10 RAILWAY TRACK

10.1 TRACK WORK SPECIFICATION

10.1.1 General

1 All tracks for the Network are slab track systems according to the requirements as described herein. The Contractor shall propose an integrated system, which can be used for tunnel, elevated and at-grade sections, on railway track and in turnouts/rail expansion joints.

2 Where necessary, the slab track shall be modified for noise and vibration mitigation, High Resilient Fasteners (HRF), Light Mass-Spring-Systems (LMSS) and Heavy Mass-Spring-Systems (HMSS).

3 Trackforms other than slab track may be utilised for vibration mitigation systems with special rail fasteners for LMSS and HMSS, which shall be similar to the standard (turnout) trackform, but equipped with bearings for vertical and horizontal support.

4 Trackwork shall be designed in accordance with the following standards:

(a) EN 1990 Basis of structural design;

(b) EN 1991 Actions on structures;

(c) EN 1992 Design of concrete structures; and

(d) EN 1993 Design of Steel Structures.

10.1.2 Rail Inclination

1 The rails shall be inclined towards the centre line of the track at 1:40.

10.1.3 Track Stiffness

1 The Track Stiffness C_{tr} is defined as the vertical force that creates a unit deflection of the continuous rail. Throughout standard tracks, turnouts and crossings the Track Stiffness shall be

$$C_{tr} = 64 \pm 5\ kN/mm.$$

10.1.4 Rail Fastener Spacing

Table 10.1

Rail fastener spacing

Track Geometry	Rail Fastener Spacing	
	Standard [mm]	Exceptional* [mm]
Straight and curved with radius R≥500m	700	800
Curved with radius 500>R≥300m:	650	750
Curved with radius R<300m	600	700

(*) Exceptional with mean spacing over 5 lengths (e.g. at structural expansion joints).

10.1.5 Clear Distance between Slab Surface and Rail Bottom

1 The clear distance between slab surface and rail bottom shall be determined taking into account possible cable crossings and welding allowances and shall not be less than 50 mm.

2 For at-grade sections passing through exposed sand dunes the clear distance between slab surface and rail bottom shall be 100 mm minimum.

10.1.6 References

1 The following standards are approved and/ or referred to in this Section:

EN 206 .....Concrete - Specification, performance, production and conformity

EN 1990 .....Eurocode - Basis of structural and geotechnical design

EN 1991 .....Eurocode 1: Actions on structures:

EN 1991-2 .....Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges

EN 1992 .....Eurocode 2: Design of concrete structures:

EN 1993 .....Eurocode 3: Design of steel structures:

EN 13146 .....Railway applications - Track - Test methods for fastening systems -

EN 13674 .....Railway applications - Track - Rail -

EN 13674-1 .....Railway applications - Track - Rail - Part 1: Vignole railway rails 46 kg/m and above

EN 13481 .....Railway applications - Track - Performance requirements for fastening systems -

EN 13481-1 .....Railway applications - Track - Performance requirements for fastening systems - Part 1: Definitions

EN 13481-2 .....Railway applications - Track - Performance requirements for fastening systems - Part 2: Fastening systems for concrete sleepers in ballast

EN 13481-5 .....Railway applications - Track - Performance requirements for fastening systems - Part 5: Fastening systems for ballastless tracks

EN 13674-2 .....Railway applications - Track - Rail - Part 2: Switch and crossing rails used in conjunction with Vignole railway rails 46 kg/m and above

EN 50122 .....Railway applications - Fixed installations - Electrical safety, earthing and the return circuit -

EN 50122-2 .....Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 2: Provisions against the effects of stray currents caused by DC traction systems

EN 50162 .....Protection against corrosion by stray current from direct current systems

UIC - International union of railways Standards; UIC 774-3 Track - bridge Interaction. Recommendations for calculations

United States of America Department of Transport – Transit Noise and vibration Impact Assessment Handbook

10.2 REINFORCED CONCRETE DESIGN

10.2.1 General

1 The reinforced concrete design shall be based on EN 1992.

2 The track slab shall be designed for crack prevention. In areas with embedded anchor devices the calculated crack width shall not exceed 0.1 mm.

3 Notwithstanding the Contractor's calculated minimum reinforcement, the Contractor shall provide the following minimum longitudinal reinforcement content (as percentage of the cross sectional area):

(a) Elevated and at-grade sections: 0.80%;

(b) Tunnel and other underground sections: 0.50%.

10.3 RAIL STRESS AND TRACKWORK – STRUCTURE INTERACTION

10.3.1 General

1 The Contractor shall check Additional Rail Stress according to EN 1991-2 and Code UIC 774-3.

2 In calculating Additional Rail Stress the following shall be considered:

(a) elevated structure temperature variation;

(b) braking and/or traction;

(c) elevated structure end rotation from vertical axle loads ;

(d) impact; and

(e) the effects of the concrete creep and shrinkage.

3 Unless the Contractor verifies other temperature variations, the following maximum temperature changes shall be considered for prestressed concrete superstructures:

(a) maximum temperature drop = 35K; and

(b) maximum temperature rise = 20K.

10.4 TRACKFORMS FOR VIBRATION MITIGATION (MASS-SPRING SYSTEMS)

10.4.1 General

1 The extent and nature of vibration mitigation measures shall be based on the Contractor's vibration mitigation prediction report and vibration mitigation design.

2 The natural frequency f_0 of mass-spring systems shall be calculated taking into account the permanent mass "m" consisting of rails, fasteners, sleeper/bearer and slab concrete:

$$f_0 = \sqrt{\frac{c_{dyn}}{4\pi^2 m}}$$

where c_{dyn} is the dynamic stiffness of the bearing material.

3 The discontinuity at expansion joints of mass-spring system slabs shall be minimised.

4 Transition zones shall be inserted between track slab systems with different stiffnesses. A gradual change shall be provided.

5 Displacement limits of mass-spring system slabs shall be as follows:

Table 10.2

Allowable displacement differences

Type	Limit	Remarks
Total transverse displacement	5 mm	Caused by centrifugal force and impact
Vertical displacement difference at expansion joint under normal track	2 mm	
Vertical displacement difference at expansion joint under turnout and/or crossing	1 mm	
Angular change in vertical plane from slab end rotation	0.003 rad	
Transverse displacement difference at expansion joint	2 mm	
Angular change in horizontal plane from slab end rotation	0.003 rad	

10.5 RAILS

10.5.1 General

1 All running rails shall be 60E1 profile manufactured and supplied according to EN 13674-1. The minimum length of rail supplied shall be 25 m. The minimum closure rail length to be installed in the system shall be 6.0 m.

2 The Contractor shall verify an optimal rail – wheel profile compatibility.

3 All running rails for straight tracks and for curved tracks with radius equal or greater 500m shall be supplied as standard Grade R260. For curved tracks with radius less than 500m running rails shall be of Grade 350HT heat treated or head hardened.

4 Rails to be used for turnouts, crossovers and crossings shall be of Grade 350HT according to EN13674-1.

5 The whole surface area of all rails shall be corrosion protected to cover shipping, delivery and storage. The corrosion protection shall be maintained until completion as far as possible.

6 Rails shall be supplied undrilled unless specified otherwise and be marked in accordance with EN13674-1 and EN13674-2.

7 Rails shall be prepared by flash-butt welding to form Long Welded Rails (LWR).

8 The Contractor shall submit the LWR schedule to the Engineer for review.

9 The Contractor shall prepare the LWR schedule with the objective to minimise the number of joints of Grade 350HT rails, for which aluminothermic welding must be carried out.

10 The minimum length of one LWR shall be 125 m. In exceptional cases the minimum length may be revised to fit local conditions.

11 The LWR shall be connected by mobile flash-butt or aluminothermic welding.

12 Rail straightness, surface flatness and twist shall be in accordance with EN13674-1.

10.6 GUARD RAILS

10.6.1 General

1 Guard rails or reinforced concrete upstands shall be installed to avoid collision of derailed vehicles with major structural elements:

(a) steel truss bridges with distance track axis to truss diagonals smaller than 3.50m; and

(b) single columns with a clear distance from track axis of less than 3.20m.

2 Guard rails shall be of 60E1 profile in Grade R260 according to EN 13674-1.

3 The guard rail fastening system shall be independent of the running rail fasteners.

4 Removal of the running rail shall be possible without removal of the guard rail.

5 The clear spacing between running rail and guard rail shall be 180 to 300 mm.

6 At the end of guard rail sections the guard rails shall be installed such that they are able to catch an already derailed vehicle and guide the wheels into the 180 to 300 mm flange way.

10.7 RAIL FASTENERS

10.7.1 General

1 The Contractor's attention is drawn to the local conditions under which rail fasteners have to perform. Surface temperatures up to 84°C have been recorded and it is likely that rails in at-grade and viaduct tracks may reach such temperatures. Therefore, the Contactor shall demonstrate that the non-metallic materials of rail fasteners are suitable to retain their specified properties in the local climate.

2 Rail fasteners shall be supplied by the original manufacturer, who shall have a supply record of similar rail fastenings installed for more than five (5) years with a minimum length of 10 km.

3 In order to facilitate maintenance procedures fastening assemblies and their components shall be of a single type and delivered by one supplier to the highest possible standard.

4 Rail fasteners shall ensure support and guidance, secure track gauge and rail inclination, provide resilience as required to maintain the specified track stiffness, electrical insulation and adequate creep resistance.

5 The rail fasteners shall be categorised according to EN 13481-1.

6 Rail fasteners shall comply with EN 13481-1, EN 13481-2, EN 13481-5, and be tested in accordance with EN 13146.

7 Rail fasteners shall be designed to provide a high degree of electrical insulation. As a minimum the Contractor shall demonstrate that the proposed fastening system is suitable to meet the requirements of EN 50122-2.

8 The fatigue resistance of the rail fastening system shall be tested in accordance with EN 13146-4. After testing changes of the fatigue resistance of the rail fastening system shall not exceed the limits specified in Clause 5.3 of EN 13481-5.

9 If the Contractor proposes fastening systems with components for which records of five (5) years satisfactory performance cannot be submitted, acceptance may be granted based on satisfactory type test results. The test programme and laboratory shall be submitted to the Engineer for review.

10 To achieve the specified track stiffness the vertical static secant stiffness of one fastening assembly shall be 22.5 ± 2.5 kN/mm. The static secant stiffness shall be determined from the vertical deflection of the assembly measured under test loads in accordance with EN 13481-5.

11 The toe load exerted by the fixed rail clips shall be 18±2 kN (per fastener).

12 The rail fasteners shall have a minimum creep resistance of 9.0 kN. The creep resistance (longitudinal restraint) shall be measured in accordance with EN 13146-1. Where a low longitudinal restraint is required, rail fasteners with a lower creep resistance shall be applied.

13 The maximum creep resistance of one rail fastener shall not exceed 13.0 kN. The creep resistance shall be measured in accordance with EN 13146-1.

14 The resistance against the effect of severe environmental conditions shall be determined in accordance with EN 13146-6.

15 Rail fastening systems shall have provisions to raise and lower the rail with a total vertical adjustment of at least +30 mm, and a lateral adjustment of each rail of at least ±5 mm. The Contractor shall not use this adjustability for his installation method, and the full adjustability shall be available after installation of the track.

16 Rail fastening systems shall be designed to prevent corrosion. Clips and all other steel components shall be coated. The Contractor shall propose the coating material to the Engineer for review.

10.7.2 Direct Fixation Systems

1 Direct fixation systems are fastening systems for prefabricated concrete components (sleepers, prefabricated slabs), which are formed to allow direct transfer of lateral forces (without anchored base plates).

2 If the Contractor proposes a trackform with direct fixation fasteners, all standard trackforms shall be equipped with direct fixation fasteners.

3 The main components of direct fixation fasteners are:

(a) HDPE rail pad;
(b) steel spreader plate;
(c) elastic rail pad;
(d) insulating elements;
(e) tension clamps (rail clips);
(f) sleeper screws or similar; and
(g) embedded inserts/shoulders.

10.7.3 Indirect Fixation Systems

1 Indirect fixation systems are fastening systems with base plates that are separately anchored with embedded bolts or with bolts and embedded inserts.

2 If the Contractor proposes indirect fixation fasteners, all standard trackforms shall be equipped with indirect fixation fasteners.

3 The main components of indirect fixation fasteners are:

(a) HDPE rail pad;
(b) steel spreader plate;
(c) elastic rail pad;

(d) insulating elements;

(e) tension clamps (rail clips) with fixing bolts or similar;

(f) steel base plate (SG casting);

(g) insulation and adjustment pads;

(h) helical springs; and

(i) anchor bolts separated by insulation bushings.

4 The base plates shall have two to four anchor bolts depending on the track geometry and the Contractor's design.

5 Anchor bolts, which are designed for bending from horizontal rail forces, shall be checked to have satisfactory fatigue resistance. For this purpose the possible play between bolts and insulation bushings and between insulation bushings and base plates shall be taken into account. Unless the Contractor can verify that his design does not allow for any play, it shall be assumed that in case of a 2-bolt base plate one bolt takes at least 75% of the horizontal force to be transmitted. In case of a 4-bolt plate one bolt shall take 40% of the total horizontal force.

6 High Resilient Fasteners (HRF) shall be fasteners of the indirect fixation type.

10.8 INTERFACE LAYER FOR AT-GRADE SLAB TRACKS

10.8.1 General

1 The Contactor shall place an interface layer between the track slab and the top surface of the protection layer to prevent any over-stressing of the protection layer due to dynamic forces from train operation. The interface layer shall be of concrete or hydraulically bound mixtures.

2 The Contractor shall propose the thickness and type of interface layer.

3 The Contractor shall design the type and distance of joints (crack inducers) in order to avoid cracks.

10.9 TRACKFORMS FOR VIBRATION ATTENUATION

10.9.1 General

1 For areas with vibration sensitive receptors, the Contractor shall propose vibration mitigation trackforms suitable to reduce the vibration impact as required.

2 If areas of vibration sensitive receptors have been identified in the Employer's Environmental Impact Assessment (EIA) Report, the Contractor shall review and update the information on vibration sensitive receptors.

3 The Contractor shall undertake further investigations to identify the sensitivity categories of all areas along the alignment, such as hospitals, schools, and residential buildings etc. which require noise and vibration protection.

4 Depending on the required level of vibration attenuation for a classified area, the Contactor shall propose one of the following vibration mitigation systems:

(a) standard track with high resilient fasteners;

(b) light mass-spring system (LMSS); or

(c) heavy mass-spring system (HMSS); or

(d) another suitable system.

10.9.2 Noise and Vibration Prediction Report

1 In coordination with and under guidance of the Employer's Environment Consultant, the Contractor shall submit for the Engineer's review a Noise and Vibration Prediction Report to identify type, location and dynamic properties of required vibration mitigation trackforms.

2 Measurements for the verification of assessed transmission functions shall be performed. The Contractor shall propose possible procedures (e.g. simulations). A test plan shall be prepared that defines the method, including specification of test equipment, test sites, and number and distances between measurement points. The test plan shall be in accordance with the EIA targets as agreed by the MOE.

3 The Contractor's Noise & Vibration Prediction Report shall be based on the procedures outlined in "United States of America Department of Transport – Transit Noise and vibration Impact Assessment Handbook" (May 2006).

4 Acceptance criteria in terms of vibration velocities and ground borne noise levels, as specified in the "United States of America Department of Transport – Transit Noise and vibration Impact Assessment Handbook", are given in Table 10.3.

Table 10.3

Acceptance criteria for vibration and ground borne noise

Receptor type	**Frequent events (>70 events per day)**		**Infrequent events (<30 events per day)**	
	Vibration velocity limit	**Lmax(fast)[2]**	**Vibration velocity limit**	**Lmax(fast)[2]**
	[mm/s]	**[dB(A)]**	**[mm/s]**	**[dB(A)]**
Residential (Urban)	0.1	35	0.254	43
Residential (non-urban)	0.1	35	0.254	43
Commercial	0.143	40	0.359	48
Industrial	N/A	N/A	N/A	N/A
Rural	N/A	N/A	N/A	N/A
Schools and mosques	0.143	50	0.359	58
Category 1 buildings where vibration would interfere with internal operations; research and manufacturing facilities, hospitals with vibration sensitive equipment; university research departments[1]	0.045	N/A	0.045	N/A
Concert halls, TV studios and recording studios	0.045	25		25
Auditoriums and theatres	0.1	35		43

Note 1: *The criteria will depend on the use; a detailed assessment shall be carried out at such facilities.*

Note 2: *Ground borne noise levels*

(Source: Qatar Integrated Rail Project – Environmental Impact Assessment Scoping Addenda – Noise and vibration (13. September 2012)

10.9.3 High Resilient Base plates (HRB)

1 To avoid potential derailments, the two ends at a fracture gap should remain at a similar level under approaching wheels. HRF fasteners are softer than standard fasteners and need special features to restrict vertical deflection under accidental conditions. HRB fasteners shall have suitable features to restrict possible vertical steps of rail fracture gaps to 30mm.

2 HRBs shall have a static secant stiffness as specified in the Contractor's noise and vibration design, but not less than 6 kN/mm.

3 HRBs shall have a minimum creep resistance of 9.0 kN. The creep resistance (longitudinal restraint) shall be measured in accordance with EN 13146-1.

4 The maximum creep resistance of one HRB shall not exceed 13.0 kN. The creep resistance shall be measured in accordance with EN 13146-1.

5 HRBs shall be designed for high damping (impact reduction > 30%), which shall be measured in accordance with EN 13146-3.

6 The effect of repeated loading shall be tested in accordance with EN 13146-4. Test loads and positions are:

$$\frac{P_v}{cos\alpha} = 60\ kN;$$
$$\frac{L}{V} = 0.49;$$
$$\alpha = 26^o;$$
$$x = 15\ mm.$$

7 As alternative to high resilient fasteners the Contractor may propose a bi-block booted sleeper track system with direct fixation fasteners and soft elastomeric pads below the sleepers blocks.

10.10 TRACK SLAB CONCRETE

10.10.1 General

1 Minimum concrete grade of slab/plinth concrete is C30/37 in accordance with EN 206, with maximum aggregate size ≤20 mm.

2 Track slabs/plinths shall be reinforced as proposed and verified by the Contractor.

3 Surface finish of track slab/plinth shall be:

(a) upper surfaces: compacted concrete levelled and steel towelled under firm pressure; gradual irregularities < 5 mm in 2 m; and

(b) formed surfaces: sealed plywood; abrupt irregularities < 1 mm.

4 Tunnels track slabs with sleepers shall be cast in lengths not exceeding 30m.

5 Track slabs shall be separated by a 150mm wide gap at drainage inlets for water runoff.

6 Cast in-situ plinth tracks or slabs without sleepers/bearers shall be cast in lengths not longer than 5600 mm with 100 mm gaps between consecutive slabs/plinths. This requirement applies to all track areas.

7 On elevated sections track slabs with sleepers shall be cast in lengths not exceeding 8000 mm with 100 mm gaps between consecutive slabs.

8 For at-grade sections the Contractor shall propose the maximum length of slabs with sleepers.

9 For at-grade sections the Contractor shall design and implement anchorage provisions for free slab ends.

10.11 INFILL CONCRETE

10.11.1 General

1 Infill concrete for tunnel track base shall be of grade C25/30 in accordance with EN 206.

10.12 EMC, STRAY CURRENT PROTECTION AND EARTHING

10.12.1 General

1 All trackforms shall include a stray current protection system in accordance with EN 50122-2 and EN 50162.

2 The Contractor shall demonstrate that the leakage between rails and track slab cross section is ≤ 0.1 S/km per track under new built condition.

3 The Contractor shall design electrical insulation provisions suitable to limit leakage of the system in operation and during design life to 0.5 S/km per track.

4 For the calculation of stray currents and failure currents and for the design of conductors inside structures (e.g. stray current earthing conductors, reinforcement or other structural elements) the following shall be considered:

(a) maximum operational current;

(b) maximum short circuit current;

(c) leakage rails to ground: 0.7 S/km per track (2 rails); and

(d) the Contractor shall calculate with full current along the slab track body.

5 Stray current transfer between Trackwork to and from other systems (including gas and water pipelines) is prohibited.

6 All earthing and bonding measures shall be based on EN 50122 and EN 50162.

7 The return current path shall be strictly separated from other conductors.

8 In the upper layer of the concrete slab structure a minimum of six (6) continuous reinforcing bars with a minimum diameter of 16 mm shall be placed in the vicinity of the running rails (three pieces per rail).

9 At slab/plinths ends the continuous reinforcing bars shall be connected by flat steel plates with a minimum cross sectional area of 120 mm^2. The steel plates shall be connected by welds of a minimum cross sectional area of 20 mm^2 per connected reinforcing bar. The steel plates shall be bolt-connected to earthing terminals according to EN 50122-2, which shall be preferably located at the lateral edges of slabs/plinths.

10 The Contractor shall connect the earthing terminals of the slabs/plinths by insulated copper wires with a minimum cross sectional area of 80 mm^2.

10.13 TRANSITIONS

10.13.1 General

1 To minimise the displacement differences induced by different trackform stiffnesses a transition with a gradual change of the track stiffness shall be provided

2 between different trackforms, and

3 between different track bearing structures (for example between embankment and bridge/tunnel).

10.14 CLOSURE OF SPACE BETWEEN AT-GRADE TRACK SLABS

10.14.1 General

1 The Contractor shall provide and install a water-permeable gravel-sand mix in order to fill the space between parallel tracks in at-grade sections.

10.15 DERAILMENT CONTAINMENT

10.15.1 General

1 Derailed trains shall be prevented from tilting, running into the structure gauge of the opposite track and from colliding with bridge/tunnel equipment. For that reason derailment containment is required for all tracks.

2 Derailment containment may be provided by reinforced concrete upstands that are integral part of the track slab or by guard rails.

10.16 BUFFER STOPS

10.16.1 General

1 The Contactor shall install buffer stops at the ends of all main lines, siding and depot access tracks.

2 Buffer stops shall be designed to be capable of stopping two coupled Train Sets with AW0 mass (i.e. vehicle without passengers, complete and provisioned for service), operating with a speed in Restricted Manual Mode at impact, without major damage to the train or to the stopping device. (In Restricted Manual Mode the speed is limited to a maximum speed defined taking into account the constraints of, but not limited to the following: track geometry, line side signals visibility, driver reaction time & maximum line slope.)

3 All buffer stops shall be positioned such that the required braking length can be safely achieved.

4 The Contractor shall submit a painting specification to the Engineer for a SONO. The painting specification shall ensure a design life of 10 years before repainting.

10.17 INSULATED RAIL JOINTS

10.17.1 General

1 Insulated rail joints are required for all depot access tracks.

2 For the insulated rail joints the Contractor shall propose a design suitable for main line track conditions and in accordance with the following requirements:

(a) All insulated rail joints shall be factory-made and welded to the track;

(b) The prefabricated rail joint shall be manufactured from rail which has been cut in its centre for the insulated rail joint, matching profile and rail type of a length >5 m;

(c) Insulated rail joints shall be of a glued design with fishplates of approximately 1000 mm length and six high strength bolts; and

(d) The rail head shall be suitably treated to reduce wear.

3 The Contractor shall submit a insulated rail joint design to the Engineer for SONO.

10.18 RAIL EXPANSION JOINTS

10.18.1 General

1 Rail Expansion Joints are required for the following cases but are not limited to:

(a) elevated superstructure temperature variation;

(b) braking and/or traction; or

(c) elevated superstructure end rotation from vertical axle loads including impact.

2 The Contractor shall perform Trackwork structure interaction analyses according to EN1991-2 to determine structural expansion joints for elevated structures where rail expansion joints are installed.

3 The required movement capacity of rail expansion joints shall be based on the following load cases:

(a) movement of superstructure from temperature;

(b) movement of superstructure from creep and shrinkage;

(c) movement from braking and/or traction; and

(d) movement of the rail ends from temperature.

4 If rail expansion joints are required, expansion joint types shall be used that are suitable to bridge the variable expansion joint gap of the bridge superstructure. The function shall follow the work principle of movable stock rails/fixed switch rails according EN 13232-8.

5 **Continuous welded rail (**CWR)

6 Closure welds shall be made while the rail temperature is within the Neutral Temperature Range.

7 The Neutral Rail Temperature Range shall be defined such that rail temperature variations after closure will not exceed ±45 K.

8 Unless the Contractor verifies other maximum and minimum rail temperatures, the following rail temperature limits shall be considered:

(a) maximum rail temperature in open air is +83°C;

(b) maximum rail temperature in tunnel is +50°C; and

(c) minimum rail temperature is +7°C.

9 The Contractor shall define the Neutral Rail Temperature Range and submit to the Engineer for SONO.

10.19 CABLE CROSSINGS AND RECESSES

10.19.1 General

1 The Contractor shall provide cable crossings in track slabs with pipes supplied by Interfacing Parties and reviewed by the Engineer.

2 The Contractor shall provide recesses in the slab concrete for other system components, as advised and accepted by Interfacing Parties and reviewed by the Engineer.

10.20 TRACKSIDE LUBRICATION

10.20.1 General

1 For curves with radius smaller than 300 m the Contractor shall propose suitable means to reduce wear and noise. The Contractor shall consider the permanent presence of fine sand in the local environment that might obstruct certain types of lubrication.

10.21 PERMANENT MARKERS

10.21.1 General

1 Permanent markers shall be manufactured from aluminium plates with a thickness of 3mm. The background colour shall be washable reflective yellow with the characters in matt black.

2 Permanent markers are required for:

(a) chainage markers at distances of 100 m;

(b) turnout markers at every switch toe; and

(c) fouling point markers at all locations where tracks converge.

3 The Contractor shall propose the details and positions for fixing permanent markers to the Engineer for SONO.

4 The Contractor shall provide holes in rails as required for cable connections.

10.22 GRATINGS

10.22.1 General

1 The Contractor shall design, deliver and install gratings including appropriate support structures for inspection chamber covers and for covers of space beside mass-spring system trackforms in tunnels.

2 Gratings and support structures shall be made of steel and galvanised.

3 As a minimum, gratings shall resist 5 kN/m^2 uniform distributed load or 1.0 kN point load at any positions.

4 Gratings shall be fixed to avoid unintended dislocation

5 Fixing devices shall be suitable for easy removal of gratings for maintenance purposes.

END OF PART