics of retaining walls shall be in accordance with the general guidelines in the Municipal Urban Design Guidelines for Kitchener, Cambridge and Waterloo and in accordance with DGSSMS

(e) Noise walls

(i) Noise control and reduction measures shall be taken where the noise level exceeds the acceptable level required by the relevant codes due to the installation of the LRT. Noise reduction measurements, such as earth berms, is preferred where sufficient land is available to construct the berms. Noise wall shall not be used except where absolutely warranted.

(ii) Ensure noise wall design provides through access to adjacent neighbourhoods and appropriate land uses.

(iii) Noise walls shall be designed as per the following requirements:

A. Building Code, MOE provincial methods and Region Policy;

B. Noise reduction coefficient better than 0.8;

C. Constructed using a system on the MTO's Designated Sources for Material (DSM) with sufficient density to provide a minimum transmission loss of 25dB at a frequency of 500 Hz; and

D. AASHTO LRFD Bridge Design Specifications, 6th edition.

(f) Sign, Traffic signals, Lighting Structures

(i) Project Co shall design, fabricate and install all structures required for signs, traffic signals, lighting in accordance with CAN/CSA-S6-06, MTO Sign Support Manual and the Electrical and Signing Materials Standards. Levelling nuts below the base plates are not permitted.

(ii) Existing sign structures may be re-used provided that they are inspected, regalvanized or painted prior to re-use, approved and certified by a Professional Engineer as meeting the project requirements. All components to be re-used shall be power washed clean prior to re-use.

(g) Platforms

(i) The structural design shall meet all applicable Region of Waterloo Standards and specification identified in this Article.

(ii) For buildings and stations, the design shall meet all Occupational Safety and Health Act (OSHA) standards.

15.6 Load Factors and Loading Combinations

(a) The effects of seismic loads shall be combined with the live load. When the seismic loads are considered concurrently, a live load factor of 0.5 shall be taken.

(b) For bridges, structural culverts, retaining walls, slab tracks, and OCS poles, the load factors and load combinations required in the CAN/CSA-S06-06 shall be applied.

(c) For structures that carrying truck and transit vehicles, load factors of 1.5 and 1.4 for transit vehicle shall be used for Ultimate Limit States ULS1 and ULS2, respectively,

(d) For platforms, the building codes shall be adopted for the load factors and load combinations.

(e) The design, evaluation, and/or strengthen of any new or existing structures located shall be in compliance with all other requirements of any party involved, such as the railway authority.

15.7 Materials

(a) Concrete

(i) The design of concrete structures shall be in accordance with CAN/CSA-S6-06 for bridges, structural culverts and retaining walls and in accordance with CAN/CSA-A23.3-04 for buildings. Design loads, load factors, resistance factors and loading combinations shall be as specified in this Article.

(ii) Materials specifications and method of testing shall conform to the following CSA and ASTM standards:

1. CAN/CSA A3000-08 - Cementitious materials compendium
2. CAN/CSA-A23.1-09/A23.2-09 - Concrete materials and methods of concrete construction/Test methods and standard practices for concrete
3. ASTM C260/C260M-10a Standard Specification for Air-Entraining Admixtures for Concrete
4. ASTM C494/C494M-12 Standard Specification for Chemical Admixtures for Concrete
5. ASTM C1017/C1017M-07 Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete

(b) Reinforcing Steel

(i) Non-prestressed reinforcing steel shall conform to the following CSA and ASTM standards:

1. G30.18-09 - Carbon steel bars for concrete reinforcement
2. ASTM A82/A82M -07 Standard Specification for Steel Wire, Plain, for Concrete Reinforcement
3. ASTM A185/A185M-07 Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete
4. ASTM A276-10 Standard Specification for Stainless Steel Bars and Shapes
5. ASTM A497/A497M-07 Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete
6. ASTM A955/A 955M- 12e1 Standard Specification for Deformed and Plain Stainless-Steel Bars for Concrete Reinforcement

(ii) All reinforcing steel to be used in this project shall be deformed bars and Grade 400W. Coated reinforcing steel bars are not allowed to be used on this project. Stainless steel reinforcement type 316LN and Type 2205 Duplex or Glass Fibre Reinforced Polymer bars are only permitted to be used in this project as premium reinforcing where required.

(iii) For bridges and culverts, black steel bars shall be used only as specified in the Structural Manual, MTO. Premium reinforcing materials shall be used in locations vulnerable to salt-induced corrosion as per MTO Structural Manual, unless otherwise specified .

(c) Prestressing Strands

(i) Prestressing strands shall be uncoated, seven-wire, 1860 MPa ultimate grade material, stress-relieved strand for prestressed concrete conforming to CAN/CSA-S6-06. The strands may be nominal 13 mm or 15 mm diameter. Unbounded post tension tendons shall not be used.

(d) Structural Steel

(i) Structures or structural components made of structural steel shall be in accordance with provision of CAN/CSA-S16.1-01, Limit States Design of Steel Structures and CAN/CSA-S6-06, insofar as they are applicable. Sacrificial thickness for each surface exposed to water, soil or below the water shall be computed as follows:

A. Carbon Steel Loss 12 micrometers/year

(ii) The structural steel shall conform to the followings standards:

A. G40.20-04/G40.21-04 (R2009) - General Requirements for Rolled or Welded Structural Quality Steel/ Structural Quality Steel

(e) Fibre Reinforced Polymer (FRP) bars

(iii) The FRP bars shall conform to CSA S807-10 Specification for fibre-reinforced polymers and S806-12 - Design and construction of building structures with fibre-reinforced polymers. If FRP bars are to be used in any structural components, they shall conform to the following specifications:

A. Glass Fibre Reinforced Polymer (GFRP) reinforcing bars shall be Grade 1 or 3.

B. Bends are not permitted for GFRP bars Grade 3

C. Reinforcing bars shall be obtained from approved supplier

D. All GFRP components shall be obtained from the same supplier for the same structure.

E. S6S1-10 - Supplement #1 to CAN/CSA-S6-06, Canadian Highway Bridge Design Code.

15.8 Culverts

(a) Culverts shall be designed as per CAN/CSA-S6-06, MTO Culvert Design Manual and the following design criteria shall be adopted:

(i) Culverts are to be designed for the 100-year flood with a minimum of 1.0 m freeboard;

(ii) Protection for the embankment shall be ensured using a proper slope protection method;

(iii) Culverts shall be provided with headwalls and wingwalls with appropriate angles where necessary.

(b) Existing culverts shall be inspected and certified by a qualified Professional Engineer that the structure comply with the specified design criteria and the remaining operational life of the structure of at least 30 years. The existing culverts may be upgraded, lengthened, rehabilitated or replaced if required.

(c) The following requirements shall be applied for existing structural culverts:

(i) All existing culverts shall be evaluated using CAN/CSA-S6-06 for all applicable loads and loading conditions.

(ii) If existing culverts are widened or lengthened, then they shall be upgraded to meet the requirements of this Article for new structures.

15.9 Existing Bridges

(a) The following requirements shall be applied for existing bridges with the LRT corridor:

(i) If the superstructure of an existing bridge or the entire bridge is replaced, the existing clearance shall be in accordance with the current relevant codes. The existing clearance of any other existing bridge shall be at least maintained or improved.

(ii) Existing bridges subjected to the LRT loads, shall be evaluated using CAN/CSA-S6-06 for all applicable loads and loading conditions.

(iii) If existing bridges are widened or lengthened, then they shall be upgraded to meet the requirements of this Article for new bridges.

(iv) If the existing bridges are not widened or lengthened then any new components required to modify existing bridges shall be designed to meet the requirements for this Article for new bridges.

(v) If any structural component becomes substandard with respect to the relevant design code or standard requirements due to changes in the structure configurations or function, the structural component(s) shall be modified to comply with the requirements of the relevant design code or standard.

15.10 Special Design Considerations

(a) Vibration Limitations - To limit potential dynamic interaction between bridge structure girders and rapid transit vehicles, the bridge structure shall be designed so that the unloaded natural frequency of the first flexural mode of vibration of the bridge span is not less than 2.5 cycles per second.

(b) Deflection Limitations - To ensure rider comfort, the deflection of longitudinal girders under live load should not exceed 1/1000 of the span length.

(c) Fatigue - Consideration shall be given to the effect of the change in stress levels caused by passage of the LRT trains over structures. Fatigue stress limits for concrete reinforcement and allowable fatigue stress range for structural steel shall be in accordance with the requirements of CAN/CSA-S6-06.

(d) Uplift - In general uplift forces are not permitted at any support due to any loading or combination of loadings. Under certain circumstance and with prior permission only, provisions shall be made for adequate attachment of the superstructure to the substructure, should any loading or combination of loading produce uplift at any support.

(e) Friction - Frictional effects shall be considered in the structural design.

(f) Column Locations - Proper consideration shall be given to areas where the LRT trackway spans existing bridges. In particular, the design shall be such that the construction and final location of columns supporting the trackway structure shall in no way adversely impact these existing bridges.

(g) Rail/Structure Interaction Force (RS) - During the design of non-ballasted bridge structures, an analysis shall be made of the forces resulting from rail/structure interaction.

(i) The design of the decks, girders, bearings, frames, pier caps, piers and foundations shall include the forces resulting from the interaction between the rails and the structure when:

A. The superstructure expands and contracts beneath the rail

B. One rail breaks

C. The structure restrains the rail from displacing radially on horizontal curves

D. Any combination of the above.

(ii) An allowance shall be included, in the design of bridge structures, to account for additional seismic loads imparted on the structure due to facilities used for noise abatement, such that noise abatement facilities which may currently not be required can be added in the future without trackway modifications.

(h) Seismic Design

(i) All structures designed in accordance with CAN/CSA-S6-06 shall be classified as emergency-route structures.

(ii) The importance requirements of all Buildings and platforms shall be classified as “High” in accordance with the National Building Code of Canada.

(i) King Street Grade Separation

(i) The minimum perpendicular span of the King St. Grade Separation is 32.4 m

(ii) The minimum span parallel to the Guelph Subdivision Rail Centreline is 40.8 m.