SEISMIC ANALYSIS OF ELEVATED METRO BRIDGE

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ABSTRACT

A metro system is a railway transport system in an urban area with a high capacity, frequency and the grade separation from other traffic. Metro System is used in cities, agglomerations, and metropolitan areas to transport large numbers of people. An elevated metro system is more preferred type of metro system due to ease of construction and also it makes urban areas more accessible without any construction difficulty. An elevated metro system has two major elements pier and girder. The present study focuses on two major elements, Double Decker pier, of an elevated metro structural system. Which is located to ShyamNager metro station in Mumbai, Conventionally the Double Decker pier of a metro bridge is designed using a force based approach? During a seismic loading, the behavior of a Double Decker pier elevated bridge relies mostly on the ductility and the displacement capacity. It is important to check the ductility of such single piers. Force based methods do not explicitly check the displacement capacity during the design. The codes are now moving towards a performance-based (displacement-based) design approach, which consider the design as per the target performances at the design stage. Performance of a pier designed by a Direct Displacement Based Design is compared with that of a force-based designed one. The design of the pier is done by both force based seismic design method and direct displacement based seismic design method in the first part of the study.

***Keyword : -** , Elevated Metro Structure, Bridge Pier, Direct Displacement Based Seismic Design, Performance Based Design, Force Based Design, Staad prov8i.*

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1. INTRODUCTION

This paper conducts investigation at determining the Strength of the reinforced concrete bridge designed as per the current seismic provisions of the Indian codes for bridge design in zone-3,Ussing code namely the IRC: 6-2011, IRC: 21–2010 and IRC: 78-2012. In this paper multi span RCC metro bridges with simply supported at ends are modeled and analyzed using IRC Class AA loading and structural response parameters such as Bending Moment, shear and deflection are obtained to obtain the serviceability. Bridges are first analyzed, the bending moment and shear force distribution are calculated due to the applied loads. For this, the finite element method Further, seismic analysis if the bridge structure is performed on structural analysis software Staad pro v8i.

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Seismic analysis of Double Decker pier as per strength based method and performance based method. The force based design (FBD) and Direct displacement based design (DDBD)method both analysis for single degree of freedom structure as per IRS {15,16}, IS 1893 (part1):2002 and RDSO guideline {13} The both method are comparative study of different configuration. A typical Elevated Double Decker pier model show in fig 1.1.

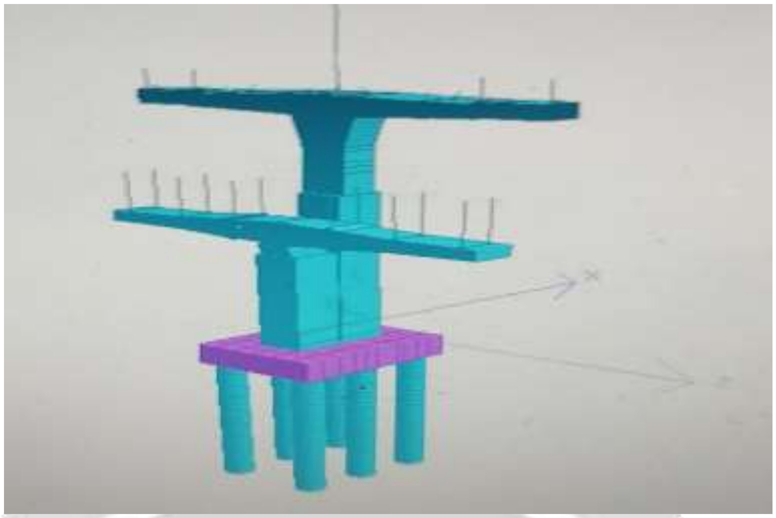

Fig 1 :- Double Decker pier model

1.1 Objective

- To study the performance of a double decker pier designed by force based design method and direct displacement based design method.
- Seismic analysis of double Decker pier metro bridge for zone-3.
- To find the results Displacement, Bending moment and shear force by finite aliment method to double Decker pier are calculated due to the applied loads.

1.2 Scope

- The present study is limited to these practical case the come cross in an Double Decker pier metro bridge projects.
- With regard to the geometry of the pier considered the present study is limited to.
- Rectangular pier cross section.
- Double pier structural system.
- Reinforcement concrete pier

2. DESIGN OF PIER

Conventionally the pier of a metro bridge is designed using a force based approach. Recent studies (Priestley et al., 2007) show that the force based design may not necessarily guarantee the required target performances. The codes are now moving towards a performance-based design approach, which consider the design as per the target performances at the design stage. As the present study focus on the application of displacement based approaches to pier design, a brief introduction of the two methods, force-based and displacement based design is summarized in the following sections.

2.1 Force Based Design Method

Force Based Design Method (FBD) is the conventional method to design the metro bridge pier. In Force based design method, the fundamental time period of the structure is estimated from member elastic stiffness's, which is estimated based on the assumed geometry of the section. The appropriate force reduction factor (R) corresponding to the assessed ductility capacity of the structural system and material is selected in the force based design and applied to the base shear of the structure. The design of a pier by force based seismic design method is carried out as per IS 1893: 2002 Code. The design procedure to find the base shear of the pier by FBD method is summarized below.

Step 1: Study on structural geometry of the pier .

Step 2: Member elastic stiffness are estimated based on member size.

Step 3: The fundamental period is calculated by:

$$T = 0.075\, h^{0.75}$$

Where h = Height of Building, in m

Step 4: Seismic Weight of the building (W) is estimated.

Step 5: The design horizontal seismic coefficient Ah for a structure determined by

$$Ah = Z * I * Sa/2*R*g$$

Where,
Z = Zone factor
I = Importance factor
R = Response reduction factor,
Sa/g = Average response acceleration coefficient
Z, I, R and Sa/g are calculated as per IS 1893:2002 Code.

Step 6: The total design lateral force or design seismic base shear force (VB) along any principal direction is given by

$$VB = Ah\, W$$

Where
Ah = Design Horizontal Seismic Coefficient
W= Seismic Weight of the Building

2.2 Direct Displacement Based Design Method

The direct displacement based seismic design (DDBD) is proposed by Priestley et al. (2007) is used in the present study to design a metro bridge pier. The design philosophy of DDBD is based on the determination of the optimum structural strength to achieve a given performance limit state, related to a defined level of damage, under a specified level of seismic intensity., Priestley et al. (2007). The pier designed by DDBD method gives the uniform risk factor for the whole structure.

The design procedure to find the base shear of the pier by DDBD method is summarized below.

Step 1: Yield Curvature is calculated by

$$\Phi y = (2.10 * \varepsilon y)/hc$$

Where,
εy is the yield strain and
hc is the section depth of rectangular column

Step 2: Yield Displacement is calculated by

$$\Delta y = \Phi y\, (H + Lsp)\, 2 / 3$$

Where,
H is the Column Height
Lsp is the Effective additional height representing strain penetration effect
Step 3: Design Displacement is lesser of

$$\Delta d = \theta d * H \text{ or } \mu * \Delta y$$

The ductility at design displacement is, $\mu = \Delta d / \Delta y$
Where,
θd = Drift limit

Step 4: Equivalent viscous damping $\xi eq = 0.05 + 0.444(\mu - 1/ \mu\, \pi)$
Step 5: Maximum spectral displacement is calculated from Design Displacement Spectra given in Priestley et al. (2007). Step 6: Design Strength/Base Shear is given by VB = Ke Δd Where, Ke = Effective Stiffness at peak response Te = Effective response period of pier ξ = Damping c,nΔ = Displacement at the corner period for n % damping.

3. PERFORM STUDY OF A DOUBLE DECKER PIER

The present study is based on the design basis report of the Mumbai Metro Rail Corporation (MMRC) Limited Performance study displacement of the pier designed by a Force Based Design (FBD) Method and Direct

Displacement Based Design (DDBD) Method is described in this chapter. Performance assessment is carried out for the designed pier and the results are discussed briefly The geometry of pier is located in Mumbai Shyam nager metro station structure and The piers are located in Seismic Zone III, as per IS 1893 (Part 1): 2002. The modeling and seismic analysis is carried out using the finite element software STAAD Pro. The typical pier models considered for the present study are shown in figure 3.1.

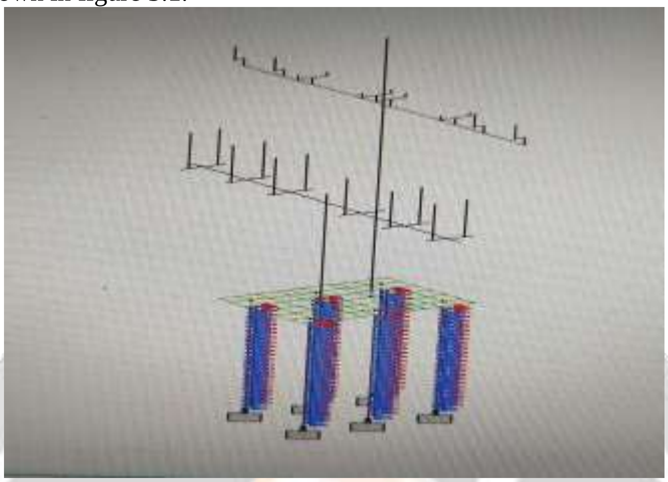

Fig -2:-Double Decker pier model by Staad pro v8i software.

3.1 Material property

The material property considered for the present pier analysis for concrete and reinforcement steel are given in Table 1.

Table 1: Material Property for

Pier Properties of Concrete Compressive Strength of Concrete	= 60 N/mm2
Density of Reinforced Concrete	= 24 kN/m3
Elastic Modulus of Concrete	= 36000 N/mm2
Poisson's Ratio	= 0.15
Thermal Expansion Coefficient	= 1.17 x 10 -5 / 0C
Properties of Reinforcing Steel Yield Strength of Steel	= 500 N/mm2
Young's Modulus of Steel	= 205,000 N/mm2
Density of Steel	= 78.5 kN/m3
Poisson's Ratio	= 0.30
Thermal Expansion Coefficient	= 1.2 x 10 -5 / 0C

3.2. Design Load

The elementary design load considered for the analysis are Dead Loads (DL), Super Imposed Loads (SIDL), Imposed Loads (LL), Earthquake Loads (EQ), Wind Loads (WL), Derailment Load (DRL), Construction & Erection Loads (EL), Temperature Loads (OT) and Surcharge Loads (Traffic, building etc.) (SR). The approximate loads considered as per MMRC DBR report for the analysis are shown in Table 2. The total seismic weight of the pier is

Table 2: Approximate design load case

Load from platform level	Load	Load from track level	Load
Self weight	120kN	Self weight	160KN
Slab weight		Slab weight	100KN
Roof weight		Total dl	260KN
Total dl		SIDL	110KN
SIDL		Train load	190KN
Crowd load		Breaking +Tractive load	29KN

LL on roof		Long welded rail forces	58KN
Total ll		Bearing load	20KN
Roof wind load		Temperature load	
Lateral		For track girder	20KN
Bearing load		Platform girder	14KN
		Derailment load	80 kN/m

The force based design is carried out for Pier as per IS 1893:2002 and IRS CBC 1997 Code and the results are shown in Table 2. From the FBD, it is found out that the minimum required cross section of the pier is only 2m X2.2m m for 0.8 % reinforcement.

Table 3.2: Approximate design load case

Pier type	Cross section (m)	Dia. Of bar (mm)	Number of bar	Required	Provided by MMRC
Flyover pier	2 x 2.2	32	36	0.8%	1.48 %
Viaduct pier top level	2 x 2.2	32	38	0.8%	1.48%

3.3 Performance Assessment result

The performance assessment is done to study the performance of seismic analysis is conducted for the designed pier using Saad pro v8i Software Performance parameters Displacement, max shear force max banding moment, behavior are found for both x and z directions and the results are shown in fig 3.3.1 and 3.3.2

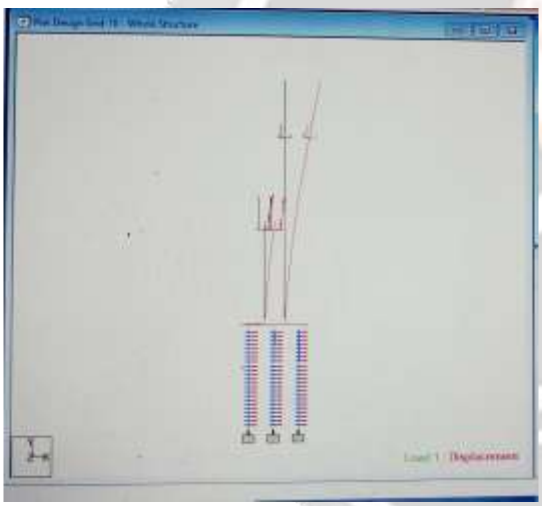

Fig3.3.1: Performance displacement by Staad pro

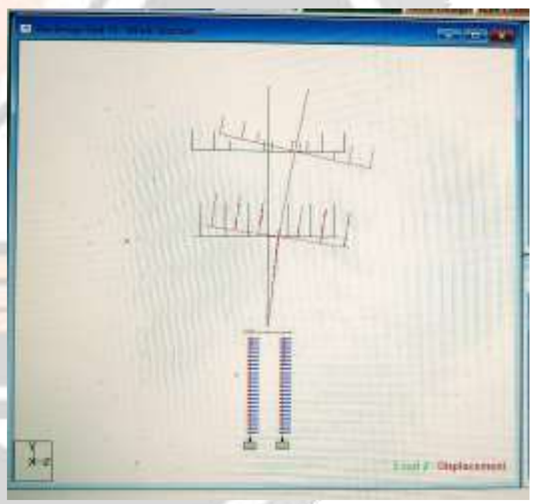

Fig3.3.2: Performance displacement by Staad pro

Table 3.3: Displacement result of double Decker pier

			Horizontal	**Vertical**	**Horizontal**	**Resultant**	**Rotational**		
	Node	**L/C**	**X mm**	**Y mm**	**Z mm**	**mm**	**rX rad**	**rY rad**	**rZ rad**
Max X	**11208**	**1 SLX**	**21.324**	**-0.121**	**0**	**21.324**	**0**	**0**	**-0.001**
Min X	**12341**	**2 SLZ**	**-0.64**	**-6.324**	**6.043**	**8.77**	**0.001**	**0**	**0**
Max Y	**5090**	**2 SLZ**	**0.18**	**9.697**	**16.316**	**18.98**	**0.001**	**0**	**0**
Min Y	**5102**	**2 SLZ**	**-0.18**	**-9.699**	**16.316**	**18.981**	**0.001**	**0**	**0**
Max Z	**11208**	**2 SLZ**	**0**	**0**	**24.147**	**24.147**	**0.001**	**0**	**0**
Min Z	**11272**	**1 SLX**	**5.791**	**-0.542**	**-0.078**	**5.817**	**0**	**0**	**-0.001**
Max rX	**9001**	**2 SLZ**	**0.178**	**9.551**	**18.702**	**21**	**0.001**	**0**	**0**
Min rX	**11526**	**1 SLX**	**0.51**	**0.337**	**0.001**	**0.611**	**0**	**0**	**0**
Max rY	**12341**	**1 SLX**	**5.847**	**0.116**	**0**	**5.848**	**0**	**0**	**-0.001**

Min rY	**11253**	**2 SLZ**	**0.585**	**5.755**	**6.123**	**8.423**	**0.001**	**0**	**0**
Max rZ	**11542**	**2 SLZ**	**0.021**	**-0.337**	**0.562**	**0.656**	**0**	**0**	**0**
Min rZ	**9001**	**1 SLX**	**16.431**	**0.331**	**-0.007**	**16.434**	**0**	**0**	**-0.001**
Max Rst	**11208**	**2 SLZ**	**0**	**0**	**24.147**	**24.147**	**0.001**	**0**	**0**

In this table view . horizontal and vertical direction displacement are given it is get result by staaad pro software .

4. CONCLUSIONS

- Force Based Design Method may not always guarantee the performance parameter required and in the present case the pier just achieved the target required.
- In case of find the seismic analysis of double decker perform in selected pier and achieved the behavior factors by software bases and result get.
- In this paper parametric study on behavior of double decker bridge pier of 29.4m hight and fly over pier height 12.29m with span 20m both side were analyzed using DDBD method as per RDSO:2015. It is observed that behavior of double decker pier seismic design loading for zone-III .
- As the span length increases, responses parameter longitudinal stresses at the top and bottom, shear, Displacement, torsion, moment and Deflection are increases .
- The conclusion can be considered only for selected pier. for generals conclusions large numbers of case studies are required as a scope in future work.

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