A Study on Seismic Response of an Irregular Structure with Different Angle of Incidence

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Abstract— *Earthquakes are a natural calamity, feared by most and cause great destruction in and around the seismic zone where they occur. In seismic design of buildings, the earthquake motions are considered in principle directions of building which may not be true in all cases. The present study is focused on the earthquake incidence angle and its effect on the structure's column axial force and to obtain the critical angle using Non Linear Time History Analysis. A set of values from 0 to 90 degrees, with an increment of 10 degrees, have been used for angle of excitation. An asymmetrical structure of 10 storeys was considered. It can see that the critical angle may vary the column axial force from column to column. The models are analysed using ETABS 15 software. The structural parameters such as column axial force, displacement and story shear in columns are studied. The paper concludes that the internal forces of structural elements depend on the angle of incidence of seismic wave data. There are different critical angles for different parameters, not necessarily that it should be the same of the column axial force.*

Keywords— Incidence angle, Non Linear Time History, Column axial force, Displacement, Story shear.

I. INTRODUCTION

Earthquakes are natural hazards under which disasters are mainly caused by damage to or collapse of buildings and other man-made structures. Experience has shown that for new constructions, establishing earthquake resistant regulations and their implementation is the critical safeguard against earthquake-induced damage. As regards existing structures, it is necessary to evaluate and strengthen them based on evaluation criteria before an earthquake. Earthquake damage depends on many parameters, including intensity, duration and frequency content of ground motion, geologic and soil condition, quality of construction, etc. Building design must be such as to ensure that the building has adequate strength, high ductility, and will remain as one unit, even while subjected to very large deformation. Sociologic factors are also important, such as density of population, time of day of the earthquake occurrence and community preparedness for the possibility of such an event. Up to now we can do little to diminish direct earthquake effects. However we can do much to reduce risks and thereby reduce disasters provided we design and build or strengthen the buildings so as to minimize the losses based on the knowledge of the earthquake performance of different building types during an earthquake. Observation of structural performance of buildings during an earthquake can clearly identify the strong and weak aspects of the design, as well as the desirable qualities of materials and techniques of construction, and site selection. The study of damage therefore provides an important step in the evolution of strengthening measures for different types of buildings.

1.1 Earthquake Incidence Angle

Earthquakes are well known for the damage and destruction that they leave behind. Present scenario demands the need for designing the structures to withstand seismic forces. In seismic design of structures, the earthquake motions are considered in principle directions of structure. Insalmostdall seismic design codes, consideration of simultaneous effects of two horizontal components of earthquake excitations is taken into account by applying 100% of earthquake lateral forces in the direction of one of the structure main axes and 30% of those forces in the direction of other main axis. In reality the direction of the dominant component of excitations might not be one of the main directions of the structure axes and applying the main component in a direction other than main axes direction may lead to higher internal forces and stresses in the structure's structural elements. Therefore the structure should be resistant under different excitation angles of earthquake. Some researchers have worked on the effect of angle of excitation on the response values since mid-80s. Over the period of time, Time History Analysis has become an important tool is assessing the behavior of a structure subjected to seismic loads. Time History Analysis is a method by which earth motion input of a particular earthquake can be used to determine the response of the structure. The main advantage of using this method is that the accuracy of the system response is higher when compared to Response Spectrum analysis, as the actual earth motion record from an earthquake can be used to simulate the structure.

II. METHODOLOGY

2.1 Project Details

Multi-storeyed apartment, Safe bearing capacity of soil (SBC) = 300 KN/mm2, Height of each floor = 2.95m (typical),Height of basement = 3.3m,Height of ground floor = 4.05m,Total height of the structure = 41.4m, Software = E-Tabs, AutoCAD. The structure given is to be used for residential purpose. Basement + Earth+ 13 Upper Floors + Overhead Water tank. The height of the basement and earth floor is 3.3m and typical floor height is 2.95 m .Total height of the structure is 41.1m above the plinth and each floor of the structure comprises of six houses, where four of them have one Living room, one Master Bedroom and two other Bedrooms with three toilets, one foyer, one Kitchen and one Dining room, one balcony and one utility and two of them have one Living room, one Master Bedroom and one Bedroom with two toilets, one foyer, one Kitchen and one Dining room, one balcony and one utility.

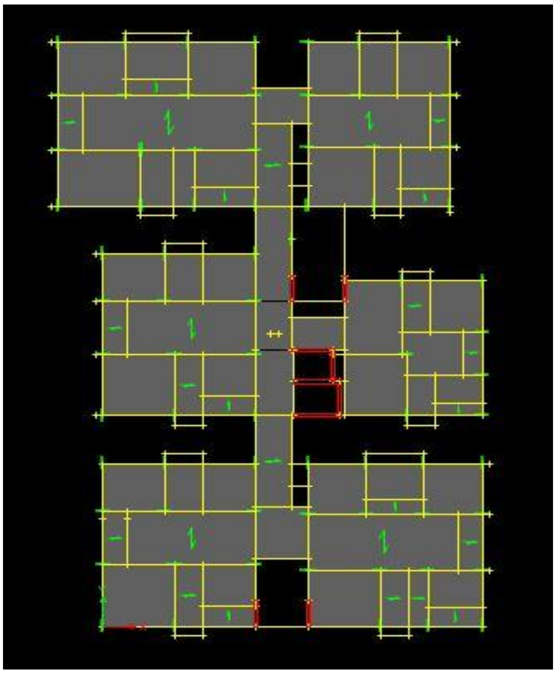

FIG. 1: E-TABS MODEL- PLAN

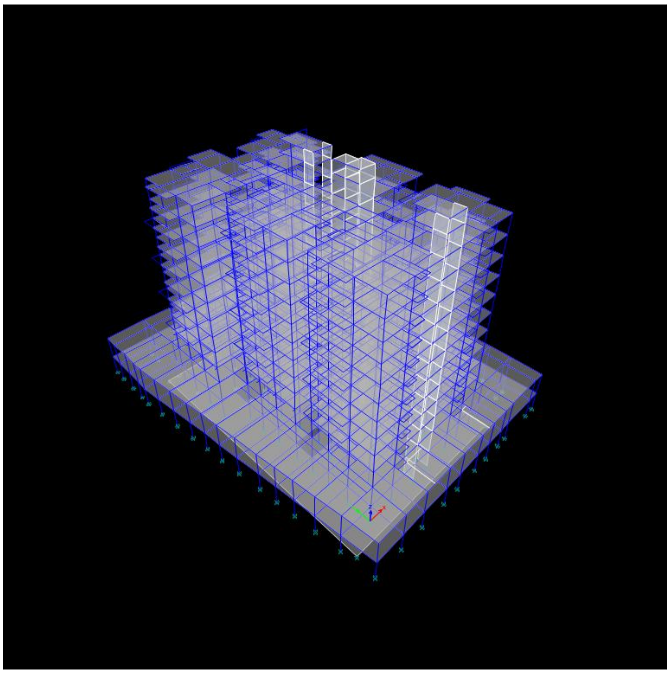

FIG. 2: E-TABS MODEL- 3D

III. RESULTS AND DISCUSSION

The results of Time History Analysis in the form of maximum column forces, column moments, maximum displacement and storey shear were studied.

3.1 Maximum Column Forces

The values of maximum column forces and the variation with incidence angle is shown in Table 1.The max column force was found to be -3693.42 kN for the load combination 1.5(TDL-ELX-0.3ELY) Max for column C-20 at the basement-1at 70^0 angle.

TABLE 4.1
COLUMN FORCES FOR ALL THE ANGLE OF INCIDENCE (0°- 90°)

Story	Column	Unique Name	Load Case/Combo	P	Angle
				kN	Deg.
Basement-1	C20	2578	0.9TDL+1.5(0.3THX-THY) Min	-2217.3	0
Basement-1	C20	2578	1.2(TLD+LL+0.3THX-TY) Min	-3232.67	0
Basement-1	C20	2578	1.5(TDL+0.3EX-EY) Min	-3693.38	0
Basement-1	C20	2578	0.9TDL+1.5(0.3THX-THY) Min	-2217.35	10
Basement-1	C20	2578	1.2(TLD+LL+0.3THX-TY) Min	-3232.7	10
Basement-1	C20	2578	1.5(TDL+0.3EX-EY) Min	-3693.42	10
Basement-1	C20	2578	0.9TDL+1.5(-0.3THX-THY) Min	-2217.33	20
Basement-1	C20	2578	1.2(TLD+LL-0.3THX-TY) Min	-3232.69	20
Basement-1	C20	2578	1.5(TDL-0.3EX-EY) Min	-3693.41	20
Basement-1	C20	2578	0.9TDL+1.5(-0.3THX-THY) Min	-2217.24	30
Basement-1	C20	2578	1.2(TLD+LL-0.3THX-TY) Min	-3232.62	30
Basement-1	C20	2578	1.5(TDL-0.3EX-EY) Min	-3693.32	30
Basement-1	C20	2578	0.9TDL+1.5(-0.3THX-THY) Min	-2217.05	40
Basement-1	C20	2578	1.2(TLD+LL-0.3THX-TY) Min	-3232.47	40
Basement-1	C20	2578	1.5(TDL-0.3EX-EY) Min	-3693.13	40
Basement-1	C20	2578	0.9TDL+1.5(-THX-0.3THY) Min	-2217.11	50
Basement-1	C20	2578	1.2(TLD+LL-THX-0.3TY) Min	-3232.51	50
Basement-1	C20	2578	1.5(TDL-0.3EX-EY) Min	-3692.85	50
Basement-1	C20	2578	0.9TDL+1.5(-THX-0.3THY) Min	-2217.27	60
Basement-1	C20	2578	1.2(TLD+LL-THX-0.3TY) Min	-3232.64	60
Basement-1	C20	2578	1.5(TDL-EX-0.3EY) Min	-3693.35	60
Basement-1	C20	2578	0.9TDL+1.5(-THX-0.3THY) Min	-2217.34	70
Basement-1	C20	2578	1.2(TLD+LL-THX-0.3TY) Min	-3232.7	70
Basement-1	C20	2578	1.5(TDL-EX-0.3EY) Min	-3693.42	70
Basement-1	C20	2578	0.9TDL+1.5(-THX+0.3THY) Min	-2217.37	80
Basement-1	C20	2578	1.2(TLD+LL-THX+0.3TY) Min	-3232.72	80
Basement-1	C20	2578	1.5(TDL-0.3EX+EY) Min	-3691.77	80
Basement-1	C20	2578	0.9TDL+1.5(-THX-0.3THY) Min	-2217.3	90
Basement-1	C20	2578	1.2(TLD+LL-THX-0.3TY) Min	-3232.67	90
Basement-1	C20	2578	1.5(TDL-EX-0.3EY) Min	-3693.38	90

3.2 Maximum Column Moments

The values of maximum column moments and the variation with incidence angle is shown in Table 2. The maximum moment was in 1ST FLOOR for the column C-32 with the load combination 1.2(TLD+LL-0.3THX+TY) Max of 225.3083 kN-m for an incidence angle of 80°.

TABLE 2
COLUMN MOMENTS FOR ALL THE ANGLE OF INCIDENCE (0°- 90°)

Story	Column	Load Case/Combo	P	M3	Angle
			kN	kN-m	Deg.
Ground floor	C32	0.9TDL+1.5(THX-0.3THY) Min	-1621.179	-95.8313	0
1st Floor	C32	1.2(TLD+LL-THX+0.3TY) Max	-2028.8649	225.2589	0
Ground floor	C32	1.5(TDL+EX+0.3EY) Min	-2696.5294	-159.1	0
Ground floor	C32	0.9TDL+1.5(THX-0.3THY) Min	-1621.3585	-95.8373	10
1st Floor	C32	1.2(TLD+LL-THX+0.3TY) Max	-2028.8187	225.2588	10
Ground floor	C32	1.5(TDL+EX+0.3EY) Min	-2696.6017	-159.108	10
Ground floor	C32	0.9TDL+1.5(THX+0.3THY) Min	-1621.3182	-95.8335	20
1st Floor	C32	1.2(TLD+LL-THX+0.3TY) Max	-2028.913	225.2804	20
1st Floor	C32	1.5(TDL-EX+0.3EY) Max	-2211.2698	150.3738	20
Ground floor	C32	0.9TDL+1.5(THX+0.3THY) Min	-1621.2853	-95.8191	30
1st Floor	C32	1.2(TLD+LL-THX+0.3TY) Max	-2028.8427	225.2352	30
Ground floor	C167	1.5(TDL-EX+0.3EY) Min	-469.6913	-239.32	30
Ground floor	C32	0.9TDL+1.5(THX+0.3THY) Min	-1621.0826	-95.7812	40
1st Floor	C32	1.2(TLD+LL-THX+0.3TY) Max	-2028.9545	225.1234	40
Basement-1	C32	1.5(TDL-0.3EX-EY) Min	-2966.8733	-70.2712	40
Ground floor	C32	0.9TDL+1.5(THX+0.3THY) Min	-1620.7625	-95.7169	50
1st Floor	C32	1.2(TLD+LL-0.3THX+TY) Max	-2029.8786	225.0561	50
Basement-1	C32	1.5(TDL-0.3EX-EY) Min	-2967.814	-70.4311	50
Ground floor	C32	0.9TDL+1.5(-0.3THX-THY) Min	-1619.9548	-95.7232	60
1st Floor	C32	1.2(TLD+LL-0.3THX+TY) Max	-2029.4102	225.2217	60
Basement-1	C32	1.5(TDL-0.3EX-EY) Min	-2968.5768	-70.5425	60
1st Floor	C32	0.9TDL+1.5(-0.3THX+THY) Max	-1324.0325	91.6141	70
1st Floor	C32	1.2(TLD+LL-0.3THX+TY) Max	-2029.1073	225.3066	70
Ground floor	C32	1.5(TDL+0.3EX-EY) Min	-2696.2622	-159.065	70
1st Floor	C32	0.9TDL+1.5(-0.3THX+THY) Max	-1323.8518	91.6161	80
1st Floor	C32	1.2(TLD+LL-0.3THX+TY) Max	-2028.9627	225.3083	80
Ground floor	C32	1.5(TDL+0.3EX-EY) Min	-2696.497	-159.082	80
Ground floor	C32	0.9TDL+1.5(0.3THX-THY) Min	-1621.1683	-95.8352	90
1st Floor	C32	1.2(TLD+LL+0.3THX+TY) Max	-2028.8649	225.2589	90
Ground floor	C32	1.5(TDL+0.3EX-EY) Min	-2696.5294	-159.1	90

3.3 Maximum Story Displacement

The values of maximum story displacement and the Comparison between displacements for different angles is shown in Figure 3 and Table 3.Displacement is more in 40° in x-direction 5.47mm and 20°in y-direction 2.73mm for the combo 1.5(TDL+0.3EX-EY).

TABLE 3
COMPARISON BETWEEN DISPLACEMENTS FOR DIFFERENT ANGLES

Angle	X direction(mm)	Y direction(mm)
10	2.58	5.63
20	2.73	5.76
30	2.84	5.47
40	2.96	5.47
50	2.81	5.39
60	2.7	5.49
70	2.5	5.53
80	2.56	5.54
90	2.503	5.526

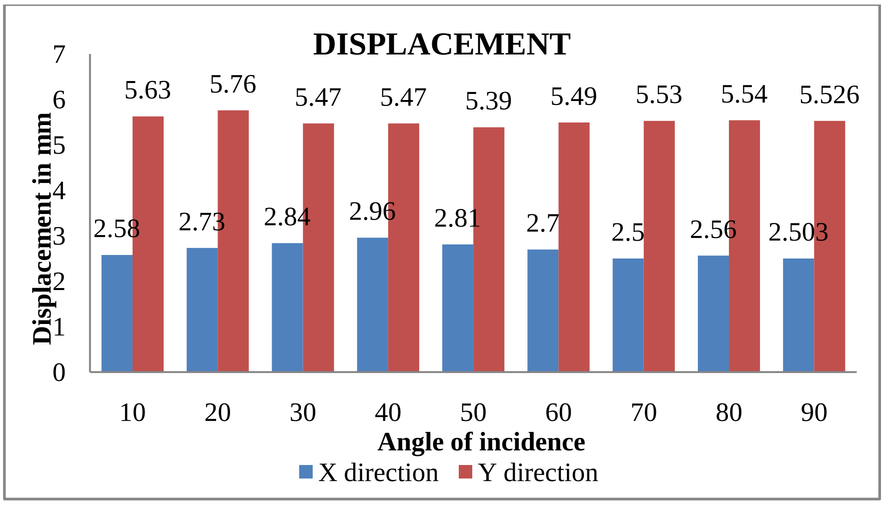

FIGURE 3: COMPARISON BETWEEN DISPLACEMENTS FOR DIFFERENT ANGLES

3.4 Maximum Story Shear

The values of maximum story shear and the Comparison between story shear for different angles is shown in Figure 4 and Table 4. Story shear is more in 70° with 128 kN in x-direction and 50° with 105kN in y-direction for the combo 1.5(TDL+0.3EX-EY).

TABLE 4
COMPARISON BETWEEN STORY SHEAR FOR DIFFERENT ANGLES

Angle	X direction(kN)	Y direction (kN)
10	128	57
20	127	73
30	123.6	87
40	115	101
50	120	105
60	126	93
70	128	78
80	126	61
90	126	46

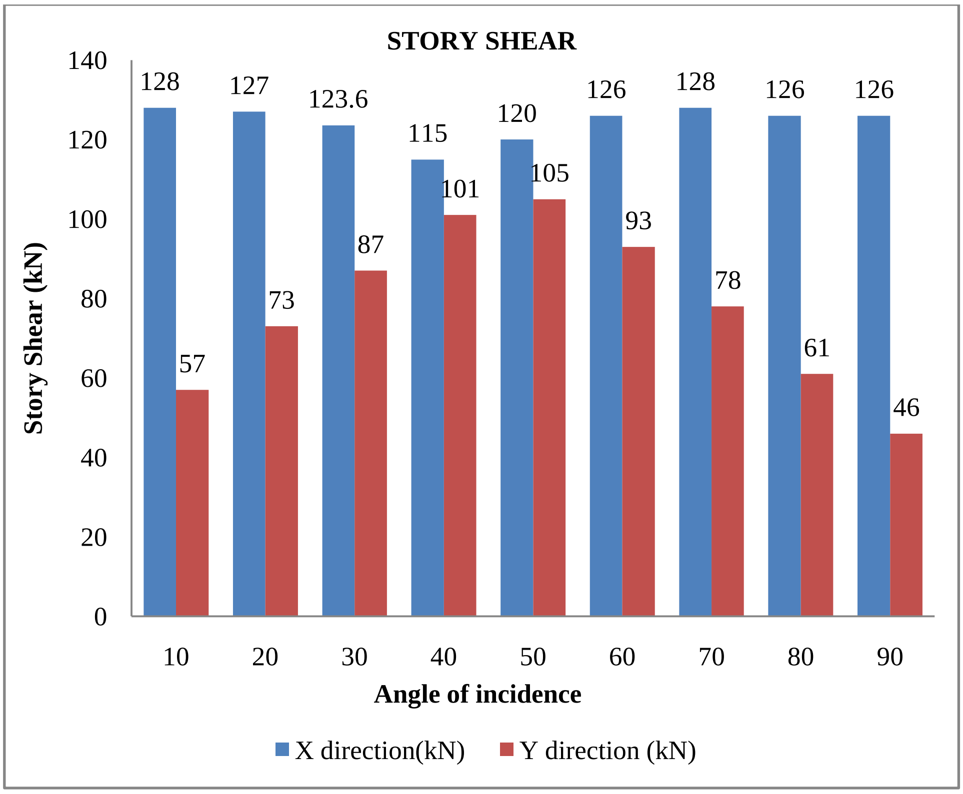

FIGURE 4: COMPARISON BETWEEN STORY SHEAR FOR DIFFERENT ANGLES

IV. CONCLUSION

- The internal forces of structural elements depend on the angle of incidence of seismic wave data.
- There are different critical angles for different parameters, not necessarily that it should be the same of the column axial force.
- The maximum displacement and maximum column axial forces are of same angle i.e. 70° for EL CENTRO earthquake data.
- The critical angle depends on the geometry of the structure.
- The objective of this study is to highlight that, the earthquake motions are considered in principle directions of structure but excitations might not be in one of the main directions of the structure axes.

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