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Effect of Earthquake Frequency Content on Torsional Responses of Reinforced Concrete Framed Structure

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Abstract: ***An Earthquake is vibration of earth's surface due to sudden release of energy from earth crust. Earthquakes not only have social consequences of causing injury and death to living things but also has economic consequences of damaging the natural and built environment. So, it is significant to study the dynamic characteristics of ground motions. The objective of this research work is to study the torsional behavior of the six storey regular and irregular buildings when bi-directional earthquake excitation is also considered in the direction other than along principle axes of the building. Ground motions considered are having three different frequency contents like low frequency, intermediate frequency and high frequency content. Angle of incidence of earthquake excitation is varied with respect to X and Y axis respectively from 0° to 360° with an increment of 30°. Scaling of ground records are done using Seismosignal software. Linear modal time history analysis is done in the ETABS-2016 software. The torsional rotation of the building models is studied and compared. It is concluded that critical angle of incidence of earthquake excitation causing maximum responses may not always occur along principle axes of the building. Practically this research work gives idea about torsional behavior of regular and irregular buildings under varying frequency content and it also helps to know which frequency content results more torsion in the building.***

Keywords: ***Peak ground acceleration (PGA), Frequency content, Linear time history analysis, Ground motions.***

I. INTRODUCTION

An earthquake is vibration of earth surface due to sudden release of energy from earth crust. The sudden movement of the earth's tectonic plates causes earthquake. Seismic waves such as primary waves, secondary waves, Love waves and Rayleigh waves are emitted due to the energy release in earth's crust. Earthquakes are a major threat to safety of structure. The structure constructed must be able to withstand the most sever condition of earthquake. For protection against earthquake we can use either earthquake resistant design or seismic isolation technique. The failure of structure, under an earthquake occurs due to the resonance between frequency of earthquake and the natural frequency of the structure. To prevent death rate and damage to structures because of ground motions, it is very significant to study the dynamic characteristics of ground motions. Duration, frequency content and peak ground acceleration are the dynamic characteristics of the ground motions. Ground motions are categorized into three types of frequency contents [1-3].

The ratio of peak ground acceleration (PGA) in terms of acceleration of gravity (g) to peak ground velocity (PGV) in unit of (m/sec) is defined as the frequency content of the ground motions [1-3].

Frequency content = PGA(g) / PGV(m/sec)

Table 1: Classification of frequency content [1-3].

Frequency content	PGA/PGV
Low frequency	<0.8
Intermediate frequency	≥0.8 - ≤1.2
High frequency	>1.2

Uni-directional earthquake excitation is considered for the design of the structure. but, during earthquake, structure may get subjected to bi-directional excitations also [5]. So, if the structure designed only for Uni-directional earthquake excitation it may not respond well to bi-directional earthquake excitation [4]. Hence for our study bi-directional excitation is considered.

During seismic action, torsion mode of the structure may activate and causes severe damage to the structure. Torsion usually results due to non-uniform distribution of mass, stiffness, strength in structures and torsional components of the ground movement etc. In asymmetrical structure, there is an eccentricity between the centre of mass and centre of stiffness. During an earthquake, the torsional moment is induced in structure due to an action of resistive force through the centre of rigidity of structure and inertia force about the centre of mass [8]. hence for our study torsional rotation is also considered. Earthquake measuring stations, record the ground motions in three orthogonal directions, two of them in the horizontal direction and third in a vertical direction.

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For structural analysis, three components of ground motion are transformed into those corresponding to the principal direction. In the design of buildings, earthquake loads are considered only along principal axes of buildings. However, an earthquake can also act along with other axes of building [6-7]. Many seismic codes including IS 1893(part 1):[9] consider the seismic excitation along the principle axes of structure, but the earthquake direction and principle axes of structure are different. Hence, the building must be able to withstand under various seismic angle of excitation other than principle axes seismic excitation. So, it is necessary to know seismic behavior of building models by considering the angle of incidence of seismic force.

II. OBJECTIVE

The objective is to study the effect of earthquake frequency content on the torsional responses of six storey building with bi-directional excitation and angle of incidence of earthquake.

III. METHODLOGY

The building plans considered for the study is shown in fig 1. All models are six storey building and height of each story is 3.5m. Concrete grade considered for columns, beams and slabs is M30. The grade of steel considered is Fe500 for all considered models. The dimensions of the beams and columns are 0.45 m x 0.60 m and 0.6 m x 0.6 m respectively. Slab thickness is 0.20 m. The thickness of the wall is 0.23 m. Live loads considered on all floors is 3 kN/m^2 and for the roof slab is 1.5 kN/m^2. Dead loads considered on all floors is 2 kN/m^2 and for roof slab is 1 kN/m^2. Wall load considered on all floor beams is 13.5 kN/m and parapet wall load considered on all roof beams is 4.5 kN/m. The unit weight of reinforced concrete cement (RCC) is 25 kN/m^3. The unit weight of masonry infill is 20 kN/m^3. The building is considered to be located in zone v category of IS 1893 (part 1):[9] and also building is considered to be located on medium soil (type 2) as per IS 1893 (part 1) [9].Linear time history analysis is carried out using computer software ETABS 2016. For the analysis, three earthquake records of different frequency content are considered and ground motions considered are listed in the table 2. These ground motions are selected in such a way to match the target response spectrum of IS 1893(part 1):[9] for seismic zone v and medium soil (type 2) with damping of 5% as shown in fig 2. Scaling of ground records are done using Seismosignal software.

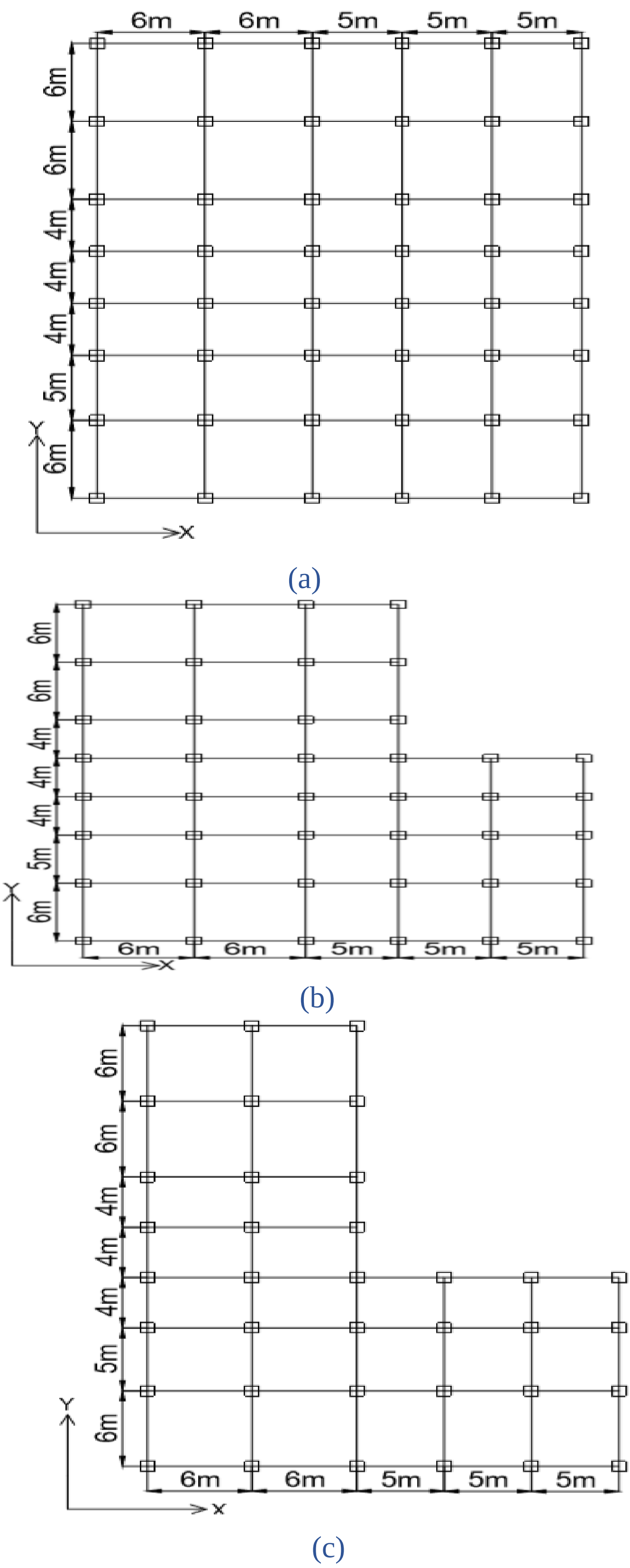

Fig. 1: (a) plan of regular building (model 1), (b) Plan of the Re-entrant L shaped building model with < 50% projection in both X and Y direction (Model 2). (c) Plan of the Re-entrant L shaped building model with > 50% projection in both X and Y direction (Model 3).

Table 2: Details of unscaled accelerograms

Record number	Earthquake Name	Recording station	Component	Year	Magnitude	Scale factor	Mechanism
864	Landers	Joshua tree	LANDERS_JOS090.AT2	1992	7.28	1.0565	Strike slip
6	Imperial valley – 02	EI Centro array #9	IMPVALL.I_I-ELC180.AT2	1940	6.95	1.063	Strike slip
999	Northridge – 01	La-Obregon park	NORTHR_OBR090.AT2	1994	6.69	0.8459	Reverse

To see the effect of frequency content, we are maintaining constant Peak ground acceleration and constant duration so we are scaling the considered ground motions. Duration of all the ground motions is considered to be 40 seconds. To maintain constant Peak ground acceleration, all considered grounds motions are scaled to PGA of 0.3 g magnitude. Scaling of the ground motions is done in Seismosignal software. The details of scaled records are given in Table 3. The accelerograms of scaled earthquakes are shown in fig.2, fig.3 and fig.4.

Table 3: Details of scaled accelerograms.

Record number	Earthquake name	Component	Duration	PGA(g)	PGV(m/sec)	PGA/PGV	Frequency content
864	Landers	LANDERS_JOS090.AT2	40	0.3	0.4499	0.667	low
6	Imperial valley - 02	IMPVALL.I_I-ELC180.AT2	40	0.3	0.3305	0.907	intermediate
999	Northridge-01	NORTHR_OBR090.AT2	40	0.3	0.1401	2.141	high

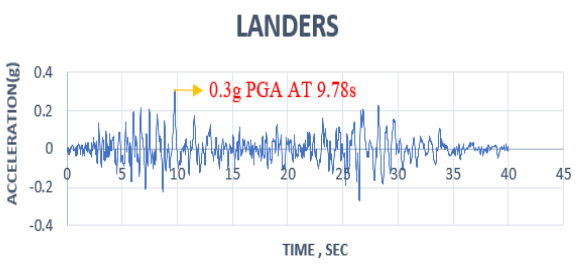

Fig. 2: Accelerogram of the Landers earthquake

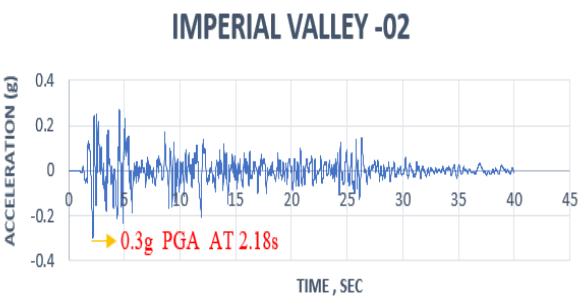

Fig. 3: Accelerogram of the Imperial valley-02 earthquake

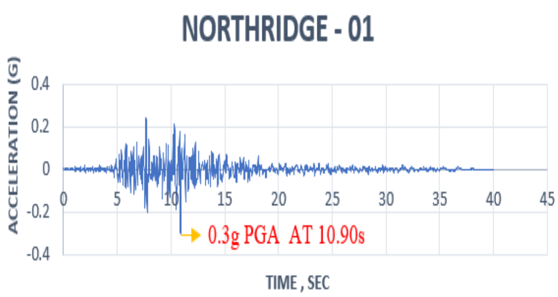

Fig. 4: Accelerogram of the Northridge-01 earthquake

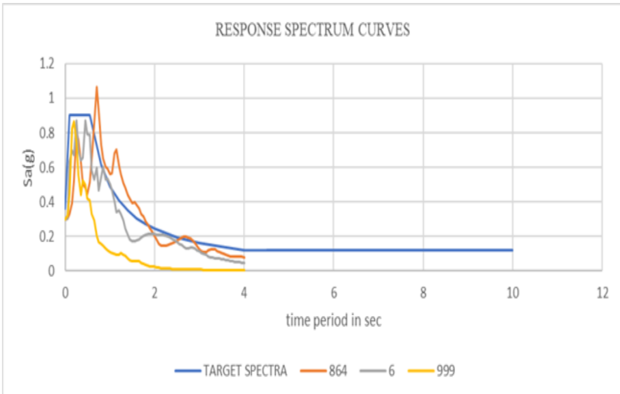

Fig. 5: Comparison of response spectra of considered ground records of 0.3g PGA with the IS 1893(part 1):[9] response spectra for medium soil and zone V.

IV. RESULTS AND DISCUSSIONS

The following figures 6-11 shows variation of roof storey torsional rotation for regular and irregular buildings with the variation in direction of earthquake excitation under different frequency contents. The critical angle of earthquake which produces maximum and minimum roof storey torsional rotation is determined for considered building models under low, intermediate and high frequency contents respectively and are listed in the below tables 4-6

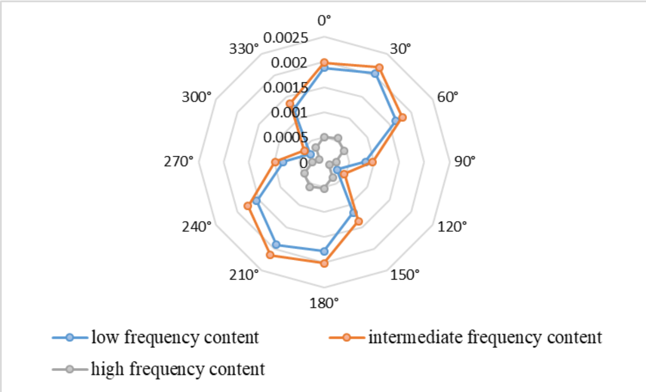

Fig. 6: Roof storey Torsional rotation of building model 1 for various angle of incidence of earthquake excitation under varying frequency content ground motions.

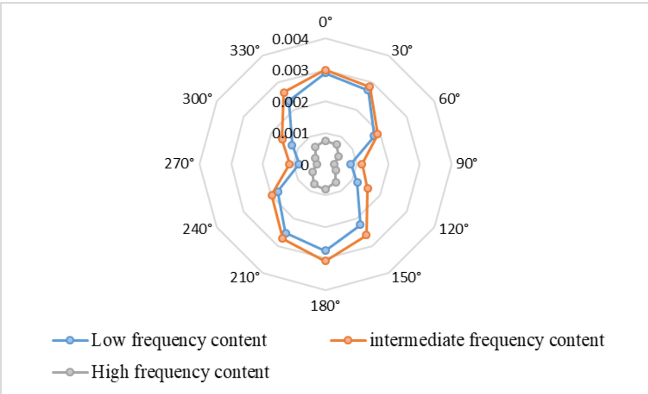

Fig. 7: Roof storey Torsional rotation of building model 2 for various angle of incidence of earthquake excitation under varying frequency content ground motions.

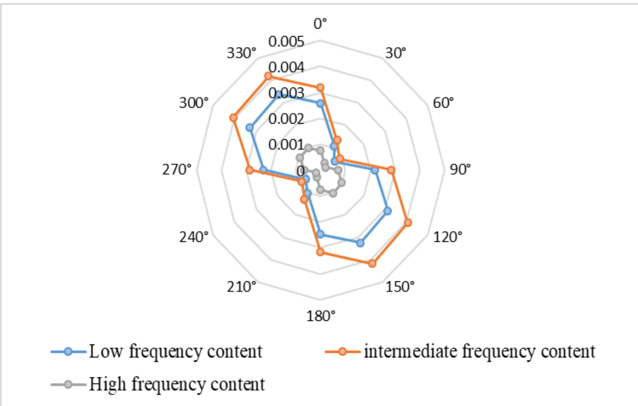

Fig. 8: Roof storey Torsional rotation of building model 3 for various angle of incidence of earthquake excitation under varying frequency content ground motions.

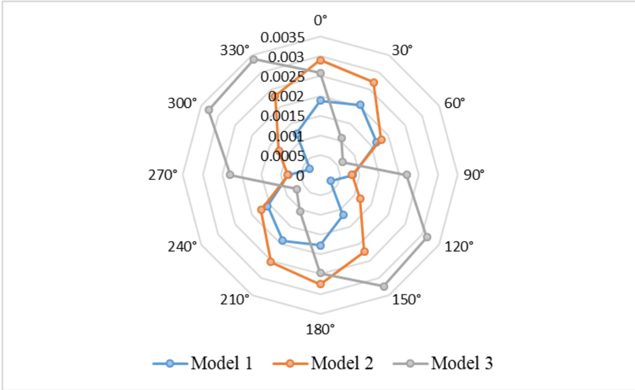

Fig. 9: Roof storey Torsional rotation of building models for various angle of incidence of earthquake excitation under low frequency content ground motions.

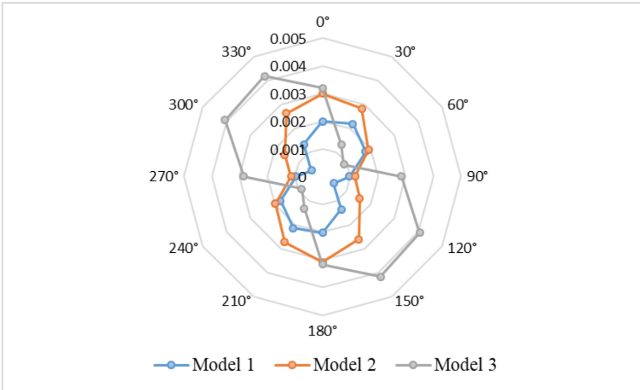

Fig. 10: Roof storey Torsional rotation of building models for various angle of incidence of earthquake excitation under intermediate frequency content ground motions.

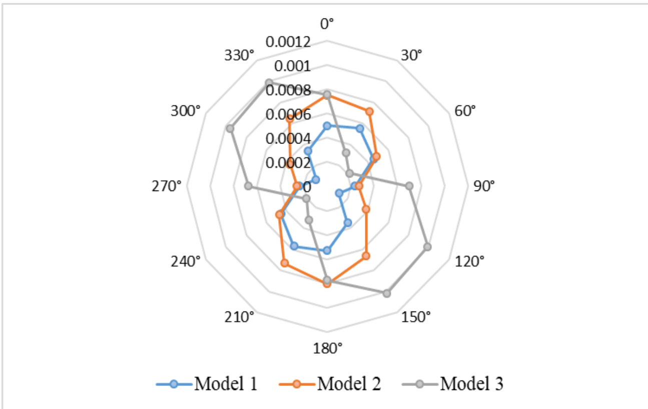

Fig. 11: Roof storey Torsional rotation of building models for various angle of incidence of earthquake excitation under high frequency content ground motions.

Table 4: Critical angle of earthquake excitation that produces maximum and minimum roof storey torsional rotation for building models due to low frequency content ground motion.

Building	Maximum Responses		Minimum Responses	
	Angle	TR	Angle	TR
Model 1	30°	0.00204	120°	0.000297
Model 2	0°	0.0029	90°	0.000811
Model 3	330°	0.00338	60°	0.000662

Table 5: Critical angle of earthquake excitation that produces maximum and minimum roof storey torsional rotation for building models due to intermediate frequency content ground motion.

Building	Maximum Responses		Minimum Responses	
	Angle	TR	Angle	TR
Model 1	30°	0.002186	300°	0.000457
Model 2	180°	0.003088	270°	0.001146
Model 3	330°	0.004188	240°	0.000876

Table 6: Critical angle of earthquake excitation that produces maximum and minimum roof storey torsional rotation for building models due to high frequency content ground motion.

Building	Maximum Responses		Minimum Responses	
	Angle	TR	Angle	TR
Model 1	210°	0.000568	300°	0.000113
Model 2	180°	0.000805	270°	0.00026
Model 3	150°	0.001018	240°	0.000204

The variation of roof storey torsional rotation plotted above for different building models under different frequency content shows the clear uncertainty in the defining the critical angle of incidence that gives the maximum response. As plan irregularity induces torsion, hence as irregularity increases in the building, torsional rotation also increases. so, in our case building model 3 is more irregular than the building model 2 and building model 1 hence torsional rotation is more for model 3.

V.CONCLUSION

Following conclusion can be drawn from the study:

1. A critical angle of incidence of earthquake excitation causing maximum responses may not always occur along principle axes of the building.
2. From the Linear time history analysis along different direction shows that there is a significant variation in the building responses with different angle of incidence.
3. There is no particular angle of incidence for a structure (or) earthquake causing the maximum response in all structural elements.
4. When the critical angle of incidence is in the direction other than principle axes, there is a significant variation between the maximum building responses compared to zero-degree component responses.
5. Roof storey torsional rotation is minimum for high frequency content and maximum for intermediate frequency content when the earthquake excitation is in any direction.
6. At critical maximum and minimum angle of incidence of earthquake, roof storey torsional rotation is maximum for Intermediate frequency content and minimum for High frequency content for all building models.

REFERENCES

1. T.Cakir, "Evaluation of the effect of earthquake frequency content on seismic behavior of cantilever retaining wall including soil-structure interaction", Soil Dynamics and Earthquake Engineering,vol. 45, pp. 96-111, 2013.
2. Gound Ajit B and Padhye Rajesh D, "The effect of earthquake frequency content on the Seismic behavior of Regular R.C.C. Buildings", International Journal for Innovative Research in Science & Technology, vol. 2, no. 11, 2016.
3. M.R. Kianoush and A.R. Ghaemmaghami, "The effect of earthquake frequency content on the seismic behavior of concrete rectangular liquid tanks using the finite element method incorporating soil-structure interaction", Engineering Structures, vol. 33, pp. 2186-2200, 2011.
4. R.S Jangid, "Seismic Response of Sliding Structures to Bidirectional Earthquake Excitation", Earthquake Engineering and Structural Dynamics, vol. 25, pp. 1301-1306, 1996.
5. F. Khoshnoudian and M. Poursha, "Responses of Three Dimensional Buildings under Bidirectional and Unidirectional Seismic Excitations", 13th World Conference on Earthquake Engineering, 2004.
6. Prajwal T P, Imtiaz A Parvez and Kiran Kamath, "Nonlinear Analysis of Irregular Buildings Considering the Direction of Seismic Waves", Materialstoday: Proceedings, vol. 4, pp. 9828-9832, 2017
7. M. Hosseini and A. Salemi, "Studying the Effect of Earthquake Excitation Angle on the Internal Forces of Steel Building's Elements by Using Nonlinear Time History Analyses", 14th World Conference on Earthquake Engineering, 2008.
8. H. Gokdemir, H.Ozbasaran, M.Dogan, E. Unluoglu and U. Albayrak, "Effects of torsional irregularity to structures during earthquakes", Engineering Failure Analysis,vol. 35, pp. 713-717, 2013.
9. IS 1893(Part I): 2002, "Criteria for earthquake resistant design of structure", Bureau of Indian Standards, New Delhi.

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