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A Comparative Study on High Rise Building for various Geometrical Shapes Subjected to Wind Load of RCC & Composite Structure using ETABS

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Abstract - *In today's modern construction of high rise buildings, lateral loads such as wind load is of major concern. However Steel – Concrete Composite construction has gained wide acceptance worldwide as an alternative to pure steel or pure concrete construction. The review shows that, the composite structures are best suited for high rise buildings compared to that of RCC structures. They offer high stiffness, stability and strength which can be utilized to resist large lateral wind loads and simultaneously support the gravity loading of the structure. In this project, a comparative study has been carried using ETABS 15 software on high rise building for various geometrical shapes subjected to wind load for both RCC and Composite structure. The three geometrical shape of Rectangular, Triangular and a Plus shape are taken with each of similar base plan and same floor to floor height. All the frames are analyzed firstly using RCC frame and then Steel – Concrete Composite frame. The building frame is comprised of G+15 storey. By the analysis done using ETABS 15 software the values such as maximum storey displacement, maximum storey shear and maximum storey moment for both Reinforced Concrete and Steel – Concrete Composite structure and comparison has been done for all three geometrical shapes to compare which has more stability and resistance against wind load among all the cases considered.*

Key Words: ETABS, RCC, Composite Structure, Wind Load, G+15, Geometrical shapes.

1. INTRODUCTION

There has been an increasing demand for construction of tall buildings due to ever-increasing urbanization and need of the population with it. As we increase the height of the building the risk of wind pressure increases. Thus a careful modeling of such wind pressures needs to be done, so as to evaluate the behavior of the structure with a clear perspective of the damage that is expected. Composite structures are generally made up of the interaction of different structural elements and may be developed using either different or similar structural materials. Composite construction has gain wide acceptance because of their many advantages such as they are faster to erect, lighter in weight, better quality control, speedy in terms of construction time, has better ductility than RCC structure and hence superior lateral load resisting behavior. Composite construction also enhances the life expectancy of the structure.

In this project analysis of the different structural models of two different geometrical shapes namely triangular and rectangular having total of 16 storied structure (G+15), with both Conventional RCC and Composite Structure and comparing them using ETABS software, to get the optimum and most reliable structural system with the most suitable geometrical shape of the assumed two shapes. A total of Six different cases of the model have been analyzed and designed as a frame structure by the computer application software ETABS, keeping the floor area of each model the same. The design involves load calculations and analyzing the whole structure modeling software and the design method used for analysis is Limit State Method conforming to the Indian Standard Code of Practice.

ETABS is a powerful program that can greatly enhance an engineer's analysis and design capabilities for structures. Part of that power lies in an array of options and features. The other part lies in how simple it is to use. ETABS is a completely integrated system. Embedded beneath the simple, intuitive user interface are very powerful numerical methods, design procedures and international codes, all working from a single comprehensive database. This integration means that you create only one model of the floor system and the vertical and lateral framing systems to analyze and design the entire building. ETABS is very convenient to perform wind loading analysis of the buildings.

2. METHODOLOGY

For this study, building of three geometrical shapes of Rectangular, Triangular and Plus shape base have been considered with both Conventional RCC structure and Steel-Concrete Composite structure. G+15 storied buildings are modelled using conventional structure of RCC beams, columns & slabs and composite structure of composite column and steel beam of three different shapes (Rectangular, Triangular and Plus shape). These buildings were given dimensions such that their base area would be same.

Table 1: Description of Case Model Used in Frames

S. No.	Specifications	Model No.
1	G+15 Storied RCC structural model with Rectangular Base Plan	Case 01

2	G+15 Storied Composite structural model with Rectangular Base Plan	Case 02
3	G+15 Storied RCC structural model with Triangular Base Plan	Case 03
4	G+15 Storied Composite structural model with Triangular Base Plan	Case 04
5	G+15 Storied RCC structural model with Plus Base Plan	Case 05
6	G+15 Storied Composite structural model with Plus Base Plan	Case 06

Now, the model has to be designed for steel – concrete composite structure as well as conventional RCC beam column structure using ETABS software. For the purpose of comparison between the RCC structure and steel-concrete composite structure best efficient and economical section sizes are selected through assessing the maximum bending moment, shear force, maximum deflection, and nodal displacement of column due to load combination. The focus is on steel-concrete structural members, their connections and the effects of their interactions and reliability of the composite structure with general loading and wind loading applied on the structure over conventional reinforced concrete structure.

2.1 Assumptions for the modelling-

- Only the main block of the building is considered. The staircase are not considered in the design procedure.
- The beams are resting centrally on the column so as to avoid the conditions of eccentricity. This is achieved automatically in ETABS.
- For all structural elements, M25 and Fe415 grade of concrete and steel are used.
- The footing are not designed. Supports are assigned in the form of fixed supports.

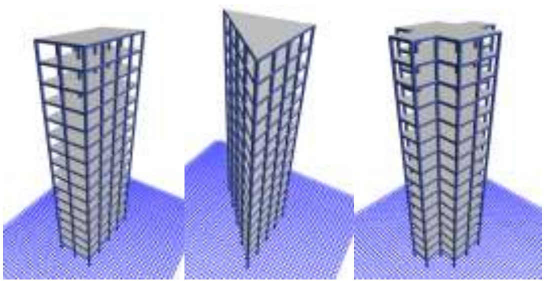

Fig. 1 – ETABS generated rendered model for cases 01, 02, 03, 04, 05, 06

Table 2 – Member Properties & Specifications for the Model

S. No.	Specification			Size
1	Base Area			200 sq. m. (as per plan)
2	Floor to floor height			3.5m
3	Total height of the building (G+15)			56m
4	Slab Thickness			150mm
5	Type of structure			Conventional RCC & Composite
6	Soil type (as per 1893:2002)			Medium
7	Importance Factor			1
8	Seismic Zone			Zone II
9	Grade of Concrete			M25
10	Grade of Steel			M415
11	Beam Size			300mm X 450mm
12	Column Size			500mm X 500mm
13	Loads Applied	D.L.	Deal Load	calculated as per self-weight
			Floor Finish	1 kN/m2
		L.L.	Live Load	2.5 kN/m2
		W.L.	Wind Load	calculated as per IS 875 part3
14	Load Combination			1.2(DL + LL + WL)

2.2 Section Properties -

The built-up area considered are taken equal for all plans of different shaped frames, with base plan are of 200 sq. m. The floor to floor height is taken as 3.5 meter making the total height of the structure 56 meter and the whole analysis has been carried out using ETABS software. Assigning the material properties for concrete grade M20 and Fe415, then assigning the section properties of beam of size 300mm x 450mm and column size of 500mm x 500mm with concrete grade of M20 and steel grade of Fe415 which are same for all frame structural cases considered.

The cross-section properties of the beam that are taken in the ETABS software are as shown in the figure below. RCC beam of size 300mm x 450mm for Conventional RCC frame structure and I-section (ISHB400) hot rolled beam for Composite structure for all three shaped model structure.

The cross-section properties of the Column that are taken in the ETABS software are as shown in the figure below. RCC Column of size 500mm x 500mm for Conventional RCC frame structure and Tabular section filled with concrete column section for Composite structure for all three shaped model structure.

3. RESULT AND DISCUSSION

3.1 Comparison of Maximum Storey Displacement -

The Maximum displacement (along Y-axis) for the each storey as per the output generated from the ETABS Software is given below in table.

Table 3 – Storey Displacement for Rectangular Frame

Storey Maximum Storey displacement (mm)		
Storey	Case 01	Case 02
	RCC-Rectangular	Composite-Rectangular
Sixteen	315.614	310.783
Fifteen	310.178	305.981
Fourteen	303.111	299.615
Thirteen	294.162	291.351
Twelve	283.317	281.120
Eleven	270.616	268.936
Ten	256.111	254.839
Nine	239.865	238.883
Eight	221.949	221.131
Seven	202.450	201.660
Six	181.469	180.553
Five	159.112	157.889
Four	135.474	133.703
Three	110.546	107.863
Two	83.813	79.681
One	52.074	46.566

Table 4 – Storey Displacement for Triangular Frame

Storey Maximum Storey displacement (mm)		
Storey	Case 03	Case 04
	RCC-Triangular	Composite-Triangular
Sixteen	545.389	518.385
Fifteen	535.980	511.302
Fourteen	523.931	501.667
Thirteen	508.652	488.819
Twelve	490.090	472.602
Eleven	468.293	453.011
Ten	443.347	430.100
Nine	415.354	403.947
Eight	384.434	374.649
Seven	350.735	342.323
Six	314.433	307.097
Five	275.708	269.083
Four	234.714	228.305
Three	191.394	184.472
Two	144.771	136.314
One	88.998	79.249

Table 5 – Storey Displacement for Plus Frame

Storey Maximum Storey displacement (mm)		
Storey	Case 05	Case 06
	RCC-Plus	Composite-Plus
Sixteen	254.731	250.097
Fifteen	250.791	246.595
Fourteen	245.500	241.793
Thirteen	238.652	235.424
Twelve	230.237	227.439
Eleven	220.286	217.852
Ten	208.839	206.694
Nine	195.944	194.009
Eight	181.654	179.844
Seven	166.038	164.259
Six	149.175	147.323
Five	131.150	129.101
Four	112.043	109.629
Three	91.869	88.818
Two	70.253	66.119
One	44.477	39.237

Graph 1 – Comparison of Maximum Storey Displacement for all cases

From the comparison of maximum storey displacement for Rectangular, Triangular & Plus plan the following results has been derived

- The value of maximum storey displacement in Composite Structure get decreased by about 1% for rectangular plan as compared to RCC Structure.
- The value of maximum storey displacement in Composite Structure get decreased by about 5% for triangular plan as compared to RCC Structure.
- The value of maximum storey displacement in Composite Structure get decreased by about approx. 2% for Plus plan as compared to RCC Structure.
- The value of maximum storey displacement in top floor get increased by about average 42% for RCC model and as we change the structure from Rectangular to Plus, the value of maximum storey displacement in top floor decreased by around 23% for RCC Structure model.

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- The value of maximum storey displacement in top floor get increased by about average 40% for RCC model and as we change the structure from Rectangular to Plus, the value of maximum storey displacement in top floor get Decreased by about 24% for Composite Structure model.

3.2 Comparison of Maximum Storey Shear (in kN) -

Table 6 – Storey Shear for Rectangular Frame

Maximum Storey Shear (kN)		
Storey	Case 01	Case 02
	RCC-Rectangular	Composite-Rectangular
Sixteen	4033.297	2601.662
Fifteen	8066.594	5203.323
Fourteen	12099.891	7804.985
Thirteen	16133.188	10406.647
Twelve	20166.484	13008.308
Eleven	24199.781	15609.970
Ten	28233.078	18211.632
Nine	32266.375	20813.294
Eight	36299.672	23414.955
Seven	40332.969	26016.617
Six	44366.266	28618.279
Five	48399.563	31219.940
Four	52432.860	33821.602
Three	56466.156	36423.264
Two	60499.453	39024.925
One	64532.750	41626.587

Table 7 – Storey Shear for Triangular Frame

Maximum Storey Shear (kN)		
Storey	Case 03	Case 04
	RCC-Triangular	Composite-Triangular
Sixteen	3664.510	1370.139
Fifteen	7329.019	1240.278
Fourteen	10993.529	4110.417
Thirteen	14658.038	5480.555
Twelve	18322.547	6850.694
Eleven	21987.057	8220.833
Ten	25651.566	9590.972
Nine	29316.076	10961.111
Eight	32980.585	12331.249
Seven	36645.095	13701.388
Six	40309.604	15071.527
Five	43974.114	16441.666
Four	47638.623	17811.805
Three	51303.133	19181.944
Two	54967.642	20552.082
One	58632.152	21922.221

Table 8 – Storey Shear for Plus Frame

Maximum Storey Shear (kN)		
Storey	Case 05	Case 06
	RCC-Plus	Composite-Plus
Sixteen	1921.973	1668.110
Fifteen	3843.946	3336.220
Fourteen	5765.919	5004.330
Thirteen	7687.893	6672.439
Twelve	9609.866	8340.549
Eleven	11531.839	10008.659
Ten	13453.812	11676.769
Nine	15375.785	13344.879
Eight	17297.758	15012.989
Seven	19219.731	16681.098
Six	21141.705	18349.208
Five	23063.678	20017.318
Four	24985.651	21685.428
Three	26907.624	23353.538
Two	28829.597	25021.648
One	30751.570	26689.757

Graph 2 – Comparison of Maximum Storey Shear for all cases

From the comparison of maximum storey Shear for Rectangular, Triangular & Plus plan the following results has been derived

- As we change the structure from conventional RCC to composite, the value of maximum storey displacement in top floor get decreased by about 35.50% for rectangular plan.

- As we change the structure from conventional RCC to composite, the value of maximum storey displacement in top floor get decreased by about 62.61% for triangular plan.

- As we change the structure from conventional RCC to composite, the value of maximum storey displacement in top floor get decreased by about 13.21% for Plus plan.

- As we change the structure from Rectangular to Triangular, the value of maximum storey displacement in top floor get decreased by about 9% for RCC model and as we change the structure from Rectangular to Plus, the value of maximum storey displacement in top floor get decreased by about 52% for RCC Structure model.

- As we change the structure from Rectangular to Triangular, the value of maximum storey displacement in top floor get decreased by about 47% for Composite model and as we change the structure from Rectangular to Plus, the value of maximum storey displacement in top floor get decreased by about 36% for Composite model.

3.3 Comparison of Maximum Storey Moment (kN-m) -

Table 6 – Storey Moment for Rectangular Frame

Maximum Storey Moment (kN-m)		
Storey	Case 01	Case 02
	RCC-Rectangular	Composite-Rectangular
Sixteen	20550.052	13391.876
Fifteen	41862.899	27546.547
Fourteen	63930.339	42455.811
Thirteen	86741.215	58108.511
Twelve	110284.144	74493.264
Eleven	134547.835	91598.779
Ten	159521.081	109413.849
Nine	185192.424	127927.016
Eight	211544.788	147121.204
Seven	238556.624	166974.864
Six	266206.331	187466.395
Five	294470.166	208572.054
Four	323320.715	230264.427
Three	352779.727	252515.263
Two	382689.353	275316.713
One	401000.241	298668.760

Table 7 – Storey Moment for Triangular Frame

Maximum Storey Moment (kN-m)		
Storey	Case 03	Case 04
	RCC-Triangular	Composite-Triangular
Sixteen	25825.711	9565.601
Fifteen	52414.215	19893.995
Fourteen	79757.314	30976.984
Thirteen	107843.848	42803.408
Twelve	136662.436	55361.886
Eleven	166201.784	68641.125
Ten	196450.689	82629.920
Nine	227397.690	97316.811
Eight	259025.712	112684.723
Seven	291313.206	128712.107
Six	324238.572	145377.363
Five	357778.065	162656.746
Four	391904.272	180522.844
Three	426588.943	198947.404
Two	461824.226	217922.578
One	497610.108	237448.350

Table 8 – Storey Moment for Plus Frame

Maximum Storey Moment (kN-m)		
Storey	Case 05	Case 06
	RCC-Plus	Composite-Plus
Sixteen	15645.845	12894.392
Fifteen	30359.527	26551.577
Fourteen	46675.282	40963.357
Thirteen	63734.471	56118.572
Twelve	81525.715	72005.841
Eleven	100037.720	88613.871
Ten	119259.280	105931.456
Nine	139178.937	123947.138
Eight	159779.615	142643.842
Seven	181039.765	162000.017
Six	202937.786	181994.064
Five	225449.935	202602.238
Four	248548.798	223797.126
Three	272206.125	245550.478
Two	296414.065	267854.442
One	321172.602	290709.005

Graph 3 – Comparison of Maximum Storey Moment

From the comparison of maximum storey Moment for Rectangular, Triangular & Plus plan the following results has been derived

- As we change the structure from conventional RCC to composite, the value of maximum storey displacement in top floor get decreased by about average 35% for rectangular plan respectively.

- As we change the structure from conventional RCC to composite, the value of maximum storey displacement in top floor get decreased by about average 63% for triangular plan respectively.

- As we change the structure from conventional RCC to composite, the value of maximum storey displacement in top floor get decreased by about average 18% for Plus plan respectively.
- As we change the structure from Rectangular to Triangular, the value of maximum storey displacement in top floor get increased by about 20% for RCC model and as we change the structure from Rectangular to Plus, the value of maximum storey displacement in top floor get decreased by about 31% for RCC Structure model.
- As we change the structure from Rectangular to Triangular, the value of maximum storey displacement in top floor get decreased by about 29% for Composite model and as we change the structure from Rectangular to Plus, the value of maximum storey displacement in top floor get decreased by about 4% for Composite Structure model

4. CONCLUSIONS

In all the cases considered the values of storey displacements are within permissible limits as per IS code limits.

It is safe to conclude that case-06 with Plus plan of Composite frame structure gives best result from all the cases that has been compared and is more stable than other cases.

As we chamfer the edged of rectangular or square plan frame structure the resistance to the lateral wind load increases and with the help of Steel – Concrete Composite structure the stability of the structure can be further increased.

The size of the steel beams of Steel-Concrete Composite frame structure from RCC frame structure reduces by about 25% approximately. Thus dead load of the composite structure is less as compared to RCC frame structure, which gives economical foundation design.

Also as time required for construction of composite structures is less compared to that of RCC structures as no formwork is required. Thus Steel-Concrete Composite structures are more economical in case of high rise buildings.

Steel-Concrete Composite frame follows strong column weak beam behaviour, as hinges are formed in beam element rather than column element.

Composite columns are also used widely in practice to resist predominantly compressive loading and appear in different form including concrete filled section, recently using high strength high performance concrete.

The further development of steel framed buildings depends largely on the use of composite construction as its construction is speedy and reduces the erection time.

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