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Dynamic Response of Steel Structure with Bracings and Pendulum Tuned Mass Dampers

Naveena K N*, Chethan K**
*(PG Student, M. Tech in Earthquake Engineering, Dept of Civil Engg, UVCE, Bangalore University,)
** (Associate Professor, Dept of Civil Engg, UVCE, Bangalore University,)

ABSTRACT
In this work the Dynamic response of Steel Structure with Bracings and Pendulum Tuned mass damper (PTMD) are studied. Bracings are added to the structure to provide additional stiffness and strength. PTMD is a device that consists of a mass which is connected to the structure by means of a spring and a damper. The mass is tuned to vibrate at the different frequency as the structure, which allows it to cancel out the vibrations of the structure.
G+5, G+15 and G+25 Storeyed steel structure models with the different combinations of Bracings and PTMD are considered in this study. Following which the FE Analysis involving the Modal, Equivalent static and Response spectrum analyses are performed and results are obtained in terms of Time period, Base Shear, storey displacement and Storey drift.

***Keywords* -** Modal Analysis, Equivalent Static Analysis, Response Spectrum, Time Period, Displacement.

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I. Introduction

Earthquakes induce complicated ground vibrations that are converted into dynamic loads which damage buildings and other structures by causing the ground and everything linked to it to oscillate. Steel structures perform differently during earthquakes and their behavior changes from being elastic to being inelastic in nature. Steel constructions' strength and stiffness are maintained by releasing a significant amount of energy during seismic effects. Moment resistant frames along with bracing systems efficiently improve the structure's rigidity. However, these systems limit the flexibility of the structure. Tuned mass damper is a device which is used to reduce the acceleration of building during earthquake. The tuned mass damper is one type of energy dissipation method in which earthquake energy was dissipated with the help of counter sway of Tuned mass. TMD is also known as a Harmonic absorber or seismic damper. It is mounted on the top storey of building to reduce the displacement of the building.

II. Objective of the project

i. To study the Dynamic Response of Steel Structure with Bracings and Pendulum Tuned Mass Dampers
ii. To design the Pendulum Tuned Mass Dampers.
iii. FE Analysis involving Modal, Equivalent Static and Response Spectrum Analyses to be performed on steel structure with different bracing systems and Pendulum Tuned mass dampers.

III. Methodology

i. Three types of Bracings consider for the study are namely X, V and Inverted V bracings.
ii. The Design of Pendulum tuned mass damper are carried out as per procedure adopted in Connor J and Laflamme S. (2014).
iii. FE Analyses performed on G+5, G+15, G+25 Storey steel structure with three different types of bracings and Pendulum tuned mass damper to obtain Time period, Base shear, Storey displacement and Storey drift.

IV. Modelling

The Nomenclature and description of the G+5, G+15, G+25 Storey steel structure modelling has been tabulated in Table 1. All the models are having been analyses by using Etabs software.

Table 1: Nomenclature of the Models

Models	**Nomenclatur**
G+5 Storey steel structure	
Bare frame	BF5
Bare frame + X-Bracing	X5
Bare frame + V-Bracing	V5
Bare frame +Inverted V-Bracing	IV5
Bare frame +Pendulum TMD	PD5
Bare frame + Pendulum TMD + X-Bracing	PDX5
Bare frame + Pendulum TMD + V-Bracing	PDV5
Bare frame + Pendulum TMD + Inverted V-Bracing	PDIV5
G+15 Storey steel structure	
Bare frame	BF15
Bare frame + X-Bracing	X15
Bare frame + V-Bracing	V15
Bare frame +Inverted V-Bracing	IV15
Bare frame +Pendulum TMD	PD15
Bare frame + Pendulum TMD + X-Bracing	PDX15
Bare frame + Pendulum TMD + V-Bracing	PDV15
Bare frame + Pendulum TMD+ Inverted V-Bracing	PDIV15
G+25 Storey steel structure	
Bare frame	BF25
Bare frame + X-Bracing	X25
Bare frame + V-Bracing	V25
Bare frame +Inverted V-Bracing	IV25
Bare frame +Pendulum TMD	PD25
Bare frame + Pendulum TMD + X-Bracing	PDX25
Bare frame + Pendulum TMD + V-Bracing	PDV25
Bare frame + Pendulum TMD+ Inverted V-Bracing	PDIV25

The Plan of Bare frame model are created in software as shown in figure 1.

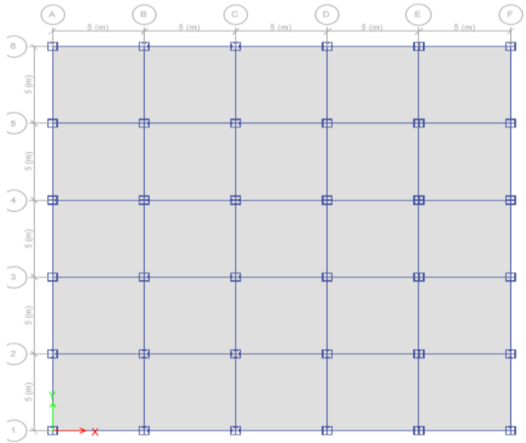
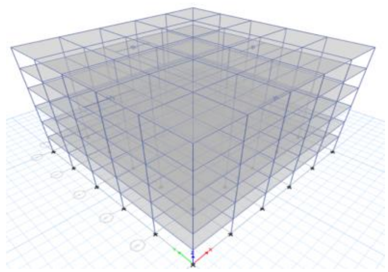
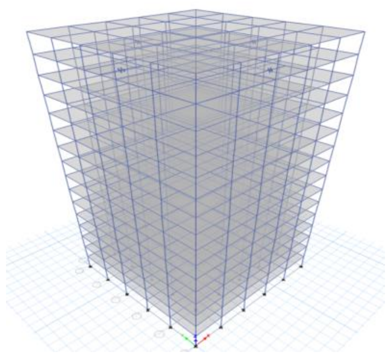


Figure 1: Plan of BF5, 15, 25

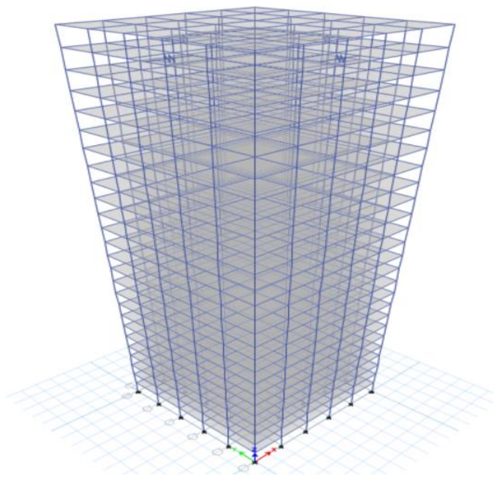
The 3D View of Bare frame model are created in software as shown in figure 2.



G+5Storey



G+15 Storey



G+25 Storey

Figure 2: 3D View of Bare Frame model (BF)

The structural configuration is FE modal creation using data are have been tabulated in table 2.

Table 2: structural configuration

Description	**Data**
Number of storeys	G+5, G+15, G+25
Seismic Zone	V
Seismic Zone Factor (Z)	0.36
Importance Factor (I)	1.5
Response Reduction Factor (R)	4.0
Damping Ratio	0.05
Soil Type	Medium Soil (Type II)
Span Length	5m
Column Size used	ISMB600@122.6 Kg/m
Beam Size used	ISMB500@86.9 Kg/m
Thickness of Slab	125mm
Floor Finish Load	1.5KN/m²
Live Load	3KN/m²
Story to story Height	3.0m
Bottom story Height	3.0m
Grade of Concrete (f_{ck})	M25
Grade of Structural Steel (f_{ys})	Fe345
Grade of Reinforcing Steel (f_{yr})	Fe 500
Load Combination	1.5 (DL+LL) 1.2 (DL+LL $\pm$ EQ) 0.9DL $\pm$ 1.5EQ

V. Results and discussions

Time period:

Modal analyses Time Period are plotted in Figure 3

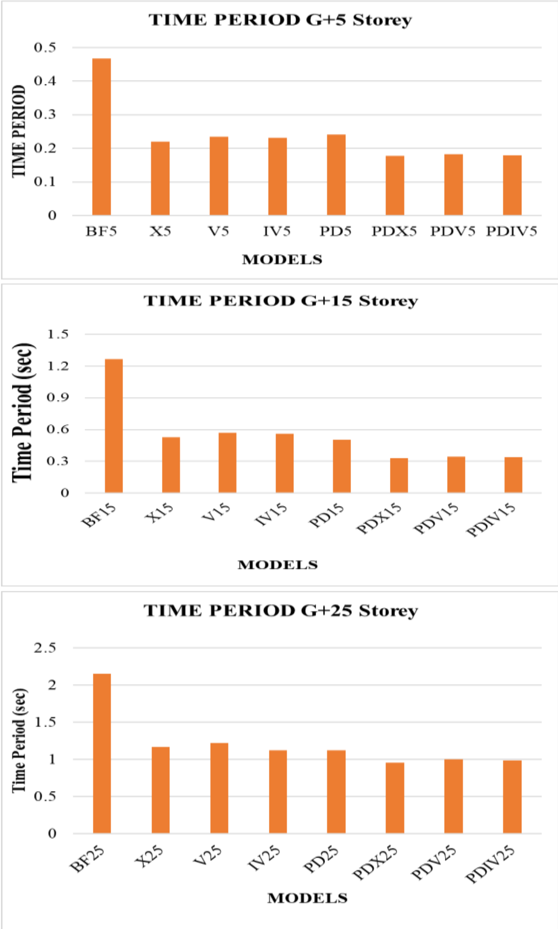


Figure 3: Time period

i. The Time Period increases as the height of structure increases due to an increase in mass for all the models.
ii. The Time Period is lowest in X-Bracings followed by IV-Bracings and V-Bracings for all the floor height due to the increase in stiffness by X-Bracings.
iii. Excluding the Bare frame condition PDX is having the lowest Time Period due to the increase in stiffness by PDX and V-Bracing is having the highest Time Period for all the floor height due to the less stiffness in V-Bracing, when compare with all the models.

Dynamic base shear:

The base shear obtained from Response spectrum analysis are plotted in Figure 4,

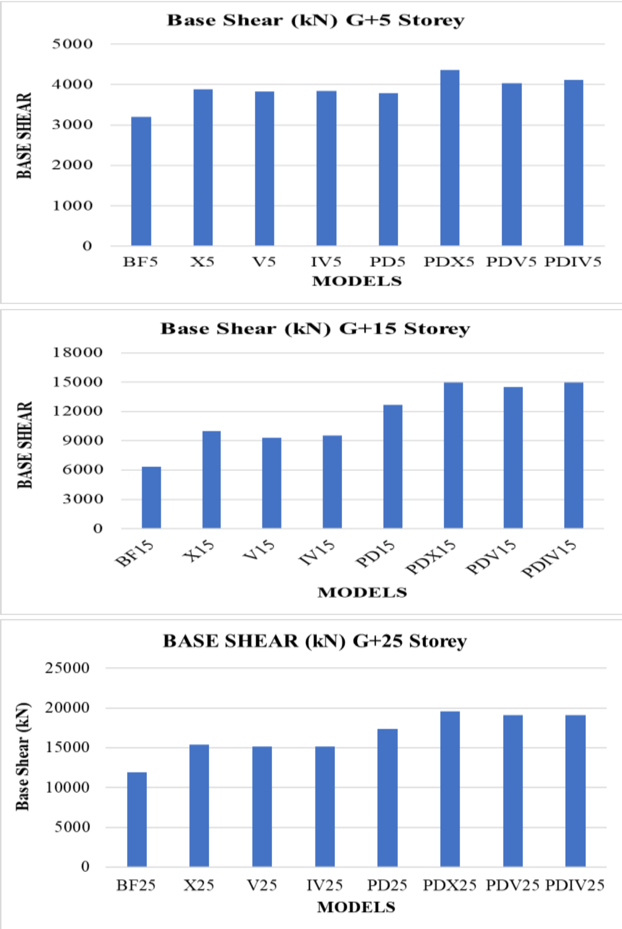


Figure 4: Dynamic base shear

i. As height of the structure increases, Base Shear increases due to increase in self-weight of the structure for all the models.
ii. The Base Shear is highest in X-Bracings followed by IV-Bracings and V-Bracings for all the floor height due to the increase in stiffness by X-Bracings.
iii. Excluding the Bare frame condition PDX is having the highest Base Shear due to the increase in stiffness by PDX and V-Bracing is having the least Base Shear for all the floor height due to the lower stiffness in V-Bracing, when compare with all the models.

Storey displacement:

Maximum storey displacement is plotted in Figure 5

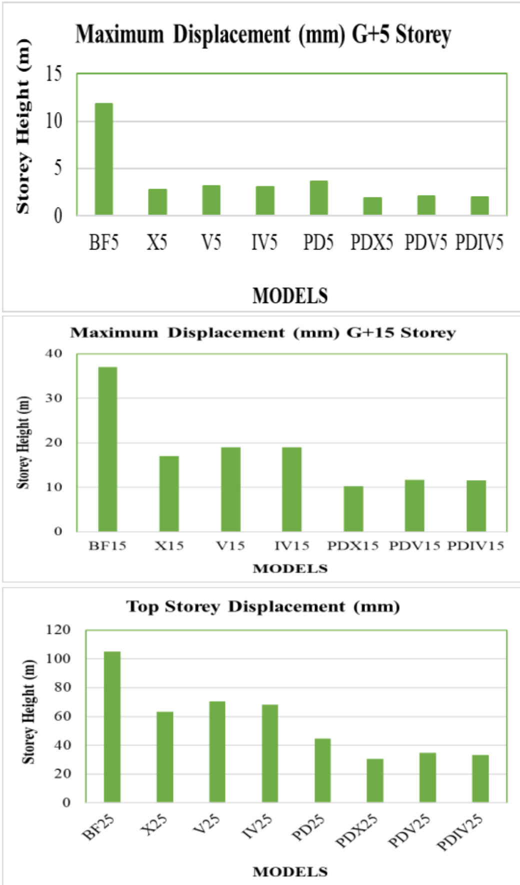


Figure 5: Maximum Storey Displacement

i. The Displacement is lowest in X-Bracings followed by IV-Bracings and V-Bracings for all the floor height due to the increase in stiffness by X-Bracings.
ii. Excluding the Bare frame condition PDX is having the lowest Displacement due to the increase in stiffness by PDX and V-Bracing is having the highest Displacement for all the floor height due to the lower stiffness in V-Bracing, when compare with all the models.

Storey drift:

Maximum storey drift is plotted in Figure 6

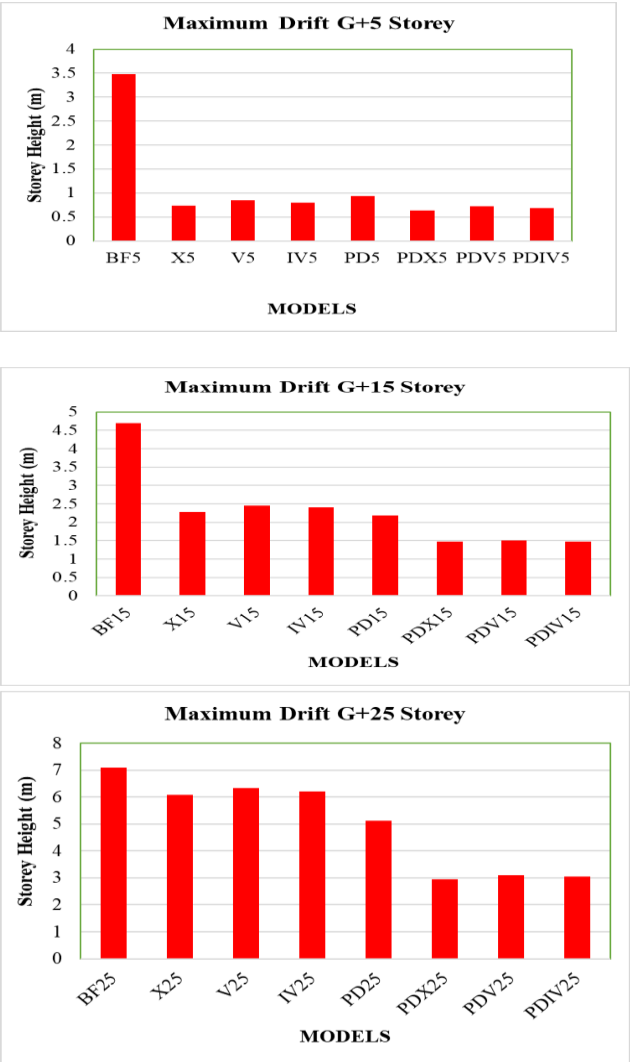


Figure 6: Maximum Storey Drift

i. The Drift is lowest in X-Bracings followed by IV-Bracings and V-Bracings for all the floor height due to the increase in stiffness by X-Bracings.

ii. Excluding the Bare frame condition PDX is having the lowest Drift due to the increase in stiffness by PDX and V-Bracing is having the highest Drift for all the floor height due to the lower stiffness in V-Bracing, when compare with all the models.

VI. CONCLUSION

Bare frame Steel Structure with PTMD and X-Bracing is having the highest Base shear and lowest Time period, Displacement and Drift due to the increase in stiffness whereas same structure with V-Bracing is having the lowest Base shear and highest Time period, Displacement and Drift due to lower stiffness when compared with all the models.

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