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Seismic Analysis of Industrial Structure Using Bracings and Dampers

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Abstract: Resistance of structures against earthquake plays an extensive role in construction industry. A structure should consist of strength, stability and ductility to accommodate both horizontal and vertical loadings. Horizontal loading leads to the production of sway and further results in vibration and storey drift. Strength and stiffness are two major keys for any structure to resist gravity and lateral loads. Provision of bracings or dampers to any structure contributes to lateral stability. After assigning dampers or bracings, the general system changes to lateral load resisting system (LLRS). However, this involves high economy, it is only suitable for high rise, important buildings which are suspected to be affected by lateral load and structures damaged by lateral load. The present work involves in proposing the suitability of type of damper or bracing for controlling the seismic activity on industrial structures in respective seismic zones III and V of India. Industrial structures also associate high dead load as it provides residence to heavy sized members. Therefore, this is necessary to investigate seismic response of buildings with various bracings and dampers to control vibration, lateral displacement and storey drift. Natural time period, frequency, roof displacements are the major parameters considered for observing response of structures. Response spectrum analysis of 3D industrial structure with distinct concentric bracings and dampers using SAP 2000 and ETABS is carryout in this research under respective base shear.

Index Terms: bracings, dampers, horizontal load, lateral displacement, response spectrum analysis, storey drift.

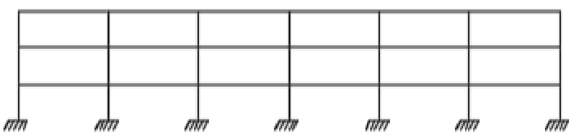
I. INTRODUCTION

Steel moment resisting frames are susceptible to undergo lateral displacement during earthquake. Horizontal (seismic/wind) load is the unreliable load that is coming on the structure. Any structure should be designed in such a way that, it should resist from both gravity and lateral loads. Gravity loads includes dead load, live load, dust load etc. Whereas lateral load includes seismic load, wind load and blast load. Due to this lateral loads, high stresses are produced which then leads to sway or vibration. So, every structure should contain strength to resist vertical (gravity) loads and stiffness to resist (horizontal). The present experimental investigation involves the analytical investigation of a Pre-Engineered building.

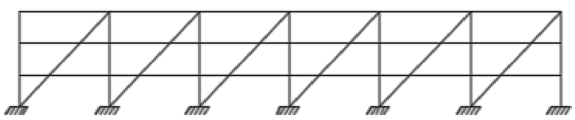
Horizontal or lateral loading results in production of storey drift, overturning moment, storey displacement etc., which are responsible for failure of the structure. To inhibit these responses bracings and dampers are used for high-rise and important structures. Structures with bracings, dampers show better performance in reducing structural parameters (stress ratio) and systematic parameters (time period, base shear, lateral displacement). Dampers are more economical than bracings [1]. Aspect ratio plays a vital role in performance of structure. As aspect ratio increases, there will be reduction in base shear carrying capacity and roof displacement of steel frame with aspect ratio 1 [2]. Arranged bracings to the structure should be of buckling resistant. Buckling restrained frames with special concentric bracings have effective performance than moment resisting and conventional frames [3].

Based on the arrangement of bracing, there are concentric and eccentric bracings. Concentric bracing system is effective in reducing storey displacement, storey drift, and base shear than without bracing system [4]. X-bracing avoids the instability and plastic hinging of floor beams [5] and reduces storey displacement, inter storey drift, time period effectively [6, 7]. Eccentrically braced frames provide a unique combination of stiffness, strength and ductility [8]. Compared to X-bracing system, inverted-V bracing reduces lateral displacement [9]. Steel frames with double Knee bracings have more lateral stiffness and shows effective behavior than eccentric bracings during earthquake [10]. Knee bracing system increases ductility of structure and is economical for corner arrangement [11].

Safety of structure from collapse is the essential objective of seismic resistant designs. Dampers are adopted for high-rise and important structures to resist from wind load and seismic load and to reduce sway. Stresses and displacement reduce significantly by placing visco-elastic dampers [12]. Placing of supplementary dampers for seismic isolation is misplaced attempt as it increases the inter storey drifts and floor acceleration in super structure [13]. Tuned Mass Damper (TMD) in high-rise structure do not contribute in decreasing the lateral force at base of the structure and are not effective in reducing the seismic response [14].Basic Structural Configurations being studied have been shown in Fig. 1.



1a) Pre-Engineered Building



1b) Diagonal bracing

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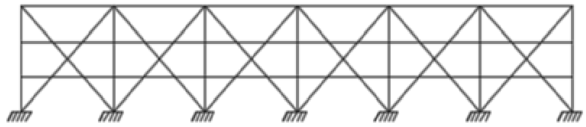
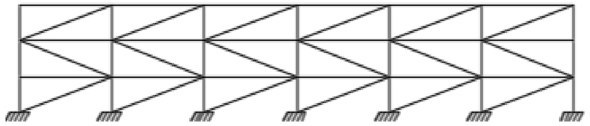
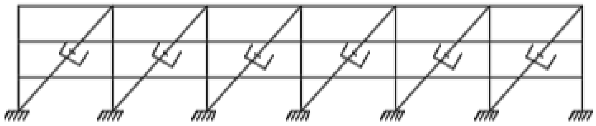


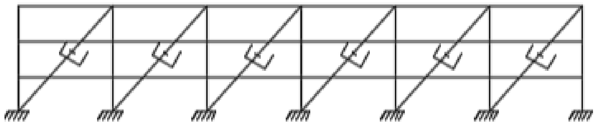
1c) X-bracing



1d) Knee-bracing



1e) Friction damper



1f) Material damper

Fig. 1: Basic structural configurations being studied

II. RESESARCH SIGNIFICANCE

The objective of this present study to suggest the suitability of type bracing or damper for seismic zones III and V of India for controlling the seismic activity on industrial structures. Dead load, live load, wind load, earthquake load is considered while designing the building. Design of building and load considerations are done based on the IS codes which are represented in Table II and Table III. Pre-Engineered building is subjected to earthquake load and wind load is analyzed with different types of bracings and dampers through response spectrum analysis for this study.

III. RESPONSE SPECTRUM ANALYSIS

Response spectrum analysis is a linear dynamic analysis method. This method is used for obtaining peak response of structure during the earthquake. Here the principle of superposition is not applicable because elastic analysis of structure is not directly transferable to inelastic analysis. In this approach numerous mode shapes are considered based on the model frequency and model mass.

IV. PRE-ENGINEERED BUILDINGS

Growing industries is a sign for developing a country. Rapid growth of steel industry is observed around the world. Large column free area is the basic specification of any industry. Pre-Engineered buildings came into existence from this concept. Pre-Engineered Buildings (PEB) are buildings whose structural components are predesigned and prefabricated. Structural components are designed using tapered sections based on the design calculations as per requirements. The basic concept of PEB was started developing since 1960. The idea behind this was, the section should be provided based on the bending moment diagram by varying length, which is known as non-prismatic sections. Along with tapered sections, hot-rolled sections and cold-formed sections, roofing sheets etc. are used. Using of tapered sections reduces the consumption of steel and construction cost. Also, PEB includes many advantages like flexibility to expansion, quality control, low maintenance, easy erection.

V. MODELLING

To evaluate seismic performance, structural analysis of mathematical model is recommended for finding the force and displacement demands of a structure. For predicting the seismic demands of a structure, elastic and inelastic analysis of a structure is required. In this present work a series of frames with bracings and dampers were designed for seismic zones III and V of India. The configuration of building and loading conditions are developed according to IS 800:2000 [17], IS 875:1987 (Part 1, 2, 3) [18, 19, 20] and IS 1893 (Part 1):2002 [21].

A Pre-Engineered building of 5.5m eave height is designed with plan dimensions of 15 × 30m. 5m bays are employed in Y-direction and a roof angle 10^0 is adopted. The braced bays and bays with dampers are placed throughout the perimeter. The columns are non-prismatic sections up to eave height. Details of PEB have been given in Table I. A total of 7 models with 3 different arrangements of bracings and 2 different dampers are analyzed using SAP2000 and ETABS and are as below:

1. Structural model without bracing and damper in Zone III.
2. Structural model without bracing and damper in Zone V.
3. Structural model with diagonal bracing in Zone V.
4. Structural model with X-bracing in Zone V.
5. Structural model with Knee bracing in Zone V.
6. Structural model with Friction damper in Zone V.
7. Structural model with material damper in Zone V.

Dynamic analysis of PEB using bracings and dampers under wind load and earthquake load is studied. The dampers mass ratio has been considered as 2%. The present work deals with the suitability of type of bracings or dampers for seismic zone V of India by linear dynamic analysis (Response Spectrum Analysis) of 3D industrial structures with different configurations of bracings and dampers using SAP2000 and ETABS.

Table I: Details of PEB

Plan	15 × 30m
Height of frame (upto eave)	5.5m
Roof angle	10^0
Grid spacing in x direction	7.5m
Grid spacing in y direction	5m
Yield strength of steel	Fe345

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Table II: Wind load details

Wind Coefficents	Values
Basic wind Speed	50 m/sec
Terrain category	3
Structural classes	C
Risk coefficient, k_1	1.08
Terrain, height and structural size factor, k_2	0.88
Topography factor, k_3	1
Design wind speed, V_z	47.52 m/sec
Design wind pressure, P_z	1.35 kN/m^2

Table III: Seismic Coefficients of PEB

Coefficents	Values
Importance factor, I	1.0
Reduction factor, R	5
Zone factor, Z	0.36 (for Zone v), 0.16 (for Zone III)

VI. RESULTS AND DISCUSSIONS

The forces and displacements obtained from the analysis are presented in the form of graphs below. The results itself indicates the behavior of PEB as a bare frame and with bracings and dampers under lateral loading. Here each model with specific type of bracing and damper is given a model number like: Zone III (I), Zone V (II), Diagonal bracing (III), X-bracing (IV), Knee-bracing (V), Friction damper (VI) and Material damper (VII). The variation in Time Period, Acceleration and Frequency is studied using SAP2000 and the behavior of storey like Storey Stiffness, Base Shear and Maximum Lateral Displacement is studied from ETABS. The detail variation in each parameter is as follows:

A. Time Period

The deviation in time period is considered for models with and without bracings and dampers for a PEB with fixed base and the deviation are as follows:

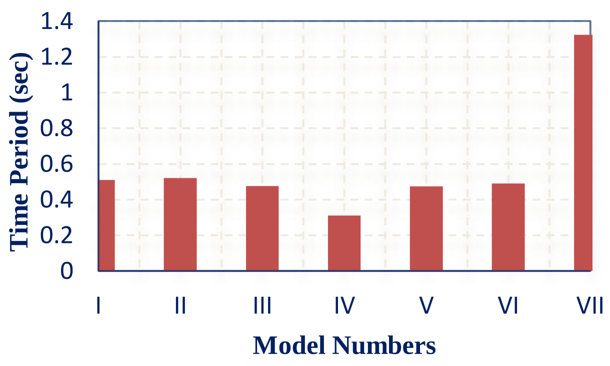

Fig. 2: Time Period variation for models with and without bracings and dampers

The Fig. 2 shows the variation of time period in each model. It observed from the analysis that model V i.e., Knee-bracing reduces the time period than other types of bracings and dampers.

B. Acceleration

Change in velocity per unit time is known as acceleration. Shaking of ground occurs during an earthquake, the earthquake wave passing through the ground possess some

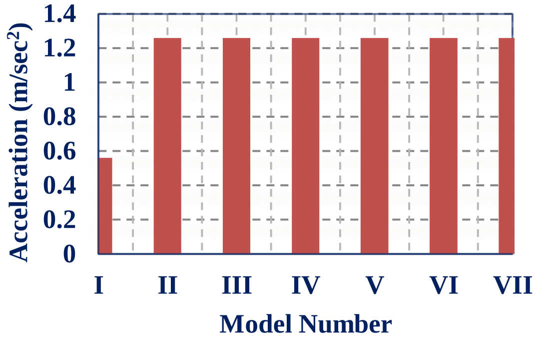

Fig. 3: Acceleration of different models before and after placing bracings and dampers

acceleration. A PEB with different bracings and dampers are analyzed using SAP2000 and ETABS inorder to findout the amount of acceleration based on the time period of structure. From Fig. 3 it is observed that the acceleration remains constant for models with and without dampers.

C. Frequency

Number of cycles of a particular earthquake wave occurs per unit time is known as frequency of an earthquake wave. Frequency is inversely proportional to time period.

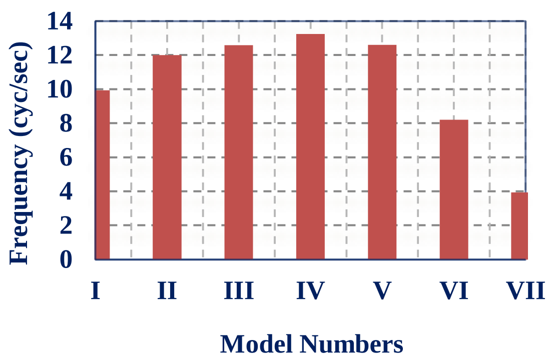

Fig. 4: Frequency of different models

Frequency increases with increase in time period and vice-versa. Since there is no change in acceleration, here the bracings and dampers in Zone V will not influence acceleration they are inversely proportional. The frequency of a model with X- bracing is high compared to other models.

D. Storey Stiffness

The ability of a member to resist against deformation under bending is known as member stiffness. Stiffness is one of the important parameters required for a member to restrict deformation under loading. Storey shear to storey drift ratio is defined as lateral stiffness.

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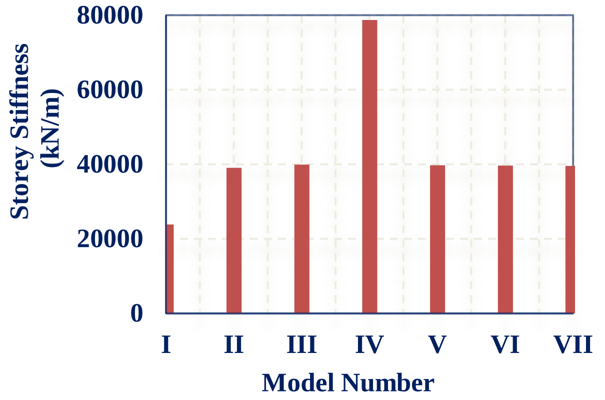

Fig. 5: Storey Stiffness of Structure

Storey stiffness indicates the resistance of a structure to restrict deformation. As stiffness increases, deformation of the structure decreases. From the below Fig. 5, it is shown that the stiffness of structure is varying depending on type of bracing and damper. Model IV i.e., X-bracing system is more resistant to deformation.

E. Base Shear

It is an expected maximum horizontal force that is going to act on the structures base due to ground motion. Spectral acceleration coefficient, zone factor, importance factor, reduction factor, weight of the structure and time period is the factors influencing base shear.

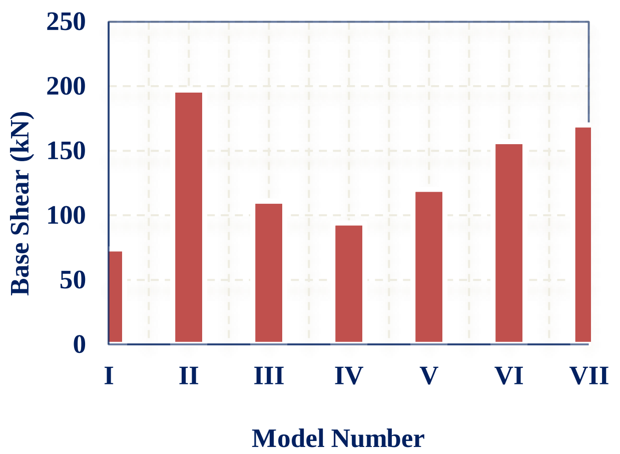

Fig. 6: Base shear of PEB models without and with bracings and dampers

The base shear values of without and with bracings and dampers PEB are presented in the graph above. The graph is expressing that base shear of X-bracing model less when compared to others. Therefore, X-bracing reduces the base shear coming on the structure.

VII. MAXIMUM LATERAL DISPLACEMENT

Maximum lateral displacement is the predicted maximum lateral deflection of each and every storey of a structure due to the action of horizontal loading.

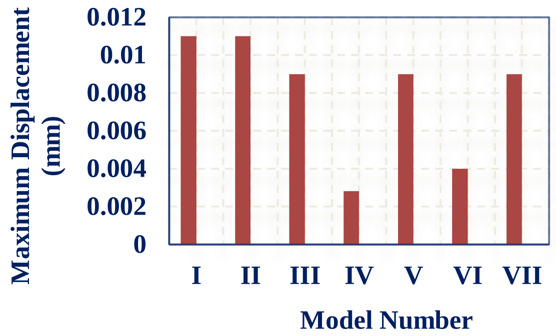

Fig. 7: Maximum lateral displacement of PEB without and with bracings and dampers

This can be restricted by placing a damper or bracing. Placed damper or bracing restricts the displacement of structure. Fig. 7 is obtained by after analyzing the PEB under response spectrum analysis. Here lateral displacement of the structure decreases after application of bracings and dampers. X-bracing reduces lateral displacement when compared to other types of bracings and dampers.

VIII. CONCLUSION

The present study is an attempt to understand the behavior of PEB in seismic zone III and V of India with different types of bracings and dampers. Structural parameters are reduced by using bracing to the models than dampers. X-bracing is more effective and economical for structure in seismic Zone V. The following are the conclusions drawn from present study:

1. As stiffness of structure increases, time period decreases.
2. While comparing bracing and damper, bracing reduces the time period.
3. Acceleration is inversely proportional to time period and as time period decreases, acceleration of structure increases.
4. Similar to acceleration, frequency also inversely proportional to time period.
5. X- Bracing system greatly influences the base shear of structure and reduces it.
6. Using of X-bracing greatly reduces the lateral displacement of the structure when compared to other bracings and dampers.
7. Also, dampers require regular maintenance for their effective behaviour.

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