SEISMIC RESPONSE OF UN-SYMMETRICAL BUILDING FRAME WITH VARIOUS INCIDENT ANGLE OF EARTHQUAKE FORCES

[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. The El Centro (1940) time history is used to study the variation in the acceleration. The experimental results are validated by performing analytical study on the same model using application software (ETABS 2016. The performance of building changes at various incident angles of earthquake forces. So the study is carried on various unsymmetrical building frames at various incident angles 0^0, 30^0 and 60^0.

***IndexTerms* - Seismic Response, Time History Analysis, Shake Table and Scale Down Model, Incident Angle.**

I. INTRODUCTION

India is one of the most disaster prone country, unsafe to almost all natural and manmade disasters. About 85% area is unsafe to one or multiple disasters and about 57% area is in high seismic zone including the capital of country. 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. In north eastern region of India the great earthquakes are observed in symmetry of the building both in elevation and plan which 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 on various unsymmetrical structures at various incident angles.

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.

Seismic forces can act on building from any direction. Thus seismic performance of a building depends on angle of incidence of earthquake forces. In the present study the incident angle 0^0, 30^0 and 60^0 is considered.

II. OBJECTIVE

The objective of the present study is to investigate the seismic response of building frames using time history 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.
3) To identify the effectiveness of plan geometry.
4) To study variation in acceleration of building frame having different plan geometry.
5) To study effect of various incident angle of earthquake force on building frame.

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:

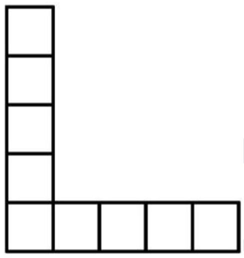
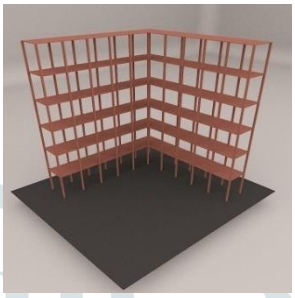
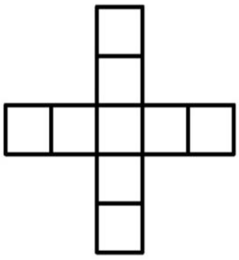
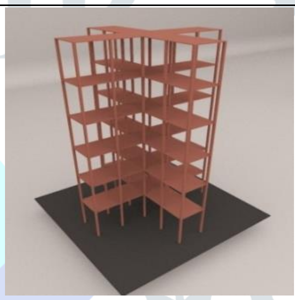
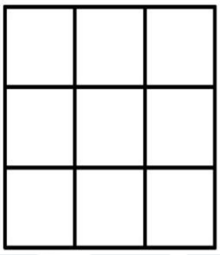
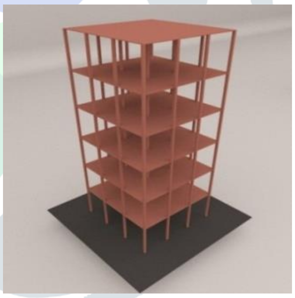
$$M_m = \rho_m \times V_m$$
$$= 201\times (0.96\times0.36\times0.36)$$
$$= 25.00 \text{ Kg}$$

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 and 4.

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

Shape	Plan	Isometric View
L		
PLUS		
SQUARE		

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

El Centro Time History: Imperial Valley, California**,** 19th May 1940 04:36 UTC, Magnitude 7.1the main earthquake took nine lives and caused property damage estimated at $6 million. The first shock damaged about 80 percent of the buildings in Imperial. Many buildings in the business district were condemned, and older residences sustained severe damage. Damage to a lesser extent occurred at El Centro.

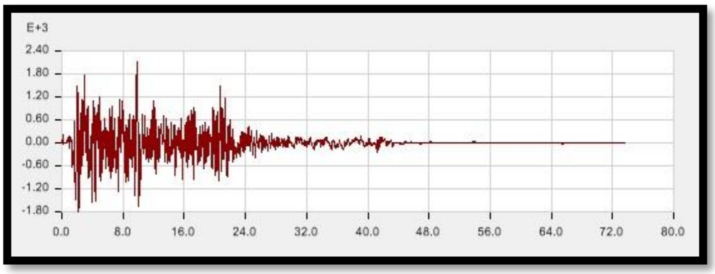
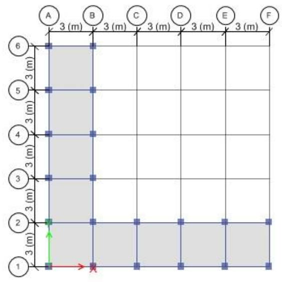
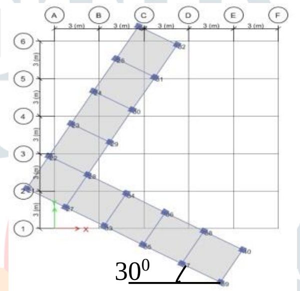
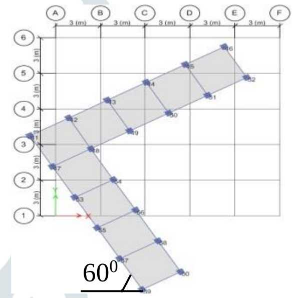
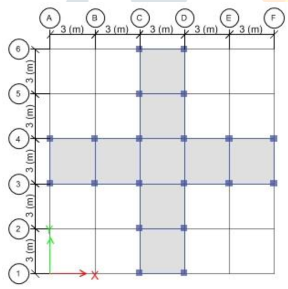
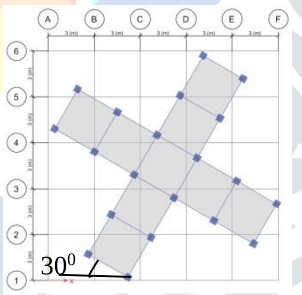
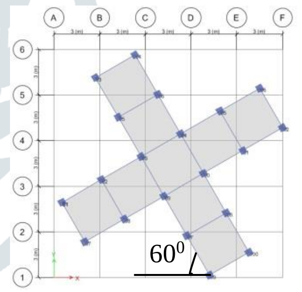
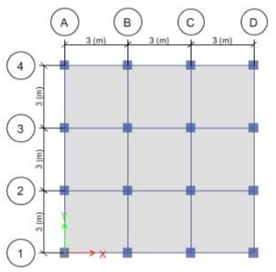
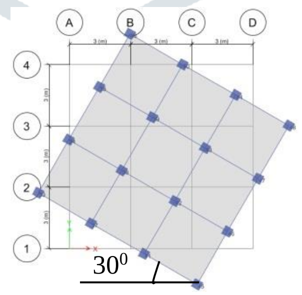
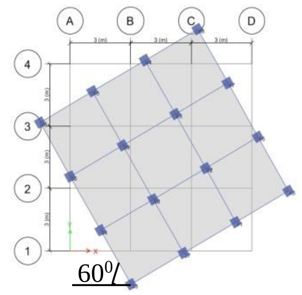


Fig. 2 El Centro Time History

VIII. ANALYTICAL STUDY

Analysis of L shape, Plus shape and Square shape building is carried out using ETABS 2016 software for various incident angles and the performance of these structures are studied by applying the El Centro time history. The ETAB models for various incident angles are presented in Table 5.

Table 5 Various Incident Angles for Various Shapes

Shape	0^0	30^0	60^0
L			
PLUS			
SQUARE			

IX. RESULTS

The present study is carried out by using El-Centro time history. The results are obtained from time history on different plan geometry buildings (L shape, Plus shape and Square shape). The study is carried out experimentally as well as analytically. The results obtain from both the studies are compared. The analytical and experimental results are obtained for various Angle of Incident (0^0, 30^0, 60^0). The Incident Angle is presented as I.A.

All the results obtained from experimental study and analytical studies are shown in the following figures.

Table 6 Roof Accleration for L Shape Building

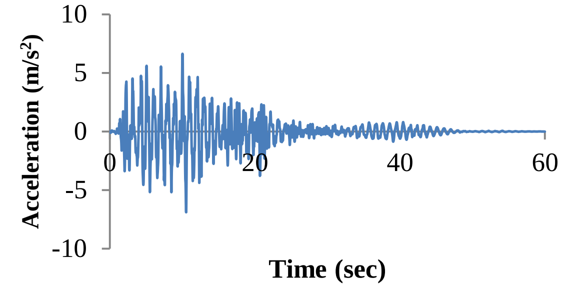
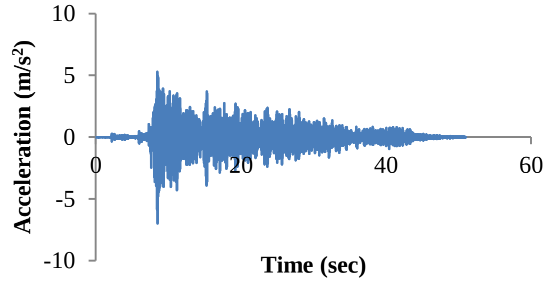
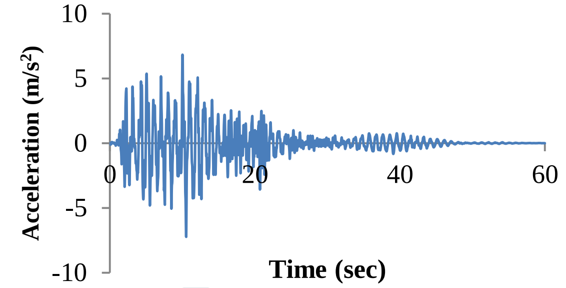
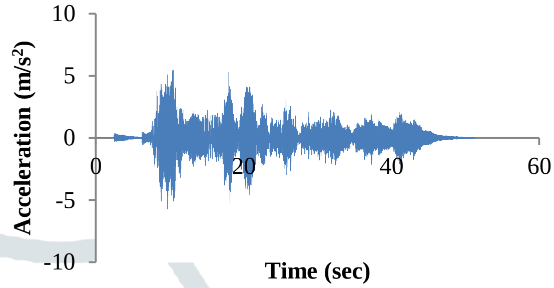
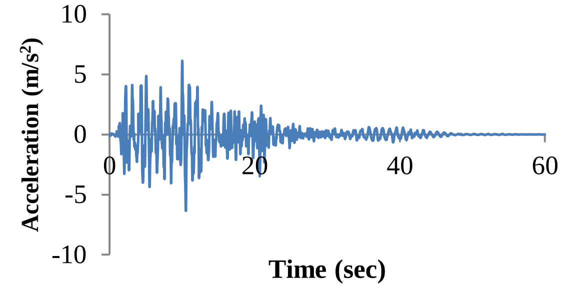
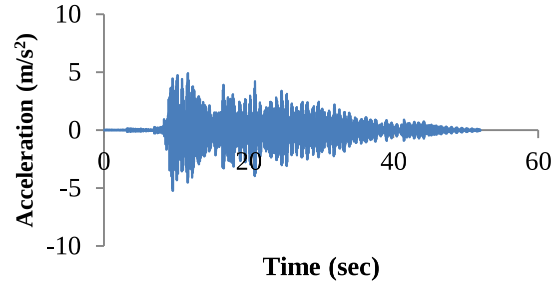
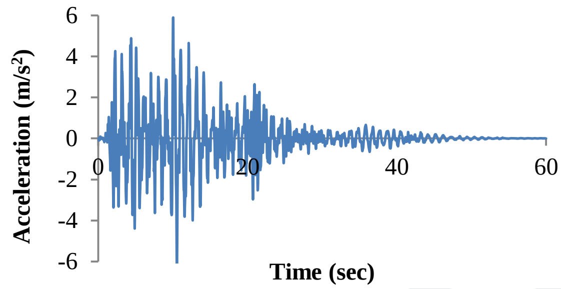
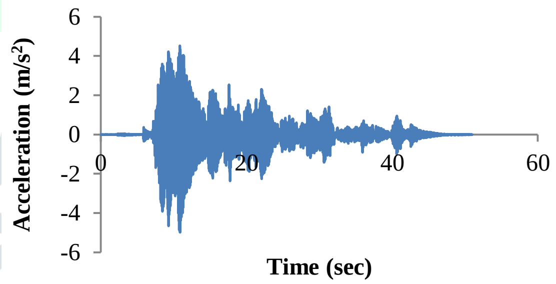
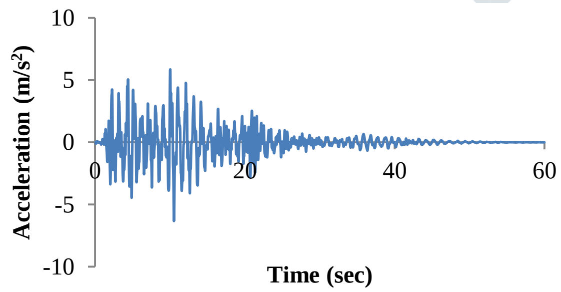
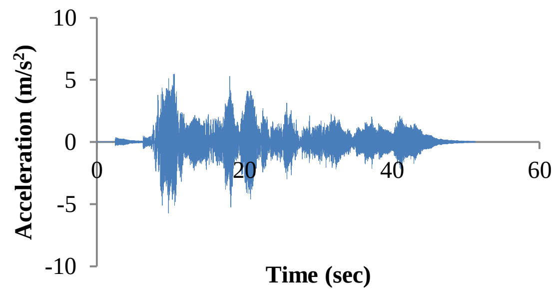
	Analytical	Experimental
L - 0^0 I.A.		
L - 30^0 I.A.		
L - 60^0 I.A.		

Table 7 Roof Accleration for Plus Shape Building

PLUS - 0^0 I.A.		
PLUS - 30^0 I.A.		

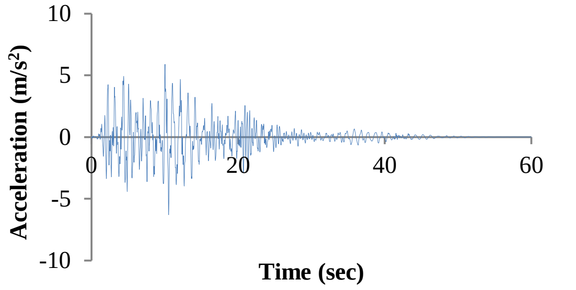
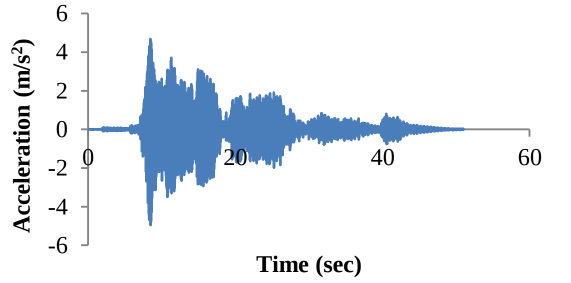
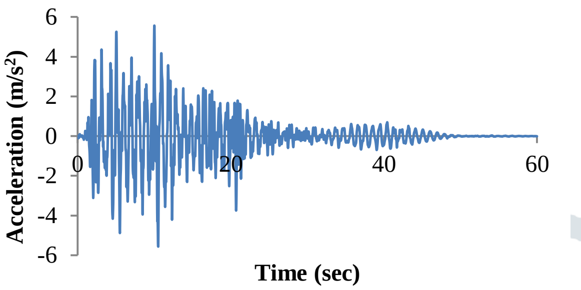
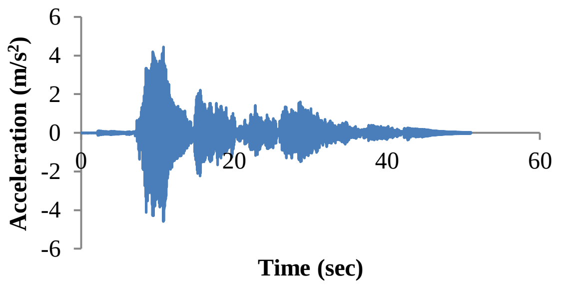
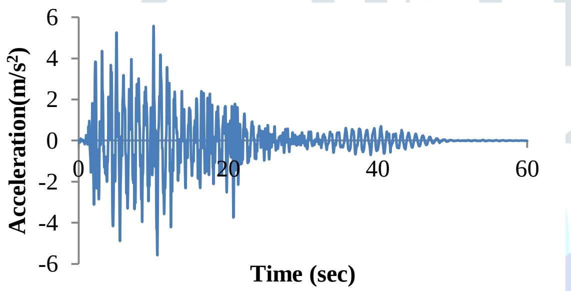
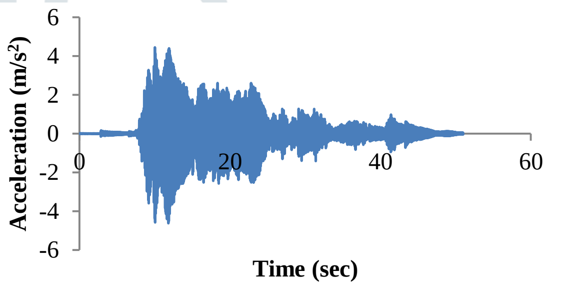
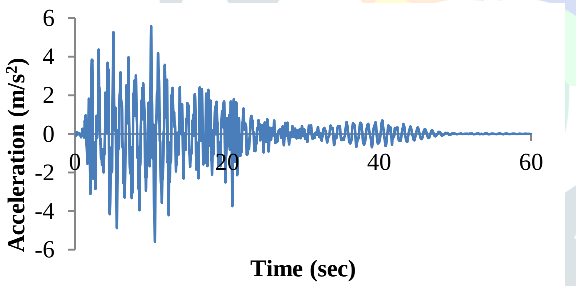
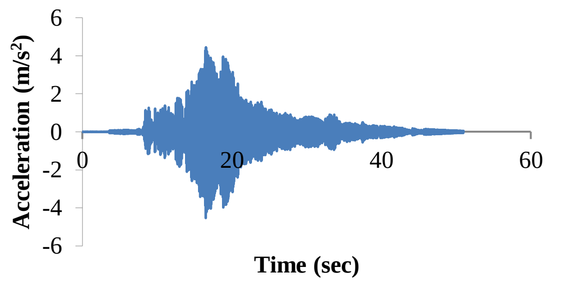
	Analytical	Experimental
PLUS - 60^0 I.A.		

Table 8 Roof Accleration for Square Shape Building

SQUARE-0^0 I.A.		
SQUARE- 30^0 I.A.		
SQUARE- 60^0 I.A.		

X. COMPARISION OF ROOF ACCLERATION FOR VARIOUS INCIDENT ANGLE

The result obtained for various shape are studied and the maximum accleration produced at roof level is identified and a comparision is for various plan geometry is presented in fig 6 and 7.

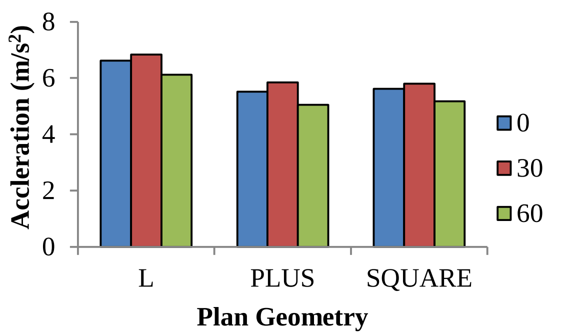


Fig 6. Analaytical Result

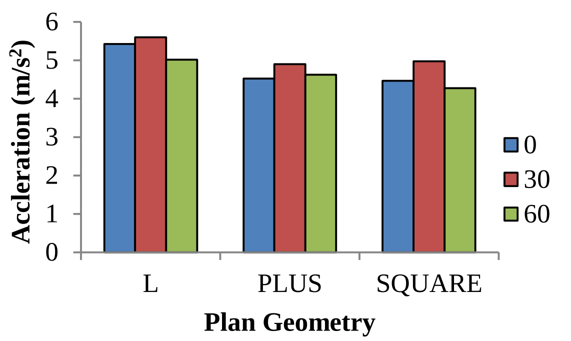


Fig 7. Experimental Result

Fig.6 shows the variation of acceleration for analytical study. It is observed from the fig. 6 that roof acceleration increases about (2%-3%) from 0^0 to 30^0 incident angle. However, it decreases by about (7%-8%) from 30^0 to 60^0 incident angle. This trend is observed to be same for all the shapes. Among all the shape it is observed that the acceleration produced in L shape building are 14.34% higher. This revels that building produces maximum acceleration for 30^0 incident angle. Also it can be stated that the variation from 30^0 to 60^0 need to be studied by changing incident angle with small increment, so that the severe effect can be identified. The pattern of graph is same for both plus and square shape building.

Fig.7 shows the variation of acceleration for experimental study. It is observed from the fig. 7 that roof acceleration increases about (1%-2%) from 0^0 to 30^0 incident angle. However, it decreases by about (5%-6%) from 30^0 to 60^0 incident angle. This trend is observed to be same for all the shapes. Among all the shape it is observed that the acceleration produced in L shape building are 11.25% higher. This revels that building produces maximum acceleration for 30^0 incident angle. Also it can be stated that the variation from 30^0 to 60^0 need to be studied by changing incident angle with small increment, so that the severe effect can be identified. The pattern of graph is same for both plus and square shape building.

XI.CONCLUSION

Based on the results following conclusion are drawn.

1) The response of accleration is maximumfor 30^0 I.A. in all shape of buildings. However, it is recommended to study the performance by taking smaller increment from 30^0 to 60^0, in order to exactly identify the severe incident angle.
2) It is observed that L shape building is less effective in resisting earthquake forces as the acceleration 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.

XII. ACKNOWLEDGMENT

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.

XIII. REFERENCES

[1] Kalyanshetti, M. and Konkeri, S. "Seismic Performance of Building Frame Considering soil Structure Interaction (SSI), International Journal of Emerging Technologies and Innovative Research, ISSN: 2349-5162, Vol. 6, Issue 4, page no. pp. 534-541, April 2019.

[2] Kalyanshetti, M. and Wale, A, "Seismic Performance of Building Frame Considering soil Structure Interaction (SSI),International Journal of Research in Engineering and Technology, Vol 7, Issue 8, eISSN: 2319-1163, pISSN: 2321-7308, 2017.

[3] Kalyanshetti, M. and Hirave, V. "Seismic Response of Steel Braced Building Frame Considering Soil Structure Interaction (SSI): An Experimental Study, Journal of the Institution of Engineers (India): Series A, Volume 99, Issue1, pp. 113-122, 2018.

[4] Chinndam, C. and Autade, P. "Seismic Time History Analysis of Six Storey Shear Building with Newmark-β Method and ETABS", International Journal of Research in Engineering and Technology, Vol 7, Issue 3, eISSN: 2319-1163, pISSN: 2321-7308, 2018.

[5] Jain, S. K, "Codes, Licencing and Education." Earthquake Spectra, Vol.18,No.S1, pp. 319-339, 2002.

[6] Bilham, R, "Earthquakes in India and the Himalaya: Tectonics, geodesy and history," Ann. Geophys., vol. 47, no. 2–3, pp. 839–858, 2004.

[7] Iyengar, R. N, Sharma, D. and Siddiqui, J. M "Earthquake history of India in medieval times," Indian J. Hist. Sci., vol. 34, no. 3, pp. 181–237, 1999.

[8] Mittal, Kumar, A. and Ramhmachhuani, R. "Indian National Strong Motion Instrumentation Network and Site Characterization of Its Stations," Int. J. Geosci., vol. 3, no. 6, pp. 1151–1167, 2012.

[9] Archuleta, A. Steidl, A. and Squibb, M, "The COSMOS Virtual Data Center," in 13th World Conference on Earthquake Engineering no. Paper No. 1566, 2004.

[10] BIS, "Criteria for Earthquake Resistant Design of Structures," Bureau of Indian Standards, India, IS 1893 Part 1, 2016.

[11] K. Chopra, Dynamics of Structures: Theory and Applications to Earthquake Engineering. New Delhi: Dorling Kindersley (India) Pvt. Ltd, 2006.

[12] "ETABS Lateral Loads Manual.", Computers & Structure, 2016.

[13] P. R. Vaidya, "ETABS- Time History Analysis",pp.1-4, Available at www.academia.edu, 2017.