Structural Analysis of a Multi-Storeyed Building using ETABS for different Plan Configurations

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***Abstract*—ETABS stands for Extended Three dimensional Analysis of Building Systems. ETABS is commonly used to analyze: Skyscrapers, parking garages, steel & concrete structures, low and high rise buildings, and portal frame structures. The case study in this paper mainly emphasizes on structural behavior of multi-storey building for different plan configurations like rectangular, C, L and I-shape. Modelling of 15- storeys R.C.C. framed building is done on the ETABS software for analysis. Post analysis of the structure, maximum shear forces, bending moments, and maximum storey displacement are computed and then compared for all the analyzed cases.**

Keywords*- *Structure Design, ETABS, High Rise Buildings, Plan Irregularity

I. INTRODUCTION

Structural analysis means determination of the general shape and all the specific dimensions of a particular structure so that it will perform the function for which it is created and will safely withstand the influences which will act on it throughout its useful life. ETABS was used to create the mathematical model of the Burj Khalifa, designed by Skidmore, Owings and Merrill LLP (SOM). The input, output and numerical solution techniques of ETABS are specifically designed to take advantage of the unique physical and numerical characteristics associated with building type structures. ETABS provides both static and dynamic analysis for wide range of gravity, thermal and lateral loads. Dynamic analysis may include seismic response spectrum or accelerogram time history.

This analysis mainly deals with the study of a rectangular, L, C and I shaped plan using ETABS. A 32m x 24m 15-storeys structure having 4m x 4m bays is modelled using ETABS. The height of each storey is taken as 3m, making total height of the structure 45m. Loads considered are taken in accordance with the IS-875(Part1, Part2), IS-1893(2002) code and combinations are acc. to IS-875(Part5). Post analysis of the structure, maximum shear forces, bending moments, and maximum storey displacement are computed and then compared for all the analysed cases.

II. MODELLING OF RCC FRAMES

An RCC framed structure is basically an assembly of slabs, beams, columns and foundation inter-connected to each other as a unit. The load transfer mechanism in these structures is from slabs to beams, from beams to columns, and then ultimately from columns to the foundation, which in turn passes the load to the soil. In this structural analysis study, we have adopted four cases by assuming different shapes for the same structure, as explained below.

1. Rectangular Plan
2. L-shape Plan
3. I-shape Plan
4. C-shape Plan

The building is 32m x 24m in plan with columns spaced at 4m from center to center. A floor to floor height of 3m is assumed. Plan of the building for all the cases is shown in the following figure.

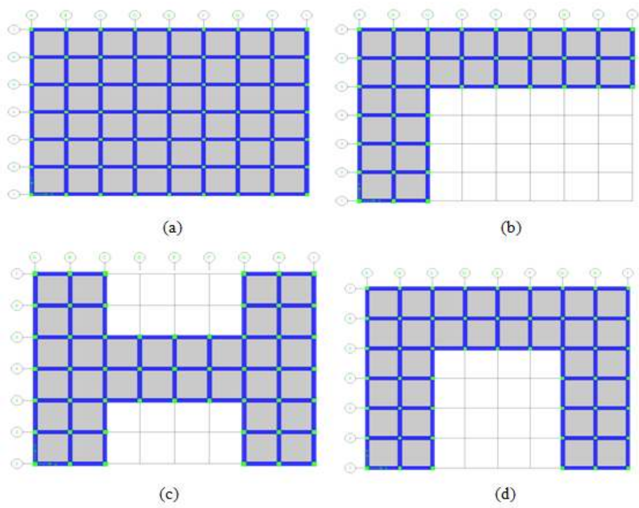

Fig 1: Plan (a) Rectangular (b) L shape (c) I shape (d) C shape of the Building

TABLE 1

Building Description	
Length x Width	32m x 24m
No. of storeys	15
Storey height	3m
Beam dimensions	450x450mm
Column 1-5 storeys dimensions	600x600mm
Column 6-12 storeys dimensions	500x500mm
Slab thickness	125mm
Thickness of main wall	230mm
Height of parapet wall	0.90m
Thickness of parapet wall	115mm
Support conditions	Fixed

III. MATERIAL SPECIFICATIONS

TABLE 2

Material Specifications	
Grade of Concrete ,M30	f_{ck}= 30N/mm^2
Grade of Steel	f_y= 415N/mm^2
Density of Concrete	Υ_c= 25kN/m^3
Density of Brick walls considered	Υ_{brick}= 20kN/m^3

IV. LOADING

Loads acting on the structure are dead load (DL), Live load and Earthquake load (EL).

1. Self weight comprises of the weight of beams, columns and slab of the building.
2. Dead load: Wall load, Parapet load and floor load (IS 875(Part1))
   a) Wall load= (unit weight of brick masonry X wall thickness X wall height)
      = 20 kN/m^3 X 0.230m X 3m
      = 13.8 kN/m (acting on the beam)
   b) Wall load (due to Parapet wall at top floor)
      = (unit weight of brick masonry X parapet wall thickness X wall height)
      = 20 kN/m^3 X 0.115m X 0.90m
      = 2.07 kN/m (acting on the beam)
3. Live load: Floor load: 4kN/m^2 and Roof load: 2 kN/m^2 (IS 875 (Part 2) acting on beams
4. Seismic Load: Seismic zone: V (Z=0.36), Soil type: I, Importance factor: 1, Response reduction factor: 5, Damping: 5%. IS 1893(Part-1):2002.

Here Seismic load is considered along two directions EQlength and EQwidth

V. LOADING COMIBINATION

The structure has been analyzed for load combinations considering all the previous loads in proper ratio. Combination of self-weight, dead load, live load and seismic load was taken into consideration according to IS-code 875(Part 5).

TABLE 3

Sr. No.	LOAD COMBINATION	PRIMARY LOAD	FACTOR
1	DCON1	Self load Dead load	1.5 1.5
2	DCON2	Self load Dead load Live load	1.5 1.5 1.5
3	DCON3	Self load Dead load Live load EQ (along length)	1.2 1.2 1.2 1.2
4	DCON4	Self load Dead load Live load EQ (along length)	1.2 1.2 1.2 -1.2
5	DCON5	Self load Dead load Live load EQ (along width)	1.2 1.2 1.2 1.2
6	DCON6	Self load Dead load Live load EQ (along width)	1.2 1.2 1.2 -1.2
7	DCON7	Self load Dead load EQ (along length)	1.5 1.5 1.5
8	DCON8	Self load Dead load EQ (along length)	1.5 1.5 -1.5
9	DCON9	Self load Dead load EQ (along width)	1.5 1.5 1.5
10	DCON10	Self load Dead load EQ (along width)	1.5 1.5 -1.5
11	DCON11	Self load Dead load EQ (along length)	0.9 0.9 1.5
12	DCON12	Self load Dead load EQ (along length)	0.9 0.9 -1.5
13	DCON13	Self load Dead load EQ (along width)	0.9 0.9 1.5
14	DCON14	Self load Dead load EQ (along width)	0.9 0.9 -1.5

VI. MODELLING IN ETABS

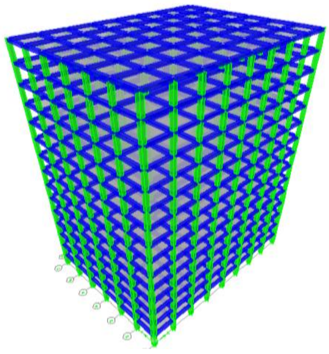

Fig 2: 3-D View of the 15-storeys Rectangular-shape building

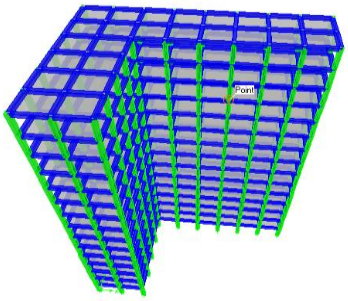

Fig 3: 3-D View of the 15-storeys L-shape building

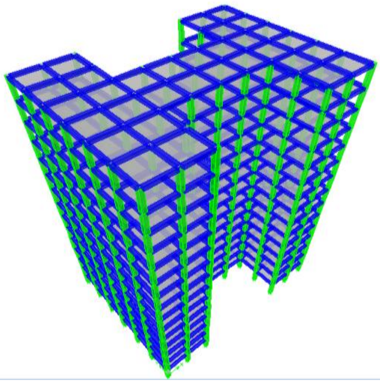

Fig 4: 3-D View of the 15-storeys I-shape building

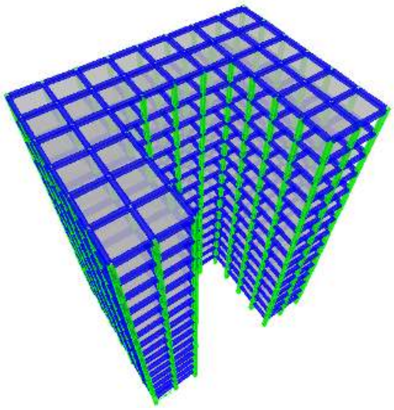

Fig 5: 3-D View of the 15-storeys C-shape building

VII. RESULTS AND DISCUSSIONS

TABLE 4

Max B.M. and Shear Force of Beam				
Forces	**Rectangular**	**L-shape**	**I-shape**	**C-shape**
B.M. M_y	92.99	97.38	101.54	99.74
B.M. M_z	0.11	1.56	0.64	1.12
Shear Force F_y	161.09	159.18	158.18	159.27

Units –kN-m

TABLE 5

Max B.M. and Shear Force of Column				
Forces	**Rectangular**	**L-shape**	**I-shape**	**C-shape**
Axial Force F_x	399.265	453.41	400.40	435.03
Shear Force F_y	88.16	87.68	91.96	90.59
Shear Force F_z	90.11	86.15	95.23	87.59
B.M. M_y	181.93	172.35	174.40	173.63
B.M. M_z	182.11	172.24	173.64	172.39

Storey Overturning Moments for different Plan Configurations

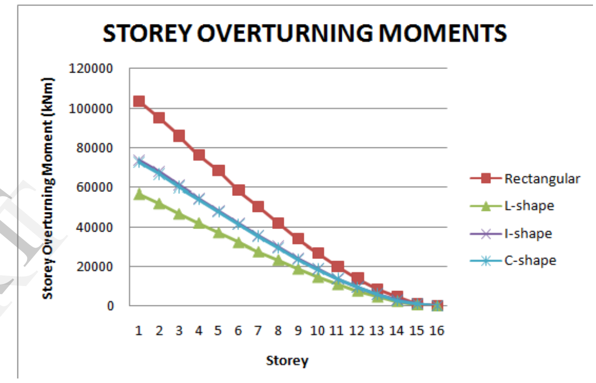

Fig 6: Storey Height Vs Overturning Moments

The figure shows that the overturning moment varies inversely with storey height. In case of rectangular plan, a moment produced is higher than other shapes. Storey overturning moment decreases with increase in storey height for all cases.

Comparison of Storey Shear for 1st, 5th, 10th, 15th storey for different configurations

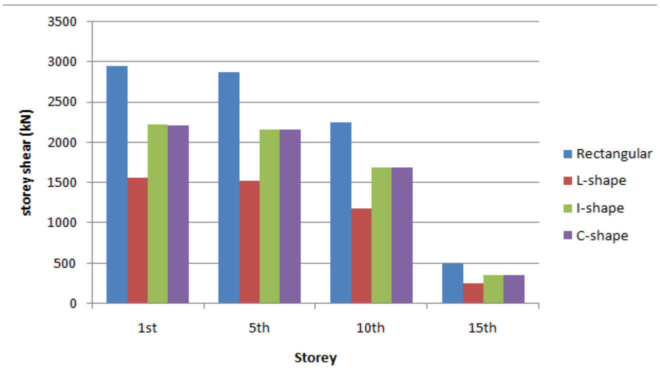

Fig 7: Graph of Storey Shear for different Plan configurations

As per above fig. it has been concluded that the storey shear decreases with the increase in storey height. Storey shear is less in L-shape building among all the cases.

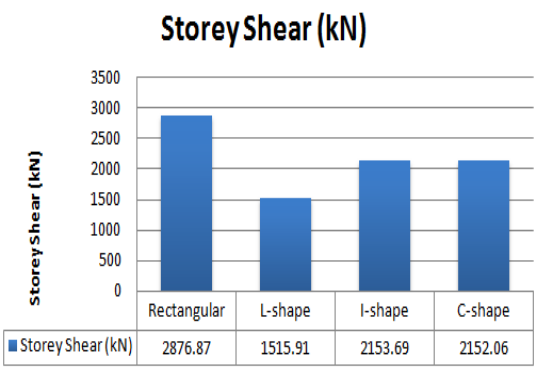

Fig 8:Graph of Storey Shear for 5th Storey

Roof Displacement Vs Height of the Building

TABLE 6

STOREY	LATERAL DISPLACEMENT (mm)			
	Rectangular	L-shape	I-shape	C-shape
0	0	0	0	0
1	1.37	1.30	1.27	1.37
2	3.41	3.58	3.51	3.41
3	5.95	6.29	5.85	6.05
4	8.49	9.11	8.29	8.59
5	11.12	12.03	10.93	11.32
6	13.76	15.07	13.76	14.24
7	16.78	18.32	16.49	17.37
8	19.51	21.57	19.41	20.39
9	22.24	24.72	22.15	23.22
10	24.59	27.64	24.49	25.85
11	26.83	30.46	26.93	28.49
12	28.88	32.95	28.88	30.63
13	30.15	34.91	30.34	32.49
14	31.61	36.86	31.71	34.15
15	32.39	38.16	32.78	35.02

Above table shows that the storey displacement increases with the increase in storey height. Displacement in rectangular shape building is less than other cases.

Max Lateral Drift for various storey heights

TABLE 7

STOREY	LATERAL DRIFT (mm)			
	Rectangular	L-shape	I-shape	C-shape
0	0	0	0	0
1	3.9	3.8	3.8	3.8
2	7.3	7.3	7.2	7.4
3	8.1	8.4	8.1	8.4
4	8.2	8.7	8.4	8.8
5	8.2	8.9	8.5	9
6	9.5	10.04	9.7	10.03
7	9.4	10.01	9.6	10.01
8	9.0	9.8	9.3	9.9
9	8.5	9.4	8.9	9.5
10	7.9	8.8	8.3	9.0
11	7.1	8.0	7.6	8.3
12	6.2	7.2	6.7	7.4
13	5.1	6.1	5.6	6.3
14	3.7	4.8	4.3	5.0
15	2.3	3.7	3.1	3.9

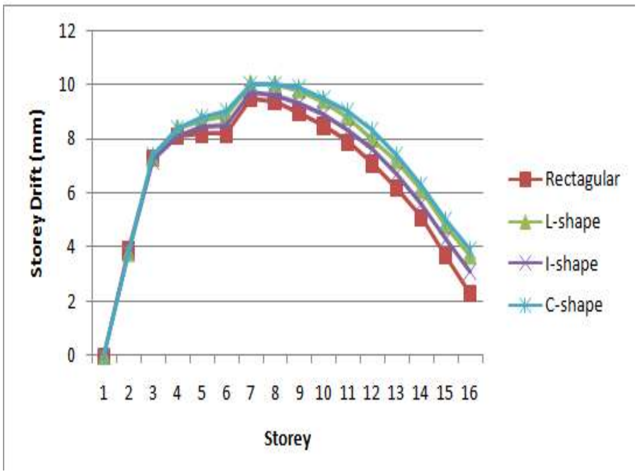

Fig 9: Graph of Storey Drift Vs Storey height

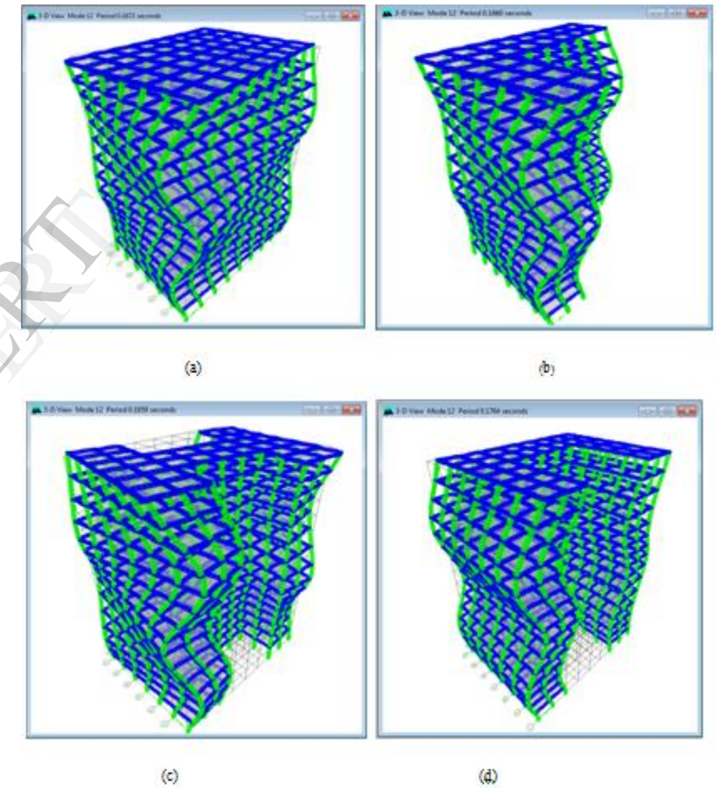

Fig 9: Mode Shape for 12th mode for (a) Rectangular (b) L-shape (c) I-shape (d) C-shape of the building

VIII. CONCLUSIONS

The analysis of the multi-storeyed building reflected that the storey overturning moment varies inversely with storey height. Moreover, L-shape, I-shape type buildings give almost similar response against the overturning moment. Storey drift displacement increased with storey height up to 6th storey reaching to maximum value and then started decreasing. From dynamic analysis, mode shapes are generated and it can be concluded that asymmetrical plans undergo more deformation than symmetrical plans. Asymmetrical plans should be adopted considering into gaps. The Fig. 9 shows that asymmetrical plans undergo more deformation and hence symmetrical plans must be adhered to.

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