DRAFT

MODEL DESIGN BASIS REPORT (DBR)

FOR

CONSTRUCTION OF UNDERGROUND STRUCTURES

BY

CUT AND COVER METHOD

FOR METRO RAILS

(JANUARY-2022)

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1. Brief Description and Salient features of the Project

The Project's brief (name, alignment, section, number and type of stations) to be described by the Metro, for which the DBR is submitted.

The type of construction should be selected to meet the traffic and land availability requirements. This

may be decided by concerned Metro, depending on terrain & requirements. Salient features in brief on the above need to be given in the DBR.

1.2. Geometric Design Criteria

There may be technical details like Gauge, Max. Operating speed, Max. Axle load, Max./ Min. gradient, Min. Vertical/horizontal curve radius, Max. Cant /cant deficiency, Rail profile, Inclination of rail, Wheal thread profile, Type of power supply, etc. as per approved SOD/ Track structure.

2.0 SCOPE OF DBR

The DBR is only for structural design of Underground Stations/sections, station entrance/exit, box tunnels, open U ramp structures etc. construction by cut and cover method (other than bored tunnels).

This is meant to serve as guide to the designer but compliance with the rules there in does not relieve them in any way of their responsibility for the stability and soundness of the structure designed. The design of Underground Stations require an extensive and thorough knowledge and entrusted only to specially qualified engineers with adequate practical experience in structure designs.

Extended platform portion, which is generally on level-change station structure, shall be designed as part of viaduct, if any.

The structural elements connected to the member on which metro live loads are supported may also be designed with taking loads and load combination, as specified in "Model Design Basis Report (DBR) for Viaduct of Metro System". Other structural elements such as secondary beams, stub columns etc., may be designed as per IS: 456.

Structures, where Metro Live loads are not applicable, the design of Plain and Reinforced Concrete structures will generally be governed by IS:456, pre-stressed 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.

The design of the permanent and temporary supporting works shall comply with code of practice and standards. Regulations made and requirements issued by the Indian Government and by relative utility authorities shall be followed and specified.

In addition to design data and criteria, key design data extracted from reference design standards, approach towards design of various elements, a summary of design methods, assumptions and software used shall be provided in this document.

Design of structural part of bored tunnel, in Underground station, shall be dealt by "Model DBR for Bored Tunnel."

3.0 DESIGN PRINCIPLES

I. The proposed structure of Underground station may be a rigid box section with permanent walls as external wall support system and beam-slab & column forming the internal structural framing. The roof slab may support the soil and vehicular surcharge, while the passenger and plant loads may be carried by the concourse slab. The track and platform loads may be supported by the base slab. The permanent walls may resist the lateral earth and hydrostatic pressures in addition to the surcharge, services/structural loads.

II. In the design of Underground station structures, following factors should be taken into account:-

a) Method of construction, including temporary works and construction sequence;

b) Ground/structure interaction, including the effects of temporary works;

c) Ground pressure, shear force and bending moment distribution during construction and in the long-term;

d) Short- and long-term ground and groundwater response;

e) Other static loads changes such as; excavation, surcharge, traffic loadings and the like;

f) Long-term surface water level changes;

g) Dynamic (such as seismic or vibratory plant) loads and displacements.

h) Safe evacuation of passengers in case of accident/derailment/fire etc..

III. For the purposes of assessing ground and groundwater pressures, the underground station structures may be considered to be effectively impermeable rigid box structures subject to earth pressure.

IV. The Design shall minimise the effects (such as movement, distortion of the ground and the like) on all Existing Building Structure (EBS) that may be affected by the Works. Wherever necessary, the additional support for these EBS will be provided.

V. The design of all cut-and-cover structures may take into account, but not be limited to the following:-

a) The variation in ground conditions along the alignment; The geological/ hydro-geological features and their variations including rock joint orientation and spacing etc.

b) The variation in engineering properties of soil or rock within the influence of the proposed Works;

c) All dewatering and groundwater cut-off systems required to maintain dry and stable conditions within all excavations required for these works;

d) Any ground treatment before, during or after construction of the works (e.g., groundwater recharge), which is required to stabilise the ground and existing building structures(EBS) in order to minimise adjacent ground and EBS movement and distortion;

e) Methods by which the completed structure shall be secured against flotation. (Any temporary dewatering system shall not be turned off unless and until provisions have been made to satisfy that, the structure will not be subjected to leakage or flotation, when the groundwater returns to the design levels);

f) Differential groundwater pressures;

g) Methods of waterproofing the completed structure;

h) Any difficulties that are envisaged at site with respect of access, clearances, working space and obstruction to excavation.

i) Maintenances of traffic flows along/ on roads including access to adjoining properties and roads.

j) Control of heave, swell, piping and instability of the excavations;

k) The noise levels produced, during construction and subsequent operation of trains.

l) The depth of construction required;

m) The effects of vibration and vibration induced movements – eg, earthquake.

VI. The following methods of construction shall be used in soft ground either individually or in combination depending upon the particular requirements of the location, size and type of structure.

a) Diaphragm Walls

Particular attention need to be paid to the wall and panel alignment, the stability of excavation, the mix and condition of the slurry, placement of the reinforcement cage, methods for forming and locating box-outs, waterproofing of the vertical panel joints, placement of concrete, and the overall integrity and water-tightness of the formed wall.

b) Secant Piles/Sheet Piles/Soldier Piles and Horizontal Planks

Particular attention shall be paid to the construction/installation of the piles and ground support systems to ensure their integrity and water-tightness and to provide adequate support to the ground during excavation.

VII. Diaphragm walling is the preferred support method for the proposed deeper station, vent shaft and tunnel excavations. Other methods of support may be used for the other relatively shallow excavations such as station entrances/exits, pedestrian subways, utilities and services.

VIII. For excavation support, following design parameters shall be taken into account:

i) Earth pressure.

ii) Hydrostatic pressure.

iii) Deck load.

iv) Surcharge loads.

v) Seismic and/or vibratory loads.

vi) Temperature loads

vii) Support types and arrangement.

viii) Any other incidental load.

ix) Construction/deconstruction sequence.

x) Calculated ground and adjacent EBS movements and distortions.

xi) Calculated fluctuations in groundwater levels both within and outside of the excavation and support walls.

xii) Calculated changes in EBS loading conditions.

IX. Method Statement

A Method Statement giving the full details of materials, plant and operations involved in the construction of excavation support walls will be prepared. This Method Statement shall be incorporated into the Design Report and shall include but not be limited to the following details:

1. Sequence of excavation and concreting of panels.
2. Method of producing the workable concrete.
3. Methods of handling within the excavations and disposing of groundwater outside of the excavation.
4. Formation of the joints between panels and installation of water stops.
5. Methods of instrumenting, monitoring and reporting of the performance all adjacent EBS that may be affected by the works.
6. Type and construction of permanent lining wall.
7. Emergency procedures to be implemented in the event that monitoring indicates tolerances associated with the excavation support wall may be exceeded.

Where temporary ground support is to be provided using bentonite slurry, the following additional information may be provided in the Method Statement for these works.

1. Mixing, transporting and placing equipment for the bentonite slurry.
2. Method of disposal of contaminated bentonite slurry.
3. Type, source, chemical and physical properties of the bentonite to be used.
4. Stability, dimensions and details of guide walls.
5. Cleaning and re-use of the bentonite slurry.
6. Calculations to show that the density of the bentonite and lowest head of slurry are sufficient to maintain the stability of the trench excavated for the support wall, in the ground, conditions envisaged, to its full depth.

4.0 UNITS

The main units used for design will be: [t], [m], [mm], [kN], [KN/m2], [MPa], [^{o}C], [rad]

5.0 MATERIALS

5.1 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.

5.2 Concrete

1. In case of Plain and Reinforced Concrete structures, as per clause 6, 7, 8, 9 and 10 of IS:456, and Clause 6, 7, 8, 9 and 10 of IS:1343 for Pre-stressed concrete structures.
2. Short term modulus of elasticity (E_c) shall be taken as per clause 6.2.3.1 of IS: 456 for Plain and Reinforced Concrete structures, and IS: 1343 for Pre-stressed concrete structures.
3. The modular ratio for concrete grades shall be taken as per Annex B of IS: 456.

4. Thermal Expansion Coefficient shall be taken as per clause 6.2.6 of IS: 456.
5. The density of concrete shall be as per IS: 875 Part 1.
6. Where the concrete is to be placed under the slurry or water, such as diaphragm wall and barrettes, the design compressive strength and shear strength of structural concrete shall be reduced. The characteristic strength of the compression and shear stress shall be taken 80% of the characteristic strength of the concrete grade.

5.3 Prestressing Steel for Tendons

As per clause 5.6.1 of IS: 1343.

5.4 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.*

5.4.1 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.

5.5 Structural Steel

Structural steel used shall confirm to

a. Hollow steel sections as per IS: 4923.
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 be indicated, shall not be less than minimum grade as applicable, based on whether structure is taking moving loads or not 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.

6.0 DESIGN LIFE AND DURABILITY CRITERIA

The design life of all Civil Engineering Underground Structures shall be a minimum of 100 years unless otherwise specified or agreed upon. The design life of non load bearing element such as utility support, vent shaft etc. shall be 50 years.

Adequate measures shall be taken to ensure minimum of 100 years serviceability of Civil Structures, producing durable concrete with Micro silica (or other suitable admixtures) that shall be tested for impermeability according to DIN 1048 and ability to resist chloride ion penetration according to ASTM C1202.

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.

6.1 Concrete Grades

The minimum grade of concrete for all structural elements including piles shall be as per IS: 456 for Plain and Reinforced Concrete structures, and as per IS: 1343 for Prestressed Concrete structures. Minimum grade of concrete for blinding layers and levelling courses shall be indicated.

6.2 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. Cover of diaphragm wall may be considered in accordance with IS: 9556.

6.3 Fire Resistance Period

6.3.1 Main Station Structures

1. All structures shall be designed for fire protection as specified by the applicable standards and codes. Materials specified for the Works shall be non-combustible and should not emit toxic fumes when subjected to heat or fire, except where specifically permitted. In all cases where there is significant fire risk, materials shall be self-extinguishing, low flammability, low smoke and low toxicity.
2. All the elements of the station structures shall be designed for a minimum fire resistance period of 4 hours.
3. The minimum element thicknesses for this fire resistance shall be as per cl.21 of IS: 456, and IS: 1642 for concrete structures.
4. The minimum element thickness for this fire resistance shall be as per Section 16 of IS: 800 for Steel structures.

6.3.2 Ancillary Structures

For above-ground ancillary structures the following contents shall be adopted. The environmental exposure condition for the above-ground structures shall be as per Table 3 of IS: 456. The minimum grade of concrete shall be as per exposure condition & as per Table 5 of IS: 456.

All the structural elements shall be designed for a minimum fire resistance period of 2 hours. The minimum element thickness for this fire resistance shall be as per clause 21 of IS: 456.

6.4 Crack Width

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.

6.5 Clearances

1. **Clearances for Metro Traffic:** As per approved SOD of specific Metro system.
2. **For utility services:** The clearances to utilities, drainage etc. shall be as mandated by the utility owner/ department.

3. **Clearance for Railway Traffic:** As per the case, Indian Railways Schedule of Dimensions (SOD) shall be applicable.
4. **Clearance for Road Traffic:** As per relevant IRC specifications and Road Authority requirements.

6.6 Early age Thermal and Shrinkage Cracking

1. Suitable reinforcement shall be designed to prevent early age thermal and shrinkage cracking for walls and slabs more than 250 millimetres thick and subjected to internal and external restraints during construction. The thermal and shrinkage strains due to early age temperature differences and shrinkage shall be accounted for in the design of reinforcement for cracking.
2. It is preferred that smaller diameter bars in any direction are placed at closer intervals to prevent early age thermal and shrinkage cracks. Guidance can be sought from CIRIA C 660-2007 on Early Age Thermal Control of Concrete.
3. Minimum reinforcement shall be higher of:
   a) 0.125% of cross sectional area of structural member on each face in each direction.
   b) Reinforcement required as per early age thermal (EAT) control of concrete.

7.0 LOADS

The structures shall be designed for the most onerous combinations of loads using relevant safety factors. For the purpose of computing stresses and deformations, the following minimum load types and consequential effects shall be taken into account as applicable.

- Dead loads (including notional loads) DL
- Superimposed Dead loads SIDL
- Imposed (Live) loads LL
- Railway Live loads RL*
- Earthquake Loads EQ
- Wind Loads WL
- Accidental/Collision Load CL*
- Derailment Load DR*
- Construction/Erection ER
- Temperature loads TL
- Shrinkage S
- Creep C
- Earth Pressure & Water Pressure EP & WP
- Surcharge Loads (Traffic, building etc.) SR
- Pre-stress force PR
- Fatigue FG
- Long Welded Rail Force LWR
- Differential Settlement DS
- Movement/ Distortion MD
- Redundancy R

* Loads as applicable shall be taken.

7.1 Dead Loads (DL)

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 Underground Station and permanent in nature. It shall be calculated in accordance with IS:875 Part 1.

7.2 Superimposed Dead Loads (SIDL)

Superimposed dead loads include all the weights of materials on the 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.*

The minimum distributed and concentrated loads shall be in accordance to IS: 875, Part 2, wherever available for remaining Metro railway shall specify the loads.

7.3 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 IS: 875 (Part 2).

7.4 Railway Loads

7.4.1 Vertical Train Live Load

Live Load (LL): The train live load will be as per the "Modern Rolling Stock" axel load configuration (Light, Medium or Heavy). The loading envelope chosen shall be as per the Rolling Stock planned to be used on the Metro system.

Loads other than standard trains like track machines, cranes, any new rolling stock etc. which may come on this structure should be within the loading envelope initially decided by the metro as above.

7.4.2 Coefficient of Dynamic Augment (CDA): CDA shall be adopted as per IRS Bridge Rules.

7.4.3 Horizontal Train Live Load

A) Braking and Traction

The value of braking and traction forces will be taken as per rolling stock used, to be decided by Metro.

B) Centrifugal Force

Design for centrifugal force to be as per IRS: Bridge Rules.

7.5 Earthquake Load

Earthquake design shall follow the seismic requirements of IS: 1893 (Part –I). Ductile detailing shall be according to IS:13920.

The provision as per Design Basis Report for Viaduct of Metro System shall be followed where structures are taking moving loads of metro.

Seismic design of Underground Structures may be carried by using Free Field Racking Deformation method as per " Seismic Design and Analysis of Underground Structures" by Youssef M. A. Hashash, Jeffrey J. Hook, B Schmidt, J. C. Yao.

7.6 Wind Loads

Wind loading may affect the surface elements of underground structures such as vent-shafts, entranceways, cooling towers and pedestrian bridges. The wind load shall be calculated as per IS: 875, Part -3.

7.6.1 Air Pressure

It may be considered from the condition prevailing for the train entering and leaving the station.

7.7 Collision/Impact Loads

For road traffic as per IRC: 6.

7.8 Derailment Loads

Derailment load shall be considered according to IRS Bride Rule Appendix XXV, with relevant gauge. For ULS and stability check, loading shall be proportioned as per maximum axle load and gauge.

7.9 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 taken into account. Allowances shall be made in the permanent design for any locked in stresses caused in any member during erection.

7.10 Temperature

Temperature effect shall be assessed as per clause 2.6 of IRS: Bridge rule, temperature analysis shall be done as per IS: 875 Part 5, as applicable.
Temporary works with structural steel bracing elements or similar may also suffer adverse effects from thermal strains. These strains shall be mitigated to avoid losses in preloading and subsequent excessive deformations in structural members.

7.11 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 train loading the effects of shrinkage as per Cl. 5.2.3 of IRS-CBC shall be considered.

7.12 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.

7.13 Earth Pressure& Water Pressure

Underground vertical elements that are in direct contact with the ground shall be designed as permanent retaining walls to resist the lateral earth pressure. In the design of structures or parts of structures below ground level, 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. Effect of seasonal weather changes shall be considered as per para 9 of IS: 1904.

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.
The effects of temporary drawdown, seepage and base heave effects shall be considered in design of the temporary works, and catered to in the permanent works if there is a 'locked-in' effect from carry-over forces. The extent of the temporary walls shall be sufficient to mitigate the effects of such loads during construction.
The effects of flotation loads shall be allowed for in the design both in the temporary and permanent design stages.
The proposed structures (primarily the stations) may act as obstructions to groundwater movement. The designer shall design and subsequently construct for unobstructed movement of the groundwater through and around these structures so that these structures do not result in changes to phreatic surface that exceed normal expected diurnal fluctuations.
If liquefaction of soils be a potential risk then the design water table level for permanent structures shall include layers affected by liquefaction if this is above the design groundwater levels.

7.14 Surcharge

Traffic surcharge shall be adopted in the design as per IRC:6 for highway loading and as per IRS: Bridge rules for Railway loading respectively.

For existing buildings and other existing structures occupying areas around the excavation, detailed assessment based on building and foundation type, and loading are to be carried out to determine the applied loads and other impacts of such building loads on the proposed structures, For future buildings or planned infrastructure, the appropriate authorities and owner's Representatives shall be consulted for details.

7.15 Pre-stressing Force (PR)

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

7.16 Long welded Rail Force

Guidelines vide BS report no. 119: "RDSO guidelines for carrying out Rail structure interaction studies on Metro system (version-2)" shall be followed.

7.17 Differential Settlement

Maximum and differential settlement shall not exceed, as provided in Clause 16 of IS: 1904.

7.18 Movement and Distortion

Consideration of the forces resulting from differential movement (distortion) of foundation elements shall be checked as appropriate. All movements and distortions must not be greater than limits adhered to in the relevant codes or acceptable to the relevant Authority. These may be architectural, structural, rail performance or other types of limitations currently in force.

7.19 Redundancy loads

The temporary structure shall allow for the effects of a 'one-strut failure' condition. A single strut failing at any position and at any stage shall be evaluated with Ultimate Limit State (ULS) condition with a FOS of not less than 1.05.

7.20 Differential Movement between In-Line Structures

Differential movement between adjacent in-line structures arising from static and/or dynamic loading shall be evaluated. Due allowance for such movements shall be incorporated into the size of the structures and detailing of joints to ensure that the total and differential movements, including distortion and relative rotation, between in-line structures shall not exceed the serviceability limit of the structures for the design life of the structures.

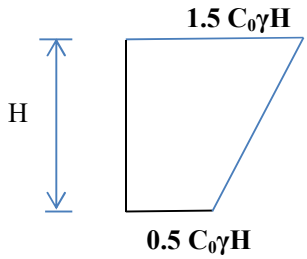
7.21 Other Forces and Effects

As per clause 19.6 of IS: 456.

7.22 Incremental Dynamic Loads On Buried Structures

General Solutions for Retaining Walls

Wood ("Earthquake Induced Soil Pressures on Structures") proposed elastic dynamic solutions for above ground ring degrees of flexibility. Based in this work it has been shown that for very flexible walls where the deflection exceeds approximately 0.5 % of the height of the wall the solution of dynamic pressures tends towards those suggested by Mononobe and Okabe which were based on the assumption that a full active wedge develops behind the wall. For buried structures it is unlikely that such an active wedge will form and it is therefore recommended that solutions based on rigid retaining walls as developed by Wood are used. The dynamic increment should be added to static earth pressure loads based on at-rest soil pressures in addition to water pressures and other imposed loads using appropriate load combinations.



γ = Weight density of soil (KN/m^3)
C_0 = Seismic coefficient

Elastic Dynamic Earth Pressure Increment for Rigid Retaining Walls

8.0 DESIGN LOAD COMBINATIONS

8.1 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 and clause 19.7 of IS: 456, IS: 875 Part 5, for Plain and Reinforced Concrete Structures.
(ii) Load combination and factors as per Table 7 of IS: 1343, IS: 875 for prestressed concrete structures.
(iii) Load combination as per Section 3.5 and factors as per Section 5 of IS: 800 for Steel structures.
(iv) Load combination for seismic consideration as per clause 6.3 of IS: 1893 (Part-I).
(v) Load combinations as per IRS CBC and IRS Seismic code 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.

8.2 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 and clause 19.7 of IS: 456 for Plain and Reinforced Concrete Structures.
(ii) Load combination and factors as per Table 7 and clause 20 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.

8.3 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. For Steel structures, Designs shall comply with the limits defined in IS: 800.

For Diaphragm Wall Deflection limit, a detailed analysis of the induced effects on buildings may be performed depending on their vulnerability. Accordingly, displacement for Diaphragm wall shall be limited.
The design shall also include provisions to limit angular distortions to 1:2,000 maximum.
Dewatering outside the station or cut and cover walls shall not be permitted.
These requirements are in addition to any other requirements imposed by applicable government agencies and the owner.

8.4 Fatigue Check

Fatigue phenomenon needs to be analysed only for those structural elements that are subjected to repetition of significant stress variation (under traffic load). Fatigue check for
(i) RCC and PSC structures – As per clause 13.4 of IRS CBC.
(ii) Steel Structures –
As per Section 13 of IS: 800.

9.0 DESIGN GROUNDWATER LEVEL

Ground water level to be assumed in design for the various stages shall commensurate the ground water fluctuation in area of construction. Following values are indicated for guidance only.

"Service/Operation" and "Extreme" stages or conditions may be as follows.

"**Construction**" - groundwater level at measured maximum elevation.

"**Service/Operation**" - groundwater level at ground level.

"**Extreme**" - groundwater level at 1 in 20 years maximum (plus 0.5m allowance for sea level rise for coastal conditions).

10.0 FLOTATION

1. The minimum depth of cover to underground structures shall be 2.3 metres or depth to the underside of major utilities (eg, sewer mains, storm water mains and the like) whichever is the greater.
2. For protection against flotation in the fully internally dry condition following shall apply.
   a) A load factor of 1.0 shall be applied to the self-weight of the structure.
   b) A load factor of 1.0 shall be applied to the weight of backfill material over the structure.
   c) The skin friction between the concrete surface and the soil may be assumed below the concourse.
   d) The overall factor of safety against flotation shall not be less than 1.1 for any of the conditions defined above.
3. Design to be checked for all proposed cut-and-cover structures for the possibility of flotation due to differential water pressure and shall design each and every underground structure such that the factors of safety against flotation are achieved for all load cases.
4. Design to ensure that the method and sequence of construction is such that an adequate resistance to uplift is maintained at all times, and shall put forward his proposal to this effect.

5. Suitable measures such as those listed below to counteract flotation forces for the Permanent Works shall be incorporated in the design. The measures chosen shall suit the particular conditions and the method of construction;
   a) Toeing-in of the base slab into the surrounding ground.
   b) Increasing the dead weight of the structure by:
      i) thickening of structural members; providing an extra thickness of concrete beneath the base slab tied into the structural base slab;
      ii) extending the excavation support walls;
      iii) providing counterweights in parts of the structure with high density material;
      iv) providing tension piles.
6. Where the base slab is toed-in to the surrounding ground a partial safety factor of 2.0 shall be applied to the shear resistance of the ground above the toe and the adhesion factor shall not apply. The value of the weight of ground above the toe shall be calculated as for the backfill material.
7. The value of the weight of any additional thickness of concrete shall take account of the increased volume of water displaced.

11.0 FOUNDATIONS

Whatever the type of foundation to be adopted, the following performance 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.

11.1 Design of 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.

11.2 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

11.3 Design of Pile

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

11.4 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.

12.0 DESIGN OF WATER RETAINING STRUCTURE

It should be designed as per IS: 3370.

13.0 CIVIL EXECUTION WORKS

13.1 Excavation Base Stability

(1) The design shall include adequate precautions against base heave, piping and failure of his excavations during construction. The stability of the excavation bases shall be checked in accordance with an acceptable method of analysis which shall allow for all reasonable loads within and outside of the excavation.

(2) The Design calculations has to explain the contribution made to the base stability of the excavation by proposed method of construction and shall state the factor(s) of safety used in the design.

13.2 Excavation Toe Stability

(1) The design will ensure adequate toe stability of retaining structure during construction. The toe stability will be checked in accordance with an acceptable method of analysis which shall allow for all reasonable loads within and outside of excavation.

(2) The conventional approach based on active and passive pressure shall be preferred with suitable factor of safety.

13.3 Waterproofing

(1) Groundwater leakage rates into the completed Permanent structures shall be limited to damp patches only and shall not under any circumstances exceed a general value of 0.1 litres per square metre per day.

(2) The quality and grade of the concrete, treatment of construction joints, areas of slab pours and external membranes shall be chosen such that the required standard of waterproofing can be achieved and maintained. Waterproofing membrane shall be provided to base slabs of all cut-and-cover structures and to walls where the structure is built in an open excavation.

(3) An external membrane shall be provided over the roof of the structure so that the roof of the permanent underground structure is completely watertight.

(4) Detailing of structure shall include provision of splays, chamfers and fillets as appropriate to facilitate the laying and performance of waterproofing membranes.

(5) Materials for expansion joints, caulking, grouting and the like shall have acceptable fire performance for use on an underground railway.

(6) Exposed diaphragm walls in cut-and-cover tunnels shall be rendered or shotcreted and trowelled, as necessary, to provide a uniform finish without distinct changes in colour or line. All rendered or shotcreted walls shall be provided with a controlled drainage system to direct any seepage permitted under the Contract to the floor drainage system.

13.4 Water Control in Excavations

(1) During construction in water-bearing ground, seepage water shall be controlled by suitable means and the design shall provide for the same.

(2) The piezometric pressure outside of the excavations shall at all times remain within the normal expected groundwater variation and permissible safe limits. .

(3) Notwithstanding the limits on groundwater leakage rates, the design shall aim to ensure that no loss of ground or groundwater occurs through any part of the structure.

13.5 Underpinning of Existing Building Structures (EBS)

(1) Where the construction of subways or other underground works necessitates the removal of existing support or foundations to existing buildings, structures, utilities, services, wells, pavements, road furniture and the like (collectively termed EBS) the Designer shall carry out investigations on the extent of the existing works, their design and loading conditions.

(2) The design to be carryout such works as are necessary to maintain the integrity of the EBS at all times including its design life.

13.6 Drainage and Flood Protection

All openings into the Metro Rail structures shall be located above the 1 in 50 year flood level plus an allowance for a 0.5 metre rise in sea level as applicable. In general structures located on flat land shall have a minimum flood protection of 1.2 metres above the surrounding ground level. This may be achieved with a combination of steps up into entrances and removable flood boards.

13.7 Seepage Barriers

(1) Design shall be done for the seepage gap with a seepage drainage channel such that discolouration or water damage to the seepage walls cannot occur. Access panels to inspect and maintain the drains shall be included. All such finishes, panels and fixings and the like shall be non-corrodible and shall comply with the design life requirements.

(2) At platform level in the stations, the visual aspect of the platform walls must be aesthetically pleasing and exposed diaphragm walls must be provided with a surface which will give a uniform finish without distinct changes in colour or alignment.

14.0 TEMPORARY WORKS

14.1 General Principles

(1) In general Temporary Works shall be designed in accordance with the same design standards as the Permanent Works. However, Temporary Works design may take into account the limited duration over which such temporary works are expected to function. The calculations and drawings shall make clear where provision for limited duration has been allowed for, particularly where this may have a substantial influence on the stability of the Temporary Works.

(2) The design of Temporary Works shall take account of all the applied external forces and imposed structural deformations and, where applicable, the effects of removal of load from the ground.

14.2 Design of Temporary Excavation Support

(1) Excavations for cut-and-cover structures in soft ground shall be supported by diaphragm walls, secant piles or similar which may be incorporated into the Permanent Works. Design

of these elements shall include full step-by-step analyses of the progressive change in the loading (including deflection of these elements and the resultant settlements/distortions of the ground surface) and required temporary support conditions as the excavation proceeds and subsequently as these temporary elements are integrated into the Permanent Works.

(2) Braced excavations shall be analysed by finite element or similar methods in which the changes in ground stresses are properly related to the deflections which occur in the structural elements, by the use of appropriate stiffness and other parameters. Relevant empirical evidence from similar excavations must be referred to in support of the conclusions of the analyses. Simplified analytical models and methods shall be employed to calibrate and support finite element analyses of the various permutations of structure geometry and loading.

(3) Temporary works shall be designed as far as possible to be removed when no longer required, and shall not be left in the ground. Temporary works which are viewed as being impossible to remove on completion of the Permanent Works shall be dismantled to a minimum depth of 2 metres below the finished ground surface and designed so that there will be no risk of ground settlement or other deleterious effects as a consequence of decay and/or collapse of these Temporary Works.

15.0 GROUND MOVEMENTS

(1) Temporary and Permanent Works designs shall limit ground movement and distortions around the site and to avoid damage to adjacent EBS.

(2) Before Dewatering, a risk assessment for all EBS within the influence of the Construction Works shall be carried out.

(a) Temporary dewatering of construction excavations will be required to provide an undisturbed, stable and dry subgrade to permit construction and backfilling of the Permanent Works under dry conditions.

(b) In general, the groundwater within the excavations shall be maintained at a level that permits achievement of the above and avoids heave, piping or base failure of the excavation.

(c) Temporary dewatering methods (including recharging methods, if required) and system operations, along with other required temporary works, shall neither lower the groundwater outside the walls supporting the excavations, nor result in settlement, distortion or loss of ground at adjacent EBS.

(d) The construction dewatering design shall include determination of subsurface conditions and geotechnical design parameters, analyses to establish feasible methods, and system definition in sufficient detail to demonstrate that the general objectives can be achieved without adverse effect on adjacent EBS. The selected system shall generally provide for continuous (24-hour-per-day) operation, adequate reserve equipment, and standby power.

15.1 Ground Improvement

Ground-improvement may be required along certain alignment segments of the Metro Rail Corridors to control ground and EBS movement and distortion that may be induced by excavation for underground structures.

16.0 INSTRUMENTATION AND MONITORING

The concerned metro shall submit a complete comprehensive instrumentation scheme including Real Time Monitoring with the Preliminary Design to achieve the following:-

a. Safety during and after the construction by providing early warning of any excessive and undue ground movement of adjoining premises/structures/utilities.
b. To provide settlement, deflection and deformation data for the verification of initial design of the permanent structures and the temporary works supporting excavations.
c. To provide information on ground movements to ensure that the tolerances associated with various structures/elements within the zone of influence are not exceeded.
d. To record generated pore water pressures to confirm the flow nets previously used to predict seepage rates and to confirm that drawdown outside station and cut and cover walls is within acceptable limit.
e. To estimate and monitor during construction the expected ground movement (allowable total settlement, differential settlement, angular distortions wall movement, earth pressure, strut load, bottom heave etc.). If the estimates are exceeded remedial measures will be prepared and implemented.

17.0 LIST OF DESIGN CODES AND STANDARDS

The designs of underground 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. BIS
ii. IRS
iii. IRC
iv. BS or Euro Code
v. AASHTO
vi. Other references may be listed.

(***Note:*** Each time latest code with the latest correction slip shall be adopted.)

This document "Draft Model Design Basis Report (DBR) for Construction of Underground Structures by Cut & Cover Method for Metro Rails" (18 pages) has been prepared by a committee, nominated by PED/ED of respective Directorate, vide letter no. UTHS/51 dated 20.052021. Draft report is submitted to Competent Authority for perusal, modification and approval as found suitable, before recommending to Railway Board for final approval. The committee comprises following members.

Director/Civil/UTHS

Director/Track-VI

Joint Director/BS-V

Joint Director/GE-I