STANDARDIZATION OF CIVIL ENGINEERING STRUCTURES OF METRO SYSTEM

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1. Introduction

Metro Rail network in India is expanding at a rapid pace in major Indian cities and around 15 cities have already been covered so far. Metro railways are undoubtedly the preferred mode for mass transport on high demand corridors in big and medium cities and lead to making growing cities more livable and sustainable. With the creation of new metro facilities in several cities (tier 1 and 2), and in view of capital intensive nature of the metro rail projects, there is a need for standardization of metro rail systems.

2. Scope

This note is being prepared to standardize the system for civil engineering structures for Metros in India.

It may however be noted that the design of civil engineering structures in a metro rail system depends mainly upon the (i) Rolling Stock parameters and (ii) Local/Geological conditions. Therefore, once the type of Rolling Stock is finalized, the standards affecting the design of civil structures get defined automatically.

3. Definitions

3.1 Structure

Organised combination of connected parts designed to carry loads and provide adequate rigidity.

3.2 Structural Member

Physically distinguishable part of a structure, e.g. a column, a beam, a slab, a foundation pile.

3.3 Structural System

Assemblage of load-bearing members and the way in which these members function together.

3.4 Elevated structure

Structure that is raised above grade for its entire length.

3.5 Superstructure

It is the part of structure above ground level that receives the loads, transfers to the substructure safely through bearings and serves the purpose of the structure's intended use.

3.6 Pier

A pier is a large dimensional column to support the superstructure and transfer large super-imposed loads to the foundation below.

3.7 Pier cap

The upper part of a bridge pier designed to transfer the loads over the area of the pier.

3.8 Substructure:

It is the portion of the structure which supports the superstructure and transmits the loads to the foundation.

3.9 Foundation

It is the part of structure that transmits loads to the earth.

3.10 Viaduct

It is a long elevated roadway/railway consisting of a series of short spans supported on piers.

3.11 Underground structure

The structures built beneath the earth's surface and serve the purpose of the structures intended use.

3.12 Bored Tunnel

It is an underground passageway of circular cross section, bored through the surrounding soil/rock and enclosed except at each end for entrance and exit.

3.13 Cross Passage

Cross Passage is the connecting passage provided between the two running tunnels and provided for emergency and maintenance access.

4. Rationalization of size of Viaduct

4.1 Super Structure

Proposed Superstructure System of Viaduct

The choice of superstructure has to be made keeping in view the ease of constructability and the maximum standardization of the formwork for a wide span ranges. **The track centre to centre distance shall be kept minimum as per approved Schedule of Dimensions (SOD) to minimize the cost.**

4.1.1 Types of Superstructures for Viaduct

(a) Pre-cast post tensioned segmental box girder
(b) Pre-cast post tensioned segmental U-girder Superstructure
(c) Pre-cast prestressed I-girder
(d) Pre-cast pre tensioned Double U-girder/I-Girder
(e) Steel Composite Girders
(f) Open Web Girders
(g) Continuous spans such as CLC etc.

The advantages and disadvantages of the above type of girders have been deliberated by the committee. However, advantages and disadvantages of only the widely used ones have been stated upon. Depending on the local conditions the specific metro organizations may further deliberate and adopt any type of superstructure, if feasible.

4.1.1.1 Pre-cast post tensioned Segmental Box Girder / U-Girder

This essentially consists of precast segmental construction and requires gluing and temporary pre-stressing of segments. The match cast joints at the interface of two segments are provided with shear keys as in traditional segmental construction. The main advantages for this type of superstructure are:

1. Flexibility of choosing a span configuration ranging from 16m to 41m.
2. Good Aesthetics.
3. Can be used at locations having sharp curves.
4. Ease of Transportation
5. It can be extensively used for viaduct stretches having problems of utility, road crossings etc.

4.1.1.2 Precast Pre tensioned Twin U-girder

Girders of various spans lengths are cast in casting yard and pre-tensioned. These girders are transported to site in trailers and launched in position by using double cranes of suitable capacity one on either end. Any other methodology of launching may also be adopted

The main advantages for this type of structural configuration of superstructure are:

1) Built in sound barrier.
2) Built in cable support and system function.
3) Possibility to lower the longitudinal profile by approximately 1m compared to conventional design of box girders.
4) One span can be erected in a single night hence leading to faster pace of construction.

Considering their individual advantages, the twin U-girder and box girder superstructure system may be adopted based on the alignment, road geometry, utilities, local conditions etc.

The span of the viaduct will vary from project to project depending on the local conditions. However, Metro organizations may adopt suitable standard spans, if feasible and standardize the same.

4.2 Substructure System

The viaduct superstructure is generally supported on cast-in-place RC pier, pier cap and pedestal which transfers the forces to the foundation which may be shallow or deep based on geological conditions.

4.2.1 Pier:

Pier can be circular/rectangular/square/elliptical in cross-section with minimum diameter/dimension as per structural design considerations.

It may also be ensured that pier sizes do not vary substantially in a particular viaduct stretch so that the aesthetics of the structure is also maintained.

In addition to aesthetics, the stiffness of substructures should not substantially vary for controlling rail stresses.

4.2.2 Pier cap:

Pier cap shall normally be precast or cast in situ to support the superstructure for standard spans. In case of obligatory locations, an extended pier cap (in longitudinal direction) or a table top type pier cap may also be adopted so that standard spans may be used.

4.2.3 Foundation

Type of foundation shall be decided based on local geological conditions, statutory requirements etc. In case the hard rock/weathered rock/adequate SBC is encountered at shallow depth, open foundation may be adopted. For river bridges, pile/well foundation may be provided subject to approval of concerned authority/engineer-in-charge.

5. Standardisation of diameter of Twin Bored Tunnel

The tunnel is formed from precast concrete ring segments minimum 1200mm in length; each ring is formed from 6 segments.

The segments within each ring (which have horizontal joints) and those abutting each other in adjacent rings (vertical joints) are compressed against each other during construction.

It may be advantageous to have tunnel segments manufactured in factories and transported to work site thus leading to indigenization. It will also reduce space requirements in urban cities, as the factories are generally setup outside city limits. Also, the need of having multiple casting yards can be avoided as a single factory setup may cater for multiple project requirements, thus reducing the cost.

Cross passages in the tunnel shall be provided as per National Building Code 2016.

Although there are separate SOD's for different metros, the same has been discussed in the committee and agreed by all metros to adopt finished internal diameter of tunnel as 5600mm (min) to 5800mm (max).

6. C&D waste management and use of Recycled products

Appropriate measures should be devised for management of construction and Demolition (C&D) waste generated including its processing and for using the recycled products in the best possible manner**. "Construction & Demolition (C&D) waste Management Rules, 2016" notified by Govt of India** may be followed.

Fly ash may also be used in production of concrete as per relevant IRS & IS publications.

7. Stray Current Protection

Clause no. 1.2.6 of the document on "**Standardization / Indigenization of Electrical & Electromechanical Metro Rail Components" (August 2018)** may be referred for details regarding stray current mitigation measures.

8. Loading Standards for Structures

Loading shall be as per the approved Model Design Basis Report by RDSO and Railway board and as amended from time to time:

1. Model Design Basis Report for Viaduct of Metro System September, 2017 and as amended from time to time.
2. Model Design Basis Report, version-2 for design & Construction of Elevated Stations for Metros: June, 2016 and as amended from time to time.
3. The Model Design Basis Report for Bored Tunnel Sections of Metro Systems: February, 2017 and as amended from time to time.
4. Seismic design parameters shall be governed by IRS code for Earthquake Resistant Design of Railway Bridges (Seismic Code) – 2017 and as amended from time to time.

9. Noise and Vibration

Noise and vibration in the structures shall be monitored and controlled as per RDSO "Guidelines for Noise and Vibrations" for Metro rail system, published in September, 2015

10. Reduction in ROW as a result of optimization of viaduct width.

Where the construction is to be carried out on the middle of the road, central two lanes including median will be required for construction activities. During piling and open foundation work, a width of about 9 m (minimum) will be required for construction and the same will be barricaded.

11. Minimum Grade of Concrete for viaduct

It is proposed to carry out construction work with design mix concrete through computerized automatic Batching Plants with following minimum grade of concrete for various members based on durability requirements.

i)	Pile foundation	-	M -35
ii)	Pile cap and open foundation	-	M -35
iii)	Piers	-	M -40/M50
iv)	All precast element for viaduct and station	-	M -45

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In addition, following guidelines may also be referred while designing underground and elevated metro stations:

(i) National Building Code of India 2016, Vol-1, Part 4 Fire and Life Safety, issued by Bureau of Indian Standards available on the following URL:

http://ukfireservices.com/uttarakhand_fire/wp-content/uploads/2018/04/NBC-2016-VOL.1-Part-4-Fire-and-Life-Saftey.pdf

(ii) Harmonised Guidelines and SpaceStandards for Barrier Free Built Environment for Persons with Disability and Elderly Persons, issued by Ministry of Housing and Urban Affairs available on the following URL:

https://cpwd.gov.in/Publication/Harmonisedguidelinesdreleasedon23rdMarch2016.pdf