SEISMIC BEHAVIOUR OF MULTI STORY SHEAR WALL FRAME VERSUS BRACED FRAME

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Abstract— Presently, our country, Ethiopia is growing in the way of multi disciplines, such for example as: constructing for commercial, residential, and mixed used buildings. Headed for, it requires high rise buildings, which pass up scarcity of the land. Due to this aspect there is a need to study the structural system, which resists the lateral loads due to seismic effect. In this paper the seismic behavior of reinforced concrete shear walled frame and braced frame has been studied. A symmetric plan shear walled frame and braced frame has been selected, and compared the seismic response of the structural systems with the help of storey displacement and fundamental period of the building. This study has been conducted by considering different models with the aspect of changing different parameters such as: Varying thickness of shear wall, types of bracing, and compared effectiveness of shear walled frame and braced frame. Because of the structural characteristics of the building, Modal Response Spectrum analysis has been used. All analyses were carried out using finite element software"s, ETABs version 15.

When two bays in a row are shear walled and braced at the corner of the building in both X and y direction, the result showed that, from braced frames X-braced frame showed the maximum reduction in storey displacement and fundamental time period of the frame than inverted V-braced frame and V-braced frame. And from shear walled frames, larger thickness shear walled frame which is 400mm thickness shear walled frame showed the maximum reduction in storey displacement and fundamental time period.

Key words-Shear wall, seismic load, compressive strength, bracing, building

I. INTRODUCTION

A tall building is the demand of present situation. As the height of structure increases, lateral forces due to seismic become predominant. The major portion of these shall be resisted by the structural elements. Out of different structural systems, shear wall frames and braced frames are two principal structural systems used in reinforced concrete buildings to resist earthquake forces.

Reinforced concrete shear-walls are mostly used in buildings due to better- observed performance in recent past. In areas of high seismic risk, RC shear walls have been widely used as main lateral load resisting system in medium & high rise buildings because of their high lateral stiffness.

And also the most effective and practical method of enhancing the seismic resistance is to increase the energy absorption capacity of structures by combining bracing elements in the frame. The braced frame can absorb a greater degree of energy exerted by earthquakes. Braced frame reduces the column and girder bending moments. The shear is primarily absorbed by diagonals and not by girders. The diagonals carry the lateral forces directly in predominantly axial action, providing for nearly pure cantilever behavior. Bracing members are widely used in steel structures to reduce lateral displacements and dissipate energy during strong ground motions. But, recently this concept is extended to concrete frames.

The bracing patterns namely Double diagonal bracing(X- bracing), V-bracing, and Chevron bracing (inverted-V bracing).The shear walled frames namely Shear wall with 200mm thickness, Shear wall with 300mm thickness, and Shear wall with 400mm thickness. Each of the bracings and shear walls provided on the 40 storey frame building with 6m bay width. Then this building is modeled and analyzed using finite element software"s, ETABs version 15.

II. THE OBJECTIVE OF THIS STUDY

- Compare the effectiveness of concentrically braced frame.
- To study the behaviour of braced frame. (When single bay and double bay is braced).
- To study the behaviour of shear wall thickness on shear walled frame system.
- To study the behaviour of shear walled frame. (When single bay and double bay is shear walled).
- To give a clue for structural designers and researchers during design of seismic resistance building.

III. METHODS OF ANALYSIS

The lateral load analysis of this study is based on new code ESEN: 2015 which is the direct copy of Euro code 8 designs manual. As per new code ESEN: 2015 and Euro code 8, the horizontal design forces are defined from maximum acceleration of the structure, under the expected earthquake, that is represented with the acceleration spectrum of the structure. The starting point is an elastic response spectrum, which is reduced with factors that take into consideration the ability of structure to absorb seismic energy through rigid deformation. In the horizontal plane, the seismic action acts simultaneously and independently in two orthogonal directions that have the same response. Euro code suggests two different design spectrums.

a) Type 1 for High and moderate seismicity regions (distance EQ, MS>5.5) (southern Europe)
b) Type 2 for Low seismically active regions (local EQs <5.5) (central and northern Europe). and (NDP, recommended: PGA on rock ≤0.08g)

In this study, Type1 design spectrum was selected in order to notice the effect of earthquake on each bracing systems, and shear wall which gives maximum lateral displacement. In addition, there were also different parameters that are considered as an input for analysis. Of which behavior factor (q) is one factor that affect the analysis result.

Table 1: Values of the parameters describing the recommended type 1 elastic response spectra.

Ground type	S	TB(s)	TC(s)	TD(s)
A	1.0	0.15	0.4	2.0
B	1.2	0.15	0.5	2.0
C	1.15	0.20	0.6	2.0
D	1.35	0.20	0.8	2.0
E	1.4	0.15	0.5	2.0

Several methods can be used to analyze the response of a structure subjected to an earthquake. The choice of method depends on the structure and on the objectives of the analysis. The followings are the methods used to analyze the response of the structure:

1. Lateral force method of analysis/Equivalent static analysis /linear static
2. Modal response spectrum analysis/linear dynamic analysis
3. Pushover analysis/Non-linear static
4. Time history Analysis/Non-linear dynamic

IV. STRUCTURAL MODELING

For the analysis work, the models of high rise reinforced concrete frame building (40) floors were made to know the realistic behavior of building during earthquake. The length of the model building is 48m and width is 36m. Height of typical story is 3 m. Column sizes changes at each 10 story. Generally the following assumptions were taken.

1. Modal damping 5% is considered.
2. Beams and columns are modeled as frame element and joined node to nodes. While shear walls were represented by shell-type element,
3. The effect of soil structure interaction is ignored in analysis. The columns are assumed to be fixed at the ground level.
4. Plan dimension, and beam size, are kept similar to all Storey
5. Bracing is represented by a section of steel
6. Beam column joints are taken as rigid joints
7. The same location of both bracings and shear walls are taken, to have the better seismic performance comparison
8. Shear wall is continues and the same dimension throughout the height of the frames

As such, the stiffness offered by the gusset plates to the girders or columns at the brace connections are largely ignored under a presumption that they will yield relatively early during the seismic excitation. In this paper the connection is assumed to be pin

Loading:

I. Gravity Loads: The building self-weight and slab weight is considered. But, partition loads are not considered

Table 2: Gravity load data

Components included in the slab weight	Unit weight (γ) (kN/m3)	Thickness (mm)	Force per area(kN/m2)
Marble	27	2	0.54
Cement screed	22	3	0.66
Soffit plaster	22	2	0.44
Slab	25	150	3.75
Total area load			5.39

II. Live load is taken as 4kN/m² (for shopping areas).

III. Seismic loading :

Table 3: Earthquake data

Earthquake data	
Seismic Zone	V
Bedrock acceleration ratio ($\alpha o = aog$)(ratio of design bedrock acceleration to acceleration of gravity)	0.2g
Design PGA	$\gamma\alpha o$=1*0.2g= 0.2g
Importance factor, I	1
Behavior factor, q	Depends on the structural system
Subsoil class	B

V. STUDIED STRUCTURAL CONFIGURATION

Following two types of structural configuration is studied.

1. 40 storey reinforced concrete framed structure without bracing and shear wall (MRF)
2. storey reinforced concrete framed structure with shear wall and different bracing patterns such as, X-brace, V-brace, and inverted V (chevron) brace

➢ Location of bracing patterns and shear wall used in the study

For equal treatment of the study, the location of all bracing as well as the shear wall is at the same place, which is at the corner of the frame.

I. When only single bay is braced and shear walled

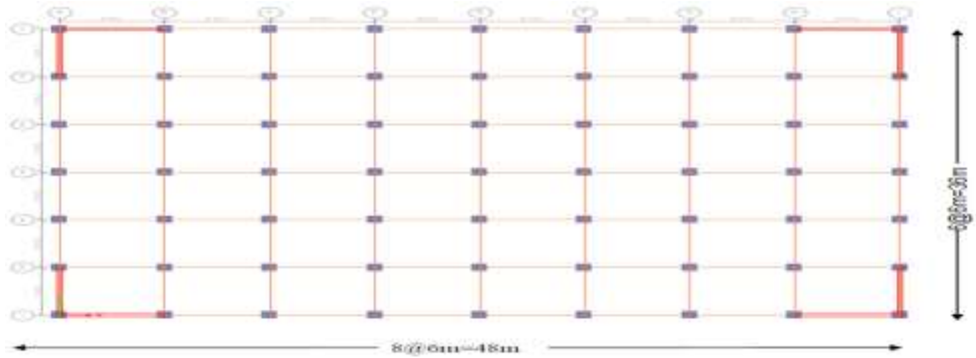

Figure 1: location of bracings and shear wall, when provided in a single bay

I. When successive two bay is braced and shear walled

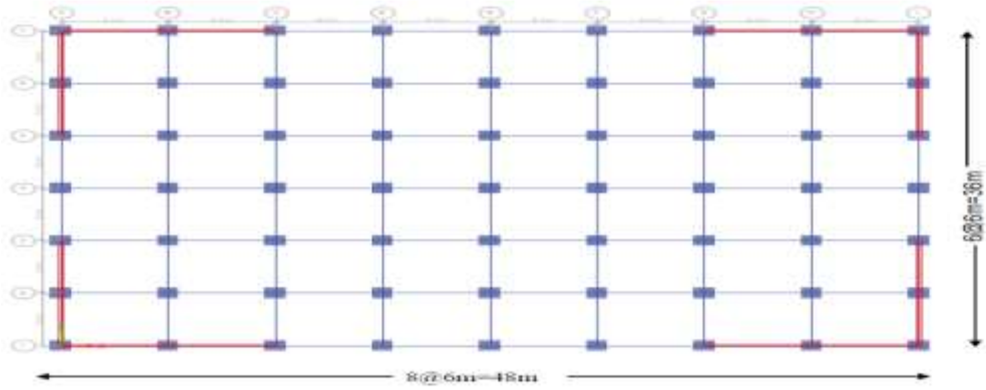

Figure 2: location of bracings and shear wall, when provided in a double bay

VI. RESULTS AND DISCUSSION

Analyses were conducted to evaluate the performance of concrete structures under seismic loading with different bracing type and shear wall. Results of Response Spectrum Analysis have been used to observe and compare floor response of all the models in terms of the following parameters.

1. Storey displacements

Storey displacements depend upon the value of Storey shear at that Storey. Greater the value of Storey shear greater the value of Storey displacement & vice versa.

1.1. Storey displacement for shear walled frame and braced frame when the shear wall and bracing is provided in a single bay

Figure 3: Maximum Storey Displacement in X- direction with 200,300, and 400 mm thickness shear walled frame with reference to bare frame. (When single bay is shear walled).

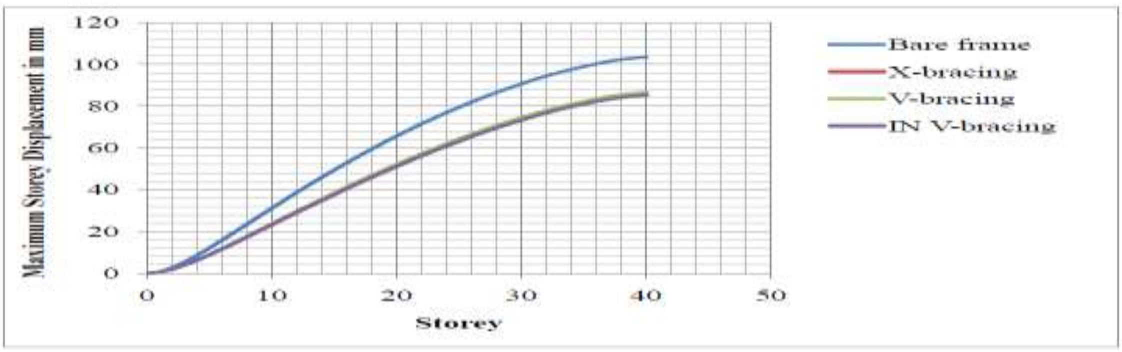

Figure 4: Maximum Storey Displacement in X- direction with X, V and inverted V bracing type. (When single bay is braced).

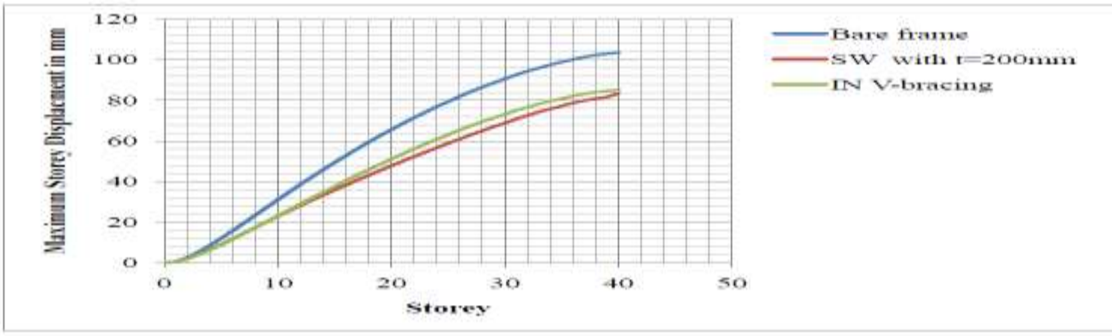

Figure 5: Maximum Storey displacement in X- direction for 200 mm shear walled frame and inverted V- braced frame. (When single bay is braced and shear walled).

The storey displacement was higher when no shear wall and bracing members were provided, but when shear wall and bracing member were provided then Storey displacement decreases. By comparison, the shear wall with thickness 300mm showed better reduction in storey displacement as compared to 200mm, and 400mm thickness shear wall, but the last three storey, 200mm thickness shear walled frame showed insignificantly higher reduction in storey displacement. The maximum reduction in storey displacement of 84.4 mm was observed for building with 300mm thickness shear wall when compared with 103.5mm for bare frame at the 40th storey. So there was 18.45% reduction for this case.

Therefore, from braced frame inverted V - braced frame showed the maximum reduction in storey displacement as compared to X and V- braced frame, and from shear walled frame 300 mm thickness shear walled frame showed the maximum reduction in storey displacement as compared to 200mm, and 400mm thickness shear walled frame, therefore when inverted V- braced frame was compared to 300 mm thickness shear walled frame, 300 mm thickness shear walled frame showed the maximum reduction in storey displacement than inverted V-braced frame with the whole stories.

Generally the following table elaborates the reduction of storey displacement in percentage.

Table 4 Reduction of top Storey displacement in % in X-direction. (When single bay is braced and shear walled)

Model	**Reduction of maximum storey displacement in % at the 40th storey**
X-bracing	17.48
V-bracing	16.33
Inverted V-bracing	17.68
SW with t= 400mm	17.29
SW with t = 300mm	18.45
SW with t = 200mm	19.42

- when the shear wall and bracing is provided in a double bay

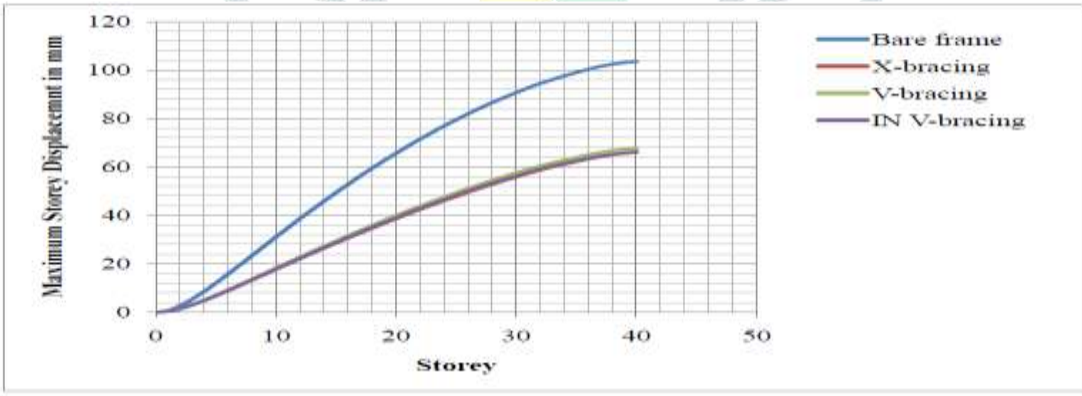

Figure 6: Double bay bracing Storey Displacement in X- direction with X, V and inverted V bracing type (When a double bay is braced).

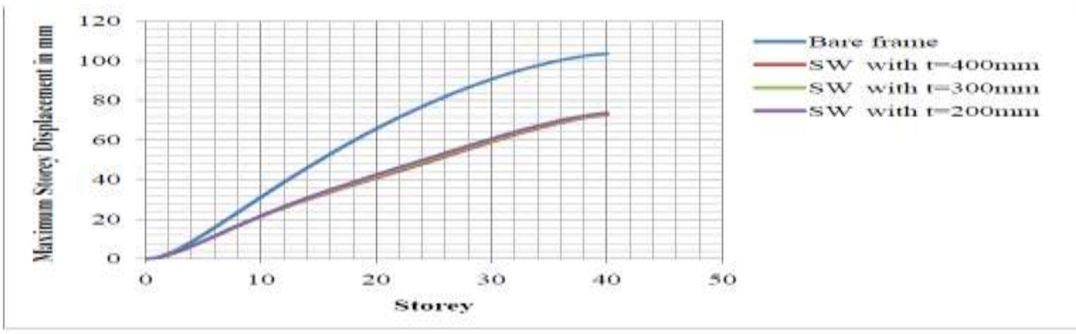

Figure 7: Double bay bracing Storey Displacement in X- direction with 200,300, and 400 mm thickness shear walled frame with reference to bare frame. (When a double bay is shear walled).

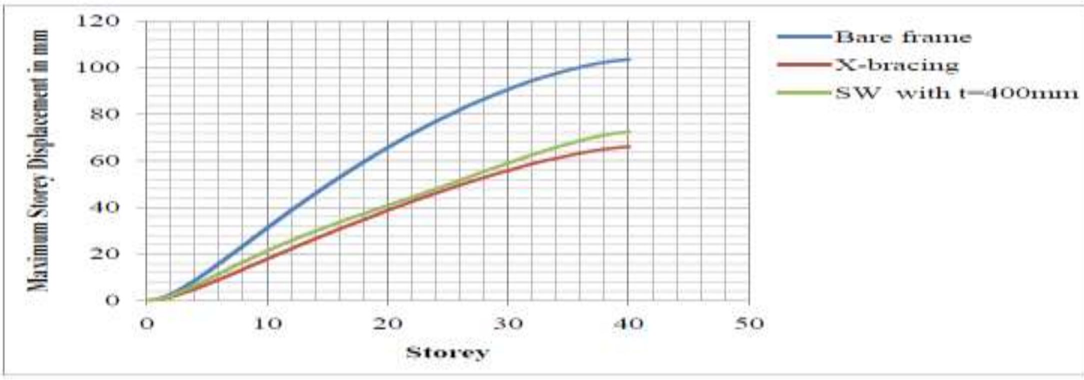

Figure 8: Double bay bracing Storey displacement in X- direction for 400 mm shear walled frame and X- braced frame. (When a double bay is braced and shear walled).

Storey displacement was higher when no shear wall and bracing members were provided, but when shear wall and bracing member were provided then Storey displacement decreases. By comparison, the shear wall with thickness 400mm showed better reduction in storey displacement as compared to 200mm, and 300mm thickness shear wall. The maximum reduction in storey displacement of 72.5 mm was observed for building with 400mm thickness shear wall when compared with 103.5mm for bare frame at the 40th storey. So there was 29.95% reduction for this case.

Therefore, from braced frame X - braced frame showed the maximum reduction in storey displacement as compared to V and inverted V - braced frame, and from shear walled frame 400 mm thickness shear walled frame showed the maximum reduction in storey displacement as compared to 200mm, and 300mm thickness shear walled frame, therefore when X- braced frame was compared to 400 mm thickness shear walled frame, X- braced frame showed the maximum reduction in storey displacement than 400 mm thickness shear walled frame with the whole stories.

Generally the following table elaborates the reduction of storey displacement in percentage.

Table 5 Reduction of top Storey displacement in % in X- direction. (When a double bay is braced and shear walled).

Model	**Reduction of maximum storey displacement in % at the 40th storey**
X-bracing	36.13
V-bracing	34.39
Inverted V-bracing	35.94
SW with t= 400mm	29.95
SW with t = 300mm	29.37
SW with t = 200mm	28.79

VII. CONCLUSIONS

: The behaviour of seismic load resisting elements, which includes concentric braced frame model, and shear wall model were studied. Models with different parameters were created and response spectrum analysis method was performed. The plot of maximum storey displacements at each story level and fundamental period of the system is done. And from the results obtained, the following conclusions are drawn

I. When shear wall and bracing provided in a single bay

1. In both X and Y direction, Inverted V- bracing or chevron bracing showed the maximum reduction in fundamental time period and storey displacement than the other types of bracing systems, which are X-bracing and V-bracing.
2. In both X and Y direction, 300mm thickness shear walled frame showed the maximum reduction in fundamental time period and storey displacement than 400mm and 200mm thickness shear walled frame.
3. It is noticed that from comparison plots of each graph, Inverted V- braced frame and 300mm thickness shear walled frame has almost equal values of maximum storey displacement and fundamental time period. The percentage difference is less than 2.4% and 3.7% respectively, that is the maximum storey displacement and fundamental time period found from 300mm thickness shear walled frame is higher by 2.4% and 3.7% respectively, compared to the values obtained in Inverted V- braced frame.
4. Even if, by comparison 300mm thickness shear walled frame is better than 200mm, 400mm thickness shear walled frame, their difference in reduction of maximum storey displacement and fundamental time period is almost the same, which is less than 2%.This is also true for bracing systems, their difference in reduction of maximum storey displacement and fundamental time period is almost the same, which is less than 2%.
5. Increase shear wall thickness was not always beneficial for earthquake resistance design. As it is seen from comparison plots, 300mm thickness shear walled frame showed the maximum reduction in storey displacement and fundamental time period.

REFERENCES

[1] Adithya, M., Swathi rani, K.S., Shruthi, H K. and Dr. Ramesh, B.R., Study On Effective Bracing Systems for High Rise Steel Structures. SSRG International Journal of Civil Engineering (SSRG-IJCE) – volume 2 Issue 2. February-2015

[2] Akbari, R., Aboutalebi, M.H. and Maheri, M.R., seismic fragility assessment of steel x-braced and chevron-braced Rc frames. Asian Journal of Civil Engineering (BHRC) Vol. 16, No. 1 Pages 13-27. 2015.

[3] Ali, M. and Kyoung Sun Moon., Structural developments in tall buildings: current trends and future prospects. Structures division, school of Architecture, University of Illinois at Urbana-Champaign, Champaign, IL 61820, USA. 13 June-2007

[4] Amol, V., Gowardhan, Dhawale, G.D. and Prof.Shende.,. A review on comparative seismic analysis of steel frame with and without bracing by using software. International Journal of emerging research online. April-2015 N.P

[5] Badoux, M. and Jirsa, JO., Steel bracing of RC frames for seismic retrofitting. Journal of Structural engineering - ASCE 116(1):55–74. 1990.
[6] Chandiwala, A., Earthquake Analysis of Building Configuration with different position of shear wall. International Journal of Emerging Technology and Advanced Engineering. December-2012.
[7] Christian Sandelin. and Evgenij Budajev., The Stabilization of High-rise Buildings an evaluation of the tubed mega frame concept. ISRN UTH-INGUTB-EX-B-2013/38-SE 15 hp. December- 2013.
[8] EN 1998 Euro code 8., 2003. Design of structures for earthquake resistance, European Committee For Standardization, English version.
[9] Halis Gunel, M.and Emre Ilgin, H., A proposal for the classification of structural systems of tall buildings. Faculty of Architecture, Middle East technical University, ankara 06531. 4 July-2006.
[10] Hamdy Abd-el-Rahim, H. A. and Ahmed Abd El-Raheem Farghaly Role of shear walls in high rise buildings. Journal of engineering sciences, Assiut University, Vol. 38, No. 2, pp. 403 -420. March-2010.
[11] Jayachandran, P., Design of Tall Buildings Preliminary Design and Optimization. Worcester Polytechnic Institute, Worcester, Massachusetts, 01609, USA jayachan@wpi.edu. National Workshop on High-rise and Tall Buildings, University of Hyderabad, Hyderabad, India, Keynote Lecture. May- 2009.
[12] Mehmet Ağar., Strengthening of reinforced concrete frames by using steel bracings. A thesis submitted to the graduate school of natural and applied sciences of the Middle East technical university. June- 2008.
[13] Maheri, M.R. internal steel bracing of Rc frames. 3rd International Conference on Concrete & Development.
[14] Maheri, M.R. internal steel bracing of Rc frames. Professor of Civil Engineering, Shiraz University, Shiraz, Iran CD6-KN08.
[15] Michael Willford., Andrew Whittaker. and Ron Klemencic., Recommendations for the Seismic Design of High-rise Buildings. CTBUH Seismic Design Guide. 2008.
[16] Rajeshwari, A., Murade. and Mohd Shahezad., "Review on Seismic Response of Multi-Storied RCC Building Infill with Masonry Infill and Steel Bracing"", www.ijress.org Vol.:1 No. 8. December- 2015
[17] Sagar Ramesh Padol. and Dr. Rajashekhar, S., Review paper on seismic response of multistoried RCC building with mass irregularity. International Journal of Research in Engineering and Technology. March-2015.
[18] Shruti Badami. and Suresh, A Study on Behavior of Structural Systems for Tall Buildings Subjected To Lateral Loads. International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 3 Issue 7. M.R., July – 2014.
[19] Siddiqi, Z.A., Rashid Hameed., Usman Akmal,.Comparison of Different Bracing Systems for Tall Buildings. Pak. J. Engg. & Appl. Sci. Vol.14. January- 2014.