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Experimental Study on Steel Frame Building with Steel Bracing by Seismic Analysis

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ABSTRACT

The study of braced steel frame response is widely studied in many branches of Structural engineering. Many researchers have been deeply studying these structures, over the years, mainly for their greater capacity of carrying external loads. Every Special moment resisting frames undergo lateral displacement because they are susceptible to large lateral loading. As a consequence, engineers have increasingly turned to braced steel frames as an economical means for earthquake resistant loads. The present study consist a Steel Moment Resisting Frame (SMRFs) with concentric bracing as per IS 800 - 2007. K bracing, Inverted V bracing, X bracing and an unbraced steel frame is considered for comparative study. Dimensions of each type of steel frame are similar having G+12 storey, 40 m height. Each floor is of 3m height and ground floor of 4 m height having four no. of bays along length (12m) and width (12m). The analysis is done by using standard package STADD pro. The comparison of these models for different parameters like Shear force, Bending Moment, Displacement, Storey drift and Lateral Forces has been presented by adding different types of bracings. Performance of each frame is studied through Equivalent static analysis.

INTRODUCTION

Seismic analysis is a subset of structural analysis and is the calculation of the response of a building structure to earthquakes. It is part of the process of structural design, earthquake engineering or structural assessment and retrofit (see structural engineering) in regions where earthquakes are prevalent. As seen in the figure, a building has the potential to 'wave' back and forth during an earthquake (or even a severe wind storm). This is called the 'fundamental mode', and is the lowest frequency of building response. Most buildings, however, have higher modes of response, which are uniquely activated during earthquakes. The figure just shows the second mode, but there are higher 'shimmy' (abnormal vibration) modes. Nevertheless, the first and second modes tend to cause the most damage in most cases.

The earliest provisions for seismic resistance were the requirement to design for a lateral force equal to a proportion of the building weight (applied at each floor level). This approach was adopted in the appendix of the 1927 Uniform Building Code (UBC), which was used on the west coast of the United States. It later became clear that the dynamic properties of the structure affected the loads generated during an earthquake. In the Los Angeles County Building Code of 1943 a provision to vary the load based on the number of floor levels was adopted (based on research carried out at Caltech in collaboration with Stanford University and the U.S. Coast and Geodetic Survey, which started in 1937). The concept of "response spectra" was developed in the 1930s, but it wasn't until 1952 that a joint committee of the San Francisco Section of the ASCE and the Structural Engineers Association of Northern California (SEAONC) proposed using the building period (the inverse of the frequency) to determine lateral forces.

Objectives of the Study

Following are the main objective of the present study:

To investigate the seismic performance of a multi-story steel frame building When unbraced and then with different bracing arrangement such as cross bracing X and K bracing, Inverted V bracing using Equivalent Static analysis, To study the seismic effects of earthquake forces on buildings under different earthquake loading and loading combinations.

To compare different response quantities such as axial force, shear force, bending moment etc. when bracings are attached at different locations.

STEEL BRACING DEVELOPMENT

Bracing is a highly efficient and economical method to laterally stiffen the frame structures against wind loads. A braced bent consists of usual columns and girders whose primary purpose is to support the gravity loading, and Cross bracing members that are connected so that total set of members forms a vertical cantilever truss to resist the horizontal forces. Bracing is efficient because the diagonals work in axial stress and therefore call for minimum member sizes in providing the stiffness and strength against horizontal shear.

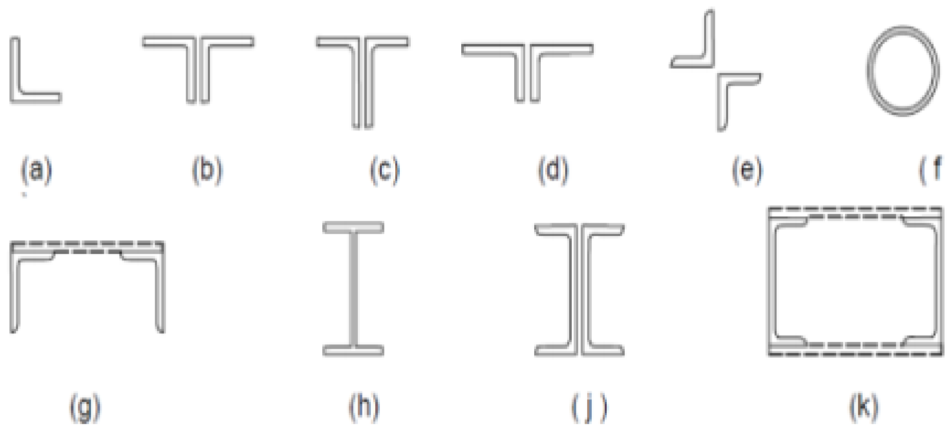

Fig 1: Different bracing sections

Bracing is a highly efficient and economical method to laterally stiffen the frame structures against wind loads. A braced bent consists of usual columns and girders whose primary purpose is to support the gravity loading, and diagonal bracing members that are connected so that total set of members forms a vertical cantilever truss to resist the horizontal forces. Bracing is efficient because the diagonals work in axial stress and therefore call for minimum member sizes in providing the stiffness and strength against horizontal shear.

Types of Bracings

There are two types of bracing systems:

- Concentric Bracing System
- Eccentric Bracing System.

The steel braces are usually placed in vertically aligned spans. This system allows to obtaining a great increase of stiffness with a minimal added weight. Concentric bracings increase the lateral stiffness of the frame thus increases the natural frequency and also usually decreases the lateral storey drift. However, increase in the stiffness may attract a larger inertia force due to earthquake. Further, while the bracings decrease the bending moments and shear forces in columns and they increase the axial compression in the columns to which they are connected.

Bracing is preferred when the availability of the opening spaces in a bay of frame are required. Diagonal bracing is obstructive in nature as it blocks the location of opening which ultimately affects the aesthetic of the building elevation. It also sometimes hinders the passage for use. The full diagonal bracing is not used in areas where a passage is required. In such cases, k-bracings are preferred over diagonal bracing because there is a room to provide opening for doors and windows etc.

Eccentric Bracings reduce the lateral stiffness of the system and improve the energy dissipation capacity. The lateral stiffness of the system depends upon the flexural stiffness property of the beams and columns, thus reducing the lateral stiffness of the frame. The vertical component of the bracing forces due to earthquake causes lateral concentrated load on the beams at the point of connection of the eccentric bracings.

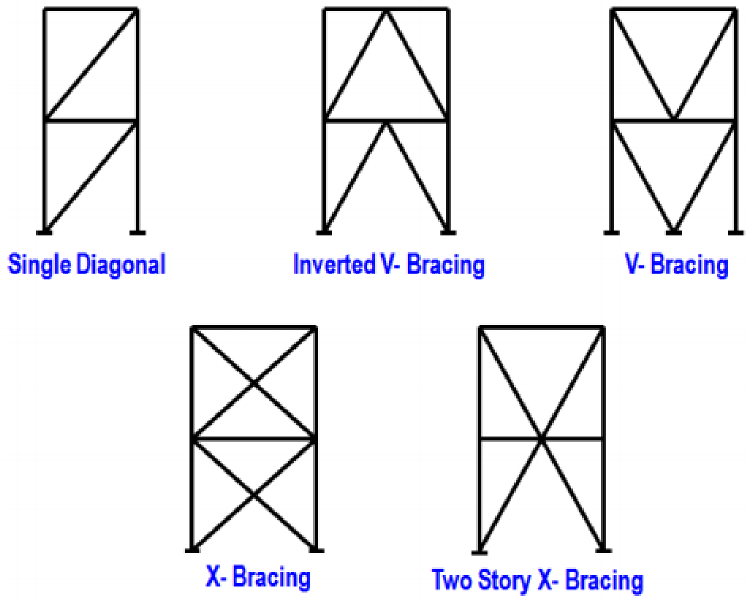

Fig 2: Different concentrically braced frames

Fig 3: Different concentrically braced frame building Diagonal

Lateral Distribution of Base Shear

The total design base shear has to be distributed along the height of the building. The base shear at any story level depends on the mass and deformed shape of the building. Earthquake forces tend to deflect the building in different shapes, the natural mode shape which in turn depends upon the degree of freedom of the building. A lumped mass model is idealized at each floor, which in turn converts a multi storey building with infinite degree of freedom to a single degree of freedom in lateral displacement, resulting in degrees of freedom being equal to the number of floors.

The magnitude of lateral force at floor (node) depends upon:

- Mass of that floor
- Distribution of stiffness over the height of the structure
- Nodal displacement in given mode

IS 1893:2002 (part 1) uses a parabolic distribution of lateral force along the height of the building. Distribution of base shear along the height is done according to this equation:

$$\mathbf{Q_i = W_i\, h_i^2 / \sum j{=}1^n\, (Wjhj^2)}$$

Where:

Qi = design lateral force at floor i

Wi = seismic weight at floor i

hj = height of floor I measured from foundation

n = number of stories in the building or the number of levels at which masses are located.

EXPERIMENTAL WORK

The structure consisting of G+12 stories with four bays in horizontal direction and four bays in lateral direction is taken. The storey height is 3 metres and horizontal and lateral spacing of bays is 3 metres. The study in this thesis is based on basically on Equivalent Static analysis of steel frames with concentric bracing models. Different configurations of frames are selected such as K bracing, inverted V bracing and X bracing and analysed. This chapter presents a summary of various parameters defining the computational models, the basic assumptions and the steel frame geometry considered for this study.

The seismic parameters of building site are as follows

- Seismic zone: 4
- Zone factor, Z: 0.24
- Building frame system: Steel moment resisting frame
- Response reduction factor: 5.0
- Importance factor: 1.0
- Damping ratio: 5%
- Storey height : 3 metres
- Seismic Analysis: Equivalent Static Analysis
- Steel Section used:

For Beams and Columns- I100012A40016
For Bracings – ISA120×120×10

The purpose of this project is to study the behaviour of high rise structures in earthquakes zones when bracings are provided at different places and to compare those values obtained to get the desired structure which is best for resisting the earthquake action. This is done with the help of STAAD.Pro software.

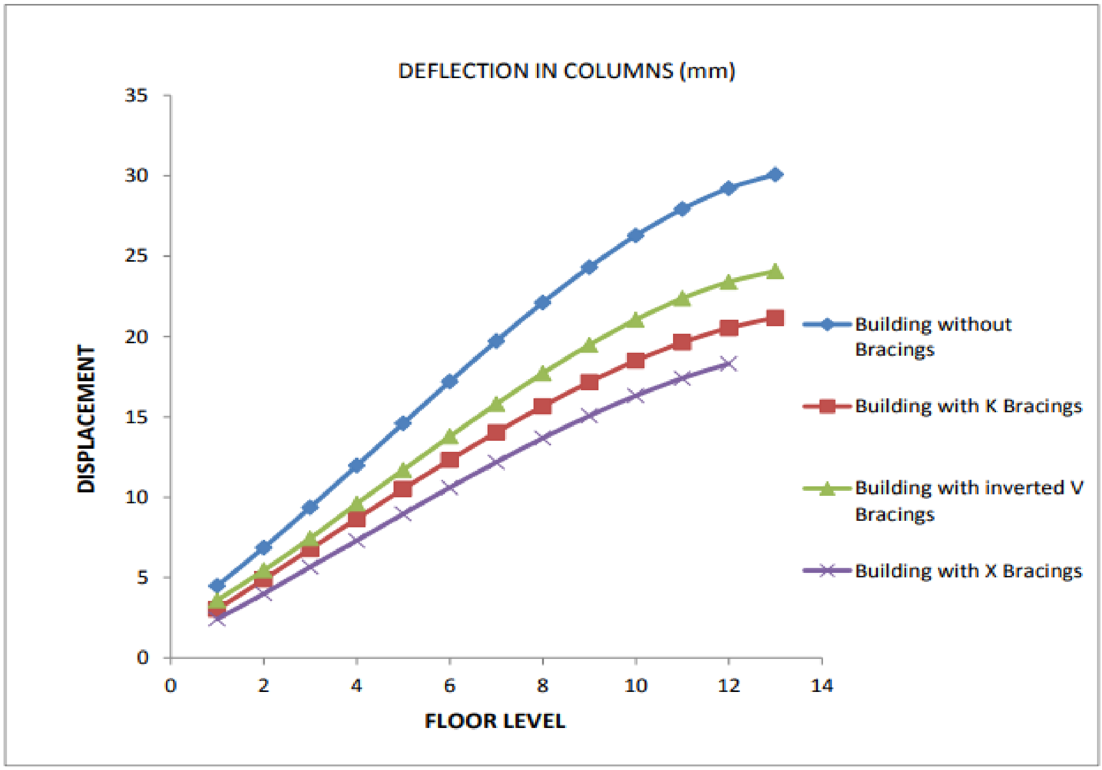

Fig 4: Comparison between deflection in columns

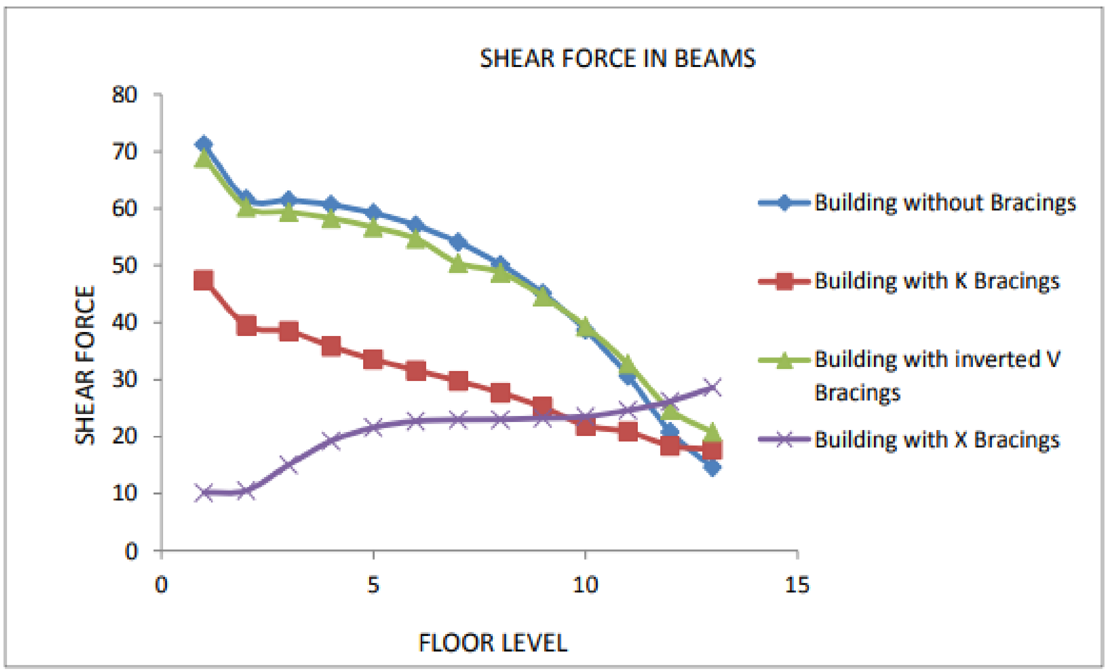

Fig. 5: Comparision between Shear forces in beams

CONCLUSIONS

The selected frame models were analyzed using equivalent static method. The 1st model was an asymmetric plan with a without braced moment resisting frame and then it was braced with K bracing, inverted V bracing and cross bracing. The bracings increased the stiffness and the frequency of the frame. Cross bracing is stiffer than K bracing, inverted V bracing. Hence, for cross bracing maximum base shear was obtained as compared to other braced model and model without bracing. Bracing decrease the lateral displacement of the moment resisting frame. Stiffer the frame least is the story drift.

- Bending moment in column decreases from unbraced to brace system. K braced and inverted V braced column undergo more bending moment than cross braced frame.
- Under the same bracing system and loading, system with larger height or more number of storey's will have more base shear than the smaller one.
- Under the same bracing system and loading, system with larger height or more number of storey's will undergo large lateral displacement on the same storey's than the smaller one.
- By considering lateral stiffness, the concentric (X) bracing has been found the most suitable one for the steel building studied under the present study.

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