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Study of performance of a pier designed by Force Based Design & Direct Displacement Based Design

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Introduction : Performance study of the typical pier designed by a Force Based Design (FBD) Method and Direct Displacement Based Design (DDBD) Method is described in this paper . The pier is designed based on FBD and DDBD Method. Performance assessment is carried out for the designed pier and the results are discussed briefly.

Design of pier using force based design

The geometry of pier considered for the present study is based on the design basis report of the Bangalore Metro Rail Corporation (BMRC) Limited. The piers considered for the analysis are located in the elevated metro station structure. The effective height of the considered piers is 13.8 m. The piers are located in Seismic Zone II, as per IS 1893 (Part 1):

2002. The modelling 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 1.

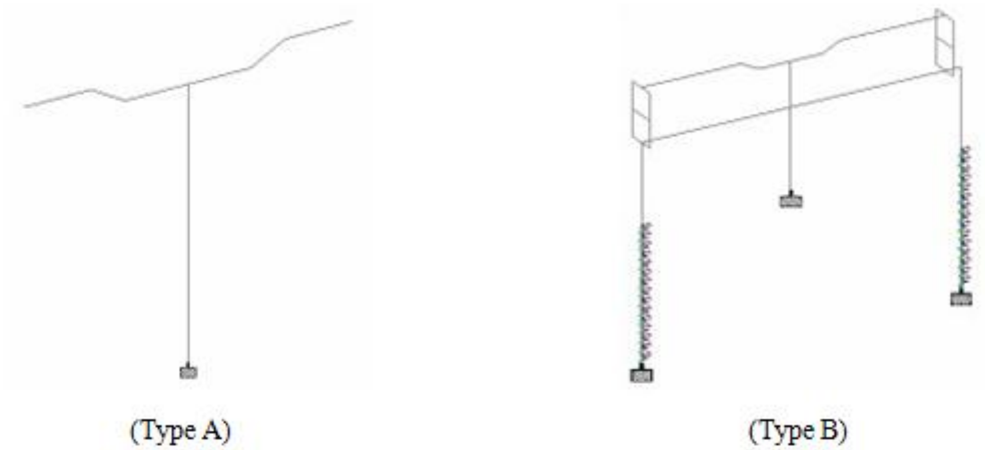

Figure 1: Typical Pier Model

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 for the analysis are shown in Table 1. The total seismic weight of the pier is 17862 kN.

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Table 1: Approximate design Load

Load from Platform Level	**Load**	**Load from Track Level**	**Load**
Self Weight	120 kN	Self Weight	160 kN
Slab Weight	85 kN	Slab Weight	100 kN
Roof Weight	125 kN	**Total DL**	260 kN
Total DL	330 kN	SIDL	110 kN
SIDL	155 kN	**Train Load**	190 kN
Crowd Load	80 kN	Braking + Tractive Load	29 kN
LL on Roof	160 kN	Long Welded Rail Forces	58 kN
Total LL	240 kN	Bearing Load	20 kN
Roof Wind Load	85 kN	**Temperature Load**	
Lateral	245 kN	For Track Girder	20 kN
Bearing Load	14 kN	For Platform Girder	14 kN
		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 1.5 m x 0.7 m for 2 % reinforcement. The base shear of the pier is 891 kN.

Table 2 : Reinforcement Details as per Force Based Design

Pier Type	**Cross Section (m)**	**Diameter of Bar (mm)**	**Number of Bars**	**% of Reinforcement**	
				Required	**Provided by BMRC**
Pier Type A	2.4 x 1.6	32	#32	0.8 %	1.48 %
Pier Type B	2.4 x 1.6	32	#38	0.8 %	1.48 %

Design of pier using direct displacement based design

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The direct displacement based seismic design method proposed by Priestley et al. (2007) and IRS CBC 1997 Code is used to design of Pier Type B and the results are shown in Table 3. The performance level considered for the study is a Life Safety (LS) level.

Table 3 Reinforcement Details as per Direct Displacement Based Seismic Design

Displacement Drift Ductility Limit (m)		Cross Section (m)	Base Shear V_b (kN)	Diameter of Bar (mm)	Number of Bars	% of Reinforcement Required
1	0.276	1.5 x 0.7	604	32	#16	1.2 %
2	0.276	1.5 x 0.7	150	32	#12	0.8 %
3	0.276	1.5 x 0.7	86	32	#12	0.8 %
4	0.276	1.5 x 0.7	60	32	#12	0.8 %

The parametric study is carried to know the effect of displacement ductility on base shear for different Performance levels and the results are shown in Figure . The figure shows that as the displacement ductility level increases the base shear of the pier decreases and also the difference between different performance levels is about 40 %.

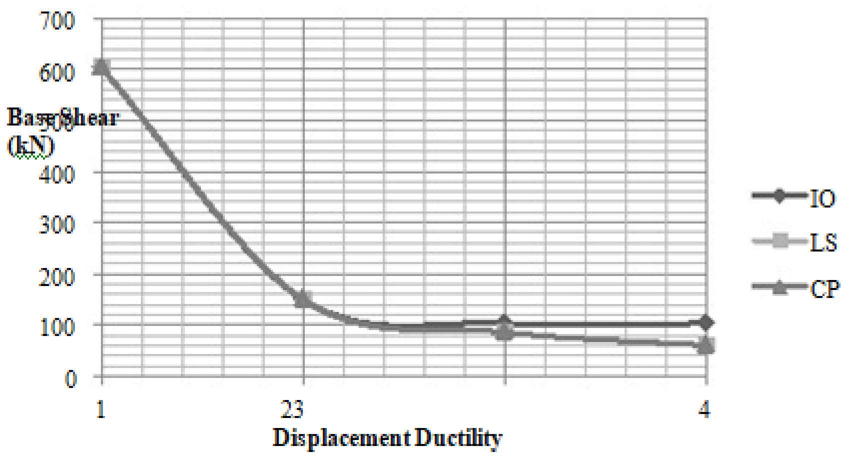

Figure : Effect of displacement ductility on base shear for different Performance levels

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Performance Assessment

The performance assessment is done to study the performance of designed pier by Force Based Design Method and Direct Displacement Based Design Method. For this purpose, Non-linear static analysis is conducted for the designed pier using SeismoStruct Software and the results are shown in Table The section considered is 1.5 m x 0.7 m. Performance parameters behaviour factor (R´), structure ductility (μ') and maximum structural drift (Δ'max) are found for both the cases.

The behaviour factor (R´) is the ratio of the strength required to maintain the structure elastic to the inelastic design strength of the structure. The behaviour factor, R´, therefore accounts for the inherent ductility, over the strength of a structure and difference in the level of stresses considered in its design. FEMA 273 (1997), IBC (2003) suggests the R factor in force-based seismic design procedures. It is generally expressed in the following form taking into account the above three components,

Table : Performance Assessment of designed Pier

Designed			Type of design	V_b (kN)	% of Steel	Φ (mm)	No. of Bars	Performance Parameters Achieved		
μ	Δ	R						μ	Δ	R
		2.5	FBD	891	2%	32	#28			2.74
1	0.276		DBD	604	1.2 %	32	#16	3.5	0.35	3.25
2	0.276		DBD	150	0.8 %	32	#12	3.4	0.34	11.63

Conclusion :

In this paper the performance study on designed pier by FBD and DDBD is carried out. The design of the pier is done by both forced based design method and direct displacement based design method. The parametric study showed that the effect of displacement ductility on base shear for different Performance levels. The performance assessment of selected designed pier showed that, FBD Method may not always guarantee the performance parameter required and in the present case the pier just achieved the target requirement. In case of DDBD method, selected pier achieved the behaviour factors more than targeted Values. These conclusions can be considered only for the selected pier.

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