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A Study on Effect of Various Bracing Systems in Rc Frame Structure Using Staad Pro

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ABSTRACT- When a tall building is subjected to earthquake under the action of lateral loads. Providing a suitable lateral force resisting system has a significant effect on the performance of the RC frame structure. The present study focuses on the study of bracing systems for RC frame structure. The effectiveness of different types of bracing on the RC frame structure has been carried out. For this study, a G+13 storied RC frame structure has been considered and structural behavior has been studied at three seismic zones (III, IV and V). The RC frame structure models are analyzed by Response spectrum and equivalent static method as per IS 1893:2016 (part1) using STAAD Pro software. The structural behavior has been studied using different types of bracing systems such as X bracing, Diagonal bracing, Chevron bracing and Eccentric bracing. A comparative study has been done on parameters story displacement, story drift, base shear, axial force, weight of the structure between braced and un-braced RC frame model. From the study, it has been observed that the lateral displacement and story drift of the braced system decrease in the structure as compared to the un-braced frame in all seismic zones (III, IV and V). Bending moment values in braced frame model get reduced and axial force value in the braced frame model increase as compared to unbraced frame model. It is concluded that the X bracing significantly contribute to structure stiffness as compared to the other bracing system.

I. INTRODUCTION

The present expanded requirement for housing in urban areas prompts the development of tall structures [1]. The main role of all wide range of structure is to transmit gravity loads effectively. The most widely known loads coming about because of the impact of gravity are dead load, live load and snow load. In addition to these vertical loads, a structure is additionally exposed to lateral loads caused by wind, earthquake, and blasting [2]. The lateral load reduces the stability of structure by producing sway moment and induce high stresses. In such a case, the stiffness of the structure is more important than the strength of the structure to resist the lateral load.Disturbance at some depth below the earth surface causes the vibration of the ground surface is called an earthquake [3]. These vibrations are absolutely uncertain and happen in all direction. Earthquake cause ground to shake and support of the structure is subjected to vibration [4]-[5]. Because of the earthquake, it causes both financial and living losses [6]-[7]. A large portion of these losses is a result of harm of structure or fall of the building [8]. Thus it is important to plan the structure to protect against such a rigorous earthquake [9]. In the course of recent decades, India has encountered a number of earthquakes made vast harm to the structure. Today, over 60% of Indian land territories lies in higher three seismic zones III, IV and V according to Indian seismic code [IS 1893 (Part-1):2016] [10]. However, just about 3% of the built environment is correctly engineered. India has the potential for powerful seismic shaking with a vast supply of powerless structures. A large portion of these losses is a result of harm of structure or fall of the building [11].

II. LITERATURE REVIEW

Sangleet al. (2012) has done research work on the sesimic performance of high rise steel framed structures with and without bracing. For this work, six models of high rise steel frame building(G+40) floors are models to get the realasticbehaviour of the building during an earthquake. The length and width of the building were 10x22m and each storey height is 3.5m. the different bracing pattern has been used such as diagonal bracing-A, X brace, K brace, Knee brace, and diagonal barce- B. The parameter which has used for analysis for analysis was base shear, interstorey drift, total lateral displacement, and stress level with in acceptable limit. Linear dynamic analysis i.e time history analysis was used according to the rule given in IS 1893(part1). Northridge earthquake time historey is utilized and maximium acceleration is applied at the base of the building. The consequence of the present investigation demonstrates that the bracing element will have a critical impact on structure behaviour under earthquake effect. Iit was found that because of bracing in both direction base shear increamentupto 38% and displacement of building reduce upto 43% to 60%. The modal time period was reduced by upto 65%. The result shows the digonal brace-B indicate the effective and economical design of bracing style.

Takey and Vidhale (2012) studied the behaviour of a linear bracing system of steel building under seismic response using software approach. The analysis of unsymmetrical building with the bracing system to resist the seismic lateral load using SAP and also compared the braced and unbraced building which was subject to seismic load has carried out in G+9 stories in zone III using response spectrum analysis with or without steel bracing. The conclusion which has come out that braced building of storey drift and displacement as compared to unbraced building decrease the storey drift and displacement. it was concluded that X bracing performanve better than another different type of braces.

Bajoriaet al. (2012) studied the seismic examination of steel outline structure with or without bracing. The examination had done in steel outline building (G+40) to check the behavior of an alternate kind of bracing (X bracing, Diagonal bracing A and B and k bracing) in steel outline building, bracing surround the building because of which it enlarges the lateral resisting capability of the building during an earthquake. The building which had taken was symmetric in x and y-course having length 40m and width 22m having storey stature 3.5 m. The parameter which has been utilized to gauge the seismic investigation of the building is natural frequency, base shear, inter-storey drift, and mode shape. It was observed through their research that with the aid of different bracing the displacement of the top roof is reduced up to 65% and base shear is increased up to 38%. The final conclusion which came out is that diagonal brace shows the highly effective and economical design of bracing style.

Viswanath and Prakash (2013) detailed steel braced frame as one of the structure reinforced concrete building which requires retrofit to expect retrofit to defeat insufficiency to oppose earthquake loads. The utilizaion of steel braced systems for retrofitting of seismically insufficient reinforced concrete frames was a practical answer for improving seismic resistance. Steel bracing is cost effective, affordable; simple to erect less spacious and has the adaptability to plan for meeting the required quality and firmness.. The bracing was accommodated in peripheral columns. A four storey building was analyzed for seismic zoneIV as per IS 1893; 2002 utilizing STAAD Pro software.

III. METHODOLOGY

A. Response Spectrum Analysis

Response-spectrum analysis (RSA) is a linear-dynamic statistical analysis method which measures the contribution from each natural mode of vibration to indicate the likely maximum seismic response of an essentially elastic structure.

In this method the response of multi-degree-of-freedom (MDOF) system is expressed as the superposition of modal response, each modal response being determined from the spectral analysis of single-degree-of-freedom (SDOF) system, which is then combined to compute the total response.

Response spectrum can then be used to pick off the response of any linear system, given its natural frequency of oscillation. One such use is in assessing the peak response of buildings to earthquakes. Dynamic analysis of the system gives the mode shapes and frequencies of the structure and has to solve an Eigen value problem. The provisions of codes per IS: 1893 (Part 1)-2016 for response spectrum analysis of the multi-storey building.

Step by step procedure for Response spectrum method

Step 1: Select the location of the building and depending on the location identify the seismic zone and assign zone factor (Z). Use Annex of IS-1893 (2016) Part I.

Step 2: Calculate the seismic weight of the structure (W).

As per clause 7.4.2, IS 1893(2016) - Seismic weight of floor (Wi)

Step 3: determination of the fundamental natural period of vibration (Ta) as per IS 1893(part 1) 2016 clause number 7.6.2 then design the seismic coefficient Ah as per clause 6.4.2 of IS 1893:2016 (part 1).

$$A_{h=}\left[\frac{S_a}{g}\,\mathrm{x}\,\frac{Z}{2}\right]_/\left[\frac{R}{I}\right]$$

Where,

Z = Zone factor as per Table 3 of IS1893:2016

I = Importance factor as per Table 8 of IS1893:2016

R = Response reduction factor as per Table 9 of IS1893:2016

Sa/g = Average response acceleration.

Then calculate the design base shear Vb=Ah W as per clause 7.6.1 of IS 1893(part 1) 2016.

Design Acceleration Coefficient for Different Soil Sites for 5% Damping (IS-1893 2016)

Step 4: The design base shear (V_b) computed in step 3, will be distributed along the height of the buildings as per the following expression as suggested by IS: 1893:2016 Clause 7.6.3

$$Q_i = V_b\{(W_i h_i^2)/(\sum W_j h_j^2)\}$$

Step 5: Establish mass [M] and stiffness [K] matrices of the structure using system of masses lumped at the floor levels with each mass having one degree of freedom.

Step 6: Using step 3 and operate the principles of dynamics calculate the modal frequency {*w*} and corresponding mode shape {ϕ}

Step 7: we can find the modal mass M_K of mode k using the following relationship where n is the number of modes.

$$M_K = \frac{[\sum_{i=1}^{n} W_i \Phi_{ik}]2}{[g \sum_{i=1}^{n} W_i \Phi_{ik}^2]}$$ as per clause 7.7.5.4a of IS 1893 part 1 2016

Where,

Φ_{ik}= Mode shape coefficient at floor i in mode k.

= Mode shape coefficient at floor i in mode k.

= Seismic weight of floor i of the structure.

Step 8: Calculate modal participation factor P_k of mode k using the following relation where n is a number of modes. Considered,

$$P_K = \frac{\sum_{i=1}^{n} W_i \Phi_{ik}}{\sum_{i=1}^{n} W_i \Phi_{ik}^2}$$ as per clause 7.7.5.4b of IS 1893 part 1 2016

Step 9: Compute design lateral force (Q_{ik}) at each floor in each mode (i.e. for i^{th} the floor in mode k) using the following relationship.

$Q_{ik} = A_{h(K)} \Phi_{ik} P_k W_i$ as per clause 7.7.5.4c of IS 1893 part 1 2016

Step 10: Calculate storey shear forces due to all modes considered, V_i in the storey I, by combining shear forces due to each mode in accordance with clause 7.7.5.3 of IS 1893 (2016) i.e. either CQC or SRSS modal combination method are used.

Step 11: Finally compute design lateral forces at each storey as $F_{roof} = V_{roof}$ and

F= $V_i - V_{i+1}$

B.PROCEDURE OF ANALYSIS IN STADD PRO

For analyzing and to study the behavior of RC frame with or without bracing system under the effect of seismic forces in different seismic zone i.e. III, IV and V, the following procedure is adopted.

Modeling procedure of braced frame RC building using Stadd pro

Step 1: Select the structure type

- Select the new project
- The space structure has to select, which is a 3D framed structure with loads applied in any plane.
- Give the file name and its location.
- Length should be in meter and force unit in kilo Newton.
- Click next and select the add beam option.
- Click finish.

Step 2: Geometrical Modelling of RC frame

- Click on geometry option on the tool and select run structure wizard.
- Select the model type as frame models.
- Double click on the bay frame.
- Describe the length, width and height of frames and respectively provide bay along the length, width and height.
- Click apply and transfer this frame into the stadd pro and click yes.
- Give coordinate 0, 0, and 0 in X, Y and Z direction and select ok.
- In snap node/beam in right hand side unselect the default grid. Continue the step until the frame profile will be obtained.

Step 3: Selection of properties of various sections

- Go to general tap and define section from the property

- Select the define option from the property and select the rectangular option and specify the value of beam and column.
- For steel bracing select section database in that select the Indian code and select the material and close it.
- Don't forget to select the material for beam and column will be concrete and for bracing it will be steel.
- Go to select beam and click on beam parallel to and select the respective direction.
- Click on assign to edit the list and click on assign.

Step 4: Assign of supports conditions

- In general tab select support option.
- Click creates an option in the dialogue box.
- From all the support select fixed support and then add.
- Select the fixed support from the dialogue box and now select the node where fixed support has to provide.
- Click on assign to the selected node and click on apply.

Step 5: Assign different loads and their combination

- In general tab select load and definition.
- Click on the definition and select seismic definition.
- Select code IS 1893-2002/2005 and give the parameter like zone, response reduction factor, importance factor, type of soil and damping ratio.
- Assign the self-weight and floor weight and then close it.
- Then select load case detail and assign seismic load, dead load and live load.
- In seismic load give self-weight, floor weight in all direction (X, Y and Z)
- Select the seismic load and click the add option after that one dialogue box will open in that select code and type of soil.
- After that give the load combination by selecting add option in load case detail, a dialogue box will open select auto load combination after that select auto load combination.
- Generate the loads and click on add.

Step 6: Analysis of the frame

- Click on the analysis/Print tab
- In analysis/print command select print option all and select add.
- Select the post print option.
- Click defines command.
- Select storey drifts value and click add.
- Click analysis in the task bar.
- Click save then click done.

Step 7: Exploration of analyzed results

- To view the output results, choose view output file.
- Member forces due to different load combinations for each and every member can be seen through member forces all option.
- Click on Results option and view results by selecting Eigen solution, Mass Participation Factors, Analysis Results and Storey Drift option in STAAD Output Viewer.
- Mode shape, time v/s acceleration graph, time v/s velocity graph and time v/s displacement graph can be seen through a dynamic tab.
- To determine the deflection, bending, shear and axial force in any beam. Select the beam then go to the post processing section.
- Select the load case and then click ok.
- Go to result on the task bar, and then click view value and then select beam result after that annotate the value.

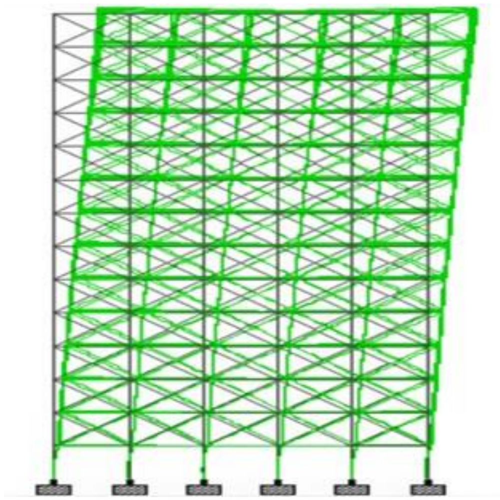
C. RESULTS AND DISCUSSION

The various types of model and parameters used in the analysis have been described in detail. In order to study the behavior and performance of the un-braced and braced system in RC structure, Equivalent static analysis, and Dynamic analysis has been carried out.In this chapter, the results obtained from analysis of different types of frame have been discussed. For this purpose, five different types of bracing system viz. X bracing, diagonal bracing, V bracing, inverted V bracing and eccentric bracing were analyzed in three seismic zones III, IV, and V using STAAD PRO and their results are compared with un-braced frame. The soil strata condition are kept same throughout the analysis of the structure.

To interpret the behavior and performance of the bracing system in the RC frame Structure, six different parameters, as given in chapter 4 (i.e. Storey Displacement, Base shear, Storey Drift, Maximum Axial Force, Maximum Bending Moment and Weight of the structure) has considered and their results are explained in the following section of this chapter.

D. STOREY DISPLACEMENT

Displacement or deflection refers to the deviation of the whole structural element from its original position by the action of lateral forces (earthquake/seismic forces) on the buildings.An RC building frame with and without bracing has been studied for lateral displacement in three seismic zones III, IV, and V. For demonstration, an example of the maximum lateral displacement for selected building frame with and without bracing is shown in Fig.1 (a) and Fig. (b) respectively. The maximum lateral displacement values obtained from analysis at each storey level are given in Table 1. Further, the maximum lateral displacement values, which have been listed in Tables, are plotted against the storey height to understand the effectiveness of different bracing system and these plots are shown in Fig 1(a and b) and Fig.2 (a) shows maximum displacement behavior at each storey height as per values given in Table 1 in zone III. Fig 1 (b) depicts maximum displacement behavior at each storey height for zone IV and Fig.3 as per in zone V.



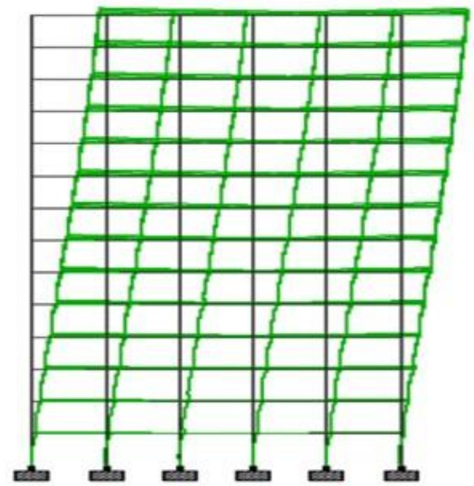
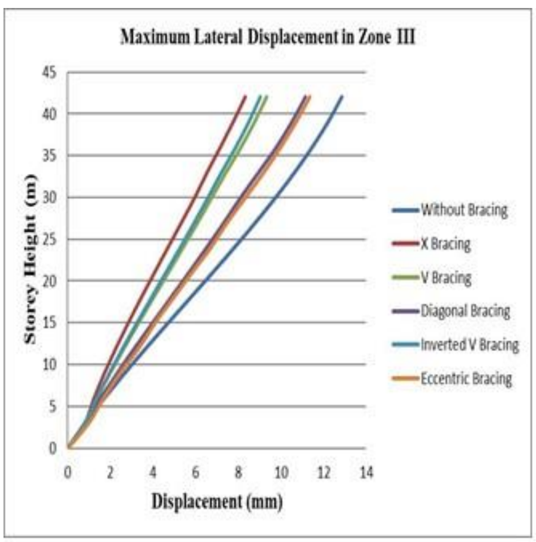


Fig 1: Lateral Displacement of Building (a) with Bracing Systems (b) without Bracing



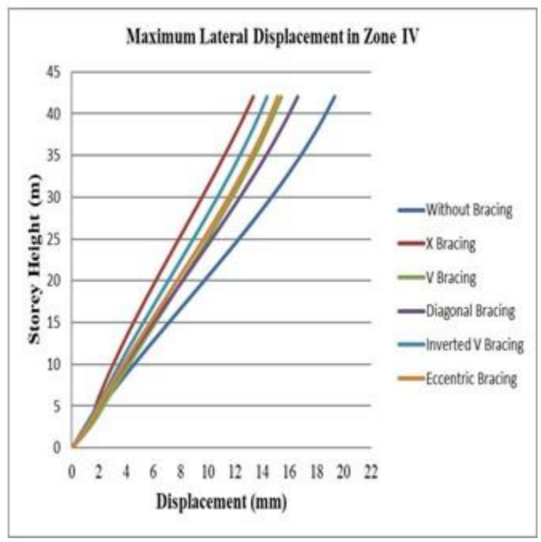


Fig 2: Maximum lateral displacement (a) Zone III (b) Zone IV

Table 1: Displacement at Storey Height 42m

Zone	Types of bracing structure			
	X bracing	V bracing	Inverted V bracing	Diagonal bracing
III	54.39%	37.82%	42.40%	15%
IV	45.05%	25.46%	34.57%	16.33%
V	54.71%	38.19%	42.87%	23.538%

Base Shear

Base shear is the maximum lateral force generated at the base of the structure. For analysis, the structure has been fixed at the base that is at the foundation level. An RC building frame with and without bracing has been studied for base shear in two seismic zones IV and V. The base shear values obtained from analysis are given in Table 2 and table 3. Table 2 provides the base shear values in zone IV and Table 3 in zone V. Further, the base shear values, which have been listed in Tables, are plotted to understand the effectiveness of different bracing system and these plots are shown in Fig 4 Fig 4 shows the plot of magnitude of the base shear for different structure systems which have been mentioned in Table 2 in zone IV. Similarly, Fig.5 is the plot as per Table 3 in zone V.

Table 2: Base Shear (kN) for Different Bracing System in Zone IV

Structure Type	Base Shear(kN)
Bare Frame	1059.9
X Bracing	1102.02
V Bracing	1093.2
Inverted V Bracing	1093.2
Diagonal Bracing	1080
Eccentric Bracing	1091.3

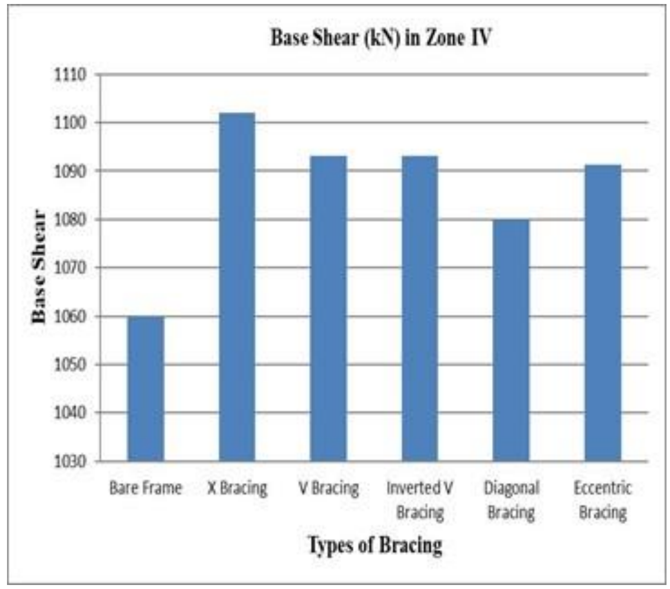


Fig 4: Base shear for bracing systems Zone IV

Table 3: Base Shear (kN) for Bracing Systems in Zone V

Structure Type	Base Shear(kN)
Bare Frame	1589.88
X Bracing	1653.03
V Bracing	1639.8
Inverted V Bracing	1639.8
Diagonal Bracing	1621.4
Eccentric Bracing	1636.9

Maximum Weight (kN)

An RC building frame with and without bracing has been studied for maximum weight in all three seismic zones. The maximum weights obtained from analysis of the structure are given in Table 4. Table 4 provides the maximum weight of structure in zone III, IV and V. The maximum weight of different structures have used in the analysis are listed in Table 4.

Table 4: Weight of different bracings in KN

Structure Type	Weight(kN)
Bare Frame	40148.54
X Bracing	41743.32
V Bracing	41409.30
Inverted V Bracing	41409.30

E. CONCLUSIONS

All the bracing frame models have been analyzed by response spectrum analysis and static analysis using software STADD PRO for all selected parameters namely, storey displacement, storey drift, Base shear, a maximum weight of the structure and maximum axial force. From the analysis of bracing models, it has been observed that the braced frame modeled structure has shown better seismic resistance than an unbraced structure in all seismic zone i.e. III, IV and V. Furthermore, it has been observed that among all models considered, X-Braced frame model is a comparatively best selection from the structural point of view. Therefore, only values of X braced frame model are shown in the following conclusions.

1.The lateral displacement of the bracing system decreases with an increase in the height of the building as compared to the bare frame. Structure model with X bracing shows less lateral displacement as compared to the structure model with other bracing (diagonal bracing, chevron bracing and eccentric bracing) and un-braced system in all

three zones (III, IV and V). The reduction in lateral displacement values for X braced model in zone III is 54.23%, in zone IV is 54.49% and in zone V is 54.71%.

- Overall comparison of base shear shows that the base shear value in case of X bracing system
- is large as compared to other bracing. However, the base shear of the braced building increases as compared to un-braced RC frame model. The base shear value increases with an increase in seismic zones.
- The Story drift of the structure is reducing by using different types of bracing system in the model. A structural model with X bracing shows less storey drift as compared to the structure with other braced and un-braced system in all three seismic zones. The reduction in storey drift values for X braced model in zone III is 82.29%, in zone IV is 82.17% and in zone V is 82.22%.
- The weight of the different braced structural model is more as compared to an un-braced structure model with the same structural configuration. All the results show that the weight in case of X bracing system is more as compared to another frame model.
- Bending moment values in braced frame model get reduced as compared to unbraced frame model. The building frame model with X bracing has the least possible bending moment as compared to other types of bracing system. Therefore, it is advantageous to provide X bracing in structures.
- Axial force values in the braced frame model increased as expected as compared to unbraced frame model. The building frame model with X bracing has a maximum possible axial force as compared to other types of bracing system. Therefore, it is advantageous to provide X bracing in structure in high rise 2 D steel buildings.

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