Deflection Analysis of High Rise Concrete Buildings for Wind and Seismic Loads Using Bracing Systems for Plan Irregularities Using ETABS

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***Abstract*--Deflection is the degree of displacement of a structural element under a load, either by an angle or distance. For a structure, such as buildings, dams, etc., deflection plays a major role in determining the stability of a structure. The more the structure is deflected, the higher the structure is susceptible to risk of damage. So, bracing systems are used to reduce the deflections in a structure. A typical 20 and 30 storeyed buildings are considered with four distinct plan shapes such as square, rectangle, plus and a T shape within an area of 40m x 40m having a span of 4m. Each building is analysed for Wind and Earthquake loads using the load combinations provided in IS code book. Three bracing types, a concrete shear wall system, steel X-bracing system and a combination of both shear wall and X-bracing for lower and upper half of the structure are used. These bracings are placed around the building with six different placement combinations, such as, bracing provided for lifts and corners of the building, etc., These buildings are analysed using ETABS software and the deflections for all the building shapes, floor, bracings and load combinations are recorded and plotted in graphs to compare and determine which combination is efficient against deflections for the given loads. A deflection for rectangular building is lesser than square building along shorter base dimension and is higher along longer base side.**

***Keywords* – Deflection analysis, Plan irregularities, Bracing systems, Shear wall, X-Bracing, High rise buildings.**

I. INTRODUCTION

A building is a structure with a roof and walls standing more or less permanently in one place, like a house or manufacturing plant. They are additionally classified based on height of the structure as Skyscrapers / High rise buildings (over 66m or 217ft), Supertall (over 300m or 984ft) and Megatall buildings (over 600m or 1969ft).

Several studies are done for deflection analysis using different methods and software. Some include determining shape effects using gust factor approach [9], SAP2000 software [4], STAAD pro [8]. The effects of bracing systems such as shear walls and steel bracings are analyzed in some papers such as analyzing effect of different types of steel bracings [6], effects of shear wall [7], effect of shear wall and bracings individually [10]. Several other studies can also be done such as studying the effect of changing the position of bracing system in the building, effect of combination bracing systems etc.,

II. OBJECTIVES

The main objective of this paper is to

- To analyse the deflections for different shapes of buildings.
- To analyse the effect of different bracing objects on buildings.
- To analyse the effect of positioning of bracing objects.
- To predict an approximate cost estimate of materials of the buildings considered for selecting optimum price to performance ratio of the structures.

III. METHODOLOGY

The study of deflection analysis for this paper was developed using a determinist methodology, with some probabilistic elements in its conception. In order to facilitate this study, it was divided in four phases of analyses,

1. Analysing the effect of plan shape of the structure, i.e., square, plus, rectangle and T plans.

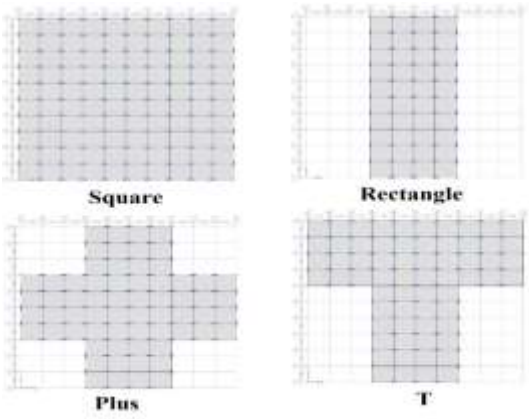

Fig 1 Plan irregularities considered

2. Analysing the effect of different types of bracing systems, i.e., concrete shear wall, steel X-Bracing, a combination bracing of X-bracing and shear wall in a 50:50 floor ratio.

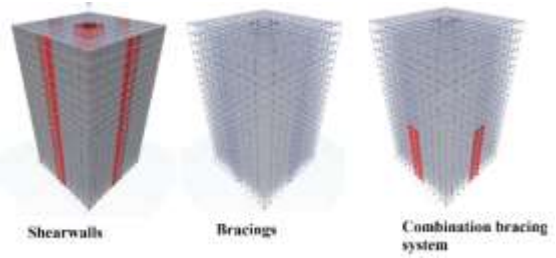

Fig 1 Types of bracings considered

3. Analysing the effect of bracing placements, i.e., normal walled (NW), shear walls at lift position (SL), shear walls at outer corners of the edges (SPE), shear walls at lift and outer corners of the edges (SPEL), shear walls centres of the edges (SPC), shear walls at lift and centres of the edges (SPCL), shear walls at inner corners of the edges (SPIL), shear walls at lift and inner corners of the edges (SPIL)

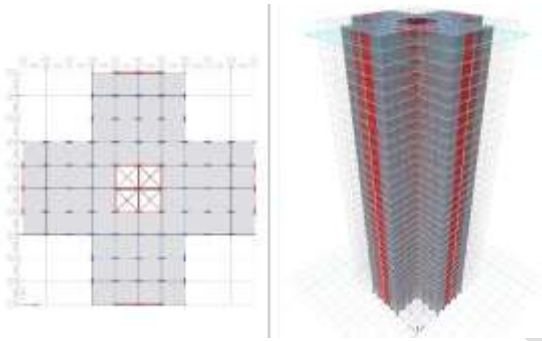

Fig 3 SPCL placement

4. Determining the average estimate of the structure.
5. Combining all those results to find out the optimum structure with bracing placements.

IV. STRUCTURAL PROPERTIES

- Columns: 1.2m x 0.3m
- Edge columns: 0.3m x 0.3m
- Beams: 0.3m x 0.6m
- Slab: 150mm
- Span: 4m
- Floor height: 3.5m
- Concrete: M30

V. RESULTS

The following results were obtained when analysing the structures in ETABS.

- Effect of plan irregularities on wind load (G+20):

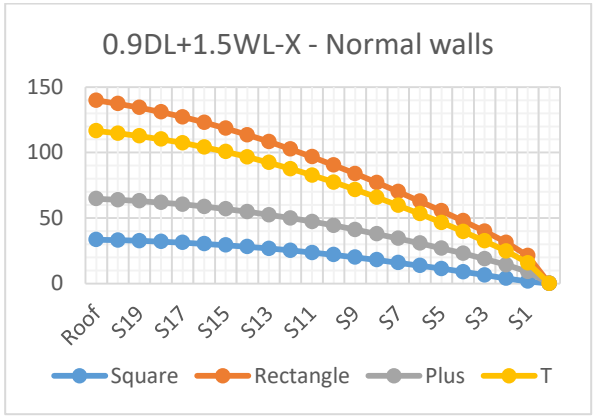

Fig 4 Effect of plan irregularities on wind load (G+20)

- Effect of plan irregularities on wind load (G+30):

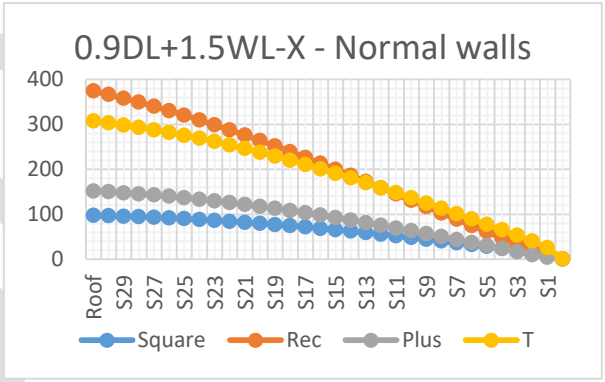

Fig 2 Effect of plan irregularities on wind load (G+30)

- Effect of plan irregularities on seismic load (G+30):

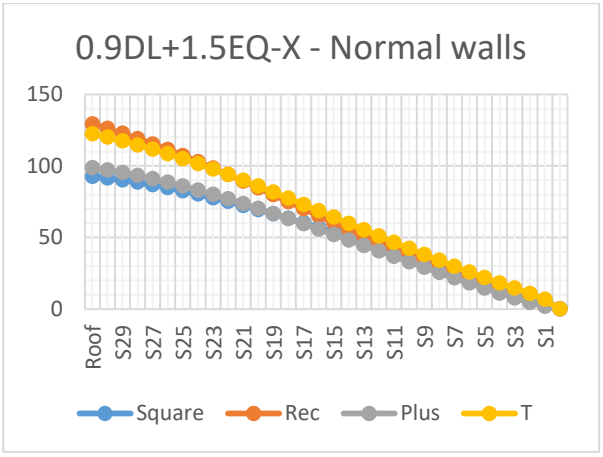

Fig 5 Effect of plan irregularities on seismic load (G+30)

- Effect of bracings on wind load (G+20):

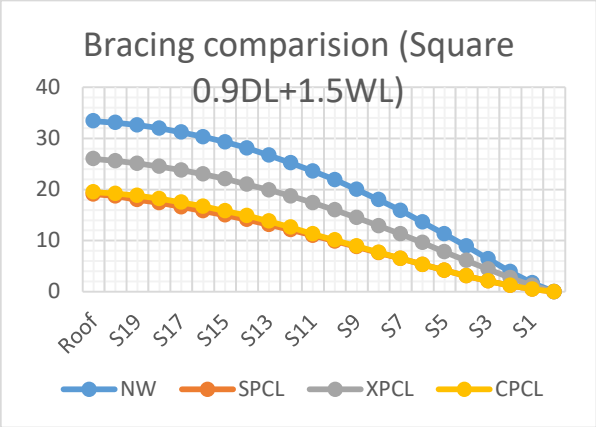

Fig 6 Effect of bracings on wind load (G+20)

- Effect of bracing placements on wind load (G+20):

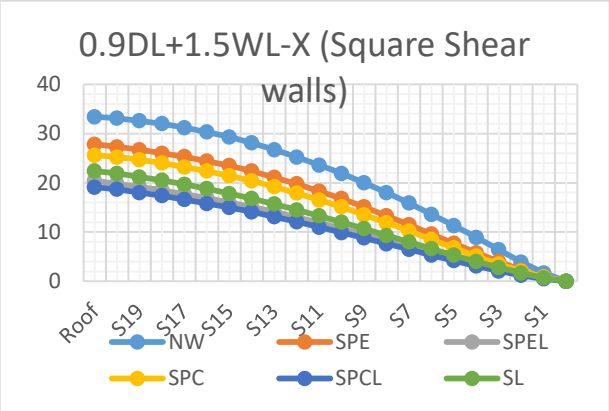

Fig 7 Effect of bracing placement on wind load (G+20)

- Effect of bracing placements on seismic load (G+30)

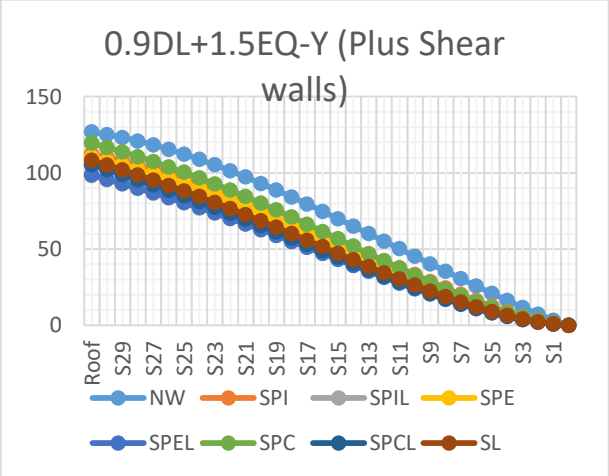

Fig 8 Effect of bracing placements on seismic load (G+30)

- % change in deflections for 0.9DL+1.5WL & 0.9DL+1.5EQ

Table 1
% change in deflections for 0.9DL+1.5WL

S.No	Plan shape (0.9DL+1.5WL)	Shear wall	X-Bracing	Combination bracing
1	Square	56.5	40	55.3
2	Rectangle	72.5	58.6	71.6
3	Plus	72.8	57.7	72
4	T	73.5	61	72.8

Table 2
% change in deflections for 0.9DL+1.5EQ

S.No	Plan shape (0.9DL+1.5EQ)	Shear wall	X-Bracing	Combination bracing
1	Square	19.8	17.3	20.4
2	Rectangle	24.9	25.4	25.6
3	Plus	29.2	27	29.5
4	T	30.6	28.2	30.9

- Material cost estimate

Table 3
Square Plan cost estimate

Square	Price per sq.mtr (in INR)		
	Shear wall	Bracing	Combination
1600sq.m*21floors=33600 sq.m			
NW	₹ 5,711	₹ 5,711	₹ 5,711
SL	₹ 6,173	₹ 5,932	₹ 6,052
SPE	₹ 6,042	₹ 5,932	₹ 5,987
SPEL	₹ 6,503	₹ 6,155	₹ 6,329
SPC	₹ 6,042	₹ 5,932	₹ 5,987
SPCL	₹ 6,503	₹ 6,155	₹ 6,329

Table 4
Rectangle Plan cost estimate

Rectangle	Price per sq.mtr (in INR)		
	Shear wall	Bracing	Combination
640sq.m*21floors=13440 sq.m			
NW	₹ 5,990	₹ 5,990	₹ 5,990
SL	₹ 7,150	₹ 6,548	₹ 6,849
SPE	₹ 6,823	₹ 6,548	₹ 6,685
SPEL	₹ 7,961	₹ 7,031	₹ 7,496
SPC	₹ 6,823	₹ 6,548	₹ 6,685
SPCL	₹ 7,961	₹ 7,031	₹ 7,496

Table 5
Plus Plan cost estimate

Plus	Price per sq.mtr (in INR)		
	Shear wall	Bracing	Combination
960sq.m*21floors=20160 sq.m			
NW	₹ 6,260	₹ 6,260	₹ 6,260
SL	₹ 7,029	₹ 6,627	₹ 6,828
SPE	₹ 7,361	₹ 6,994	₹ 7,178
SPEL	₹ 8,135	₹ 7,738	₹ 7,937
SPC	₹ 6,811	₹ 6,627	₹ 6,719
SPCL	₹ 7,579	₹ 6,994	₹ 7,287
SPI	₹ 6,811	₹ 6,627	₹ 6,719
SPIL	₹ 7,579	₹ 6,994	₹ 7,287

Table 6
T Plan cost estimate

T	Price per sq.mtr (in INR)		
	Shear wall	Bracing	Combination
960sq.m*21floors=20160 sq.m			
NW	₹ 6,260	₹ 6,260	₹ 6,260
SL	₹ 7,029	₹ 6,627	₹ 6,828
SPE	₹ 7,639	₹ 6,811	₹ 7,225
SPEL	₹ 8,408	₹ 7,183	₹ 7,795
SPC	₹ 7,088	₹ 6,811	₹ 6,949
SPCL	₹ 7,857	₹ 7,183	₹ 7,520
SPI	₹ 6,533	₹ 5,724	₹ 6,128
SPIL	₹ 7,857	₹ 7,366	₹ 7,612

VI. CONCLUSIONS

- Of all the plan irregularities considered, the increasing order of deflections is given by Square < Plus < Rectangle < T
- Of all the three combinations used, the deflection increased in the order of Shear wall< Combination < X-bracings
- The increase in deflections for different placement conditions are given by SPCL<SPIL<SPEL<SL<SPC<SPI<SPE<NW
- Deflections for rectangular building is lesser than square building along shorter base dimension and is higher along longer base side.
- Shear walls are proved to have best resistance to lateral loads whereas X-bracings with least resistance; while combination bracing is on par with shear wall bracing system.

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