DESIGN AND CONSTRUCTION OF ELEVATED STATIONS

MODEL

DESIGN BASIS REPORT

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1. INTRODUCTION

1.1 Brief Description of the project

The project brief to be given by Metro, for which the DBR is submitted.

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 in India". 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 require an extensive and thorough knowledge and should be entrusted to only to specially qualified engineers with adequate practical experience in structure designs.

The DBR is only for structural design of Elevated Stations including any ancillary and entry exit structures. Extended platform portion which is generally on single column or portal type structure shall be designed as Model DBR of viaduct.

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

Structures, where Metro Live loads are not applicable (such as secondary beams, stub columns, ancillary, entry exit, etc.), 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], [kN/m^2], [MPa], [^0C], [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 (EC) 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. The modular ratio for concrete grades shall be taken as per Annexure B of IS:456. The Density for 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 Pre-stress

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 or conform to

a) Hollow steel sections 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 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.

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.

2.2 Durability

Durability of Concrete shall be as per clause 8.0 of IS: 456 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 indicated. Minimum grade of concrete for blinding layers and levelling courses shall be indicated.

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

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.

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. It shall be calculated in accordance with IS:875 Part 1.

2.4.2 Superimposed Dead Load (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-1 wherever available. For remaining, Metro railway shall specify the loads not covered in IS:875.

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 IS:875 Part-2.

2.4.4 Earthquake Loads

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

2.4.4.1 Drift Limitation

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

2.4.4.2 Seismic Detailing

(i) For reinforced concrete structures as per IS:13920

(ii) 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

(i) For road traffic as per IRC-6.

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

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 pre-stressed concrete structures.

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 pre-stressed concrete structures.

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 Part5).

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 Bridge Sub-structure and Foundation Code.

2.4.12. Surcharge Load

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.

2.4.13. Pre-stressing Force (PR)

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

2.4.14. 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.

2.4.15. Settlement

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

2.4.16. Other Force and Effects

As per clause 19.6 of IS:456.

2.5 Design Load Combination

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 Pre-stressed 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 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 Pre-stressed 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 IRS CBC where Metro live loads are applicable.

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. For Steel structures, Designs shall comply with the limits defined in IS: 800. These requirements are in addition to any other requirements imposed by applicable government agencies and the owner.

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.

2.7 Fatigue Check

Fatigue phenomenon needs to be analysed only for those structural elements that are subjected to repetition of significant stress variation (under metro live load). Fatigue check 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 λ*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.

i) Shallow Foundation

For determining the ultimate bearing capacity and allowable bearing pressure of shallow foundation based on shear and allowable settlement criteria, IS 6403 shall be followed.

a) Spread or pad Footing and Strip Foundation

For design of spread foundation, IS 1080 may be followed.

b) Raft Foundation

IS:2950 (Part I) may be referred for design.

ii) Deep Foundation : Pile foundation

For design of pile, load capacity etc. for piles resting on soil, IS:2911 shall be followed. For piles resting on rock, IS:14593 shall be followed.

2.8.2 Design philosophy

(a) No matter the type of foundation to be adopted, the following performance criteria shall be satisfied:

(i) Foundation must not fail in shear

(ii) Foundation must not settle by more than the settlements permitted as per Table-1 of IS: 1904.

(b) For structures, where Metro live loads are applicable, design of foundation shall be as per "Model Design Basis report (DBR) for viaduct of metro system".

(c) Soil structure analysis:

When designing elements forces or estimating displacements the soil stiffness shall be assessed based on the actual ground data

2.8.3 Computation of Settlement of Foundations

The calculation for settlement of foundations shall be done as per

- IS:8009 (Part-I) for Shallow foundations
- IS:8009 (Part-II) for Deep foundations

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.

2.9 Design of Water Retaining Structure

It should be designed as per IS 3370

2.10 Masonry Wall

Masonry walls shall be designed as per IS: 1905 and IS: 4326**.**

3. <u>LIST OF DESIGN CODES AND STANDARDS</u>

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

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