Region of Waterloo

Stage 1 Light Rail Transit Project

Design and Construction Performance Output Specifications

Article 12

Trackwork

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ARTICLE 12 TRACKWORK

12.1 General Requirements

(a) Basis of Design Report

This Article sets forth standards and design guidelines to govern the detailed engineering, materials and construction standards for LRT trackwork, railroad trackwork, and its interface with other elements in the vicinity of the tracks. The purpose of this Article is to provide design guidelines for trackwork. Project Co's solution to trackwork shall expand on these guidelines. Project Co shall prepare a Basis of Design Report – Trackwork which explains Project Co's approach to trackwork in greater detail and in a site specific manner. Project Co should consider adjusting its design to meet site specific conditions in order to achieve a trackwork design which meets the design life, requirements in the most economical manner. The presentation of specific trackwork requirements within this Article must not be construed to limit or modify in any way Project Co's flexibility to meet the performance requirements or Project Co's responsibility to provide a holistic, comprehensive, and fully functional solutions to all trackwork components and trackwork related appurtenances. The Basis of Design Report – Trackwork shall address every aspect of the trackwork design requirements cited in this Article. The rationale for all deviations or variances from any requirement cited this Article must be fully described in the Basis of Design Report – Trackwork.

(b) Track Alignment Requirements

For additional information on track alignment and clearances see Schedule 15-2 Article 11.

(c) Trackwork Standard/Directive Drawings and Construction Specifications

All track material, special trackwork and practices described herein shall govern the design of track and include the required interfacing of trackwork with other elements of the system such as trackway, bridges, track slabs, transition slabs, electrification system, signal system, drainage, etc. Project Co shall prepare Standard/Directive Drawings and construction specifications for trackwork and related track materials addressing interface requirements as well as other trackwork requirements. Project Co shall include this information in the Basis of Design Report – Trackwork and provide all of the key trackwork design aspects.

(d) Proposed Changes in Track Systems

The track is a structure in which the weight of the running rail, tie spacing, type and size of track fastener, depth of foundation slab, and elastomer stiffness are all interrelated. The characteristics of the track system provided in their Submission must not be changed without submitting the change to the Region and considering the impact on: public safety, track stability, track stiffness, noise & vibration, electrical insulating characteristics, track maintainability and track life cycle cost.

(e) Alternative Trackwork Solutions

The trackwork solutions described within this Article are guidelines for Project Co's trackwork designer as to what approaches are acceptable to the Region. Due to the wide range of potential trackwork solutions, this Article provides a broad range of requirements many of which may not be applicable to Project Co's trackwork solutions. Alternative designs will be accepted provided Project Co's trackwork designer can demonstrate equal/appropriate performance along with other advantages such as improved maintainability, capital cost savings, installation efficiencies, etc. It

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is required that Project Co demonstrate in their Submission that the final design for all trackwork systems address all of the key technical and key environmental issues.

(f) Key Environmental Conditions

The key environmental conditions relate to winter conditions including resistance to the effects of heavy salt and deicing chemicals, cold temperatures, heavy snow falls, icing conditions, the high potential for frost heaving conditions and design solutions that are not susceptible to damage from snow plowing. One of the key technical issues is designing embedded tracks for the rubber tired traffic. In some locations, such as street intersections, the embedded track will experience significant loading from rubber tire traffic. In other locations, the rubber tire traffic will only occur during emergencies or from Project Co's maintenance activities. Project Co may vary their design for embedded trackwork for these conditions. The design for ballasted tracks may also vary depending upon whether the ballasted track will be restricted to LRT trains or will also have to accommodate railroad freight service. Project Co shall discuss in their Submission how the proposed trackwork solutions address the key environmental issues.

For added clarity, an embedded track solution is required throughout the alignment section between the intersection of Erb Street and Caroline Street and the intersection of Mill and Ottawa (including the freight railroad trackage from King Street to Erb Street but excluding the area of the connecting turnout) and throughout the alignment section from the intersection of Conestoga road and King Street to the Intersection of Northfield Drive and the Waterloo Spur. An embedded track solution or a roadway at-grade crossing solution can be used at all other roadway crossings.

(g) Design Coordination

Project Co's trackwork designers shall coordinate with facilities and systems designers to identify areas where additional lateral space is required for the placement of wayside equipment such as track switch machines and rail lubricators. This coordination includes consultation with the rail car supplier to ensure the trackwork design compatibility with the characteristics of the rail car to provide a safe and comfortable ride. The trackwork shall appropriately interface with civil structures provided to manage surface runoff within and/or adjacent to the track Right-of-Way. The trackwork design shall accommodate this interface without compromising track strength or stability. In some locations such as below grade utility crossings that must be at a shallow depth, Project Co shall coordinate with the utility and shall develop unique trackwork solutions to accommodate the special utility installation.

(h) Key Design Considerations

Project Co's Submission for trackwork must address in detail the approach to controlling stray current, controlling noise and vibration and achieving compatibility between LRT and railroad freight equipment. Specific design and performance information on rubber boot specifications, ballast mat or similar solutions for noise and vibration and special trackwork solution is required in the Submission.

(i) LRT Stop platform Considerations

Embedded track shall also be used in all LRT Stop platform areas to promote a stable track to platform relationship needed to address cleanliness, safety, facilitate bus bridging and promote AODA requirements by resisting the potential for frost heaving. It is anticipated that the LRT stops at Pine Street and Cedar Street would be used for bus bridging in conjunction with the adjacent crossovers. The design of the embedded tracks at these LRT stops needs to address the

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bus operating and loading conditions over the entire length of the platform loading zones as all as access to and from the platform loading zone.

(j) Trackway Identification Considerations

All areas of embedded track within or adjacent to roadways shall be bounded by a flush curb, a mountable curb or other delineation feature proposed by Project Co that defines the limits of the LRT's Maximum Vehicle Dynamic Envelop (MVDE) both within street or pedestrian intersections and in non-intersection areas. This delineation shall deter roadway vehicles from entering the MVDE of the LRT while not impeding access for maintenance or emergency vehicles. A rumble strip is not a suitable solution delineation feature for this purpose. The curb or delineation feature shall be designed by Project Co to be readily distinguishable visually and by feel for the visually impaired as the zone reserved for LRT rail car movement. The inside or trackside face of the curb or delineation feature shall be established beyond the MVDE and adjusted for curvature and superelevation. In areas such as roadway or pedestrian crossings, the curb or delineation feature shall be extended into the intersection but flush with the roadway or pedestrian crossing. In other areas of the trackway especially in skewed track/road crossings additional delineation is required to guide traffic or as a warning element for driveways or other crossing configurations. A rumble strip is a suitable solution for this situation. Where the track is adjacent to a roadway, a standard curb configuration may be used in lieu of the mountable curb configuration. However, the design configuration provided by Porject Co must consider that driveway crossings will need to be accommodated.

(k) Service Proven Trackwork Components

For any trackwork component or assembly to be accepted for inclusion in new construction, it shall be based on existing, service proven technology and have a record of performance satisfactory to the Region. If Project Co proposes any trackwork component that is not service proven, Project Co shall perform prototype testing, as noted in Schedule 15-2 Article 13 Section 13.2(d) Subsystem Supplier Test Requirements, to the satisfaction of the Region.

(l) Freight Railroad Tracks

Freight railroad tracks are tracks that are designed and constructed by Project Co but returned to the CN railroad to maintain. Project Co shall design and construct the site work for the freight railroad tracks to CN standards, Go Standards, and Via Standards at the King Street Grade Separation. Project Co shall design and construct the site work for the freight railroad tracks to CN standards for the relocation of the Huron Spur track. The trackwork materials and trackwork installation at the King Street Grade Separation and along the Huron Spur will be provided or performed by the CN. For additional information on roles and responsibilities in these two areas, refer to Appendix X. The Waterloo Spur track from the ends of the turnouts that connect the freight track to the LRT track and through the grade crossings of King Street and Northfield Drive shall be built of all new track materials as per this Article. Project Co shall maintain the turnout that connects the freight tracks to the LRT tracks.

12.2 Codes and Standards

In addition to the requirements specifically stated within this Article, construction plans and specifications shall generally comply with the current editions of the appropriate industry standards as referenced, which include:

A. American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering

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B. AREMA Portfolio of Trackwork Plans

C. TCRP Report 155 – Track Design Handbook for Light Rail Transit, 2nd Edition

D. VDV OR 14 – 2008 – Association of German Transport Companies, Permanent Way Guidelines, Turnouts and Crossings

E. EN14811 – Special Purpose Rail

F. EN 13674-4 – Part 3: Check Rail

G. CN – Engineering Specifications for Industrial Tracks

12.3 Trackwork Systems

(a) Systems Design Approach

Trackwork systems are composed of a number of elements, each of which has a definite interaction with the other elements of the System. Because of this interaction, the design for trackwork shall be undertaken as a systems approach with a cause and effect analysis being undertaken on each of the elements. In performing this trackwork design, consideration of associated factors such as safety, stray current, ride comfort, noise, and vibration shall not be overlooked. In addition, the relationship of trackwork design to the design of other elements of the System, such as train control, drainage and type of rail car shall be recognized and accommodated early in the design process.

(b) Site Specific Design Approach

Project Co may propose different trackwork solutions based upon site specific conditions. Project Co may use one standard design approach for embedded track or more than one approach if desired. For example, an embedded track which is subject to rubber tire traffic at roadway intersections or for local access when the track is in a side running configuration may be more robust than an embedded track located in the median of a street and subject only to emergency traffic and maintenance vehicles owned by Project or by others. A ballasted track that must accommodate railroad freight loading and LRT loading may be different from a track designed solely for freight railroad service or solely for LRT service. In addition, the continuation of railroad service along the Waterloo Spur will require special attention since special trackwork designed to be compatible for the wheel configuration of the LRT rail car may not be compatible with the wheel configuration used in railroad freight service. Project Co shall address this issue by either providing a design which accommodates both railroad and LRT wheel configuration or providing a design which dedicates an exclusive route through the special trackwork to either LRT or railroad movements. Unless the Region approves a different approach to special trackwork Project Co shall provide moveable point frogs and all related equipment for all special trackwork subject to both freight railroad and LRT trains, Site specific designs by Project Co will be necessary to address utility interface issues or for the purpose of installing tracks on existing structures or structures modified by Project Co. Project Co shall coordinate all the site specific design approaches with the owner of the utility or structure.

(c) Trackwork System Elements

Some of the essential elements of a trackwork system are:

A. Roadbed, Drainage, and Track Foundation Slab

B. Loads and environment factors

C. Direct Fixation Structure or Embedded Track Structure

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D. Ballasted Track Structure

E. Rail

F. Rail Fastening Systems (including elastomers)

G. Special Trackwork

H. Other Track Devices (rail heaters, lubricators, switch machines, bumping posts, etc.)

Development of the trackwork requirements for the above consideration of maintainability, reliability, parts standardization, capital costs, and maintenance costs is required. Maintainability and reliability are of particular importance since train frequencies make it difficult to maintain track during normal operating hours. Parts standardization is also important in it allows inventories to be minimized and promotes mass production by suppliers, thereby reducing unit costs and enabling purchase of "off the shelf" items.

(d) Rail Loading

Vertical and horizontal loading from the light rail vehicle shall be in accordance with Schedule 15-2 Article 5 and information provided by the LRT vehicle supplier. Vertical and horizontal loading from the freight railroads vehicles shall be in accordance with the requirements of the freight railroad. Project Co shall coordinate with the freight railroad on their requirements.

(e) Corrosion Mitigation

Track components shall be protected from corrosion caused by excessive leakage of stray return current by providing barriers to electrical currents and moisture. Additionally, track components shall be protected from corrosion caused by environmental conditions.

(f) Rail Grinding

Project Co shall consider space requirements for rail profile grinding and rail corrugation grinding. Designs for embedded, ballasted and direct fixation track shall provide adequate space to accommodate this maintenance activity. Project Co shall coordinate rail grinding requirements with the LRT Vehicle supplier to achieve the optimal wheel to running rail interface. Project Co shall grind the newly constructed track to these requirements and perform maintenance rail grinding as needed to maintain the rail head profile within the desired profile.

(g) Drainage

(i) Ballasted Tracks

A. Ballasted LRT tracks shall generally be configured with open ditches alongside of both sides of the trackway. Where insufficient Right-of-Way is available for full ditches, underdrains may be utilized. The flow line of either ditches or underdrains shall be not less than 30 cm below the bottom of the subballast layer. Drainage for relocated freight railway tracks shall be configured with open ditches, unless other arrangements are accepted by the freight railroad. In all ballasted tracks, the sub-ballast surface shall be crowned/graded, as necessary, to divert water to the drainage system.

B. The drainage of ballasted tracks within the Operations, Maintenance and Storage Facility (OMSF) shall be integrated with the overall drainage system for the facility. Where ballasted yard track is constructed and conventional side ditches

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impractical,; water shall infiltrate through clean ballast to the sub-ballast surface where it shall be intercepted by underdrains.

(ii) Embedded Tracks

A. Where embedded track is provided; it is preferred the finished paving surface be shaped to direct water to a low point between the running rails. Track drains to intercept storm water flowing along the pavement surface and in the flangeways shall be provided at all low point and at regular intervals. These track drains shall connect through buried pipe to the appropriate municipal sewer. Where long sustained grades exist, additional track drains shall be provided along the grade at intervals similar to the roadway drains.

B. At locations where the track(s) are located within the median of semi-exclusive Roadway Right-of-Way and provided that non-emergency rubber tired traffic, bicycles, and pedestrians can be normally excluded from crossing the trackway, and other factors do not preclude it, the entire surface of the pavement within the gauge of the track may be lowered, omitting the flangeways so that all stormwater can flow to a low point between the running rails.

C. Where embedded special trackwork is constructed, a track drain connected through (150 mm minimum diameter) buried pipes to the appropriate municipal stormwater sewer shall be provided upgrade of the special trackwork to intercept water and minimize the amount of debris entering and possibly accumulating within the switch boxes. Drains shall also be provided upgrade of intersections and crosswalks that intersect embedded tracks.

D. At embedded special trackwork locations, all switch boxes shall be connected to a storm sewer drainage system through drain pipes of appropriate size but not less than 150 mm diameter.

E. For primary embedded track, margin or linear drains shall be provided at platforms, pathways, or trackway/roadway curbs where water could otherwise pond and/or splash onto waiting patrons.

(iii) Direct Fixation Tracks

A. Direct fixation track slabs and the top surfaces of plinths supporting direct fixation rail fasteners shall be designed to drain. Stormwater and debris shall not be allowed to accumulate adjacent to direct fixation rail fasteners to compromise the electrical isolation of the track system.

(h) Electrical Continuity

Electrical continuity of the track is essential to ensure negative return of traction power to the substation and to facilitate track signals (where provided). All primary and secondary tracks shall employ continuously welded rail. The Project Co’s track designer shall be responsible for identifying appropriate locations for bonding in consultation with the designers of the traction power and train control systems. This includes standard cross-bonding as well as special bonding requirements at special trackwork and at rail expansion joints.

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12.4 Trackwork Classification

The tracks shall be classified as follows:

A. Primary Track: Primary track is used for the operation of vehicles carrying revenue passengers and referred to as mainline track. Non-revenue tracks which are critical to the system operation may also be classified as Primary track for maintenance purposes.

B. Secondary Track: Secondary track is used for switching, storing or maintaining LRT vehicles not carrying revenue passengers and referred to as yard track. They are located in Maintenance & Storage Facilities. Some critical secondary tracks may be treated as primary track for maintenance purposes.

C. Shop Track: Tracks located in maintenance shops and include tracks embedded in the floor, and tracks constructed over maintenance pits. The latter can include several configurations with the rails supported on sidewalls or elevated on pedestals, so as to permit shop crews to perform various types of maintenance on the LRVs. Shop tracks are usually grounded for the safety of shop crews.

12.5 Wheel Profile and Wheel Gauge

(a) LRV Manufacturer Data

The LRT vehicles will incorporate a wheel profile supplied by the vehicle manufacturer. The maximum wheel set gauge, measured at a distance of 15.875 mm below the tread datum, shall be 1425 mm. The wheel back-to-back distance is 1378.6 mm. The wheel guard check gauge is 1405.1 mm. The flange depth is 20.14 mm and the flange width (measured from wheel back) is 23.2 mm. Key dimensions are shown in the table below. Since these values are subject to change, Project Co's trackwork designer shall validate all wheel dimensions with the LRT vehicle supplier.

Table of Key dimensions

Parameter		Nominal (mm)
Wheel back-to back distance	A_R	1378.6
Vertical measurement height (gauge point)	Z	15.875
Flange depth	D	20.14
Flange width (measured from wheel back)		23.2
Wheel set gauge	S_m	1425
Wheel guard check gauge	L_m	1405.1

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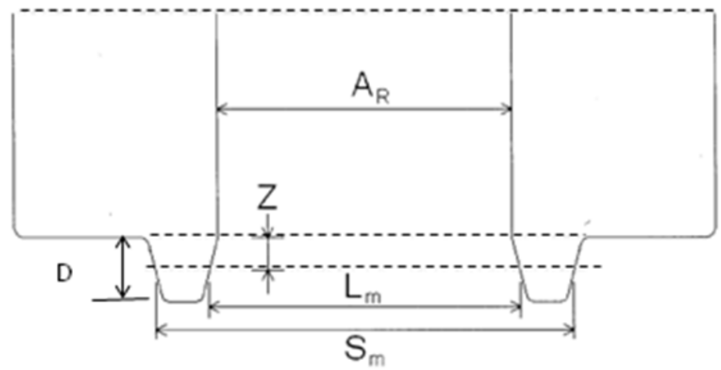

12.6 Track Gauge and Rail Cant (Inclination)

(a) Track Gauge

Track gauge is nominally 1435.1 mm, measured between the inner (gauge) sides of the heads of the rails at a distance of 15 mm below the top of rails.

(b) Track Gauge Wear

Once the system is operating primary and secondary track gauge wear shall be maintained below 12.5 mm with a maximum of 10 mm wear on a single rail.

(c) Track Gauge Widening

Gauge widening beyond that already included within this Article shall occur only if justified by detailed Nytram Plot analysis conducted in accordance with TCRP Report 155, Chapter 4. When used, it is preferred that gauge widening shall be achieved by moving the low rail outward, as required. In simple curves with no spirals, gauge widening shall be accomplished on the tangent approaching to the point of curve and removed following the point of tangent. In spiraled curves, gauge widening shall be applied and removed within the length of the spirals. If the spiral is too short for full gauge widening to be accomplished, gauge widening shall be placed in the approach tangents. If adjacent curves which both require widening are too close together to allow run out of the gauge widening, the widened gauge shall be maintained between the curves.

(d) Rail Cant

The LRT vehicle supplier has performed a track-train dynamic analysis and has determined that the running rail installed without a cant will provide the optimal track-train dynamics. Therefore the running rails shall be installed with zero cant toward the centerline of track including all rails in special trackwork. Project Co shall incorporate this design requirement into all aspects related to trackwork.

12.7 Track Electrical Insulation and Vibration Damping

(a) Electrical Insulation

(i) With the exception of Shop track, as discussed below, all track components which have direct contact with the vehicle shall be electrically insulated from the ground. For the purposes of electrical insulation systems, concrete slabs or concrete ties shall be regarded as ground. Electrical insulation shall be provided between the rails, etc. and the concrete slab or concrete ties. Project Co shall determine the minimum electrical insulation properties of the electrical insulation system that will achieve the desired electrical

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isolation under new track conditions expressed in ohms per 1,000 feet as required in Schedule 15-2 Article 17. That value will be utilized during acceptance testing of the trackwork. In the Basis of Design Report - Trackwork, Project Co shall include the analysis for the electrical insulation system and provide an electrical insulation system which exhibits the required properties to achieve the required in-service level of insulation.

(ii) For the safety of shop personnel, rails within maintenance shops shall be deliberately grounded so the touch potential between the light rail vehicles and ground is reduced to zero. A separate rectifier shall provide traction power in the shop versus the yard. Insulated joints shall be placed outside of the shop; in locations where they will not routinely be bridged by stationary rail vehicles.

(iii) The in-service resistance-to-earth values shall comply with and be maintained to the values provided in Exhibit 12.7-1 below. Project Co shall monitor and promptly correct any deficient track in which the in-service resistance-to-earth values are less then shown in Exhibit 12.7-1.

Exhibit 12.7-1 In-Service Track to Earth Resistance Values.

Type of Track	Insulation Requirement. ohms per 300 meter of single track (both rails)
Ballasted Track on Concrete Crossties	300
Direct Fixation Track	500
Embedded Track	200
Special trackwork - Ballasted	300
Special trackwork – Embedded Track	200
Shop Track	As required for Grounding

(iv) Project Co's track designer is also responsible to provide adequate encapsulation to isolate bond cables from ground in embedded track.

(b) Noise and Vibration Dampening

(i) All trackwork systems shall be designed and constructed so that vibrations transmitted to the rail from the vehicle, or generated within the rail, will be dampened before reaching the track slab or underlying soils. This can be accomplished through the rail fastening system or through other means.

A. Ballasted Track

1. The pad between the rail and the concrete crosstie rail seat is expected to provide sufficient acoustic attenuation for this Project. Where additional

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attenuation is required in ballasted track, the use of ballast mats shall be considered.

B. Embedded Track

1. An extruded elastomeric (rubber) 'rail boot', or similar system, shall be fitted to all running rails in tangent and curved embedded track. This rail boot shall act as a continuous resilient mechanical barrier between the rail and the concrete infill material. The shape of the rail boot cross-section shall be designed to allow a controlled amount of vertical deflection under dynamic loading of the track. Where additional attenuation is required in embedded track, the use of special rail boots, slab mats, or floating slabs shall be considered.

C. Direct Fixation Track

1. Direct fixation track shall be designed utilizing rail fasteners incorporating elastomeric elements that permit a controlled amount of vertical deflection under dynamic loading. Although not precluded, the use of Direct Fixation track with high attenuation trackforms such as floating slabs and booted tie blocks is not anticipated on this Project.

2. Where vibration dampening is included for special trackwork, provisions shall be made to ensure trackwork stability.

(ii) Track shall be designed incorporating appropriate materials to both attenuate noise and ground-borne vibration in all areas and in all areas designated in the EPR as requiring additional mitigation measures to achieve environmental compliance.

12.8 Trackwork Construction and Maintenance Manual

(a) Trackwork Construction and Maintenance Manual

Project Co shall develop track construction and track maintenance manuals with the construction and track maintenance procedures that must be adhered to for each type of track installation that Project Co will implement for the LRT System. The manual with construction and maintenance procedures shall be submitted as part of the Phase 1 submission and shall address all construction elements and specifications related to trackwork, special trackwork, wayside clearances including specifying details such as the rail laying temperatures, material storage, and handling, and construction/maintenance tolerances.

(b) Trackwork Construction and Maintenance Tolerances

The manual shall incorporate the following system-wide track construction and maintenance tolerances as shown in Exhibit 12.8-1

Exhibit 12.8-1

PARAMETER	CONSTRUCTION TOLERANCE	MAINTENANCE TOLERANCE
Track Gauge Variation (without wear)	-0 mm / +3.0 mm	See 12.6 (b)

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Exhibit 12.8-1

PARAMETER	CONSTRUCTION TOLERANCE	MAINTENANCE TOLERANCE
VERTICAL IRREGULARITIES – Vertical track alignment deviations for both rails:		
Total deviation (direct fixation or embedded track)	± 5 mm	± 10 mm
Total deviation (ballasted track)	5 mm	± 20 mm
Total deviation at platforms	± 2.5 mm	As per Project Co's analysis for AODA compliance
Relative deviation over a 1 m length	N/A	± 1.5 mm
Relative deviation over a 5 m length	± 1.5 mm	± 5 mm
Relative deviation over a 50 m length	± 5 mm	± 20 mm
Cross level and superelevation variation (direct fixation and embedded track)	2 mm	3 mm
Cross level and superelevation variation (ballasted track)	4 mm	20 mm
Short wave track twist over 4 m from geometric deviations	1 mm per 1000 mm	1 mm per 273 mm
Short wave track twist over 4 m, sum of track layout and geometric deviations	1 mm per 233 mm	1 mm per 143 mm
Track twist over bogie distance, sum of track layout and geometric deviations	N/A	1 mm per 250 mm

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Exhibit 12.8-1

PARAMETER	**CONSTRUCTION TOLERANCE**	**MAINTENANCE TOLERANCE**
HORIZONTAL IRREGULARITIES – Horizontal track alignment deviations for both rails:		
Total deviation (direct fixation or embedded track)	± 5 mm	± 10 mm
Total deviation (ballasted track)	± 5 mm	± 15 mm
Total deviation at platforms	0 mm toward / 2 mm away	As per Project Co's analysis for AODA compliance
Relative deviation over a 16 m length in tangent track	± 2 mm	
Relative deviation over a 4 m length in curved track	± 2.5 mm	
Relative deviation over a 1 m length		± 1 mm
Relative deviation over a 5 m length		± 2.5 mm
Total deviation is measured between the theoretical and actual at any point in the track. Relative deviation is measured between any point in the track and a point in the stated distance.		

12.9 Standard Track Construction Types

(a) Embedded Track

(i) Embedded track is typically constructed in layers consisting of steel ties, rail fasteners, extruded rubber rail boot, and foundation slab, which are typically completely encased in concrete or some other medium. However, other configurations for an embedded track solution are acceptable providing that the embedded track solution meets all of the general requirements of this Article including providing a suitable running surface for expected rubber tired traffic, meeting corrosion control requirements, providing suitable walking surface for expected pedestrian movements, and presents a clean and aesthetically appropriate appearance for the site specific area. Because of the numerous general requirements for embedded, the Technical Submission must clearly describe each type of embedded track solution proposed for the Stage 1 LRT Project and clearly show where each type of embedded track solution is being installed. It is also recommended that the work category codes for trackwork be defined by Project Co to correspond to the directive drawings for the types of embedded track being proposed, E.g. Type 1

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embedded track, type 2 embedded track etc. Ready access to the rail fastenings for inspection or maintenance is not required in embedded track but is preferred in areas where rail wear will be more pronounced. The concrete paving or equivalent is typically placed up to the level of top-of-rail, except on the field side of the rail head. The top slab may be depressed below the top of rail by not more than 5 mm so as to avoid contact between the pavement surface and the outer edge of the LRV wheel tread.

(ii) It is preferred that embedded and direct fixation track designs are suitable for "top-down" track construction methods to reduce construction deviations from the horizontal and vertical design location.

(iii) Any design for embedded track must accommodate emergency vehicles, snow plows, and other maintenance vehicles to access the Right-of-Way with relative ease.

(iv) Where embedded mainline tracks are constructed in a semi-exclusive Right-of-Way, and pathways for bicycle and pedestrian movements are not a factor, it is preferred for drainage purposes that the track shall be elevated above the grade of the street where possible. The profile of the track shall be adjusted to match the plane of the roadway where the tracks cross a major intersection. At minor intersections, both the grade of the track and the grade of the intersecting roadway shall be adjusted to minimize variations in the LRT track profile.

(v) The subgrade is a key element in embedded track designs. The sub-grade is the material below the track foundation slab, usually in situ material graded. The sub-grade is compacted to the required configuration to support the loads transmitted through the track structure. A key element of trackway design is the stability of the sub-grade. The requirements for uniformity in the sub-grade are essential since differential settlement due to settlement or differential displacement due to frost heaving leads to unsatisfactory track geometry. Project Co shall base the embedded track design on the results of specific geotechnical investigations and recommendation which may require replacement of existing material or other measures to avoid settlement or frost heaving. The sub-grade requirements for embedded track also apply to direct fixation track.

(vi) The foundation slab for embedded track is typically made from reinforced slab for a two pour design or unreinforced concrete for a three pour design. The design shall provide a 80-100-year service life. The top surface of the foundation concrete pour(s) is rough to provide good mechanical lock between it and the next pour.

(vii) To satisfy strict system-wide accessibility requirements for level boarding of the LRT, the surface platforms and the surface trackbed slabs shall not heave due to frost action. The surface platform foundations shall be designed utilizing foundations bearing below the frost depth of 1.5 metres. In addition, the surface trackbed slab adjacent to the platform shall be supported on non-frost susceptible soil backfill placed to depth of 1.5 meters below track level. A non-frost susceptible soil backfill transition zone shall be designed beneath the surface trackbed slab at each end of platform to allow smooth transition between platform and non-platform areas. In order to ensure the tolerance between the track and the platform edge is achieved, Project Co's track designers shall coordinate closely with station designers.

(viii) Project Co shall define concrete performance specifications and determine the appropriate thickness for each layer to achieve the goals described above.

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(ix) Project Co shall analysis the frequency of rail replacement due to rail wear and other factors and identify areas with rail replacement frequency of fifteen (15) years or less. Project Co shall employ designs that permit fast, economical access to the rails and fastenings in those areas, preferably without needing to cut and remove the adjacent poured concrete.

(x) Drainage for embedded track is to be provided by appropriate shaping of the top pour concrete combined with placement of track drains at low points. Track drains shall connect through buried pipe to the appropriate municipal sewer for mainline locations, or to the facility drainage system for vehicle maintenance and storage locations. Where long sustained grades exist, additional track drains shall be provided along the grade at reasonable intervals not to exceed spacing for street inlets. Track drains shall also be provided immediately upgrade of embedded switches to minimize accumulation of debris in the switch mechanisms.

(b) Direct Fixation Track

(i) Direct Fixation Track is typically constructed by rigidly connecting the rail fastenings directly to a concrete foundation slab. The fastenings and rail are open to the air and readily accessible for inspection and maintenance. Track vertical profile is established and maintained using a second-pour concrete plinth into which anchor inserts are cast. Plinths are generally be about 150 mm thick. Short grout pads that require core drilling anchors for the direct fixation rail fasteners into the underlying slab shall not be used.

(ii) Direct fixation track shall be used for Semi Exclusive LRT Right-of-Way where structural considerations make use of ballasted track inappropriate. Since direct fixation track, without the addition of crossing panels, eliminates the possibility of operating rubber-wheel vehicles on the trackway, it shall not be considered for areas of Semi Exclusive Roadway Right-of-Way unless the design incorporates the loading, drainage and other design parameters required to act as a roadway.

(iii) If desired and in lieu of using embedded track in LRT Stop areas, Direct Fixation track can be used to satisfy strict system-wide accessibility requirements for level boarding of the LRT. The surface platforms and the surface trackbed slabs shall not allow vertical movement due to frost action. At-Grade platform foundations shall be designed utilizing foundations that bear below the frost depth of 1.5 metres. In addition, at-grade trackbed slabs adjacent to the platform shall be supported on non-frost susceptible soil backfill placed to a depth of 1.5 metres below track level. Equivalent solutions that ensure that the platform and track relationship is compliant with AODA requirements and is resistant to frost heaving or any other differential settlement condition may be proposed based upon the recommendations of Project Co's geotechnical engineer. A non-frost susceptible soil backfill transition zone shall be designed beneath the surface trackbed slab at each end of platform to allow smooth transition between platform and non-platform areas. In order to ensure the tolerance between the track and the platform edge is achieved, Project Co's track designers shall coordinate closely with station designers. The two parties shall consider the construction sequencing and specify appropriate tolerances for each element.

(iv) Track fastener plates shall be vertically supported on concrete plinths. Top-down construction methods is preferred to accurate position the rail.

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(v) Concrete plinths shall be reinforced concrete with appropriate dimensions and concrete cover to provide secure permanent anchorage for the direct fixation rail fasteners. Fibreglass reinforcing bars are preferred to steel reinforcement.

(vi) Anchor bolts and inserts shall be selected to provide adequate resistance to lateral and vertical forces from train movements. Project Co shall use materials that resist corrosion and seizing. The design shall use female inserts and top-inserted bolts and Project Co shall ensure that the appropriate embedment depths into the plinths will resist all forces directed through the bolt.

(c) Ballasted Track

(i) Ballasted track is constructed by fastening running rails to crossties which in turn sit on top of a base of graded stone aggregate (ballast). Additional ballast is placed around and between ties to immobilize the ties and fix the track alignment and profile.

(ii) Ballasted track shall be the principle trackform for mainline track in semi-exclusive LRT Right-of-Way and considered for use on selected tracks within Semi-exclusive Roadway Right-of-Way, if appropriate. Ballasted track should be limited to areas where rubber-wheel traffic is rare or severely limited such as at highway road crossings. Emergency vehicle lanes and paved walkways may still be required within ballasted track areas of the OMSF. Appropriate transitions between areas of ballasted and non-ballasted track shall be provided.

(iii) Ties for ballasted LRT track and LRT track that is also used by freight railway equipment shall be concrete and provide a zero rail cant condition. Ties for ballasted freight railway tracks not used by LRT trains shall comply with the standards of the railway that will own and maintain those tracks. Tie spacing shall be determined by Project Co in accordance with load requirements and the requirements cited in this Article for tangent and curved track. Tie spacing for special trackwork layouts shall be determined by Project Co’s special trackwork designer.

(iv) Ballast shall fill the tie cribs to a height no greater than 25 mm below the base of rail. Ballast between tracks shall be level and shall match the height of ballast within the cribs in order to provide a reasonable walking surface for maintenance employees accessing the track on foot. Minimum ballast and subballast depths below the crossties shall be determined in accordance with AREMA, environmental conditions found in the project site, but shall not be less than 200 mm of subballast shall be provided over the entire trackbed and not less than 300 mm of ballast measured from the bottom of the ties at any point below any running rail for special trackwork or standard tracks supporting freight railroad and LRT trains. Based on analysis and a report from Project Co’s geotechnical engineer addressing train loading conditions ballast, subballast and subgrade conditions, ballast for mainline special trackwork and mainline standard tracks supporting only LRT trains may be reduced to a minimum depth of 250 mm and the subballast may be reduced to a minimum depth of 150 mm. Based on analysis and a report from Project Co’s geotechnical engineer addressing train loading conditions, ballast, subballast, and subgrade conditions, ballast for yard special trackwork and yard standard tracks may be reduced to a minimum depth of 200 mm and the subballast may be reduced to 150 mm. At all highway crossings involving highway crossing materials placed on standard ballasted tracks, ballast shall have a minimum depth of 300 mm and the subballast shall have a minimum depth of 200 mm.

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(v) Where continuously welded rail is provided, the track design shall include measures to protect against track buckling from thermal stress. Project Co shall provide appropriate rail anchoring details and the preferred rail laying temperature, both in accordance with the requirements of the AREMA Manual for Railway Engineering.

(d) Transition Tracks

(i) Where two types of track construction abut against one another a gradual change in track stiffness shall be made by introducing a transition section between the two types. The transition section consists of a gradual change in track or trackbed construction. This can be accomplished by varying the spacing of direct fixation fasteners, varying the number or stiffness of support pads under track fastening plates, gradually increase or decrease the length and/or spacing of ties or providing a concrete transition slab that decreases the depth of ballast toward the direct fixation or embedded track.

(ii) The transition track shall be of sufficient length to be traversed in a minimum of two seconds at the design speed. The track stiffness shall transition uniformly along its length. Project Co shall undertake calculations to determine the stiffness of the two adjacent tracks, to identify appropriate increments for adjustment of the stiffness along the length of the transition, and to design the transition accordingly. Transition elements are not required between trackforms when train speeds are 10 km/h or lower, such as where ballasted yard tracks abut embedded shop tracks at the entrances to the maintenance shop.

(e) Shop Tracks

(i) In areas of shops where under-vehicle access is not required, and movement of pedestrians and/or shop equipment is desired, embedded shop tracks can be used which may be constructed in a similar manner to mainline embedded tracks. If the floor slab is too thick to accommodate the steel ties, alternatives that do not require ties can be considered.

(ii) Direct fixation track can also be used on shop tracks where drainage is the primary concern, and where under-vehicle access and pedestrian or non-rail equipment movements are infrequent. A wash track is an example of where direct fixation shop track may be employed. If used, direct fixation shop tracks shall be constructed in a similar manner to mainline direct fixation track.

(iii) All Shop tracks are required to be flat and level except that the first 5 metres of track immediately inside of an exterior door. Tracks that enter a shop space shall slope slightly downward toward the door so as promote drainage and supplemental drainage shall be provided at shop doorways. Project Co shall develop shop track details to deal with drainage and spill containment within the shop, including on wash tracks and in areas where lubricants, battery acid or other liquids are handled.

12.10 Standard Trackwork Components

(a) Running Rail

(i) All running rails and restraining rails for LRT tracks shall be new and shall conform to the requirements AREMA specifications. Used or worn tee rail may be accepted for railroad freight track provided it is free from strength-impairing defects and meet the railroad's requirements.

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(ii) In all LRT track areas, except as noted in Section 12.10 (b)(viii), the 115RE rail section as per AREMA Chapter 4 shall be used. All tee rail shall be fully head hardened having a Brinell hardness of 365 to 380. Tee rail shall be pre-curved prior to installation for horizontal curves with radius less than 120 meters or vertical curves with radius less than 300 meters.

(iii) Joining Rail Ends

A. Bolted rail joints are the weakest part of the track structure and their use shall typically be avoided. Where joint bars must be used, they shall be 6-hole type and connected by D-bars and lock bolts, such as those made by Huck, or equivalent. Standard bolted insulated joints may be required in some locations for signaling or traction power purposes.

B. CWR requires rails to be joined together by welding. Rail shall be welded into the longest strings practical by means of Electric Flash-Butt (EFB) welding. The EFB equipment shall be programmed appropriately for the specific rail chemistry being welded.

C. Thermite welds may be used to join rail strings and for joining rails in situations where EFB welding is not practical.

D. Compromise joints shall be avoided for permanent installations. Instead, transitions between two different rail sections shall be accomplished by using pre-manufactured transition rails. Each end of the transition rail shall be manufactured to the cross-section of the rail to which it will be connected. It shall then be welded to the adjacent rail. Transition rails shall be made from the same material as the adjacent rail so it can be welded to the running rails. Transition rails used in embedded tracks shall be lined with an elastomer in the same manner as embedded special trackwork. The elastomer shall be designed to yield a similar track modulus to that of booted running rail.

E. Wherever it is necessary to electrically isolate contiguous rails from each other in order to comply with track signalling or traction power criteria, insulated rail joints shall be used. These insulated joints (IJs) shall have identical rail drilling pattern as standard joint bar, be compatible with the rail fastenings used on the Project, comply with the current AREMA “Specifications for Bonded Insulation Rail Joints” or for insulated joints located in areas of vertical tee restraining rail shall comply with the current AREMA “Specifications for Non-Bonded Encapsulated Insulated Rail Joints”. All insulated joints shall be located as suspended joints to obviate the need for special tie plates in direct fixation track, or special steel ties in embedded track. Special modified elastic clips may be required at insulated joint locations. Track bolts shall be equipped with self-locking nuts. It is preferred that insulated joints are manufactured plug rails that are welded into the running rail wherever possible.

F. Standard bolted joints shall not be installed in main line track unless needed to meet a requirement that can not be addressed by other means. If required, the required traction power and signal bonds must be provided.

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(b) Restraining Rail

(i) Restraining rail is an additional rail installed alongside of the gauge side of the low (inner) rail of a sharp radius curve which share with the running rails the lateral forces generated while traversing the curve.

(ii) Restraining rails require special hardware and maintenance expense. For these reasons, wherever practical, track alignment shall be designed with a horizontal curve radius sufficiently large that restraining rails are not required (greater than 150 metres).

(iii) The purpose of restraining rail is to enhance safety by providing additional vehicle truck guidance, divide lateral wheel forces between two rails, reducing forces on the rail fastening system, and divide rail wear over two rail surfaces increasing the time between rail replacements.

(iv) Restraining rail shall be used on curves having a central radius less than or equal to 150 metres.

(v) Restraining rail flangeway widths and track gauge shall be configured to result in a shared loading condition. See TCRP Report 155, Chapter 4. Restraining rail shall generally be configured to match the plane of the tops of the running rails, including consideration of zero rail cant. Project Co shall perform Nytram analyses as per TCRP Report 155 for all applicable inner and outer restraining rails configurations and include the results in the Basis of Design Report – Trackwork.

(vi) With respect to the normal direction of travel on a track, restraining rail shall start on tangent track a minimum of 3 metres prior to the beginning of a spiral or circular curve and extend a minimum of 5 metres beyond the end of a spiral or circular curve. The end flares of the restraining rails shall be neglected when determining requisite lengths.

(vii) It is preferred that restraining rail in ballasted and direct fixation track be constructed of either 33C1 (previously known as both U69 and UIC33) per EN 13674-4 – Part 3: Check Rail supported in chairs of appropriate design, vertically mounted tee rail spaced away from the running rail by adjustable spacer blocks and fabricated to match the geometric requirements for the flangeway or Strap guard, as described in TCRP Report 155, Chapter 5.

(viii) It is preferred that restraining rail in embedded track shall be constructed of either vertically mounted tee rail spaced away from the running rail by non-adjustable spacer blocks and fabricated to match the geometric requirements for the flangeway or girder rail.

(ix) Restraining rail may use bolted joints to avoid differences in thermal stress levels between the restraining rail and the adjacent CWR running rail. Restraining rail joints shall be electrically bonded at joints. The ends of the restraining rail shall be electrically bonded to the adjoining running rail except where track circuits are employed by the train control system.

(x) In all areas of track requiring restraining rail, Project Co shall ensure the restraining rail fastening assembly is compatible with the LRV dynamic envelope. Restraining rail shall be pre-curved prior to installation for horizontal curves with radius less than 120 meters or vertical curves with radius less than 300 meters.

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(xi) It is preferred that joints in the restraining rail be bolted. Restraining rail joints shall be positioned to be centred over a restraining rail support brace to provide it with additional support and to minimize deflection.

(c) Emergency Guard Rail

(i) Emergency guard rails, also commonly known as bridge guard rails, are intended to contain and guide a derailed truck, keeping the vehicle upright and on the track structure. Emergency guard rails are installed inside the running rails in primary ballasted and direct fixation track at bridges, at retained embankments, on the approaches to tunnel portals and overhead structure abutments, and at locations where a derailed train would likely impact critical non-transit facilities such as high tension power line poles.

(ii) Emergency guard rails shall be a tee rail section, neither taller nor more than 2 cm shorter than 115RE section, and positioned such that the head of the emergency guard rail does not project above the head of the running rail, and not more than 2 cm below the head of the running rail. Worn/used rail may be used for emergency guard rails; provided it is free from strength-impairing defects. All emergency guard rail used on the Project shall be the same section and rail drilling. Project Co shall consider undercar clearances and rail wear limits when determining the vertical position of emergency guard rail. The horizontal position of the emergency guard rails shall be chosen to maximize ease of maintenance access to the running rail fastening system; while ensuring the lateral travel of a derailed vehicle is constrained to a safe distance from critical wayside objects/structures.

(iii) Emergency guard rails on mainline tracks shall extend 30 metres ahead of the beginning of the bridge structure or area being protected on the approach end, and 15 metres beyond the end of the protected structure on the departure end.

(iv) Where restraining rail is used at emergency guard rail locations, emergency guard rail is installed only on the side having no restraining rail.

(v) The ends of emergency guard rail shall be bent into flares pointing toward the track centres.

(vi) Emergency guard rail shall be electrically isolated from the running rail.

(vii) Emergency guard rail is not required on tracks where structural lateral restraints occur and strong enough to contain a derailed vehicle. Acceptability of a structural lateral restraint shall be undertaken jointly by the Project Co's track designer and the structural designer.

(d) Rail Fasteners

(i) The method used to secure the rail to the track structure is an integral part of the overall track system. The fastening system has to resist the rotation of the rail under lateral loads, Resist lateral translation of the rail, resist longitudinal rail slip due to acceleration/braking or thermal forces and absorb vertical vibration energy in order to reduce noise and vibration as well as reduce loading on the crosstie, trackslab or plinth.

(ii) Care is required in the design of the fastening system to ensure the overall track stiffness optimization; and excessive forces are not imparted to the tie or other components.

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(iii) Standard Direct Fixation Fasteners

A. Standard direct fixation fasteners shall be designed for the appropriate loadings. They shall provide the required lateral and longitudinal restraint for continuous welded rail, and the electrical insulation required for the negative return current, and the proper operation of track signal circuits. Fasteners shall be designed to attenuate noise and vibration. Fasteners shall resist corrosion and have an in-service life of at least 25 years.

B. Spacing between direct fixation rail fasteners shall not exceed 750 mm (30 inches).

C. Direct fixation rail fasteners shall provide appropriate longitudinal restraint force and restrain a broken rail gap to less than 50 mm (2 inches) wide. If required to reduced forces on bridges or aerial structures, Project Co shall provide low-longitudinal restraint fasteners if required to allow the structure to expand and contract without overstressing the rail or the structure.

D. In localized areas where mitigation of noise and vibration is a particular concern, Project Co shall consider using alternative fastening designs to augment typical attenuation. Project Co shall ensure alternative fastenings do not compromise maintainability or reliability.

(iv) Direct Fixation Fasteners for Special Trackwork

A. If direct fixation fasteners are used in special trackwork, the fasteners shall be electrically isolated from ground, and attenuate noise and vibration to the greatest extent practical.

B. Project Co shall minimize height mismatch between special trackwork fasteners and standard trackwork fasteners in order to keep plinth/grout pad heights as consistent as possible.

(v) Ballasted Track Fasteners

A. Rail fastenings on wood ties shall conform to Chapter 5, Part 9 of the AREMA Manual for Railway Engineering. Where required, fastenings shall incorporate insulating materials to achieve electrical insulation from ground. Base plates shall conform to the material, manufacturing, quality control and testing requirements of the AREMA Manual for Railway Engineering, Chapter 5 – Part 1 “Tie Plates” or equivalent.

B. Elastic rail fasteners on concrete ties shall be supplied pre-installed on the ties.

C. All rail fasteners on ties shall conform to the dimensions and tolerances for track gauge and zero rail cant.

(vi) Embedded Track Fasteners

A. It is preferred; the rail fastenings used by Project Co for embedded trackwork be integral with the steel ties, but in all cases shall not result in damage to the rubber boot or other electrical isolation medium and are protect from the encasing concrete.

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(e) Cross Ties and Switch Ties

(i) Track crossties are required to maintain track gauge, distribute vehicular vertical and lateral loads to the track foundation, contribute to the stiffness of the track structure, and anchor the track against longitudinal and lateral dynamic and thermal forces.

(ii) Ties and associated fastenings shall jointly meet the requirements for track gauge and zero rail cant.

(iii) Wood Ties for Standard and Special Trackwork

A. It is preferred that wood ties only be used in those locations which involve only freight railroad service tracks or LRT tracks in the OMSF. If used wood ties shall be made from hardwood and shall conform to the requirements of Chapter 30, Part 3 of the AREMA Manual for Railway Engineering. All ties shall be treated with a suitable wood preservative and the ends of all ties shall be furnished with anti-splitting devices.

B. To prevent splitting of the ties all wooden ties shall be predrilled.

C. Hardwood ties shall have a minimum 25-year design life.

D. Wood ties within special trackwork layouts shall be provided in various lengths to suit the size and layout of the turnout. The special trackwork designer or supplier shall determine the appropriate tie layout the appropriate fastening assembly.

(iv) Concrete Ties for Standard and Special Trackwork

A. Concrete ties shall be made from pre-stressed reinforced concrete, conforming to the requirements of Chapter 30, Part 4 of the AREMA Manual for Railway Engineering. Concrete ties shall be supplied with an appropriate pre-installed elastic fastening system. Concrete ties may also be furnished with elastomeric pads attached to the underside of the tie to protect the tie from abrasion against the ballast. Concrete crossties for use in tracks used by freight railway equipment shall be structurally designed for such loadings and be visually distinctive from other concrete ties intended for LRT loadings.

B. Concrete ties shall have a minimum 40-year design life.

C. All mainline ballasted special trackwork shall use concrete ties. Concrete ties for special trackwork shall be designed and supplied by the special trackwork supplier to ensure fastener position is correctly coordinated for each layout.

(v) Steel Ties for Embedded Track

A. Steel ties for embedded track shall be fabricated from structural steel members or steel ties manufactured for this purpose.

B. The ties shall be cut to appropriate lengths, shims (if required), and fastener shoulders welded in place at the appropriate pre-set locations. The entire unit shall be coated to protect it against chloride attack. The finished product shall allow construction forces to build the track at the proper track gauge and zero rail cant with minimal additional measuring. The coating shall be repaired prior to concrete encasement.

C. Embedded steel ties shall have a minimum 40-year design life.

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(vi) Steel Ties for Embedded Special Trackwork

A. Steel ties for embedded special trackwork will be similar to those for tangent and curved embedded track modified for length, spacing, and an adjustable positioning of the rail.

(vii) Tie Spacing

A. Tie spacing shall be determined by Project Co on a system-wide basis, considering factors such as loading, allowable bearing pressure, vehicle speed, cost, allowable track deflection, lateral stability, ability to maintain gauge, etc. Tie spacing shall not result in over-stress on ballast, sub-ballast, and sub-grade. Centre-to-centre tie spacing shall never exceed 750 mm for concrete crossties in LRT-only track, 600 mm for concrete crossties in tracks used by freight equipment, 600 mm for timber crossties used in LRT only tracks and 500 mm for timber crossties in tracks used only by freight equipment or as approved by the freight railroad.

B. Tie spacing for special trackwork shall be in accordance with applicable plans for turnouts and crossovers.

C. On embedded track, infill concrete supports the rail throughout its entire length. As such, steel tie spacing may be wider than one would expect for ballasted or direct fixation track. Steel ties spacing shall be the least of the maximum spacing required to reliably maintain gauge in tangents and curves, or 3 metres.

(f) Ballast

(i) Ballast shall be made from crushed granite or trap rock. Ballast gradation, depth, shoulder dimensions and side slope guidelines shall be provided by Project Co, and shall generally comply with Chapter 1, Part 2 of the AREMA Manual for Railway Engineering, requirements cited in this Article, or CN railroad standards whichever is more restrictive in the sole judgment of the Region. Project Co shall submit to the Region for approval the source(s) of ballast that will be used by Project Co and the test results demonstrating that the ballast meets all of the requirements in the Project Agreement.

(g) Sub-Ballast

(i) Sub-ballast shall generally comply with Chapter 1, Part 2 of the AREMA Manual for Railway Engineering, requirements cited in this Article, or CN railroad standards whichever is more restrictive in the sole judgment of the Region. Project Co shall submit to the Region for approval the source(s) of subballast that will be used by Project Co and the test results demonstrating that the subballast meets all of the requirements in the Project Agreement.

(ii) Sub-ballast shall be placed on top of the contoured sub-grade.

(iii) All design details including gradation, depth, shoulder width, cross fall, side slope, geotextile requirements, etc. shall be determined by Project Co's geotechnical engineer on a system-wide basis. So as to provide a walkway for maintenance-of-way personnel, sub-ballast shall normally extend as a normally level surface for less than 600 mm beyond the toe of the ballast before sloping down to meet the sub-grade. Such walkways shall be provided on both sides of single tracks and on each side of a double track section.

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(h) Elastomers and Isolating Materials

(i) All LRT track construction types shall include materials and components that electrically insulate the rail from ground, absorb noise and vibration, and facilitate adjustment of track modulus.

(ii) Noise and vibration shall be attenuated in a manner that can be measured in accordance with ISO 3095:2005 – Railway Applications – Acoustics – Measurement of noise emitted by railbound vehicles.

(iii) Materials shall be selected that are appropriate to operate in the track environment for a design life of at least 30 years.

(iv) Extruded Rail Boot

A. On embedded track, the rail shall be physically isolated from the infill concrete through the use of an extruded elastomeric rail boot. This boot shall have a snug fit around the rail cross-section, and designed to remain firmly in position until infill concrete has been placed around it.

B. The boot absorbs impact loads from the vehicle and helps protect the concrete from cracking.

C. The material properties and cross section of the boot shall accommodate deflections suitable to achieve noise and vibration attenuation requirements as per the Rapid Transit Project Environmental Report. Deflections shall not exceed the working range of the elastomer.

D. The elastomer of the rail boot shall also provide electrical insulation from the concrete. The boot material and cross-section shall be selected to achieve resistance-to-earth values and be formulated for the environmental conditions that occur in the area of the Project.

(v) Rubber Pads

A. Electrical and vibration isolation on direct fixation track shall be achieved through the use of commercial direct fixation rail fasteners such as those manufactured by L. B. Foster Company, Pandrol, Ltd, or equivalent.

B. The shape factor of the rubber cross-section shall be designed to allow a controlled amount of deflection under dynamic vehicle loads without exceeding the working range of the elastomer, and to provide the prescribed vibration attenuation, and be formulated for the environmental conditions that occur in the area of the Project.

(vi) Encapsulation Material for Embedded Special Trackwork

A. Encapsulation material for embedded special trackwork shall be designed to achieve the same results as other embedded trackwork. However, because the special trackwork components are not of a consistent cross section, the insulating elastomer shall be attached to the outside of all components utilizing an appropriate approach.

B. Where standard joints are used in special trackwork layouts; the bars and bolts shall be fully isolated from the infill concrete.

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C. The selected elastomer (and bonding material, if required) shall be sufficiently tough to withstand impacts normally expected on a track construction site. Because embedded track switches shall be designed with the capability to accept electric heating elements for de-icing, the selected materials shall withstand the associated high temperatures.

12.11 Special Trackwork

(a) Description of Special Trackwork

(i) Special Trackwork refers to all rail installations where tracks converge, diverge or cross. Standard trackwork is made simply from rolled rails of a constant cross-section, while rails in several special trackwork components are cast or machined and have cross-sections that vary along their length. Some special trackwork components, like switches, also have moving parts and require special powering and signaling provisions.

(b) Special Trackwork Configurations

(i) Several typical special trackwork configurations may be used on the LRT alignment. Each configuration serves a different purpose. Selection of the appropriate configuration shall be based on the service requirements for the location, available space, and maintainability.

(ii) Turnouts consist of a switch and a frog. This permits vehicles to diverge to, or merge with, another track. Where oncoming traffic is split from one to two tracks; the layout is called a facing-point turnout. Where oncoming traffic is merged from two tracks into one; the layout is called a trailing-point turnout. Mainline traffic typically traverses a tangent through the switch and diverging traffic travels off at an angle. When both tracks diverge at the same angles from the lead-in, the turnout is called an equilateral.

(iii) Single Crossovers consist of two turnouts in which the track between the frogs is arranged to form a continuous passage for vehicles. This permits vehicles to transfer between two parallel tracks. Single crossovers may be laid-out with either facing-point or trailing-point turnouts.

(iv) Double Crossovers consist of a facing-point crossover and a trailing-point crossover superimposed on one another in an X-shaped configuration. Where the two crossovers intersect a ‘diamond’ or ‘crossing’ is required. Double crossovers provided the maximum service flexibility and shortest travel time in the minimum distance, and shall be used at terminals and other designated locations. Track center distances at double crossovers shall be carefully considered so as to provide proper guarding at all frog points. Track centers smaller than 4.45 meters for number 8 double crossovers are not recommended. Double crossovers shallower than a No. 12 turnout angle are not recommended as they require moveable point frogs at the crossing diamond.

(v) Universal Crossovers are similar to double crossovers, except the facing-point and trailing-point turnouts are laid-out in sequence instead of being superimposed. This layout provides the same functionality as a double crossover, however, eliminates the diamond. However, these layouts require more space than a double crossover and may lengthen headways if used at terminals.

(vi) Paired-Single Crossovers are simply two identical single crossovers positioned close together. Paired-single crossovers can be used at emergency turnback locations on semi-exclusive and non-exclusive ROWs.

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(vii) 3-Track Crossovers are arrangements that permit transfer between both mainline tracks and a third, parallel centre storage track or pocket track. Equilateral switches are usually employed for these layouts; however, standard lateral turnouts are preferred for the mainline ends if space permits.

(viii) Ladder Tracks are a series of single turnouts in sequence that permit a vehicle travelling along a line to diverge to one of several branch tracks. This arrangement is usually found in yards at the entry to storage tracks.

(ix) Gauntlet tracks are an arrangement of switch points and four running rails that shared the same ties or supporting track form. A gauntlet track is commonly used to provide an increased offset from the edge of the station platform to allow railroad freight cars to bypass a station platform without the need to building an entirely separate bypass track.

(c) Special Trackwork Components

(i) General

A. Mainline and yard special trackwork shall be of tee rail design, generally based on AREMA design details and the 115RE rail section except as noted below.

B. All turnouts shall be located on planar, tangent track. Turnouts shall not be located on superelevated track. Rails in special trackwork shall not be canted.

C. Embedded and direct-fixation special trackwork shall incorporate elastomeric materials to dampen noise and vibration, and to accommodate deflection under dynamic load. The physical properties of the elastomers and the shape factor of the elastomer cross-section shall be chosen to ensure the material does not exceed its working range for the applicable design. Ballasted special trackwork shall generally not include elastomeric elements in the trackwork unit, however, may be underlain by a ballast mat to meet noise and vibration requirements.

D. Turnouts and crossovers shall be located totally at grade or totally on a structure. No turnout or crossover shall straddle a structure expansion joint or a change in type of track construction (e.g. direct fixation to embedded, ballasted to direct fixation, etc.).

E. All turnouts with a radius 150 meters or less shall be designed with an inner restraining rail that creates a fully guarded condition throughout the turnout, and if applicable, throughout the crossover track between two turnouts.

F. It is preferred that special trackwork in ballasted, embedded, and direct fixation track areas utilize AREMA style special trackwork modified, as needed, to achieve compatibility with the LRT wheel configuration which is substantially different than the wheel configuration used by freight railroads. Particular attention to the switch point interface and the frog and guard rail flangeway is required. Special trackwork design for exclusive freight railroad use shall conform to railroad requirements and shall be submitted by Project Co to the railroad for their acceptance.

(ii) Turnout Sizes

A. Mainline non-embedded special trackwork layouts shall employ standard, commonly-available lateral turnout geometries in general accordance with the AREMA Portfolio of Track Work Plans, latest edition. Turnout sizes shall

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support minimum design headways. It is preferred that Project Co use consistent turnout sizes at all mainline double crossovers, and use straight frogs on mainline track. If proposed and accepted by the Region, custom, but non-proprietary designs for turnout geometry can be used if the design achieves all operational requirements and reduces crossover length.

B. The smallest number straight frog turnout that may be used anywhere is a No. 4 turnout with an AREMA 13-foot [3962 mm] curved split switch. Ballasted track turnouts in the yard may consider the use of a curved frog in conjunction with a standard AREMA switch point geometry.

C. The preferred turnout size for LRT double crossovers at terminal stations is a No. 8 turnout. Conestoga mall represents a constrained condition which currently does not permit a No. 8 double crossover.

D. The minimum turnout size for freight railroad service is a No. 10 turnout.

(iii) Switch Points

A. Turnouts shall employ curved switch points and uniform risers. Switch point lengths shall be determined by Project Co and shall generally conform to AREMA standards. Adjustments in the AREMA switch point details and entry angle are permit and Project Co is responsible for providing a switch point detail which is fully compatible with the LRT wheel configuration and railroad wheel configuration where applicable.

B. All embedded switches shall be enclosed within a robust track box capable of handling heavy rubber tired maintenance trucks, fire trucks, buses, or garbage trucks. Project Co shall assess the applicable load cases for the design of the enclosure.

(iv) Frogs

A. Frogs shall be of deep groove design and provide continuous tread support as the wheel transfers from the wing rail to the frog point. The contact areas shall meet the requirements of the rail car supplier but not less than 8 mm in width throughout the full length of the frog, including through the transition area.

B. Except where conditions may dictate another approach, mainline frogs, and yard frogs on direct fixation or ballasted track, shall be railbound manganese steel construction with the running surfaces of castings machined to conform to the cross-section of 115RE rail.

C. Frogs for embedded turnouts shall be all-welded monoblock construction designed be welded to abutting 115RE rail.

D. Movable point frogs and spring frogs are needed to achieve a proper wheel transfer and to achieve compatibility between LRT rail cars and freight rail cars using the same route through a turnout. Project Co may propose alternatives to the use of movable point frogs and spring frogs if those alternatives achieve compatibility between LRT rail cars and freight rail cars. Project Co should investigate all approaches in collaboration with the rail car supplier. Failure to clearly define the special trackwork solution that achieves compatibility between freight railroad and LRT trains may result in a major contract compliance issue.

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E. The location of the heel of frog of a turnout frequently governs the closest location of other trackwork features such as other turnouts, and horizontal and vertical curves.

(v) Switch Machines

A. An electrically-operated or electro-hydraulic switch machine is required to operate switch points and moveable point frogs on all mainline and most yard tracks. Selection of switch machines and the associated space requirements shall be coordinated with design of the train control system and other associated requirements. The train operator shall be able to operate all powered switch machines from the train operators console and the design of the trackwork shall include all wayside components for this function. In addition, it is preferred that all powered switches be capable of remote operation from the Central Control Facility and local operation from wayside houses or cases.

B. In all cases sufficient lateral space shall be provided to accommodate installation, inspection and maintenance of switch machines.

C. Manually operated switches are permitted in secondary tracks where low usage is anticipated.

12.12 Highway and Pedestrian Grade Crossing Materials

(i) Mainline grade crossings shall be prefabricated and made of durable, long lasting materials. Grade crossing panels shall be constructed with due regard to removability for track maintenance, electrical isolation, non-interference with electrical track circuits or rail fastenings, tire adhesion, and slip resistance for pedestrians. The flangeways at designated pedestrian and bicycle crossings shall be minimized to the extent possible and flangeway warning signs posted.

(ii) Rail joints and thermite welds shall not be located in grade crossings.

(iii) Geotextiles shall be used at grade crossings and around underdrains.

(iv) Cross tie spacing at grade crossings shall be in accordance with the grade crossing manufacturer's recommendations.

12.13 Other Track Devices

(a) Lubricators

(i) On-board lubrication is not provided by the rail car supplier. Project Co shall make provisions for wayside track lubricators to be installed in all main line curved track which has restraining rail, i.e. track with a radius of 150 meters or less and in other locations of expected high rail wear. Lubricators, including top of rail lubricators, shall be installed at other locations where noise or rail wear is or is anticipated to be a problem.

(ii) Lubricators shall be located at the start of a horizontal curve at the point of first full wheel flange - rail contact. This contact location is site-specific, however, is generally within the entering track spiral, approximately one-third of the spiral length from the tangent to spiral point (TS). The optimum location is dependent on curve radius, superelevation unbalance, actual superelevation and train speed.

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(iii) The gauge side of the high rail and the contact face of the restraining rail shall be lubricated. Under no circumstances shall the high rail be lubricated with the restraining rail dry.

(iv) Space shall be provided in the trackway for the lubricator cabinet. The size of the apparatus varies with the supplier. A minimum 1.5 metres wide by 3.0 metres long space shall be provided to accommodate the lubricator compressor, pump, drums and ancillary apparatus. Where practical, it is common practice to locate this apparatus midway between two adjacent curves.

(v) Efforts shall be made to keep the length of tubing between the pump and the applicator head to a minimum. The tubing shall be protected from impact damage. For embedded track, the tubing shall be embedded in the concrete. For direct fixation, track the tubing shall either be encased in a rigid conduit/sheath or made from a durable material.

(b) Switch Heaters, Pan Heaters & Hot Air Blowers

(i) It is critical to prevent accumulation of snow and ice around the moving parts of switches exposed to winter weather. Failure to clear snow and ice from switches may cause the switch to fail, and in the worst case, could cause a derailment. It is preferred at a minimum that Central Control has the capability to remotely activate all mainline switch heaters, pan heaters and hot air blowers.

(ii) All embedded, ballasted, and direct fixation switches exposed to winter conditions shall be installed with a functioning electric heating system.

(iii) Electric element heaters and pan heaters shall produce sufficient heat to keep the switch free of ice in a 25 mm per hour snowfall at a temperature of minus 30°C.

(iv) Ballasted and direct fixation turnouts in exposed locations shall be equipped with both hot air blowers and electric element heaters for the following situations:

A. At terminals

B. At yard entry and exit turnouts connecting yard tracks to main lines

C. At critical turnouts in yard storage locations

(v) For all other exposed locations, electric element heaters and pan heaters only shall be used.

(vi) Spring frogs, gauntlet switches, and moveable point frogs in exposed locations shall also be equipped with electric element heaters, pan heaters and hot air blowers.

(c) Rail Friction Buffers, Sliding Bumping Posts and Derails

(i) Stub-end storage/pocket/tail tracks used in main line operation shall be equipped with sliding friction buffers capable of absorbing the kinetic energy of a train to bring it safely to a stop. The speed rating for each buffer shall be optimized by Project Co based on site specific conditions and the level of train protection in place. The friction buffers shall be capable of safely stopping a 2-car train at W1 (tare) weight without damage to any of the cars at a speed of 10 km/h. It is preferred that the friction buffers have a hydraulic ram to absorb slow speed impacts of 5 km/h or less. Only the friction buffer head shall contact the passenger car or locomotive. Contact between the passenger car and the buffer head shall not cause lifting or derailment of the car. Friction buffer shoes shall not extend past

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the buffer housing. Additional rails between the running rails may be used for additional storage of buffer shoes.

(ii) Stub end yard tracks shall be equipped with sliding bumping posts. The bumping post shall be capable of stopping a 2-car train at a speed of 10 km/h.

(iii) Project Co shall submit for review and approval the length of track required behind the friction buffers or bumping posts to achieve the above-noted design goals. The design shall be coordinated with the signal design, trackwork design, and civil requirements.

(iv) Project Co shall provide derails in locations where collision mitigation from unplanned train or car movements is required. Derails are required to protect the LRT tracks from intrusion by freight railroad trains. These derails shall be powered, heated, indicated with wayside signals, and interlocked with the Train Control System being provided by Project Co for reserving routes exclusively for LRT and freight railroad movements.

12.14 System Interfaces Affecting Track Design

(a) General Interface Requirements

Project Co shall consider the design interfaces between trackwork and other design disciplines and include these interfaces in the Systems Integration and Interface Management Plan.

(b) Traction Power

(i) The design of the Overhead Catenary System (OCS) and traction power system shall be coordinated closely with trackwork and track alignment designs.

(ii) Final pole spacing and positioning for the OCS is dependent on track horizontal and vertical alignment, EMS access to side streets (for semi-exclusive Right-of-Way), and the placement of special trackwork layouts. The trackwork Project Co's shall work closely with the OCS designer to ensure the two designs are compatible.

(iii) With the possible exception at some special trackwork locations, both running rails shall be used for traction power negative return. All bolted rail joints shall be electrically bonded across the joint bars with high conductivity bonds.

(iv) Crossbonding spacing requirements shall be identified to Project Co's track designers by Project Co's traction power system designer, working in conjunction with Project Co's the signaling/train control system designer.

(v) Appropriate measures shall be taken during the design of all types of trackwork to minimize the leakage of stray current from the track structure to the ground.

(c) Signals & Communications

(i) Depending on the type of signaling/train control system implemented installation of additional insulated joints, particularly at special trackwork, at ends of station or other critical areas, may be required. Placement of insulated joints shall be coordinated with Project Co's signal designer.

(d) Electrical Power

(i) Project Co's trackwork designer shall coordinate the location of all powered wayside track systems equipment with Project Co's electrical designer. This equipment includes:

A. Powered switches

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B. Switch heaters & blowers

C. Wayside rail lubricators

(ii) Project Co's electrical designer shall also be aware of any requirement for electrical outlets along the right of way to support track maintenance activities.

(e) Corrosion Control

(i) Project Co's trackwork designer shall coordinate the location of all corrosion control test stations with Project Co's corrosion control engineer.

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