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Study of Design Criteria & Design Loads on Underground Tunnel and Bridge Bearings in Delhi Metro Structure

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ABSTRACT

Study the Design Criteria & Design Loads being adopted in Delhi Metro Rail Underground Tunnel and Bridge Bearings. The research paper thus help in the most successful and time bound Metro Rail work being executed by DMRC in Delhi NCR Region. The Delhi Metro Rail network is a masterpiece and a landmark civil work in India and matches with all International standards and practices adapted to suit local conditions.

The Delhi Metro Rail Corporation presently Phase III works are in advanced stage of execution in Delhi NCR Region in India. All the Metro Stations under the Delhi Metro's Phase III of expansion will be designed and constructed as "Green Buildings" with specific provisions for the conservation of energy as well as better CO2 saving, water saving and waste management arrangements.

The Delhi Metro Rail Corporation Phase III Line-7 Majilis Park – Shiv Vihar Total Length is 58.596 km out of which 39.479 km is elevated and 19.117 km is underground. The Projects includes the construction of 38 stations out of which 26 are Elevated Stations and 12 are Underground Stations.

KEYWORDS

Underground Tunnel, Tunnel Boring Equipment, Permanent Elastomeric Bearings, POT/PTFE Bearings, Gantry, Bearing Pedestal, down stand, Grouting,

NEED AND SCOPE OF STUDY

Tunnelling is increasingly being seen as an environmentally preferable means of providing infrastructure to densely populated urban areas, thus posing a number of challenging conditions. Historically, underground facilities have experienced a lower rate of damage than surface structures.

Requirements for the design and selection and layout of the bearings shall be consistent with the proper functioning of the bridge, and shall allow for deformations due to temperature and other time dependent causes. The loads induced in the bearings and structural members depend on the stiffness of the individual elements and the tolerances achieved during fabrication and erection. These influences shall be taken into account when calculating design loads for the elements.

METHODOLGY

In most of the districts crossed by the new line, there are neither large open spaces nor large avenues, but an irregular mesh of relatively narrow streets. Therefore cut and cover construction is not normally possible and the surface occupation of stations has to be minimized as much as possible. As the new infrastructure has to pass through mainly well established urban areas, the optimal location of the stations and their effect on the neighbourhood was explicitly studied. Beneath the surface other infrastructures exist, such as the tunnels of existing metro lines, road tunnels, large sewers and other services. The presence of these elements determines, in many places, the maximum elevation of the tunnels to be constructed.

As a project of this kind could stretch the limits of tunnel boring equipment, it proved necessary to coordinate the civil engineering requirements and the mechanical engineering capabilities at every phase of the project. Requirements and capabilities were reviewed as more information on ground and groundwater conditions became available.

Since cut and cover construction was only possible in short sections, the main decision concerned choosing either a mined tunnel or a TBM-excavated tunnel.

POSSIBLE TUNNEL SECTIONS

a).Two tunnels – one single track on each tunnel

b).One single tunnel with two tracks on same level

c).One tunnel with two tracks at different levels

Design Criteria for An underground structure

An underground structure may lose its serviceability or its structural safety in the following cases

a). The structure loses its water tightness. The deformations are intolerably large.

b). The tunnel is insufficiently durable for its projected life and use.

c). The material strength of the structural elements is exhausted locally, necessitating repair.

d). The support technique fails or causes damage.

e). Exhaustion of the material strength of the system causes structural failure, although the corresponding deformations develop in a restrained manner over time.

f). The tunnel collapses suddenly because of instability.

The structural design model should yield criteria related to failure cases, against which the tunnel should be designed safely. These criteria may be:

- Deformations and strains.
- Stresses and utilization of plasticity.
- Cross-sectional lining failure.
- Failure of ground or rock strength.
- Limit-analysis failure modes.

Design loads for an Underground structure

a). Dynamic forces due to earthquake.

b). Loads due to strength loss of the primary covering after a long term loads due to the probable saturation of the soil mass in NATM method.

c). Live loads due to the on ground traffic

d). Live load due to the train movement, if applicable.

e). Dead load on Tunnels

f). Ground pressure (soil/rock) surrounding tunnel

g). Water pressure

As the permanent bearings are not designed for the temporary construction loads, temporary bearings are used to cater for the loads and deflections.

The span weight is then required to be transferred to the permanent bearings at a later stage when the span is not supporting the launching gantry load anymore.

Installation of permanent elastomeric bearings is independent from the type of gantry used to erect the standard spans.

Before starting the permanent bearings installation and span adjustment check

- That no gantry is supported by the span
- That permanent elastomeric bearings has been checked
- Horizontal surface of the bearings are cleaned of grease and dust
- True horizontal surface of the top of the bearing pedestal
- Condition of down stands before shifting should be checked for any deformity

Place permanent bearing and grouting should be done to fill the gap between Bearing and Bearing Pedestal. The thickness of grout should be maximum up to 25mm and minimum up to 5mm, offset from the Bearing shall be 50mm from the Bearing edge.

Grouting material Conbextra GP2 shall be used.

Design Criteria for Bridge Bearings

Bridge bearing must be designed to transmit all the loads and appropriate horizontal forces. From the material point of view, these bearings can be made from metal, rubber, metal and elastomer and even concrete.

Bearings shall be designed to resist loads and accommodate movements. No damage due to joint or bearing movement shall be permitted under any appropriate load and movement combination.

Translation and Rotation movement of the Bridge shall be considered in the design of bearings.

The sequence of construction shall be considered and all critical combinations of load and movement shall be considered in the design. Rotations about two horizontal axes and the vertical axis shall be considered. The movements shall include those caused by the loads, deformations and displacements caused by creep, shrinkage and thermal effects, and inaccuracies in installation. In all cases, both instantaneous and long-term effects shall be considered, but the influence of impact need not be included. The most adverse combination of movements shall be used for design.

However following two types of bearings are recommended to be used on this project.

- Elastomeric Bearings
- POT/PTFE Bearings

Design loads on Bridge Bearings

a). The Horizontal Design Load

b). 10% of the maximum vertical load acting on all the bearings at the bent divided by the number of guided bearings at the bent.

c). Load Location

d). Contact Stress

APPAARENT COMPRESSION STIFFNESS TEST OF ELASTOMERIC BEARINGS

STRESS (Mpa)	LOAD (MT)	PRESSURE (Kg/Cm^2)	DEFLECTION				AVG DEF	STRAIN	CUM STRAIN
			1	2	3	4			
0	0.000	0.000	25.390	25.420	25.170	25.090			
			1.310	1.800	1.860	1.520	1.623	0.0107	0.0107
2	59.023	16.260	24.080	23.620	23.310	23.570			
			0.320	0.810	0.970	0.520	0.655	0.0043	0.0150
3	88.535	24.390	23.760	22.810	22.340	23.050			
			0.260	1.070	1.360	0.100	0.698	0.0046	0.0196
5.07	149.624	41.219	23.500	21.740	20.980	22.950			
			0.090	0.490	0.630	0.700	0.477	0.0031	0.0227
6	177.070	48.780	23.410	21.250	20.350	22.250			
			0.170	0.960	1.340	0.480	0.738	0.0049	0.0276
8	236.094	65.040	23.240	20.290	19.010	21.770			
			0.190	0.930	1.920	0.520	0.890	0.0059	0.0334
10	295.117	81.299	23.050	19.360	17.090	21.250			
			0.430	1.440	1.040	0.880	0.947	0.0062	0.0397
13	383.652	105.689	22.620	17.920	16.050	20.370			
			0.000	1.470	0.030	1.020	0.630	0.0041	0.0438
16.91	499.043	137.477	22.620	16.450	16.020	19.350			

A). Shape Factor of Pad-S L*B/(2*t*1.4*(L+B)) 6.00

B). Max. Test Load Applied (Fz test = 5.G..S.A/1.5) = 4895243.19 N = 16.91 Mpa

C). 30% of Max. Test Load Applied (Fz1) = 1468572.96 N = 5.07 Mpa

D). Vertical Deflection at Max. Test Load (Vz2) = 6.6575 mm

E). Vertical Deflection at 30% Max. Test Load (Vz1) = 2.975 mm

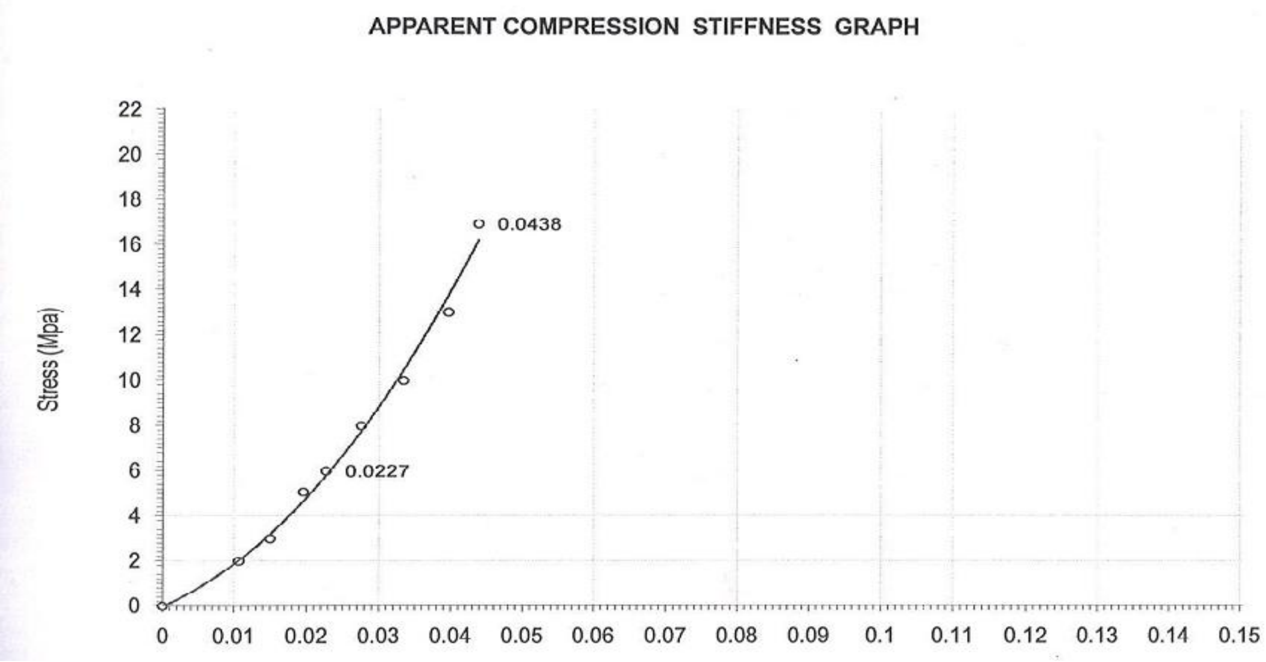
F). Diff. In Test Load from 100% to 30 %(F = Fz – Fz1) = 3426670.23 N = 11.84 Mpa

G). Defl. B/w from 100% to 30 %(V = (Vz2 – Vz1)/2) = 1.8413 mm

H). Apparent Compression Stiffness (Ea = F/V) = **1861.056 KN/mm**

Result

Ea – Permissible limits = 1457.952 to 2186.928 KN/mm



CONCLUSION

As a result of this study the conclusion have been made is that The development of a Metro line as the alignment crosses mainly dense urban areas, the design has to tried to minimize surface occupation as much as possible. This has led to the use of large diameter tunnels able to accommodate both tracks and platforms inside the same underground opening. In case of elastomeric bearings as the span length increases, responses parameter stresses at the top and bottom show variation according to the increases in span length for that particular span length the size and thickness of elastomeric bearings also changes. A comprehensive system of site monitoring for topographical, geotechnical and structural control has been implemented as an integrated past of the project.

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