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ANALYTICAL STUDY ON THE EFFECT OF STEEL BRACING IN RC HELICAL BUILDING

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Abstract — Bracing *element in structural system play vital role in structure behaviour during earthquake. Braced structures are considered to be more efficient as the number of floors and height of the building increase. Previous studies show the effectiveness of various bracings on steel as well as concrete. But the effectiveness of various configurations of steel bracings on irregular multi-storied helical building is not studied deeply. This study aims to investigate the seismic performance of a helical concrete structure by providing different configurations of bracings and performance under wind loading. Analytical model of the building is developed using structural analysis and design software, ETABS. In this work time history is carried out on (G+19) rise concrete building with v, x, inverted v steel bracing. So that it will reduce the lateral displacement in helical building*

Keywords: *helical, bracing, time history.*

I. INTRODUCTION

Always people think of better and special aesthetical appearance for their buildings. For this, architects create different irregularities in plan and in elevation. Helical buildings are irregular buildings, which have floors rotated around an axis throughout the vertical elevation. Helical shape buildings are rare around the world. The main advantage of helical building is its capability to withstand high wind loads, because of its curviness in elevation. Because of its irregularity, such buildings are prone to earthquake effects. Behaviour of a structure during an earthquake critically depends on its geometry and overall configuration. There are a lot of sophisticated methodologies and procedures for the design of earthquake-resistant structures. Shear capacity of the structure can be increased by introducing steel bracings in the structural system. There are "n" numbers of possibilities to arrange steel bracings namely X, V, inverted V type bracings etc.

The study involves equivalent static analysis and time history analysis for a helical building. The analytical model of the helical building is developed using structural analysis and design software, ETABS. Equivalent static and Time history analysis is done to evaluate the performance of the building. The design output of the different configuration of bracings in helical building is evaluated to have a comparative study of their seismic performance.

II.OBJECTIVE

The main objectives of the present study is

- To model the multi-storey steel helical building using the analysis and design software ETABS.
- To investigate the seismic performance of a multi-storey RC helical building with different bracing arrangements such as X, V and inverted V, using Equivalent Static analysis method and Response Spectrum analysis methods.

III. MODEL DETAILS

A helical building with irregular plan of area 360 sq.m and a height of 79 m above the ground level is selected for the study. Each floor is identical in plan, but each floor rotates 2.4 degree around a cylindrical elevator and service core provided at the center portion of the building. Due to the rotation of each floors, the columns look like 'step' between 30 and 35 cm to the side with every floor level. The stepped columns transfer their load through a concrete slab that works like a pile cap. The width, angle, and spacing of columns look the same from floor to floor, even as the floors themselves shift slowly, as they progress higher.

The three-dimensional centerline finite element model is generated based on the coordinates identified from the structural arrangement drawing in meters shown in Fig 1. In this integrated finite element model, BEAM elements and PLATE elements are used appropriately to idealize the structural behavior of the physical structure in the model under various loading conditions. All the structural elements that contribute towards the structural stiffness are modeled.

The floor slabs of the structure are modeled for simulating diaphragm effect of slabs in them in-plane direction. Entire structure is composed of integrated three-dimensional structure comprising of floors, roofs, walls, beams and columns forming regular orthogonal frames tied together to act as one unit.

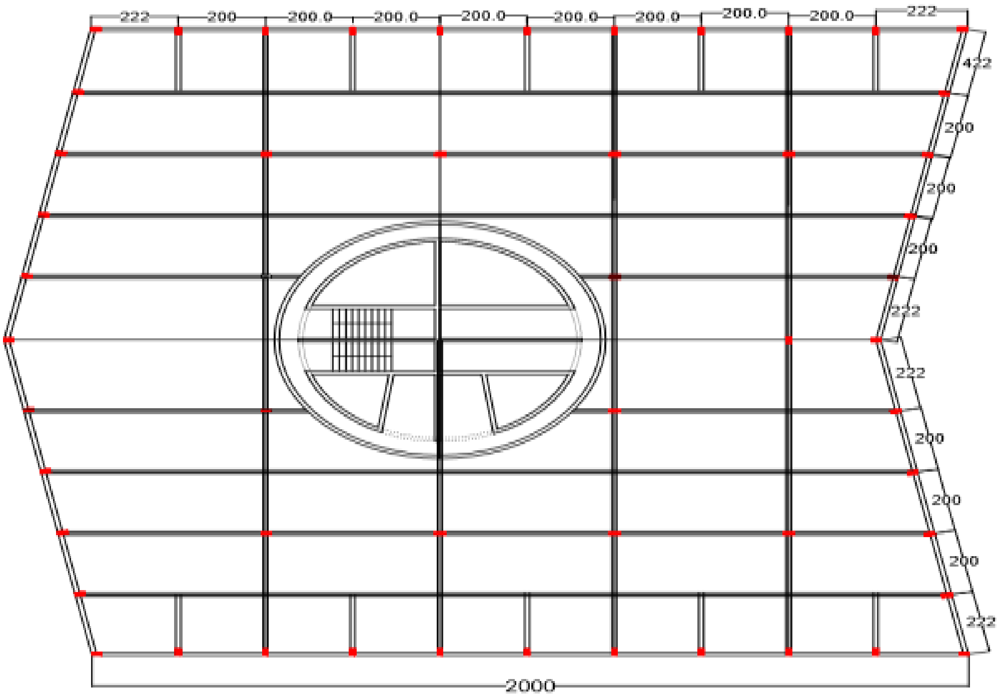

Fig. 1 Beam - column layout

TABLE I STRUCTURAL DETAILS OF THE MODE

Number of storey		G+19
Storey height		5 m for G to 5th floor (Commercial area) 3.5m for 6th to 21st floor (Residential area)
Beam Size		250 x 450 mm for plinth beam 230 x 600 mm for G to 5th storey 230 x 450 mm for 6 to 19th storey
Column Size		300 x 750 mm for 1st 6 storeys 230 x 500 for remaining storeys
Steel bracing		Angle sections used: ISA150X150X12
Slab Thickness		120mm
Grade of Materials		M30 concrete and Fe 415 steel (rebar) Fe250 steel for bracings
Loads	LL for floor	4 kN/m²
	LL for roof	1.5 kN/m²
	Floor finish	1.5 kN/m²
Seismic Zone and Soil Type		Zone II and Medium Type soil

The entire structure is modeled to study the effectiveness of the different configuration of bracings. The various bracings that are adapted to study are X, V and inverted V bracings. These are arranged through the mid bays of the structure. A normal helical building (HB), helical building with x bracing (HBX), helical building with V bracing (HBV) and helical building with inverted V bracing (HBIV) are modeled in ETABs and it is shown in Fig 2, Fig 3, Fig 4 and Fig 5.

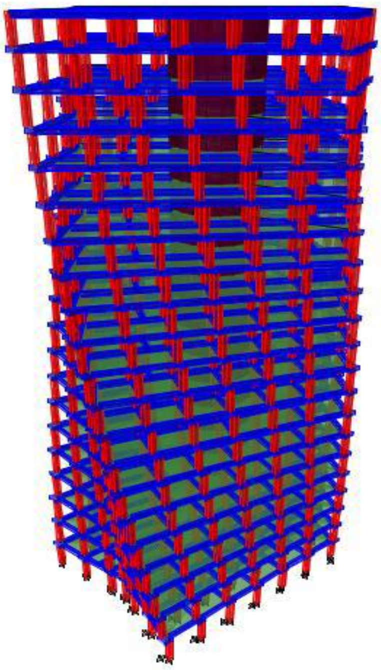

Fig.2 Helical building

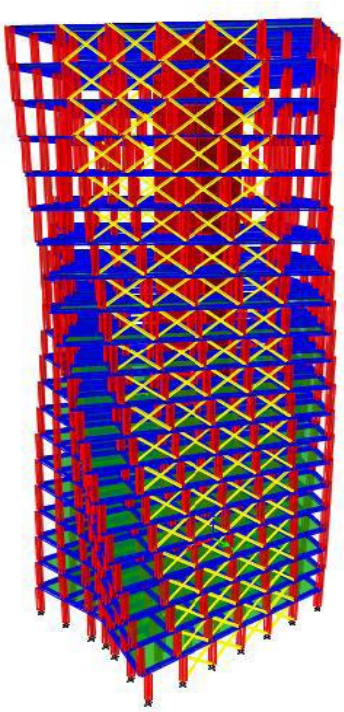

Fig 3 Helical building with X brace

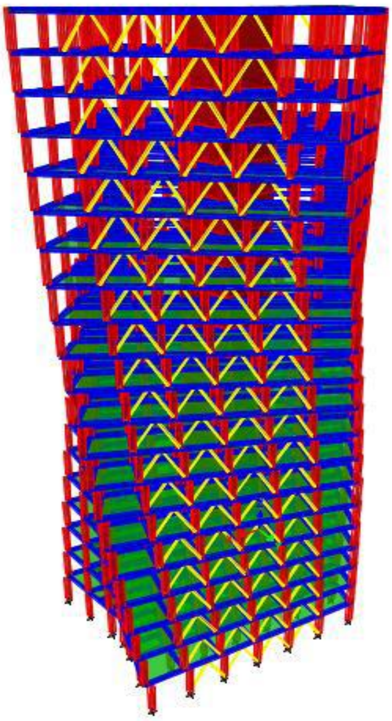

Fig.4 Helical building with inverted V brace

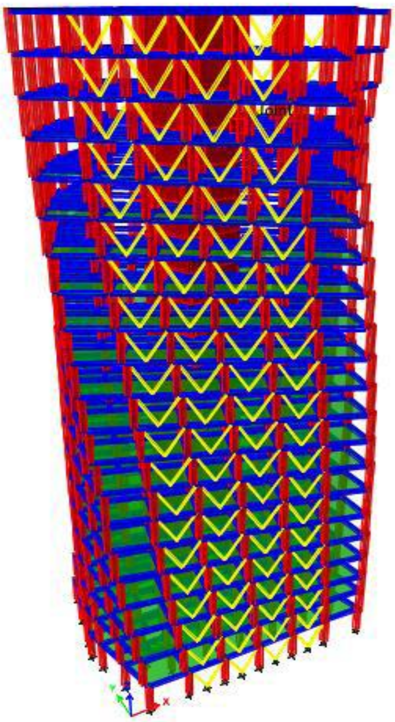

Fig.5 Helical building with V brace

IV. ANALYSIS DONE

Two types of analysis procedure are carried out to determine the behavior of the structure under the effect of seismic loads. The analyses carried out are:

4.1 Equivalent static analysis:

This procedure is according to IS 1893 (Part 1) 2002. First the design base shear is computed for the building and then it is distributed along the total height. Thus, the lateral force at each floor level is distributed to individual lateral load resisting element. Here as the live load coming in each floor is greater than 3 KN/m2 the seismic weight is taken as dead load plus 50% live load.

4.2 Time History Analysis:
In time history analyses the structural response is computed at a number of subsequent time instants. In other words, time histories of the structural response to a given input are obtained ad a result. This analysis gives the response of the structure even after loading. For the analysis data regarding El centro earthquake is selected.

V. RESULTS AND DISCUSSIONS

A normal helical building (HB), helical building with x bracing (HBX), helical building with V bracing (HBV) and helical building with inverted V bracing (HBIV) are modeled and analyzed in Etab software. The results are compared for structures with and without bracings. The results are basically compared to find which type of bracing will be more effective for a helical building to withstand earthquake loads.

5.1 Equivalent static analysis
The results of analysis compared include modal periods, storey shear, displacement and storey drift in x direction and y direction.

5.1.1 Modal periods

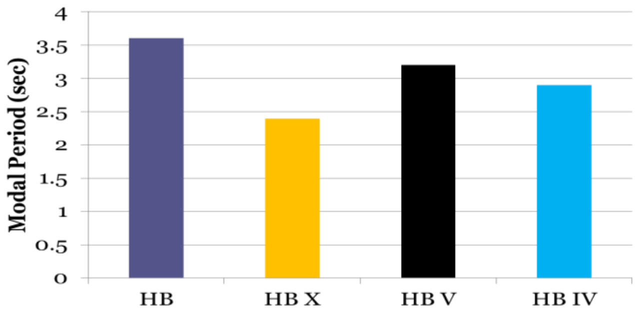

Fig 6 Result comparison of Modal periods

From above figure it is observed that, helical frame without bracing model have longest time. It takes 3.516 sec. In case of models with bracings the X bracing is showing least modal time compared to other bracings. It can be conclude that application of bracings to the structure decreases the time period of mode shapes.

5.1.2 Storey Shear
The storey shear is a function of mass and stiffness of the structure. The base shear is compared for regular and irregular structures with and without bracings in x and y directions as shown in Fig.7 and Fig.8 respectively

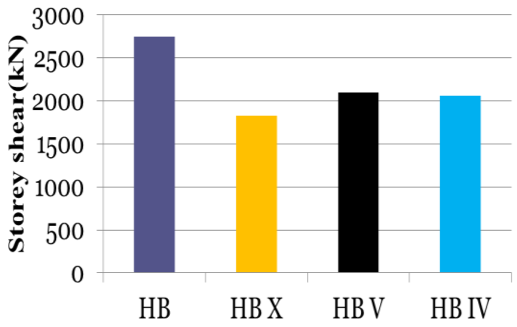

Fig. 7 Comparison of storey shear in x direction

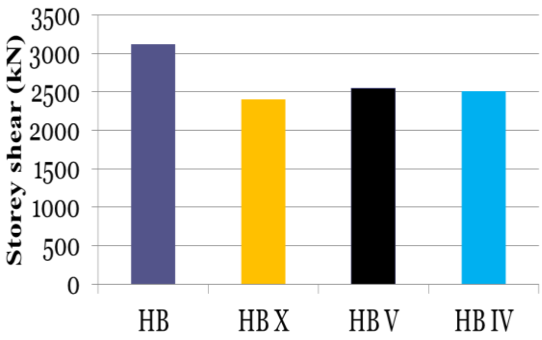

Fig. 8 Comparison of storey shear in y direction

Above figures shows that normal helical building model has the higher storey shear because of its higher mass whereas HBX has the least storey shear compared to other structures, because of higher time period and lesser seismic weight. The X bracing has lesser displacement in both directions compared to other bracing systems

5.1.3 Displacement

Storey displacement is the lateral movement of the structure caused by lateral forces. The deflected shape of the structure is most important and most clearly visible point of comparison for any structure

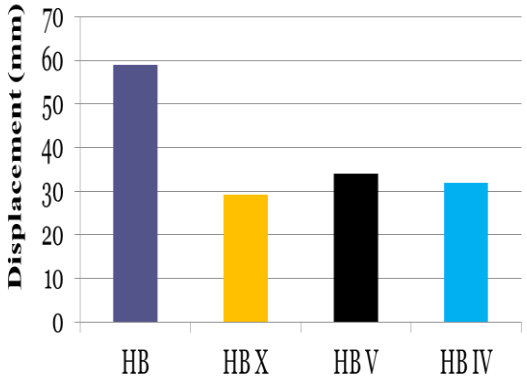

Fig. 9 Comparison of displacement in x direction

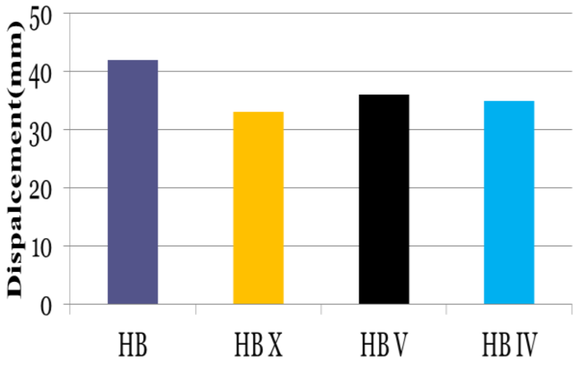

Fig. 10 Comparison of displacement in y direction

Fig.9 and Fig.10 show that helical building with x bracings has less displacement in x direction and in y direction compared to other model. But models with V bracing and inverted V bracing shows significant reduction in displacement compared to the helical model without bracing. In bracing systems X bracing has least displacement in x as well as in y directions.

5.1.4 Storey drift

In this study, storey drifts are expressed as a percentage of storey height. Damage to non-structural components of buildings depends on drift. The following figures illustrate the storey drift in x and y direction respectively.

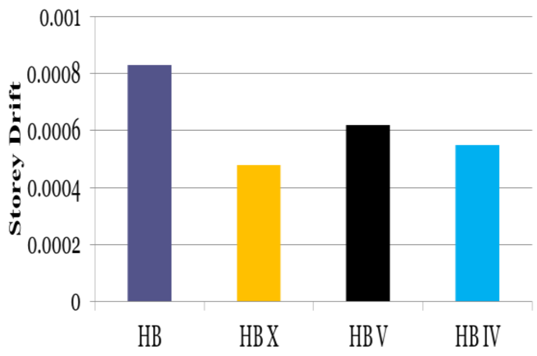

Fig. 11 Comparison of storey drift in x direction

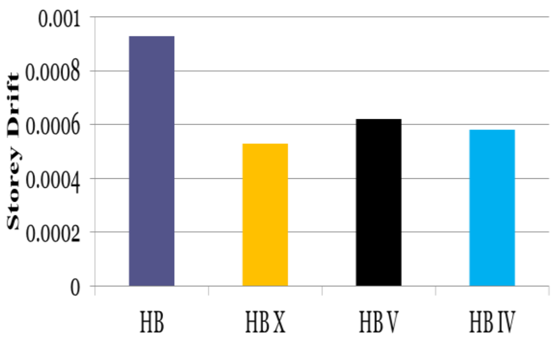

Fig. 12 Comparison of storey drift in y direction

From the above Fig.11 it is observed that normal helical building model without bracing has 63.14% more storey drift compared to model with X bracing and Fig.12 present that storey drift in Y direction is more compared to x direction, but the use of X,V and inverted V bracing significantly reduced the storey drift. The models with X bracing have less drift compared to other bracings.

5.2 Time History analysis

For the time history analysis the earthquake data of El centro earthquake is used. The parameters considered for the comparison of results in time history analysis include base shear, joint displacement and column force.

5.2.1 Base shear

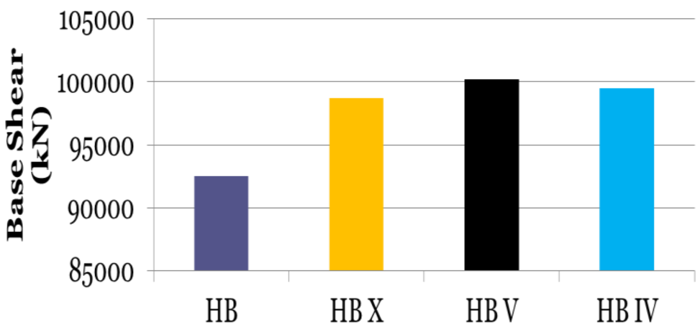

Fig. 13 Comparison of base shear

From Fig.13 it is observed that base shear is increased in the models with bracings. This is because of the increase in overall weight of the building. The X bracing models have 18.5% higher base shear compared to bare frame models. But the use of inverted V bracing reduced the base shear.

5.2.2 Joint displacement

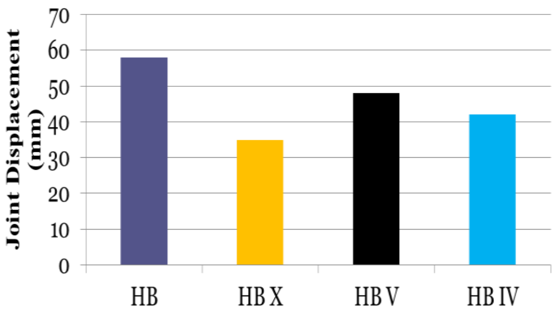

Fig. 14 Comparison of joint displacement in X direction

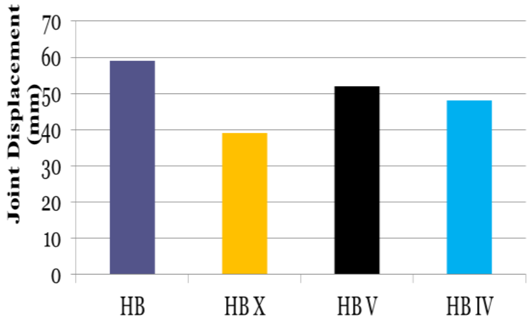

Fig. 15 Comparison of joint displacement in y direction

Fig.14 and Fig.15 show the joint displacement at the 20th storey where maximum displacement obtained during response spectrum analysis of different models. The models with X bracing have least displacement as compared to other model with V and inverted V bracing.

5.2.3 Column Force

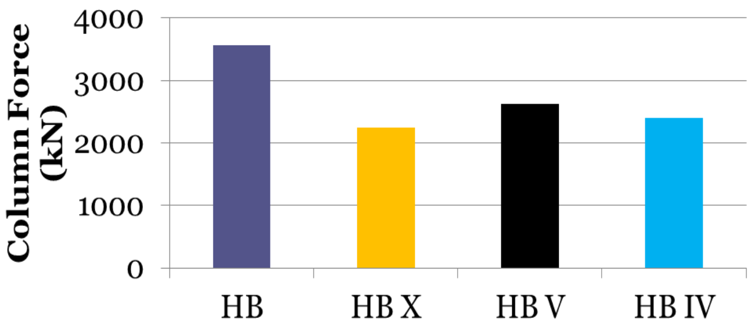

Fig. 16 Comparison of column force

Fig.16 shows the comparison of force on a column at the ground level. It is observed that model with X bracing has the less column force compared to other models.

VI. CONCLUSION

1. Equivalent static analysis and Time history analysis of a helical building with and without bracings is conducted. Different results related to seismic stability are compared.
2. Mode shape of helical model with X bracing takes less time than other models.
3. Base shear has reduced significantly by providing bracings. Base shear can be reduced to a great extent by using X bracings.
4. Displacement and storey drift are more in normal helical building model compared to brace models. The storey drift can be controlled within the limit by providing concentric bracing of X type.
5. Addition of bracings to the bare frame models shows reduction in time period, displacement and storey drift.
6. Use of X bracing to all models is found more effective compared to V bracing and inverted V bracing.
7. There is a significant reduction in column force in models with bracings.
8. To make a helical structure stable against seismic and wind force, the use of X type bracing is more advantageous as compared to V bracing and inverted V bracing.

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