

**GOVERNMENT OF INDIA  
MINISTRY OF RAILWAYS  
(RAILWAY BOARD)**

2024/Proj./Kanpur/DBR/30/71

New Delhi, dated 16.02.2024

**Managing Director,**  
Uttar Pradesh Metro Rail Corporation Limited (UPMRCL)  
Administrative Building, Near Dr. Bhimrao Ambedkar  
Samajik Parivartan Sthal, Vipin Khand Gomti Nagar,  
Lucknow – 226010

**Sub: Approval of Design Basis Reports (DBRs) for Underground Bored Tunnels and Elevated Metro Stations of Mass Rapid Transit System for Kanpur Metro Rail Project of Uttar Pradesh Metro Rail Corporation Limited (UPMRCL).**

Ref: DBRs uploaded on RDSO's online portal by UPMRCL on 11.01.2024

The Design Basis Reports (DBRs) for Underground Bored Tunnels and Elevated Metro Stations of Mass Rapid Transit System for Kanpur Metro Rail Project of Uttar Pradesh Metro Rail Corporation Limited (UPMRCL) have been examined in consultation with RDSO and approval of Railway Board is hereby conveyed for the same.

Accordingly, approved copies of DBRs are enclosed.

**Encl:** As above

  
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2. **OSD/UT & Ex-Officio Joint Secretary**, Ministry of Housing & Urban Affairs (MoHUA), Nirman Bhavan, New Delhi-110001

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DEF No: UPMRC/DESIGN/DBR/UG/2023/01  
DATE: 01/11/2023



UTTAR PRADESH METRO RAIL CORPORATION LIMITED

# Design Basis Report (DBR) For Underground Bored Tunnels



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Director/UT/Civil/RDSO

(C. P. Singh)

Director (Works & Infrastructure)  
Uttar Pradesh Metro Rail Corporation Ltd.

16/02/2024  
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Design Basis Report for Underground Bored Tunnels

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## Design Basis Report for Underground Bored Tunnels

### 1. General

Where ever applicable provisions of approved model DBR of viaduct to be followed.

#### 1.1 Brief description of Project:

Uttar Pradesh Metro Rail Corporation Limited (UPMRCL) has planned to execute metro corridors at different locations of Uttar Pradesh. The Design Basis Report is applicable for Underground Bored Tunnels of different corridors of mass rapid transit system in Uttar Pradesh.

### 2. SCOPE OF DBR

The scope of this DBR is for Bored Tunnels by TBM. The design basis report hereto provides minimum standards that are to govern the design. The design basis report shall be read in conjunction with the Outline Construction Specifications where appropriate.

The design of the permanent and temporary supporting works shall comply with code of practice and standards at the time of submission of Tender Documents, Regulations made and requirements issued by the Indian Government and by related utility authorities shall be followed and specified.

### 3. MATERIALS

#### 3.1 Cement

- (1) Ordinary Portland cement (OPC) of 33 grade, 43 grade and 53 grade conforming to IS: 269, IS: 8112-1989 and IS: 12269-1987, respectively, shall be used.
- (2) Portland pozzolana cement (PPC) conforming to IS:1489 may also be used.
- (3) The Employer's Representative may give notice for the usage of sulphate - resistant Portland cement conforming to IS:12330 for structural elements exposed to soil.
- (4) For foundation and substructure, the Engineer may direct the OPC substitution by Blast Furnace Slag Cement confirming to IS:455.

#### 3.2 Concrete

- (1) The Density of concrete adopted shall be as below:
  - a. 24 kN/m<sup>3</sup> for prestressed concrete (IS.875 part-1 table-1 item 21 value rationalized).
  - b. 24 kN/m<sup>3</sup> for reinforced concrete with 2% or less reinforcement (IS: 875 part-1 table-1 item 22 value rationalized).
  - c. 25 kN/m<sup>3</sup> for reinforced concrete with above 2% reinforcement (IS: 875 part-1 table-1 item 22 value rationalized).

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d. 23 kN/m<sup>3</sup> for plain concrete (IS: 875 part-1 item 20).

- (2) Short term modulus of elasticity 'E<sub>c</sub>' & Modular Ratio 'm' shall be as per clause no. 6.2.3.1 & B-1.3 (d) of IS: 456 respectively.
- (3) Minimum grade of concrete shall be M35.
- (4) Thermal Expansion Coefficient:  $1.17 \times 10^{-5}/^{\circ}\text{C}$  (Cl 2.6.2 IRS Bridge Rules).
- (5) Poisson's Ratio: 0.15 for all concretes.
- (6) Minimum cement content and Maximum Water-Cement ratio as per Table 5 of IS: 456.
- (7) Strength of concrete is the specified characteristic compressive strength of 150 mm cube at 28 days.
- (8) Minimum concrete cover as per IS: 456.

### 3.3 Reinforcement

Only thermo-mechanically treated reinforcement bars conforming to IS:1786 shall be adopted. (For seismic zone III, IV & V with minimum total elongation of 14.5%).

### 3.4 Structural Steel: General

- (1) Design of Structural steelwork shall comply with IS: 800.
- (2) Two types of structural steel to be used and shall comply with the following standards:
  - a) IS: 4923 "Hollow steel sections for structural use with Y<sub>st</sub> 310".
  - b) IS: 2062 "Steel for General Structural Purposes (E250-B0, E350-B0)".
- (3) Hollow steel sections shall be square (SHS) or rectangular (RHS). Other tradition rolled sections like plates, angles, channels, joists can also be used where required.
- (4) The connection with concrete shall be effected by internally threaded bolt sleeves (hot dipped galvanized @ 300 grams per square metres) manufactured from IS:2062 Grade B mild steel. The sleeve shall receive hexagon-head bolt M20 Class 8.8 as per IS:1364 (Part 1) with galvanized spring washer.
- (5) The connections within the steel structure shall be designed as direct welded members with or without gusset plates. The minimum thickness of metal for SHS/RHS sections for main chord members as well as bracings shall be 4 millimetres as applicable for steel tubes in cl. 6.3 of IS: 806.

#### 3.4.1 Material Properties

Material properties shall be as follows:

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Steel Type	Young's Modulus	Tensile Strength	Yield Strength	Density	Poisson's Ratio	Thermal Expansion Coefficient
For Hollow Steel sections (conforming to IS: 4923)	2,00,000 MPa	450 MPa	310 MPa	78.5 kN/m <sup>3</sup>	0.30	1.2x10 <sup>-5</sup> per °C
Structural Steel (Conforming to IS: 2062)		410 MPa	250Mpa (for t<20mm), 240Mpa (for 20mm<t<40mm), 230MPa (for t> 40mm)			

### 4. TUNNEL PROFILE, CONSTRUCTION METHODS

The bored tunnels comprise twin single-track tunnels. The spacing between the tunnels shall be based on the soil strata and determined by numerical analysis. The minimum internal diameter for bored tunnel shall meet all services and SOD (Schedule of Dimensions) requirements. Bored tunnels in rock and soil will be excavated mainly using tunnel boring machines, other methods if required based on geological and hydrological condition to be decided. Initial tunnel support will generally include precast concrete segments, shotcrete/wire mesh, rock bolts, lattice girders, steel sets, or forepoles wherever necessary.

### 5. DESIGN LIFE/ DESIGN SPECIFICATIONS/REQUIREMENTS/PRINCIPLES

#### 5.1 Design Life

Design life is to be kept minimum 100 years.

#### 5.2 Tunnel Design

- (1) The design of the bored tunnel shall be fully compatible with the construction methodology and shall be carried out using suitable software.
- (2) The design shall also take into account all expected loads prescribed in item no.6.
- (3) The design shall take into account all additional loads, stresses and strains imposed by or on adjacent Existing Building Structures (EBS) and assumed distortions and loads by or on the proposed bored tunnels.
- (4) Where bored tunnels are adjacent to or beneath EBS, the design shall demonstrate that these EBS shall not be subjected to unacceptable movement, distortion or loss of support which endangers the stability of the EBS and that any resulting movements and distortions will be within

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prescribed limits determined by the authority for that EBS, the Employer's Representative, or the Owner.

(5) The Designer shall ensure that ground movements and distortions, and changes to the loads and piezometric pressures which may affect adjacent EBS either at surface or underground, are within the allowable tolerances for each of those EBS

(6) The design shall consider and minimise the short- and long-term influence of the bored tunnels on the groundwater regime, and similarly the influence of the groundwater on the bored tunnels.

(7) During tunnelling, Designer to constantly review the ground conditions based on envisaged and actual condition encountered, to allow excavation to be carried out in the safest and most efficient manner. This review shall be fully integrated into the construction risk control and should typically include:

- a) Probing ahead of and around the bored tunnel face in rock conditions.
- b) Interpretation of fresh data and correlation with previous information.
- c) Prediction of ground conditions likely to be encountered.
- d) Investigation on the surface for the presence of water wells / bore wells for domestic use in residential areas that intersect the alignment.

(8) Ground Information from all construction activities shall be collated and interpreted.

### 5.3 Tunnel Lining segment

(1) The design of the segments shall be adequate for all stresses induced during stacking, lifting, transport, erection jacking and impact, including in-service stress & impact.

(2) The design shall consider in-situ ground stresses and shall provide evidence and/or measurements in support of the parameters adopted in the design as part of the calculations. The ground load on the tunnel shall be based on the actual height of overburden above the tunnel lining and the coefficient of earth pressure at rest of the soil strata surrounding the tunnel.

(3) The design of the bored tunnel linings shall take into account the proximity of the bored tunnels one to another, the sequence and timing of construction and the proximity of adjacent EBS


(4) The design shall also consider the relative rates of loading/unloading due to TBM jacking force in both the lateral and vertical directions, and the resultant induced tunnel deformations whether temporary or permanent.

(5) The segment has to be designed for 4hr fire rating as per IS:456.

(6) The design method shall take into account the interaction between the lining and the ground, the deflection of the lining and the redistribution of the loading dependent upon the relative flexibility of the lining, the variability and compressibility of the ground.

(7) The designer shall consider and conform to all durability aspects of the permanent bored tunnel lining including permeability/transmissivity and electrical resistivity.

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- (8) The design shall take into account the proximity of the lining to the tunnel face at the time of installation and the potential for additional ground loads as the face advances
- (9) The design shall allow for the expected variation in ground conditions and the size, proximity, timing and method of construction of adjacent excavations. The lining flexibility shall make due allowance for likely deflection of the lining during construction and operation.
- (10) Where a permanent or secondary lining is to be installed inside a temporary or primary lining, the ground loads used in permanent lining design shall consider all loads as described in the Contract and any additional ground loads that may arise from time-dependent ground strains,
- (11) The stiffness of the permanent lining should be such that the deflections are within permissible limits as per BS: 8110-part1 and IS: 456
- (12) The thickness of segments shall suit the method of construction and shall not be so large that part shoving of the shield becomes a general necessity.
- (13) The thickness of the segments shall be consistent with the capacity of the circle bolting arrangements to withstand the shear forces induced in linings built with staggered joints and for the planned reinforcement and required concrete cover.
- (14) A groove for a single elastomeric gasket shall be provided on all joint faces of each segment and key in accordance with the gasket dimensions. The elastomeric gasket shall be suited to the conditions under which it is required to operate for the design life. The gasket grooves shall allow for accurate mating of the gaskets of adjacent segments.
- (15) A groove for post-construction grouting/caulking as necessary shall be provided on the intrados for each segment joint.
- (16) The lengths of segments shall be chosen with regard to bending stresses during handling, storage and erection and the long term stresses due to ground loading and the resultant deflections.
- (17) The design of linings shall include tapered rings in order to negotiate the alignment curvature and to correct for line and level during construction with the minimum use of circumferential joint packers consistent with attaining the required degree of water-tightness of the bored tunnels in accordance with the contract.
- (18) The design for segment lining shall address aspects including the following, as appropriate
- a) Ring configurations,
  - b) Segment size and form,
  - c) Fixing details including for:
    - ring to ring fixings;
    - segment to segment fixings;
    - fixings for all equipment to be installed handling,
    - stacking and installation of segments;
    - holes, recesses and fixtures for other system components.



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- d) tolerances in production and installation of segments shall be accounted in the design.
- e) Installation of Other components, such as:
  - grout hole valves;
  - gaskets;
  - bedding and packing materials
- f) Cavity grout, between lining and ground.
- g) Instrumentation and monitoring to demonstrate performance of the installed linings.
- h) Short-term (during construction) intermediate (immediately after construction) and long-term (full design life) loading conditions.
- i) Stresses induced by grouting and ground pre-treatment, where applicable.

### 6. DESIGN LOADS AND LOADING CONDITIONS

#### 6.1 Loads

Linings shall be designed to withstand all environmental loadings, distortions and other effects without detriment. In general, bored tunnel linings shall be designed to fulfil the following requirements and to resist the following loads:

- a) Dead Load
- b) Superimposed surface loads from traffic, existing structures over and adjacent to the bored tunnel, and any specified future loads
- c) Appropriate ground loads, water pressure, and seismic loads
- d) Railway loads where appropriate
- e) Long- and short-term ground yield or squeeze
- f) Unequal grouting pressures.
- g) Adjacent bored tunneling or excavation
- h) Long-or short-term loads induced by construction
- i) Temperature and shrinkage
- j) Handling loads, including impact, especially in the case of unreinforced segments
- k) Jacking forces, where appropriate.
- l) Accidental loading such as fire and derailment

#### 6.2 Loading Conditions

a) Dead load comprises the self-weight of the basic structure and secondary elements supported and the weight of earth cover. The depth of cover shall be the actual depth or minimum one diameter of tunnel. The depth of cover shall be measured from the ground surface to the tunnel crown.

b) Traffic surcharge shall be as per the loading of IRC/IRS as applicable.

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- c) Loads from existing or known future adjacent structures above or within the area of influence, which will remain in place above the bored tunnels, or any specified future loading. The applicable foundation load and its influence shall be computed based on the type and use, and the foundation type which supports that structure.
- d) Additional support, ground treatment or additional lining thickening shall be provided unless it can be shown that adequate provision already exists. Any structure surrounding tunnel should be supported by grouting and shotcreting techniques, should not be supported from tunnel lining.
- e) Where provision for a specific future structure is not made a minimum uniformly distributed surcharge of 60 kilo-Pascal at the design finished ground level shall be assumed.
- f) Hydrostatic pressure, ignoring pore pressure relief arising from any seepage into the tunnel. Water at ground level to be considered for design.
- g) Loads and load changes due to known construction activity in the vicinity of the bored tunnel, such as the excavation and the formation of underpasses, basements, pile groups, bridges, diaphragm walls and cable ground anchors.
- h) The grouting pressure will not exceed the hydrostatic pressure by more than 1 bar, however the actual pressure will be decided by in-charge Chief Engineer based on the geological conditions.
- i) Structural requirements for resisting buckling is to be checked since tunnel is being designed as compression member.
- j) Additional loads / stresses in adjacent rings due to openings at cross passages locations to be considered.

### 6.3 Floatation

For floatation check, the water table is assumed to coincide with the ground level. Where the bored tunnels are relatively shallow they shall be checked for the possibility of floatation due to differential water pressure at representative typical locations. Uplift due to displaced water to be considered in the design. The overall factor of safe against floatation shall not be less than 1.1 for any of the condition.

### 6.4 Crack Width

All structural concrete elements shall be designed to prevent excessive cracking due to flexure, early & long term age thermal shrinkage. Flexural crack width shall be checked in accordance with Appendix F of IS: 456. The limits specified in cl.35.3.2 of IS: 456 has to be followed.

### 6.5 Load Cases, Load Factors and Combinations

All analysis shall clearly show the designs achieve the design factors of safety.



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### 6.5.1 Load Cases

The following load cases will be considered at each design section:

- Load case-1: Ground water table at the ground surface with uniform surcharge of 60 KN/m<sup>2</sup>.
- Load case-2: Ground water table at the ground surface with no surcharge.
- Load case-3: Ground water table at 3m below existing ground water level with uniform surcharge of 60 KN/m<sup>2</sup>.
- Load case-4: Ground water table at 3m below existing ground water level with no surcharge.
- Load case-5: Ground water table at extreme water level with no surcharge.

### 6.5.2 Load factors and Combinations

The design forces will be derived based on the following load factors Based on IS: 456-2000, BS 8110-part 1-1997

Load Case	Dead Load	Hydrostatic Pressure	Earth Pressure	Surcharge Load
Case 1	1.4	1.4	1.4	1.4/1.5/1.6#
Case 2	1.4	1.4	1.4	
Case 3	1.4	1.4	1.4	1.4/1.5/1.6#
Case 4	1.4	1.4	1.4	
Case 5	1.4	1.4	1.4	
Serviceability	1	1	1	1

# - If Surcharge load is taken as per British standards then load factor should be 1.6

- If Surcharge load is taken as per Indian standards then load factor should be 1.5

- For Special cases of conservative surcharge load (such as future flyover construction etc.) load factor 1.4 can be adopted.

\*Load factor for extreme water table (flooding case) can be reduced to 1.0.

\*\*Water level for serviceability is to be at ground level

## 7. GENERAL CONSTRUCTION METHODS

(1) Initial ground support for the bored tunnels is expected to comprise ground pre-treatment (where necessary) and/or precast concrete segments.

(2) Methods for excavation, spoil removal, ground treatment, installation of initial support and the permanent lining construction to be prepared.

(3) Excavation shall be carried out in a uniform and controlled manner, over-cutting shall be kept to a minimum.

(4) Appropriate methods and necessary steps to be taken to control flows and movement into, and to maintain the stability of the excavation.

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(5) Instrumentation and monitoring arrangements for ground and existing building structures (EBS) movement and distortion and changes to the groundwater table(s) and the trigger (Alert, Action & Alarm) levels for each and every identified EBS to be performed. Designer has to specify the required instrumentation and monitoring arrangement to maintain the safety of the EBS.

**7.1 Tunnel Lining-General**

**7.1.1 Tunnel Lining - Temporary Support**

(1) Steel sets and lattice arch girders shall be rolled to suit the dimensional requirements of the designed opening. The Contractor shall provide dimensional details of the steel sets or lattice arches girders and lagging which include all calculations regarding imposed loads before and after any ground pretreatment.

(2) Splices shall be steel rods or tubes of outside diameter not less than 25 millimetres.

(3) Pipe piles shall be steel tubes of outside diameter not less than 100 millimetres.

(4) Rock dowels shall be untensioned steel bars threaded at one end and provided with a face plate, shim plates and a conical seated washer and nut, or split or deformed steel tubes, or glass fibre reinforced resin rods.

(5) Rock bolts shall be tensioned bar manufactured out as one of the following types - solid steel bar, slit or deformed steel tube, glass fibre reinforced resin rods

(6) Alternative materials shall be subject to the notice of the Employer's Representative.

**7.1.2 Tunnel Lining - Permanent Support**

(1) The permanent bored tunnel support or lining shall generally comprise segmental spheroidal graphite iron (SGI) or precast concrete (plain or reinforced) rings that are held securely in place and the same will remain so for all known possible future conditions.

(2) Exceptions to these permanent linings may be at cross-passages (links between tunnels), enlargements of the bored tunnel and at the junction between cut-and-cover and bored tunnel sections. In such locations cast-in-place linings shall be used, or alternative types of permanent lining may be proposed subject to the notice of The Employer's Representative.

(3) The reinforcement for segmental concrete lining shall be detailed such that there is no electrical continuity across the circle joints. To prevent the stray current effects and to inhibit the corrosion, suitable property enhancers shall be added in to concrete. Such concrete shall be tested in accordance with ASTM C 1202 and DIN 1048. SGI lining segments and all concrete reinforcement shall be bonded to mitigate stray currents. The bonding shall be part of the corrosion control system designed and installed by the Contractor to the notice of the Employer's Representative. The corrosion control system shall be tested and proven to the satisfaction of the Designer that the corrosion control system functions as designed in all locations

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### 7.1.3 Gasket Grooves

Gasket grooves shall be provided around all joint faces of each segment and key in accordance with the dimensions as approved by the engineer in charge. The design shall incorporate sealing gaskets in the segmental design,

### 7.1.4 Grout holes

Grout holes shall be provided in segment as per design excluding the key.

### 7.1.5 Waterproofing

Suitable waterproofing materials and methods shall be used to meet the requirements services.

### 7.1.6 Cavity grouting

General purpose cement grout with suitable admixture shall be mixed in accordance with the proposed design mix and purpose of use. Grout shall be used within one hour of mixing.

## 7.2 Underpinning of Existing Structures

Where the construction of tunnels or other underground works would necessitate removal of existing support or foundations to existing structures, the Designer shall carry out investigations of the extent of the existing works, their design and loading conditions and propose a suitable supporting/underpinning arrangement where ever is applicable.

## 8. CROSS-PASSAGES

(1) Where tunnelling is carried out not using TBM (i.e., by hand or face excavator) temporary support using pipe piles, spiles, structural-steel sets, lattice-arch girders, base-plates, ties and connections and lagging sprayed concrete (shotcrete) or cast-in-place concrete all of which comply with the relevant standards may be used together with appropriate ground pre-treatment as deemed necessary for the expected ground conditions

(2) Passenger emergency evacuation design for cross-passages between running tunnels which are constructed by either cut-and-cover or bored method shall generally be in accordance with the requirements of NBC 2016 or latest for fixing guide-way transit and passenger Rail system as follows.

a) In single-track tunnels, the distance from the end of a station to a tunnel shaft to the surface shall not exceed 762 metres. Cross-passages shall be permitted to be used in lieu of emergency exit stairways to the surface where train ways are located within separate structures.

b) The distance between cross passages in the tunnel shall be provided as per NBC 2016 or latest.

c) Track cross-overs shall not be considered as cross-passages.

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- (3) The openings into the running tunnels shall have a width of 1.2 metres and a height of 2.1 metres. Throughout the cross-passage the minimum headroom of 2.1 metres shall be maintained over a width of 1.2m.
- (4) The cross-passage floor screed shall be laid to fall and drain into the running tunnel drainage system. Floor level shall correspond with the level of the bored tunnel escape route.
- (5) A concrete bulkhead fitted with steel door and frame shall be constructed to isolate the cross-passage from each running tunnel. This door shall be self-latching, have a fire resistance of 2 hours minimum and shall be capable of withstand the maximum differential pressures on either side created by the passage of trains. The maximum force to open the door shall be as per NBC 2016 or latest.
- (6) The cross-passage permanent lining shall comprise concrete lining designed generally in accordance with the requirements of these documents with the following exception that the maximum allowable deflection on radius shall be as per IS:456 clause 23.2(b).
- (7) The junctions with the running bored tunnels shall be steel-framed and encased with concrete. The junctions shall be designed to fully support the running tunnel linings at the openings together with the ground and groundwater loads on the junction itself.
- (8) The cross-passages and junctions shall comply with same water-tightness criteria as the bored tunnels.
- (9) Where openings for cross-passages and the like are to be formed in running tunnels with segmental concrete or SGI linings, temporary internal supports to the running tunnel lining shall be provided. These supports shall adequately restrain the ground and lining such that on completion of the openings and removal of the temporary supports the total deflection of the linings in either the opening, junction or running tunnel and water ingress do not exceed the limits.

### 9. TUNNEL WALKWAYS

- Walk ways to be designed as per approved SOD.
- The Escape Walkways shall provide continuous access from the trains to the cross-passages and/or station platforms.

### 10. TUNNEL BORING MACHINES

The TBM shall be robust with adequate safety margins for the anticipated duty designed and manufactured to comply with all safety standards. The TBM procured must be capable of efficient excavation and installation of support within the expected site and ground conditions. This includes soil, rock, soil/rock mixture and existing EBS (notably wells) all mainly below the groundwater table.

General design requirement of TBM:

- TBM design shall ensure that the cutter-head can be retracted back from the unexcavated ground to minimise the risk of the TBM jamming and to facilitate maintenance.

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## Design Basis Report for Underground Bored Tunnels

- b. TBM design shall make adequate provision for the safety of the workmen and the application of safe methods of tunnelling
- c. TBM shall be designed for and equipped with a supplemental ground stabilisation system. This system shall comprise regularly spaced grout ports built into the shield for drilling into and grouting the ground ahead of the tunnel face. The location and number of ports shall be adequate for implementation of face stabilisation measures needed for access to the face in all ground conditions. All ports shall be readily accessible and fitted with valves.
- d. TBM shall be designed to enable the void between the segment lining and the ground (tunnel extrados) to be grouted continuously from the shield as the shield is propelled forward by synchronised operation. TBM design shall allow control of the grouting volume, pressure and pipes to be cleaned in the event of a blockage. Grout pipes shall be integral within the thickness of the TBM tailskin. A minimum of four (4) separate grout pipes shall be provided. External grout pipes will not be permitted.
- e. The TBM shall be designed to maintain a pressure on the excavated ground at all times. This pressure shall at-least balance the in-place soil and hydraulic pressures making up the total overburden pressure and shall be capable of varying the face pressure as the overburden pressure changes. The design shall also take into account the soil type, density, gradation, strength and abrasion.

### 11. DRAINAGE ARRANGEMENT IN RUNNING TUNNELS

- (1) The Designer shall coordinate with the adjacent station plumbing design before finalising the design for drainage arrangement and sump location.
- (2) The reserve capacity of a groundwater seepage sump shall be calculated on the basis of the area of bored tunnel lining applicable to the sump in accordance with the following formula:

$$V_R = A * v * t * F.O.S * 10^{-3}$$

Where,

$V_R$	=	Volume of reserve, $m^3$
$A$	=	Bored tunnel lining area, $m^2$
$v$	=	Maximum leakage rate, $l/m^2/day$
$t$	=	Maximum response time, (day)
F.O.S	=	Factor of Safety

- (3) For running tunnel lows, point sumps the response time "t" shall be 24 hours and the factor of safety shall be 1.5.
- (4) The sump design shall include outlets for the longitudinal drain pipe and discharge mains, pumps of suitable capacity and power connection. Sumps shall be fitted with steel covers and provided with step irons or access ladder. Permanent discharge mains shall be installed as well as embedment of conduits for permanent electric power cables to the pumps.

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## Design Basis Report for Underground Bored Tunnels

(5) The linings of the sumps shall be designed for the appropriate ground and groundwater loads.

### 12. LIST OF DESIGN CODES AND STANDARDS

Subject to the requirements of this specification and other Control documents, all design work shall comply with the appropriate current standards issued by the Bureau of Indian Standards (BIS), or if such a standard does not exist, then the appropriate current standard issued by the British Standard Institute (BSI). If appropriate standard from BIS and BSI does not exist, then subject to approval by engineer, an appropriate current standard from a reputable institution may be used. The designer shall follow updated codes with latest correction slips.

(Note: the years of the codes mentioned below are notional, hence each time the designer shall adopt latest code with the latest correction slip)

The Order Preferences of codes will be as follows:-

- i. BIS
- ii. BSI or Euro Code
- iii. IRC
- iv. IRS
- v. AASHTO

### 13. UNDERGROUND STATION BUILDING

For design of Underground station building load factors, and other provisions in IS: 456 shall be adopted as in case of Elevated stations.

### 14. MECHANICAL & ELECTRICAL SYSTEMS

The items like Fire Detection System, Fire Suppression System, Fire Alarm PA System, Emergency Lighting, Power Supply System, Tunnel Ventilation etc. should be designed and commissioned as per best International Standards like NFPA130, NFPA101 etc. and the best international practices. These sub-systems should be got approved from the concerned STATE Authorities.



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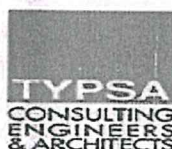
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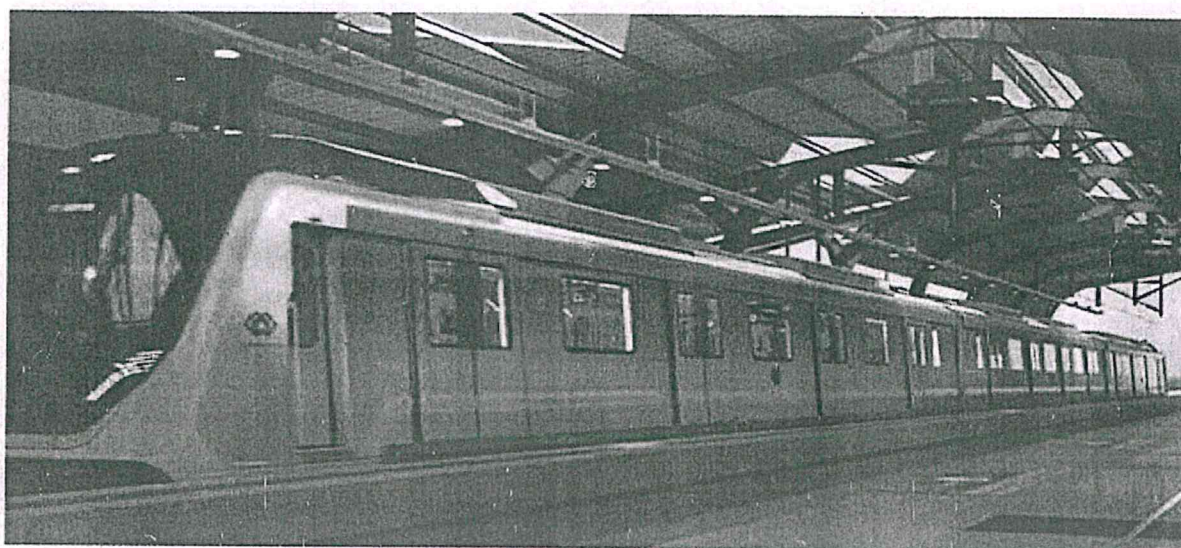
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## DESIGN BASIS REPORT FOR ELEVATED METRO STATIONS FOR UTTAR PRADESH METRO RAIL CORPORATION



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## DESIGN BASIS REPORT FOR ELEVATED METRO STATIONS

### IDENTIFICATION TABLE

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	Approved	Atanu Dhara	CSE	27-10-2023	

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## 1. Introduction

### 1.1. Brief Description of the Project

Uttar Pradesh Metro Rail Corporation Limited (UPMRCL) has planned to execute Metro Corridor's at different locations of Uttar Pradesh.

This Design Basis Report is applicable for Elevated Stations of different Corridors of mass rapid transit system in Uttar Pradesh executed by UPMRCL.

### 1.2. Scope

The objective of this Design Basis Document is to establish a common procedure for the design of "Elevated Stations for Metro Railways at different locations under UPMRCL. This is meant to serve as guide to the designer but compliance with the rules therein does not relieve them in any way of their responsibility for the stability and soundness of the structure designed. The design of Elevated Stations requires an extensive and thorough knowledge and entrusted to only to specially qualified engineers with adequate practical experience in structure designs.

The DBR is only for structural design of Elevated Stations. Extended platform portion which is generally on single column or portal type structure shall be designed as part of viaduct.

The structural elements connected to the member on which metro live loads are supported may also be designed with taking loads applicable as specified in "Model Design Basis Report (DBR) for Viaduct of Metro System".

LWR forces shall be specified by Metro, if RSI analysis is not practicable. Load combination as per "Model Design Basis Report (DBR) for Viaduct of Metro System" shall also be considered. Other structural elements such as secondary beams, stub columns etc., may be designed as per IS 456-2000

Structures, where Metro Live loads are not applicable, the design of Plain and Reinforced Concrete structures will generally be governed by IS:456-2000, prestressed concrete structures shall generally be governed by IS:1343, Steel structures design shall generally be governed by IS:800. Seismic design shall be governed by IS:1893.

### 1.3 Units

The main units used for design will be: [t], [m], [mm], [kN], [Kg/m<sup>2</sup>], [MPa], [°C], [rad].

## 2. Design specification for Station building

### 2.1. Materials

#### 2.1.1. Cement

For plain and reinforced concrete structures cement shall be used as per clause 5.1 of IS:456 and in case of pre-stressed concrete structures as per clause 5.1 of IS:1343.

#### 2.1.2. Concrete

As per clause 6, 7, 8, 9 and 10 of IS:456 in case of Plain and Reinforced Concrete structures and Clause 6, 7, 8, 9 and 10 of IS:1343 for pre-stressed concrete structures.

Short term modulus of elasticity ( $E_c$ ) shall be taken as per cl. 6.2.3.1 of IS:456 for Plain and Reinforced Concrete structures and IS:1343 for pre-stressed concrete structures.

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The modular ratio for concrete grades shall be taken as per Annex B of IS:456.

The Density of Concrete shall be as per IS: 456

### 2.1.3. Prestressing Steel for Tendons

As per clause 5.6.1 of IS:1343.

#### 2.1.3.1. Young's Modulus

As per prestressing steel used in accordance with Para 2.1.3 above.

#### 2.1.3.2. Prestressing Units

As per clause 13 of IS:1343.

#### 2.1.3.3. Maximum Initial Prestress

As per clause 19.5.1 of IS:1343.

#### 2.1.3.4. Density

Weight of strands shall be as per relevant clauses of IS codes as per material being used as indicated in para 2.1.3 above.

#### 2.1.3.5. Sheathing

As per clause 12.2 of IS:1343.

### 2.1.4. Structural Steel

Structural steel used shall confirm to

- a) Hollow steel section as per IS:4923-1997
- b) Steel for General Structural Purposes as per IS: 2062.
- c) Steel tubes for structural purpose shall be as per IS: 1161.

Note: (i) Grade of steel to be used, shall not be less than minimum E-250 grade as applicable, when structure is taking moving loads and relevant code as indicated in note (ii) and (iii) below.

(ii) Design of steel structure will be governed by IRS Steel Bridge Code in case structure is taking moving loads of Metro, otherwise will be governed by IS:800. In case of composite (steel-concrete) structures it will be governed by IS:11384 & IS:3935.

(iii) Fabrication shall be done in accordance with IRS B1 (Fabrication Code) in case structure is taking moving loads of Metro, otherwise shall be done as per IS:800.

### 2.1.5. Reinforcement

As per clause 5.6 of IS:456 for Plain and Reinforced concrete structures and as per clause 5.6.2 of IS:1343 for pre-stressed concrete structures.

Note: For Seismic zone III, IV & V HYSD steel bars having minimum elongation of 14.5 percent and conforming to requirements of IS:1786 shall be used.

#### 2.1.5.1. Reinforcement Detailing

All reinforcement shall be detailed in accordance with clause 12 and 26 of IS:456 for Plain and Reinforced concrete structures, as per clause 12.3 and 19.6.3 of IS:1343 for prestressed concrete structures. Ductile detailing of seismic resisting RC elements shall comply with ductile requirements of IS:13920.

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Design Basis Report for Elevated Stations (GCS-REP-JVTI-STE-0000P-5022)

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**2.2. Durability**

Durability of Concrete shall be as per clause 8.0 of IS: 456 for Plain and Reinforced Concrete structures, as per clause 8.0 of IS:1343 for Prestressed Concrete structures and Section 15 of IS:800 for Steel Structures.

**2.2.1. Concrete Grades**

The minimum grade of concrete for all structural elements including piles shall be as per IS-456. However minimum grade shall not be less than M30.

Minimum grade of concrete for blinding layers and leveling courses shall be as per IS-456. However minimum grade shall not be less than M15.

Concrete characteristics as detailed above might need to be improved for foundation, if the structure environment is found to be particularly aggressive (soil or water). This shall be assessed on case-by-case basis.

**2.2.2. Cover to Reinforcement**

As per clause 26.4 of IS:456 for Plain and Reinforced Concrete Structures and clause 12.3.2 of IS:1343 for prestressed concrete structures. Cover to prestressing steel shall be in accordance with clause 12.1.6 of IS:1343.

**2.2.3. Fire Resistance period**

All the structural elements in the station building shall be designed for a minimum fire resistance period of 2 hours. The minimum element thicknesses for this fire resistance shall be as per clause 21 of IS:456 for Concrete structures and as per Section 16 of IS:800 for Steel structures.

**2.2.4. Crack Width Check**

All structural concrete elements shall be designed to prevent excessive cracking due to flexure, early age thermal and shrinkage. Flexural crack width shall be checked in accordance with clause 35.3.2 and 43 of IS:456 for Plain and Reinforced Concrete Structures and clause 20.3.2 and 24.2 of IS:1343 for Prestressed Concrete structures.

**2.3. Clearances**

(i) Clearance for Road Traffic: As -per relevant IRC specifications and Road Authority requirements.

5.50m at 0.250m (0.225m (width of the 1m-high Jersey-type crash barrier) + 0.025m (clearance between crash barrier and pier shaft) from pier shaft outer line.

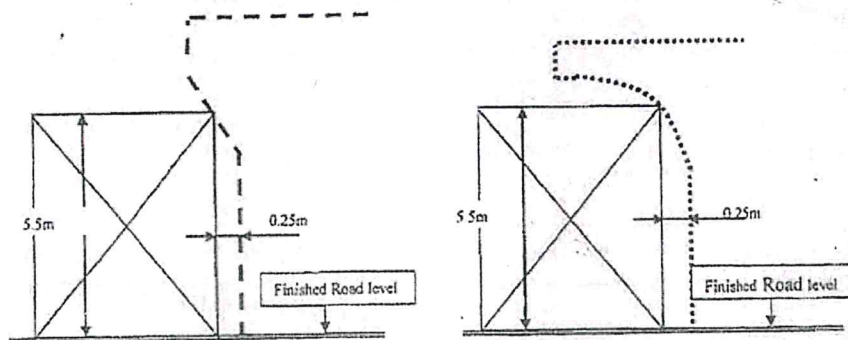


Figure 1. Clearance for Road Traffic

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Design Basis Report for Elevated Stations (GCS-REP-JVTI-STE-00003-201)

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- (ii) Clearance for Railway Traffic: Indian Railway Schedule of Dimensions (SOD) shall be applicable
- (iii) Clearances for Metro Traffic: As per approved SOD of specific Metro system.
- (iv) For utility services- The clearances to utilities, drainage etc. shall be as mandated by the utility owner/ department.
- (v) Clearances for Rolling Stock : Vertical & Horizontal clearances for rolling stock are calculated/kept as per Latest SOD for Standard Gauge

## 2.4. Design Loads

Elementary loads to be considered for design are:

Dead Loads	DL
Super Imposed Loads	SIDL
Imposed (Crowd Live) Loads	LL
Earthquake Loads	EQ
Wind Loads	WL
Collision/Impact Loads/Derailment Loads	CL*
Construction & Erection Loads	EL
Temperature Loads	OT
Shrinkage	S
Creep	C
Earth & water Pressure	EP
Surcharge Loads (Traffic, building etc.)	SR
Pre-stress Force	PR
Long Welded Rail Force	LWR
Differential Settlement	DS

\*Load as applicable shall be taken.

### 2.4.1. Dead Loads

Dead load shall be based on the actual cross section area and unit weights of materials and shall include the weight of the materials that are structural components of Elevated Station and permanent in nature.

### 2.4.2. Superimposed Dead Loads (SIDL)

Superimposed dead loads include weights of materials on the track of structure that are not structural elements but are permanent.

*Note: The SIDL can be of two types: Fixed or non-variable, and variable. In case Metro certifies that a portion of SIDL is of fixed or non-variable type and is not likely to vary significantly during the life of the structure and a special clause for ensuring the same is incorporated in the Metro's maintenance manual, the load factors applicable for dead load may be considered for this component of SIDL.*

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The minimum distributed and concentrated loads shall be in accordance to IS:875, wherever available for remaining Metro railway shall specify the loads.

- Loads due to floor finish, light partition wall, additional fill in toilets, and any other architectural related load shall be considered as per architectural requirement.
- Suspension load will be considered as load of false ceiling, plumbing & electrical equipment, Escalator Pits etc as per requirements. This load is applicable wherever necessary.
- Lift and Escalator support shall be designed as per manufacturer's details.
- Loads due to Platform screen door (PSD) and solar panels shall be consider as per actual.
- SIDL for UPS room, ASS/TSS room and other technical shall be as per specific discipline requirement.

#### 2.4.3. Imposed (Crowd Live) Load

Imposed loads on station buildings are those arising from occupancy and the values includes normal use by persons, furniture and moveable objects vehicles, rare events such as concentrations of people and furniture, or the moving or stacking of objects during times of re-organisation and refurbishment, this shall be as per clause 19.3 of IS 456.

#### 2.4.4 Earthquake Loads

Earthquake design shall follow the seismic requirements of IS:1893 (Part 1-2016). The provision as per Design Basis Report for Viaduct of Metro System shall be followed where structures are taking moving loads of metro.

Ductile detailing shall be as per IS13920 & IS4326.

##### 2.4.4.1 Drift Limitation

The storey drift in the building shall satisfy the drift limitation specified in cl. 7.11.1 in IS:1893.

##### 2.4.4.2 Seismic Detailing

- For reinforced concrete structures as per IS:13920.
- For other structures as per IS:4326.

#### 2.4.5 Wind Loads

The wind load shall be calculated as per IS:875 part 3.

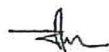
#### 2.4.6. Collision/Impact Loads/Derailment Loads

- For road traffic as per IRC 6.
- For metro as per IRS Bridge Rule.

#### 2.4.7. Construction and erection loads

The weight of all temporary and permanent materials together with all other forces and effects which can operate on any part of structure during erection shall be considered. Allowances shall be made in the permanent design for any locked in stresses caused in any member during erection.

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**2.4.8. Temperature**

As per clause 19.5 of IS: 456. Temperature gradient shall be considered as per Clause 215 of IRC-6, if applicable.

**2.4.9. Shrinkage**

The shrinkage strains shall be evaluated as per clause 6.2.4 of IS 456 for Plain and Reinforced Concrete Structures and clause 6.2.4 of IS:1343 for prestressed concrete structures.

For structure supporting Metro loading the effects of Shrinkage as per Cl. 5.2.3 of IRS- CBC shall be considered.

**2.4.10. Creep**

The creep strains shall be evaluated as per clause 6.2.5 of IS:456 for plain and Reinforced Concrete Structures and clause 6.2.5 of IS:1343 for prestressed concrete structures.

For structure supporting Metro loading the effects of creep as per Cl. 5.2.4 of IRS- CBC shall be considered.

**2.4.11. Earth & Water Pressure**

In the design of structures or parts of structures below ground level, such as retaining walls and underground pump room/water tank etc., the pressure exerted by soil or water or both shall be duly accounted for. When a portion or whole of the soil is below the free water surface, the lateral earth pressure shall be evaluated for weight of soil diminished by buoyancy and the full hydrostatic pressure. (As per IS:875 Part 5).

All, foundation slabs/footings subjected to water pressure shall be designed to resist a uniformly distributed uplift equal to the full hydrostatic pressure. Checking of overturning of foundation under submerged condition shall be done considering buoyant weight of foundation.

If any of the structure supporting Metro loading is subjected to earth pressure, the loads and effects shall be calculated in accordance with Cl. 5.7 of IRS-Substructure Code.

**2.4.12. Surcharge Load**

In the design of structures or parts of structures below ground level, such as retaining walls and underground pump room/water tank etc. the pressure exerted by surcharge from stationary or moving load, shall be duly accounted for.

**2.4.13. Pre-stressing Force (PR)**

The pre-stressing force should be as per IS-1343.

**2.4.14. Long welded Rail Force**

A Rail Structure Interaction [RSI] analysis is required because the continuously welded running rails are continuous over the deck expansion joints. The interaction occurs because the rails are directly connected to the decks by fastening system.

- 1) Rail structure interaction studies shall be done as per provisions of UIC 774-3R with the following parameters specified in consultation with track engineers.
  - I. Track resistance in loaded and unloaded conditions.
  - II. Maximum additional stresses in rail in tension as well as compression on account of rail-structure interaction.
  - III. Maximum vertical deflection of the girder at ends.
- 2) Software and general methodology to be used for carrying out Rail-Structure Interaction analysis must be validated before adopting the same.
- 3) Representative stretches must be chosen for carrying out Rail-Structure Interaction.

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- 4) Check must be performed for break in rail continuity due to unusual conditions fractures or for maintenance purposes.
- 5) RDSO Guidelines for carrying out RSI studies shall be preferred.
- 6) LWR forces shall be considered in appropriate load combination as per IRS Concrete Bridge Code.

**2.4.15. Settlement**

Maximum and differential settlement shall not exceed, as provided in Table 1 of IS:1904.

**2.4.16. Other Forces and Effects**

As per clause 19.6 of IS:456.

**2.5. Design Load Combinations****2.5.1. Ultimate Load Combinations**

Each component of the structure shall be designed and checked for all possible combinations of applied loads and forces. They shall resist effect of the worst combination. Following shall be considered:

- (i) Load combinations and factors as per Table 18 of IS:456 for Plain and Reinforced Concrete Structures.
- (ii) Load combination and factors as per Table 7 of IS:1343 for prestressed concrete structures.
- (iii) Load combination as per Section 3 and factors as per Section 5 of IS:800 for Steel structures.
- (iv) Load combination as per clause 6.3 of IS:1893 (Part-I).
- (v) Load combinations as per IRS CBC and RDSO guidelines for Seismic design of Railway Bridges where Metro live loads are applicable.

Note: (i) Load combination for construction load case shall be decided by Metro as per methodology of construction.

(ii) Reference of IRC:6 be taken for collision case if collision of road vehicles are involved.

**2.5.2. Serviceability Load Combinations**

The following load combinations and load factors shall be used for design for serviceability limit state:

- (i) Load combinations and factors as per Table 18 of IS:456 for Plain and Reinforced Concrete Structures.
- (ii) Load combination and factors as per Table 7 of IS:1343 for prestressed concrete structures.
- (iii) Load combination as per Section 3 and factors as per Section 5 of IS:800 for Steel structures.
- (iv) Load combinations as per IRS CBC where Metro live loads are applicable.

As the design criteria for checking permissible stresses for SLS Load Combinations is not covered in IS 456 codes, therefore we refer to IRS-CBC.

**2.6. Deflection Criteria**

The deflection limitations as per clause 23.2 of IS:456 for Plain and Reinforced Concrete Structures and clause 20.3.1 of IS:1343 for Prestressed concrete structures shall be followed.

**2.6.1. Lateral Sway**

The lateral sway at the top of the building due to Wind loads should not exceed  $H/500$ , where  $H$  is the height of the building.

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**2.7. Fatigue Check**

Fatigue phenomenon needs to be analyzed only for those structural elements that are subjected to repetition of significant stress variation (under traffic load). Fatigue checks for

(i) RCC and PSC structures— As per clause 13.4 of IRS CBC.

(ii) Steel Structures —

(a) In case of Metro live loads, as per clause 3.6 of IRS Steel Bridge Code shall govern. If  $\lambda^*$  values are required to be used, the train closest to the actual train formation proposed to be run on the metro system shall be used. Otherwise, detailed counting of cycles shall be done.

(b) For other cases as per Section 13 of IS:800.

\*Damage equivalence factors (As per IRS Steel Bridge Code)

**2.8 Foundations****2.8.1. Types of Foundation**

Considering the nature of ground, type of proposed structures, expected loads on foundations, the following type of foundations are considered practical.

- a) Spread or pad footing
- b) Raft foundation
- c) Pile foundation

No matter the type of foundation to be adopted, the following performances criteria shall be satisfied:

1. Foundation must not fail in shear.
2. Foundation must not settle by more than the settlements permitted as per Table-1 of IS:1904.

**2.8.2 Design of Pile**

IS: 2911 shall be followed for design of pile, load capacity etc.

**Pile Settlement**

Methods of estimating the settlement of deep foundations depend upon the type of deep foundation and the manner of transfer of loads from the structure to the soil. Theoretical estimation of settlement shall be done in accordance with IS 8009 (Part II) by integrating the vertical strain for the entire depth of soil and rock formation.

The settlement of each pile and/or pile group should be determined, and it should be demonstrated that such total and/or differential settlement can be tolerated by the structure.

**2.8.3. Shallow & Deep Foundations**

IS: 1904 shall be followed for design of foundations in soil. The safe bearing capacity for shallow foundations shall be calculated in accordance with IS:6403.

**Computation of Settlements of Foundations**

The calculation for settlement of foundations shall be done as per:

- IS:8009 Part-1 for shallow foundations
- IS:8009 Part-2 for deep foundations



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**2.9 Design of Water Retaining Structure**

It should be designed as per IS 3370.

**3. List of Design Codes and Standards**

The designs of station buildings shall be carried out as per provisions of this Design Specifications. Reference shall be made to following codes for any additional information.

Order of preferences of codes shall be as follows: -

- i. IS
- ii. IRS
- iii. IRC
- iv. BS or Eurc Codes
- v. AASTHO
- vi. Any other relevant code with the approval of UPMRC.

All codes and standards with latest revisions including all addendums/ notifications and correction slips shall only be used.



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