SEISMIC PERFORMANCE OF BUILDING FRAMES OF DIFFERENT PLAN GEOMETRY SUBJECTED TO VARIOUS TIME HISTORIES

[1]Sumit D. Konkeri, [2]Dr. Mahesh G. Kalyanshetti
[1]P.G.Student, [2]Associate Professor
Department of Civil Engineering,
Walchand Institute of Technology, Solapur, Maharashtra, India

Abstract: Seismic performances of building frames are greatly influenced by shape (plan geometry of structure). The more realistic seismic performance can be studied by applying the real life Earthquake forces i.e. Time Histories of various Earthquakes. In the present study an attempt is made to evaluate performance of structure of "L" shape, "Plus" shape and "Square" shape building frames of G+5. The study is carried out experimentally using uniaxial shake Table on scale down building Frames. Four Time Histories namely El Centro (1940), Bhuj (2001), Uttarkashi (1991) and Indo Burma (2016) are used to study the variation in the acceleration, velocity and displacement. The experimental results are validated by performing analytical study on the same model using application software (ETABS 2016) study reveals that unsymmetrical building frames are less effective in resisting the seismic forces also out of the four Time History studied El Centro (1940) Time History is producing max acceleration and displacement in the structure.

***IndexTerms* - Seismic Response, Time History Analysis, Shake Table and Scale down model.**

I. INTRODUCTION

India is one of the most disaster prone countries, vulnerable to almost all natural and manmade disasters. About 85% area is vulnerable to one or multiple disasters and about 57% area is in high seismic zone including the capital of country. Earthquake Engineering development started rather early in India. Despite an early start the seismic risk in the country has been increasing rapidly in recent years. India has a number of world's greatest earthquakes in the last century. The north eastern region of India has experienced some of the great earthquakes is observed that symmetry of the building both in elevation and plan plays important role in the seismic performance. In the event of real earthquake the forces hit the structure in various directions and depending upon the stiffness of the structure in that direction the behavior depends. However the realistic simulation of earthquake is complex. Therefore there is a scope to study unsymmetrical structures and to evaluate their performances in point of overall stability.

The multi-storey structure generally fails due to seismic forces at the location where there is a weakness. The presence of irregularities in mass, stiffness and strength contribute to those weaknesses. Excess mass on upper floors has a more unfavorable effect than those at lower floors. The collapse of structure is due to reduction in ductility of vertical load resisting element and increase in inertial force. Hence there is need to study effect on building for various time history for unsymmetrical building. Hence, the real earthquake force simulation is really difficult as it cannot be predicted. Therefore study is carried out on an occurred earthquake in the past using various time histories.

II. OBJECTIVE

The objective of the present study is to investigate the Seismic Response of various unsymmetrical building frames using Time Period analysis. The results are obtained by experimental and analytical study. Experimental study is carried out on scaled down steel model using Shake Table and analytical study is carried out by structural analysis software ETABS 2016.

The objectives are as below

1) To study the Seismic performance of building frame having different plan geometry.
2) To study experimentally performance of building frame for various Time History.
3) To identify the effectiveness of plan geometry for various earthquakes.
4) To study variation in acceleration, velocity and displacement of building frame having different plan geometry.
5) To validate result by analytical study.

III. PROTOTYPE RC BUILDING FRAME CONSIDERED FOR THE ANALYSIS

In the present work, three RC building frames are considered which are analyzed and designed as per codal provision. The structures considered are "L" shape, "Plus" shape and "Square" shape in plan. Dimensional characteristics are illustrated in Table 1.

Table 1 Geometric and Material Properties of Building Frames

Sr. No	Contents	Description		
1	Building Shapes	L	Plus	Square
2	No. of stories	G+5	G+5	G+5
3	Storey Height	4 m	4 m	4 m
4	Grade of Concrete	M 20	M 20	M 20
5	Grade of Steel	Fe 415	Fe 415	Fe 415
6	Bay width (Both Direction)	3 m	3 m	3 m
7	Slab thickness	0.15 m	0.15 m	0.25 m
8	Size of Column	0.45m X 0.45m	0.45m X 0.45m	0.45m X 0.45m
9	Size of Beam	0.23m X 0.3m	0.23m X 0.3m	0.23m X 0.3m
10	Live load	3 kN/m²	3 kN/m²	3 kN/m²
11	Seismic Zone	III	III	III

IV. PREPARATION OF SCALED-DOWN STRUCTURAL MODEL

The critical part for experimental study was to develop an experimental model able to represent with the less degree of distortion. One fundamental issue to be considered at this stage is the fact that the construction of a 'true replica' model that satisfies all the similitude requirements needed by dimensional analysis is almost an impossible task due to material limitations. The main limitations for the present study were the use of materials and the pay load capacity of the Shake Table (30 kN). The major task in the scaling down process is to achieve "Dynamic Similarity" where model and prototype experience homologous forces. According to this approach two principal test conditions are established

1) Natural frequency of the prototype should be scaled by an appropriate scaling relation to that of model.
2) Density of the prototype and model should be similar.

V. SCALE FACTOR

Adopting appropriate geometric scale factor is one of the important steps in scale modeling on Shake Table. Due to size limitation of Shake Table, the C/C distance between two columns is set as 0.12 m leading to a linear scale factor, of 3/0.12 = 25 (column spacing in prototype structure is 3m).Therefore, Employing geometric scaling factor of 1:25. The scaling relations for the various parameter adopted in this study, are shown in Table 2.

Table 2 Scaling Relations in terms of Geometric Scaling Factor (S)

Parameters	Scale factor
Mass Density	1
Stiffness	S^2
Force	S^3
Modulus	S
Acceleration	1
Frequency	$S^{-1/2}$
Time	$S^{1/2}$
Length	S
Stress	S
Strain	1
EI	S^5

Typical scaling down procedure for "Square" shape building model is described below.

According to the first principle, the relation between natural frequency of model (f_m) and prototype (f_p) is

$$f_m / f_p = S^{-1/2} = 5$$

Natural frequency of the "Square" shape prototype structure as calculated by application software (modal analysis) is, f_p=1.793 Hz. Therefore required frequency of the model (f_m) is 8.965 Hz.

Also, according to second principle density of the prototype structure (ρ_p) is work out and it is 201 Kg/m³.

Therefore the mass of the structural model (M_m) is estimated as:

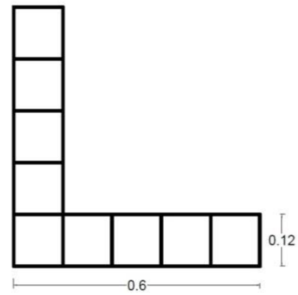
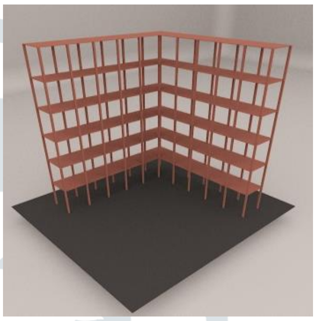
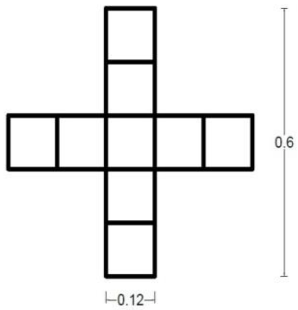
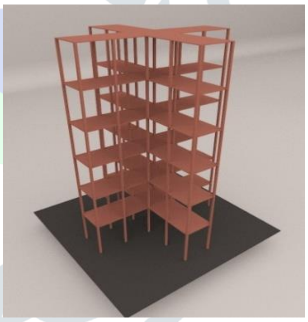
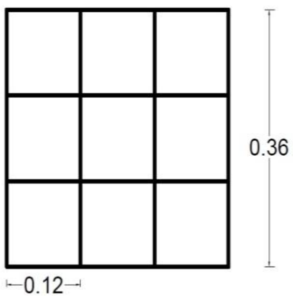
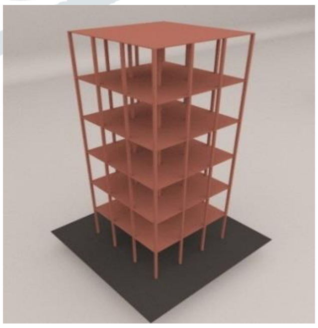
$$M_m = \rho_m \times V_m = 201 \times (0.96 \times 0.36 \times 0.36) = 25.00 \text{ Kg}$$

The dimensions of column and slab of scaled down steel model is determined so that the weight of model nearly equals to 25.00 Kg as required by simulated laws. Considering all above the details of "Square" shape scaled down steel model is worked out. Similar calculations were done for "L" Shape and "Plus" Shape steel models and the details are presented in Table 3.

Table 3 Geometric and Material Properties of Steel Scaled Down Model

Sr. No	Contents	Description		
1	Building Shapes	L	Plus	Square
2	No. of stories	G+5	G+5	G+5
3	Grid Size	120mm x 120mm	120 mm x 120 mm	120 mm x 120 mm
4	No. of column	20	20	16
5	No. of blocks	9	9	9
6	Storey Height	160mm	160mm	160mm
7	Slab thickness	2.5mm	2.5mm	2.5mm
8	Size of Column	8mm x 8mm	8mm x 8mm	8mm x 8mm

Table 4 Plan and Isometric View of Steel Scaled Down Model

<table>
<tr><th>SHAPE</th><th>PLAN</th><th>ISOMETRIC VIEW</th></tr>
<tr><td>L</td><td>
</td><td></td></tr>
<tr><td>PLUS</td><td>
</td><td></td></tr>
<tr><td>SQUARE</td><td>
</td><td></td></tr>
</table>

VI. EXPERIMENTAL STUDY USING SHAKE TABLE:

The Shake Table at the Civil Engineering Department, Walchand Institute of Technology, Solapur, is uniaxial driven having table size 2m X 2m with maximum payload capacity of 30 kN. The table has an operating frequency range of 0.01 Hz-50Hz.

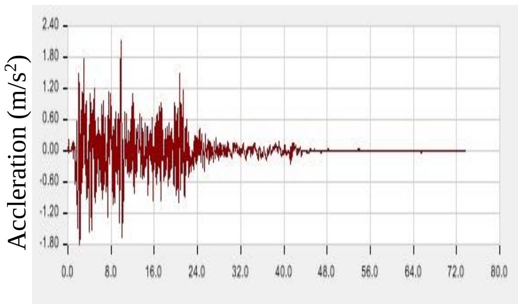
Fig.1 Experimental Setup on Shake Table

VII. TIME HISTORY USED IN THE STUDY

Table 5 Time Histories used for Experimental Study

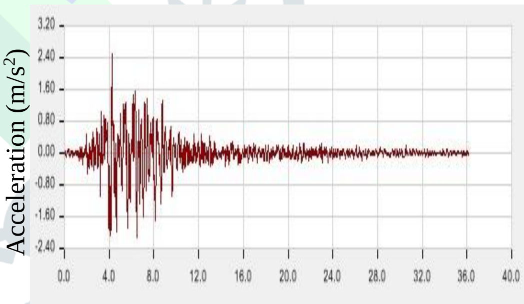
Earthquake	El Centro	Uttarkashi	Bhuj	Indo-Burma
Place	California	Uttarkashi	Gujarat	Myanmar
Date	18th May 1940	20th Oct 1991	26th Jan 2001	13th April 2016
Time	9:35pm	2:53am	8:46am	11:35am
Magnitude	6.9	6.8	7.7	5.0

Table 6 Time Histories Graphs



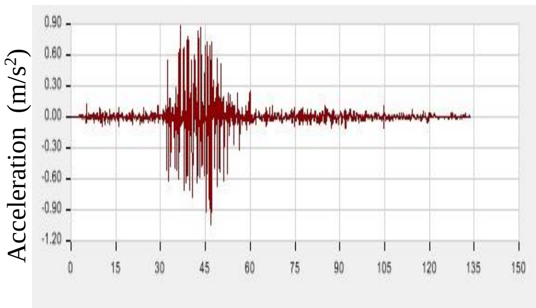
Time (sec)

Fig.2 El-Centro



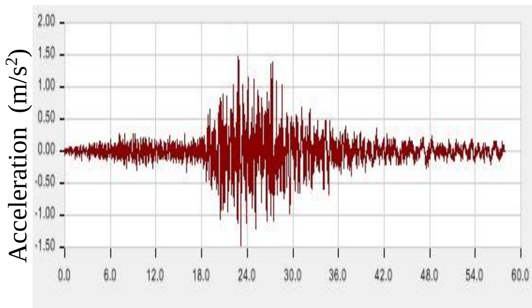
Time (sec)

Fig.3 Uttarkashi



Time (sec)

Fig.4 Bhuj



Time (sec)

Fig.5 Indo-Burma

VIII. RESULTS OF EXPERIMENTAL STUDY

The scaled down model of above mentioned building frames are mounted on shake table and the input motion is given as per the time history which are considered for the analysis namely El-Centro, Bhuj, Indo Burma and Uttarkashi. The accelerometer is placed at the roof level and the acceleration produced is recorded. Later on the acceleration are converted to velocity response and further converted to displacement response. The variation of acceleration and displacement for three plan geometry i.e. "L" shape, "Plus" shape and "Square" shape are presented below for El-Centro time history in the same way result are obtained for remaining time history. The summary of variation of acceleration and displacement for various shape building and for various time histories are presented in Fig 8 and Fig 9.

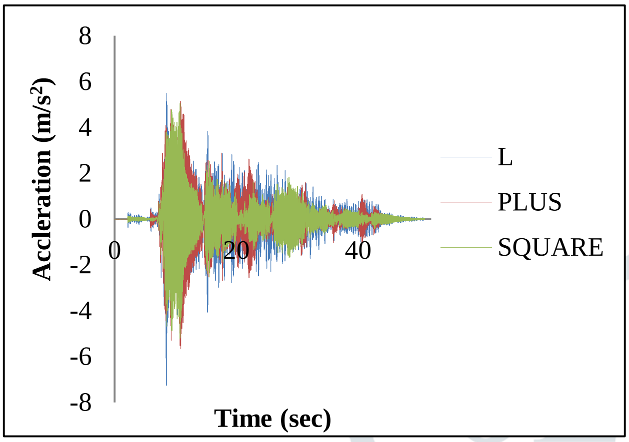


Fig.6 Acceleration Time History (Experimental) - El-Centro

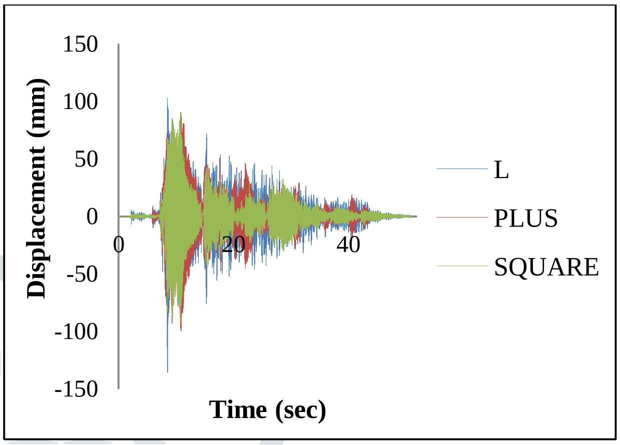


Fig.7 Displacement Time History (Experimental) - El-Centro

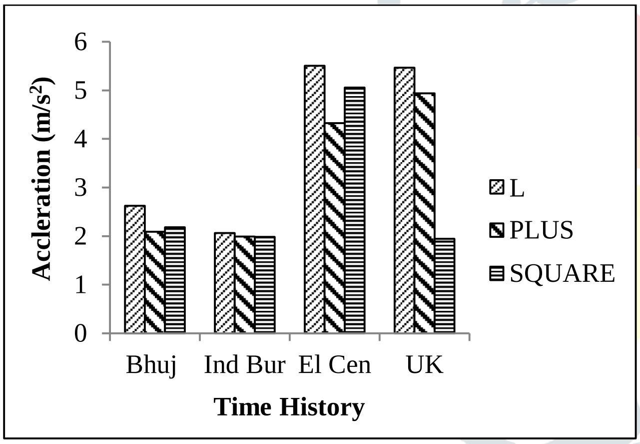


Fig.8 Variation of Acceleration for Different Time Histories (Roof Level)

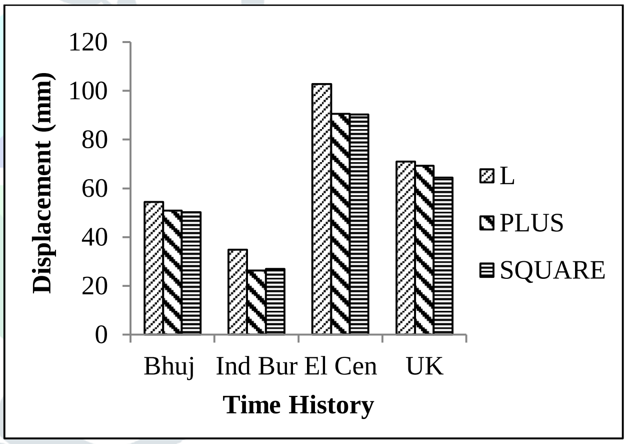


Fig.9 Variation of Displacement for Different Time Histories (Roof Level)

From Figure 6 to Figure 9 it is observed that El-Centro time history is producing higher values of acceleration in the building. It is observed that "L" shape building produces higher acceleration as compared to "Plus" and "Square" shape. Symmetric building such as plus and square is producing almost same acceleration with marginal difference. Therefore it can be concluded that unsymmetrical building frames produces more acceleration and derives less resistance to Earthquake forces. Hence, unsymmetrical structures are less preferred.

IX. ANALYTICAL STUDY

Analysis of "L" shape, "Plus" Shape and "Square" Shape building is developed by using ETABS 2016 software and the performance of these structures are studied by applying the same time histories as of experimental work. The results are obtained and presented in graph of acceleration versus time and displacement versus time.

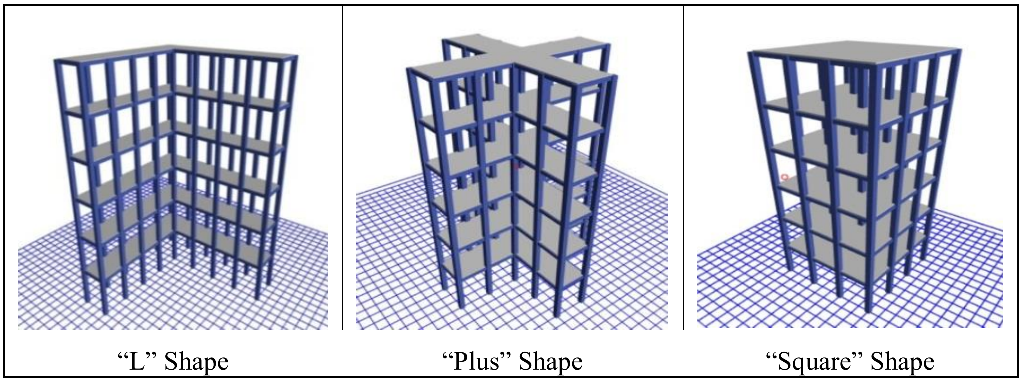


Fig.10 Building Frame models devloped in E-tabs 2016

X. RESULTS OF ANALYTICAL STUDY

The scaled down model of above mentioned building frames are used for the analytical study and the input motion is given as per the time history which are considered for the analysis namely El-Centro, Bhuj, Indo Burma and Uttarkashi. The analysis is carried by using ETABS 2016 software, the analysis is carried out for the roof level. The variation of acceleration and displacement for three plan geometry i.e. "L" shape, "Plus" shape and "Square" shape are presented below for El-Centro time history in the same way result are obtained for remaining time history. The summary of variation of acceleration and displacement for various shape building and for various time histories are presented in Fig 13 and Fig 14.

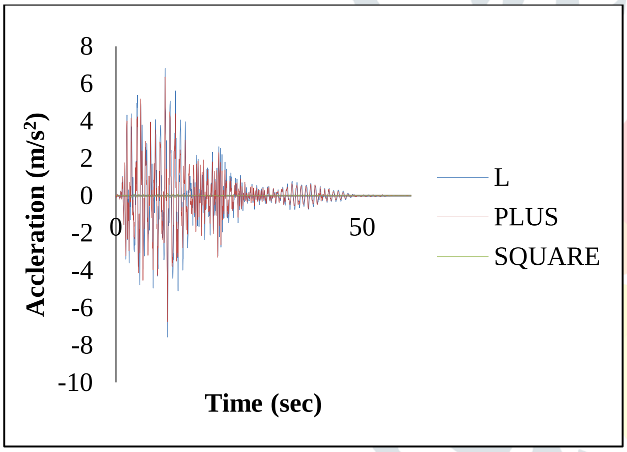


Fig.11 Acceleration Time History (Analytical) - El-Centro

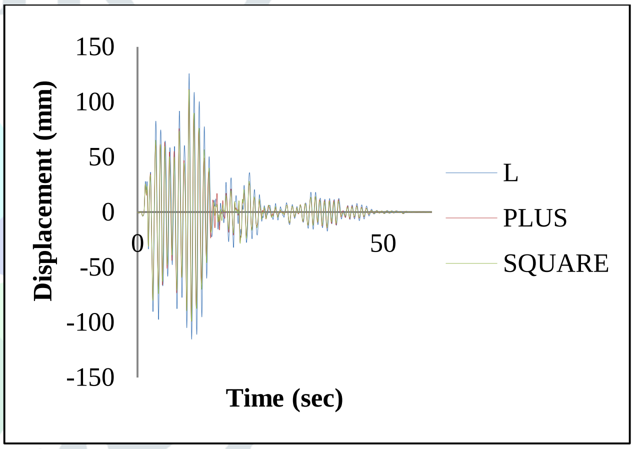


Fig.12 Displacement Time History (Analytical) -El-Centro

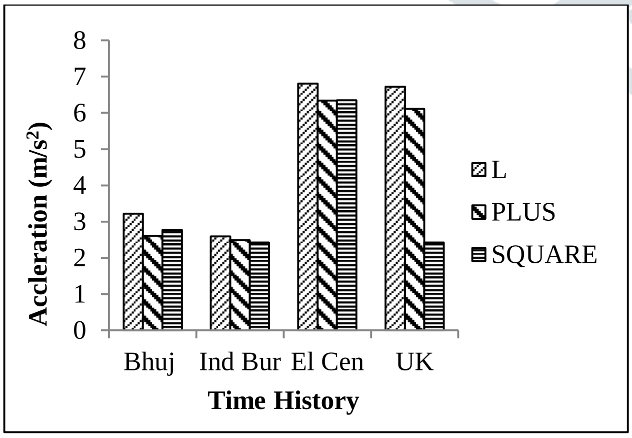


Fig.13 Variation of Acceleration for Different Time Histories (Roof Level)

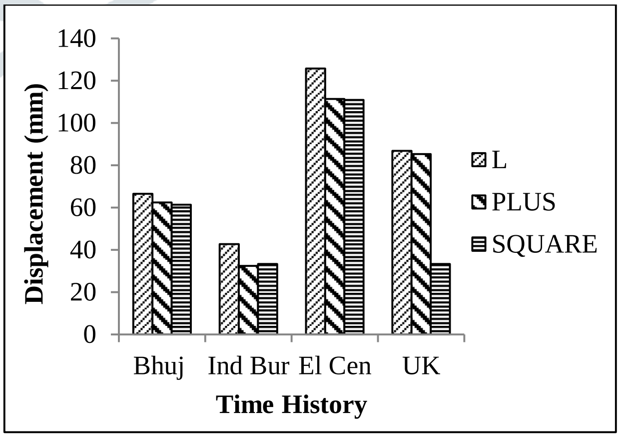


Fig.14 Variation of Displacement for Different Time Histories (Roof Level)

From Figure 13 to Figure 14 it is observed that El-Centro time history is producing higher values of displacement in the building. It is observed that "L" shape building produces higher displacement as compared to "Plus" and "Square" shape. Symmetric building such as plus and square is producing almost same displacement with marginal difference. Therefore it can be concluded that unsymmetrical building frames produces more displacement and derives less resistance to Earthquake forces. Hence, unsymmetrical structures are less preferred.

XI. COMPARISON OF ANALYTICAL AND GRAPHICAL STUDY

The results obtained by analytical and experimental study is presented below. The comparison of acceleration is shown in Fig.15 and the comparison of displacement is shown in Fig.16.

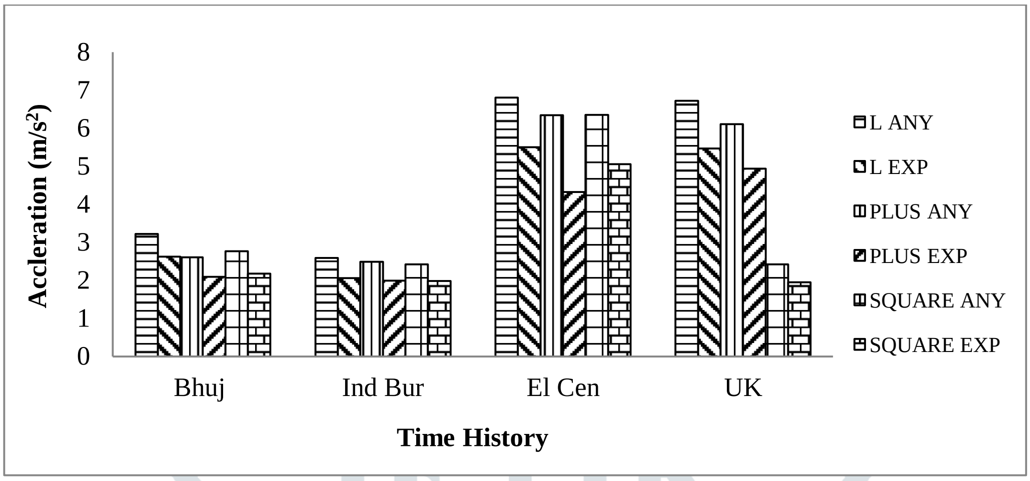


Fig.15 Comparison of Acceleration

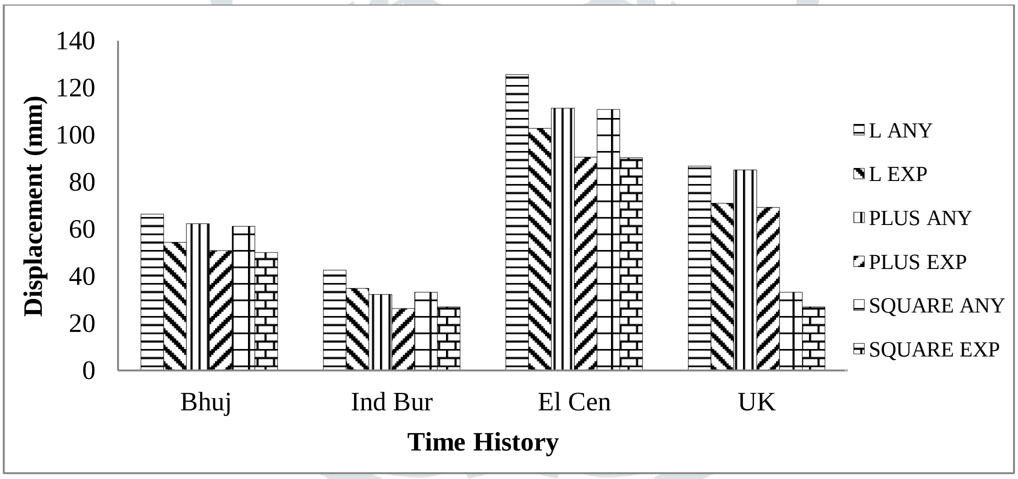


Fig.16 Comparison of Displacement

Figure 15 and Figure 16 show graph of acceleration versus time and displacement versus time of various earthquake. Here it is observed that El-Centro time history is producing higher values of displacement in building. It is observed that the analytical study is producing higher displacement about (15%-18%) variation as compared to experimental study.

XII. CONCLUSION

The study is carried out on three scaled down steel models having “L” Shape, “Plus” Shape, and “Square” Shape plan geometry. The parameters such as acceleration, velocity and displacement on different models are determined by using the various time histories like El-Centro,Indo Burma,Uttarkashi and Bhuj. Following are the conclusion

1) Among all the Time Histories studied it is obsereved that El-Centro Time History is giving maximum response where as Indo Burma is giving lesser performance.
2) It is observed that ‘L’ shape building is less effective in resisting earthquake forces as the acceleration, velosity, and displacement are observed to be more than other shape (i.e. “Plus” Shape, “Square” Shape).Thus it is concluded that unsymmetrical building is not advised as it derives less strenght and stability against seismic forces.
3) It is observed that Square shape buildings are more effective in resisting earthquake forces and also derives more resistance to seismic forces. Hence symmetrical shape buildings are recommended to ensure satisfactory performance of structure.

4) The performance of structure is studied experimentally and analytically. The results obtained are in close aggrement with each other (15%-18% variation).Thus it may be concluded that the most realastic behavior of structure is possible to study in laboratory on scale down model using experimental facility such as Shake Table.

XIII. ACKNOLEDGMENT

Authors are grateful to the Civil Engineering Department of Walchand Institute of Technology, Solapur for motivation and supporting with laboratory facility in the study. The author also expresses the gratitude toward All India Council for Technical Education (AICTE) for providing financial assistant in the form RPS grant. This has made possible to develop the shake table facility in the institute.

XIV. REFERENCES

[1] Kalyanshetti, M. and Wale, Amit 2017 “Seismic Performance of Building Frame Considering soil Structure Interaction (SSI).
[2] Kalyanshetti, M. and Hirave, V. 2018 “Seismic Response of Composite Building Frames with Alternate Bracing System Considering Soil Structure Interaction (SSI).
[3] Chinndam, C. and Autade, P. 2018 “Seismic Time History Analysis of Six Storey Shear Building with Newmark-β Method and ETABS.
[4] Jain, S. K. 1998. “Indian Earthquakes : An Overview,” Indian Concr. J., vol. 72, no. 11.
[5] Bilham, R. 2004. “Earthquakes in India and the Himalaya: Tectonics, geodesy and history,” Ann. Geophys., vol. 47, no. 2–3, pp. 839–858.
[6] Iyengar, R. N. Sharma, D. and Siddiqui, J. M 1999. “Earthquake history of India in medieval times,” Indian J. Hist. Sci., vol. 34, no. 3, pp. 181–237.
[7] Mittal, Kumar, A. and Ramhmachhuani, R. 2012 “Indian National Strong Motion Instrumentation Network and Site Characterization of Its Stations,” Int. J. Geosci., vol. 3, no. 6, pp. 1151–1167.
[8] Archuleta, A. Steidl, A. and Squibb, M. 2004, “The COSMOS Virtual Data Center,” in 13th World Conference on Earthquake Engineering no. Paper No. 1566.
[9] BIS, 2016. “Criteria for Earthquake Resistant Design of Structures,” Bureau of Indian Standards, India, IS 1893 Part 1.
[10] K. Chopra, 2006. Dynamics of Structures: Theory and Applications to Earthquake Engineering. New Delhi: Dorling Kindersley (India) Pvt. Ltd.
[11] “ETABS Lateral Loads Manual.” 2016. Computers & Structure.
[12] s P. R. Vaidya, 2017. “ETABS- Time History Analysis”.