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Seismic Analysis of G+20 Steel-Concrete Composite Building with Regular and Irregular Shaped Building

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Abstract— ***Composite construction involves more than one type of material which are not similar to each other. In Composite structures ductility of steel and weight of RCC structure is combined to provide and economical and durable structure. Present research work involves seismic analysis of G+20 steel-concrete composite building. Building with regular and irregular plan E-shaped are compared for base shears and drift for each storey. Two models for each are analysed with beam and column size same throughout the height and other with beam and column size changing at every 5th storey. Equivalent static analysis will be carried out using IS 1893-2016. Storey drifts will be calculated at each floor levels. Seismic behaviour of building will be evaluated from above. Response spectrum analysis will be carried out in ETABS.***

Keywords— Composite construction, Seismic analysis, Ductility, Response spectrum analysis, ETABS

I. Introduction

In composite construction two different materials are bonded in a manner to act as a single structural unit. If slab is connected properly to beam with help of connectors such as studs, then the slab will act compositely with beam. This type of construction saves a lot of time in construction and it also provides column free area that results into more space utilization. Life expectancy of structure increases in composite construction. Mechanical shear connectors form strong bond between steel beam and concrete slab and allows reduction of live load deflection. Concrete slabs are frequently cast on permanent steel decking with a ribbed, corrugated, cellular, or blended cellular cross section. Two distinct composite-design configurations are inherent: ribs parallel or ribs perpendicular to the supporting beams or girders.
In India, most of the buildings are medium or low rise buildings. Because the construction becomes easy and economical, reinforced concrete members are used widely. Now a day's large number high rise buildings are being constructed. For the construction of high-rise buildings, it has been found that the use of composite structural members is more effective and economical than using reinforced concrete members.
The practice of steel-concrete composite construction in cities is advantageous over the conventional reinforced concrete construction. Because of less loads in low-rise buildings, reinforced concrete frames are used. But high-rise buildings, due to increased dead load, span restrictions, less stiffness, and drift limitation the conventional reinforced concrete construction cannot be adopted.

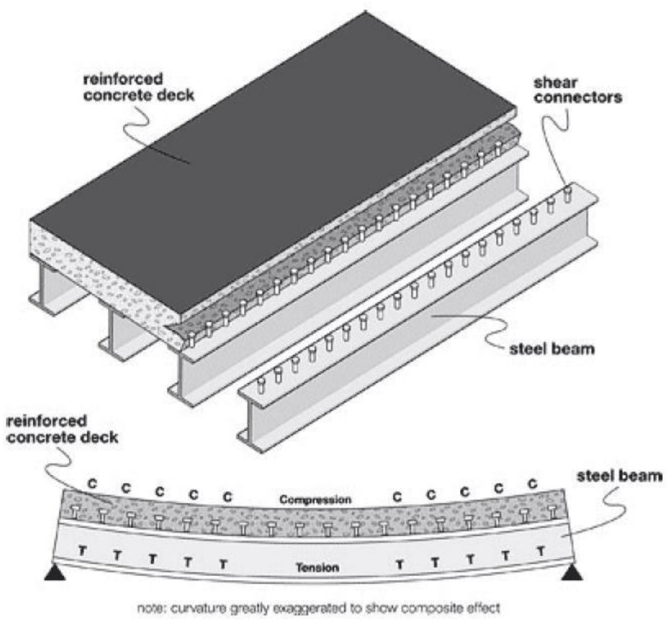

Fig. 1 Composite Slab

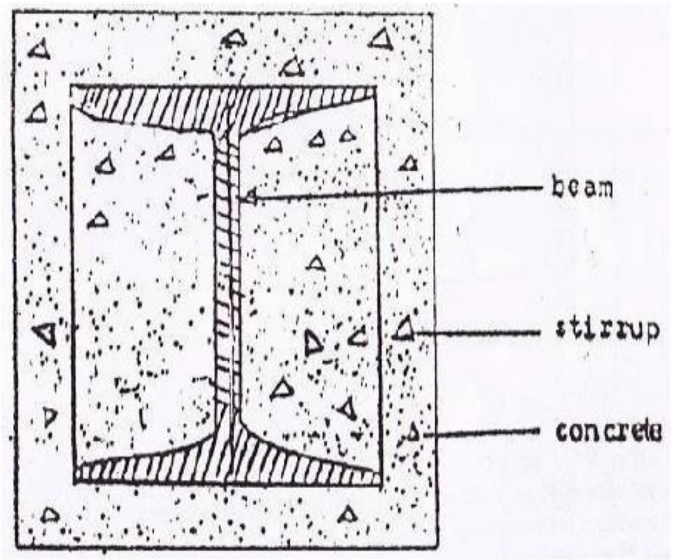

Fig. 2 Composite Column

II. METHODOLOGY

Steel-concrete composite building was analysed in ETABS with regular and irregular shape. Models with same beam and column size throughout the height were analysed and compare with models with different beam and column dimension changing at every 5^{th} storey.

Model 1: G+20 Steel-concrete composite building with regular plan and different beam and column dimensions at every 5^{th} storey

Model 2: G+20 Steel-concrete composite building with irregular plan E-shaped and different beam and column dimensions at every 5^{th} storey

Model 3: G+20 Steel-concrete composite building with regular plan and same beam and column dimensions throughout the height of building

Model 4: G+20 Steel-concrete composite building with irregular plan E-shaped and same beam and column dimensions throughout the height of building

Table 1 Structural Data of Regular Shaped Building

Dimension of building	20m x 20m
Storey height	3.35m
No. of storeys	G+20
Slab thickness	125mm
Beam size (decreasing by 25mm moving upwards)	300mm x 300mm
Column size (decreasing by 50mm moving upwards)	450mm x 450mm embedded with ISMB300
Seismic zone	V
Zone factor	0.36
Importance factor	1
Response reduction factor	5
Soil type	II (Medium)
Dead load	6.1 kN/m^2
Live load	4kN/m^2
Live load (Roof)	1 kN/m^2
Wall load	20kN/m (1-5 storey)
Wall load	18.4kN/m (6-10 storey)
Wall load	16.75kN/m (11-15 storey)
Wall load	15kN/m (16-20 storey)

Table 2 Structural Data of Irregular Shaped Building

Dimension of building	25m x 24m
Storey height	3.35m
No. of storeys	G+20
Slab thickness	125mm
Beam size (decreasing by 25mm moving upwards)	300mm x 300mm
Column size (decreasing by 50mm moving upwards)	450mm x 450mm embedded with ISMB300
Seismic zone	V
Zone factor	0.36
Importance factor	1
Response reduction factor	5
Soil type	II (Medium)
Dead load	6.1 kN/m^2
Live load	4kN/m^2
Live load (Roof)	1 kN/m^2
Wall load	20kN/m (1-5 storey)
Wall load	18.4kN/m (6-10 storey)
Wall load	16.75kN/m (11-15 storey)
Wall load	15kN/m (16-20 storey)

Table 3 Structural Data of Regular Shaped Building

Dimension of building	25m x 24m
Storey height	3.35m
No. of storeys	G+20
Slab thickness	125mm
Beam size	300mm x 300mm
Column size	375mm x 375mm embedded with ISMB225
Seismic zone	V
Zone factor	0.36
Importance factor	1
Response reduction factor	5
Soil type	II (Medium)
Dead load	6.1 kN/m^2
Live load	4kN/m^2
Live load (Roof)	1 kN/m^2
Wall load	19.2kN/m

Table 4 Structural Data of Irregular Shaped Building

Dimension of building	20m x 20m
Storey height	3.35m
No. of storeys	G+20
Slab thickness	125mm
Beam size	300mm x 300mm
Column size	375mm x 375mm embedded with ISMB225
Seismic zone	V
Zone factor	0.36
Importance factor	1
Response reduction factor	5
Soil type	II (Medium)
Dead load	6.1 kN/m^2
Live load	4kN/m^2
Live load (Roof)	1 kN/m^2
Wall load	19.2kN/m

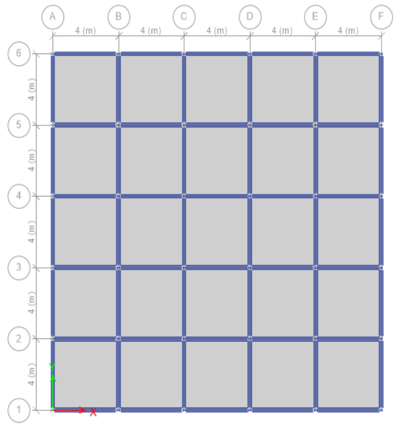

Fig. 3 Plan view for regular shaped building

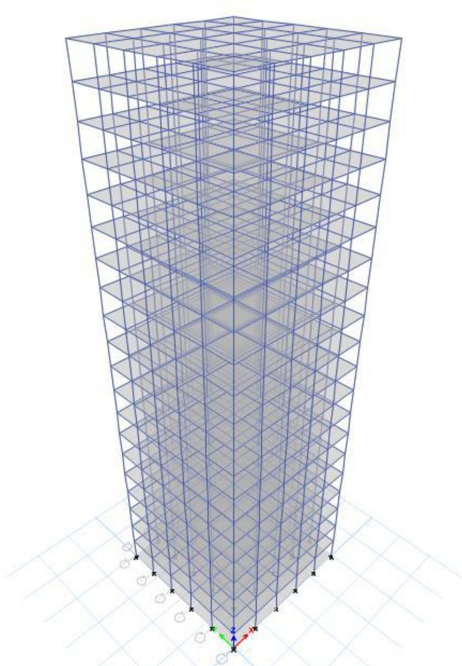

Fig. 4 3D view for regular shaped building

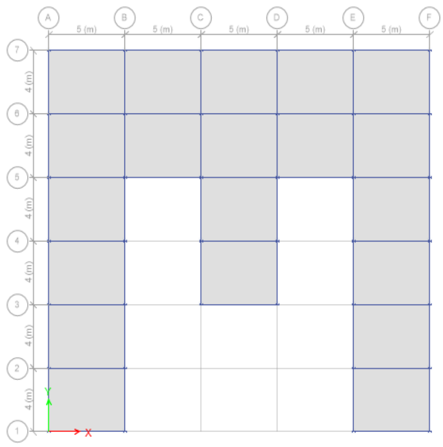

Fig. 5 Plan view for Irregular shaped building

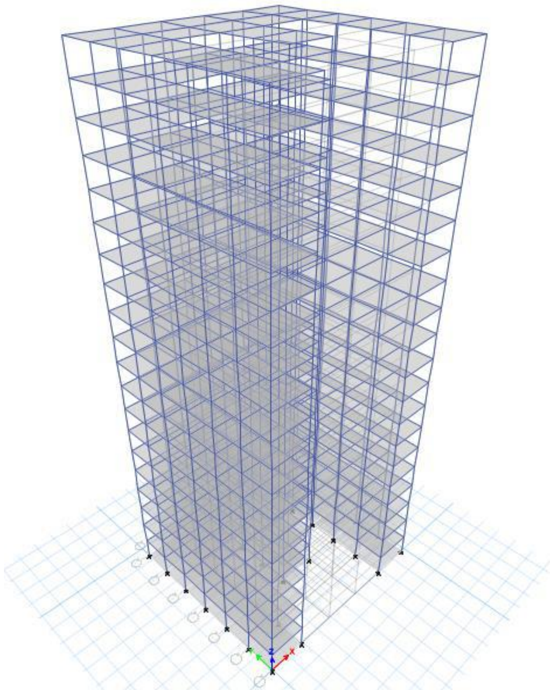

Fig. 6 3D view for irregular shaped building

III. RESULTS AND DISCUSSION

Comparing storey drifts and base shear for above building:

A. Regular shaped building with irregular shaped building (changing beam and column size)

Table 5 Comparison of drift in X and Y-direction

Storey	Regular Shaped Building		Irregular Shaped Building	
	Drift in x-direction mm	Drift in y-direction mm	Drift in x-direction mm	Drift in y-direction mm
20	1.029	1.034	2.608	1.21
19	1.901	1.927	3.611	1.94
18	2.723	2.768	4.694	2.729
17	3.356	3.42	5.706	3.474
16	3.647	3.723	6.413	4.002
15	3.241	3.317	6.053	3.636
14	3.551	3.642	6.616	4.054
13	3.858	3.963	7.171	4.467
12	4.083	4.202	7.624	4.82
11	4.02	4.141	7.697	4.899
10	3.491	3.585	6.952	4.269
9	3.6	3.703	7.149	4.443
8	3.721	3.833	7.349	4.622
7	3.775	3.897	7.445	4.741
6	3.591	3.708	7.183	4.597
5	3.137	3.21	6.406	3.98
4	3.157	3.233	6.36	4.0
3	3.231	3.307	6.327	4.025
2	3.377	3.453	6.226	3.984
1	3.798	3.908	6.035	3.769
0	0	0	0	0

Table 6 Comparison of Base Shears

Load Cases	Regular Shaped Building	Irregular Shaped Building
	Base Shears	Base Shears
EQx	1769.73kN	2440.78kN
EQy	1769.73kN	2440.78kN
RSx	1804.38kN	2495.64kN
RSy	1804.18kN	2489.80kN

B. Regular shaped building (changing beam and column size) with regular shaped building (same beam and column size)

Table 7 Comparison of Drift in X and Y direction

Storey	Regular Shaped Building (Changing beam and column sizes)		Regular Shaped Building (Same beam and column sizes)	
	Drift in x-direction mm	Drift in y-direction mm	Drift in x-direction mm	Drift in y-direction mm
20	1.029	1.034	0.279	0.248
19	1.901	1.927	0.321	0.378
18	2.723	2.768	0.363	0.504
17	3.356	3.42	0.404	0.625
16	3.647	3.723	0.442	0.74
15	3.241	3.317	0.476	0.849
14	3.551	3.642	0.507	0.952
13	3.858	3.963	0.534	1.048
12	4.083	4.202	0.557	1.137
11	4.02	4.141	0.577	1.22
10	3.491	3.585	0.593	1.295
9	3.6	3.703	0.604	1.362
8	3.721	3.833	0.611	1.422
7	3.775	3.897	0.614	1.474
6	3.591	3.708	0.613	1.517
5	3.137	3.21	0.607	1.552
4	3.157	3.233	0.596	1.576
3	3.231	3.307	0.584	1.591
2	3.377	3.453	0.596	1.595
1	3.798	3.908	0.841	1.781
0	0	0	0	0

Table 8 Comparison of Base Shears

Load Cases	Regular Shaped Building (Changing beam and column sizes)	Regular Shaped Building (Same beam and column sizes)
	Base Shears	Base Shears
EQx	1769.73kN	925.43kN
EQy	1769.73kN	401.07kN
RSx	1804.38kN	942.66kN
RSy	1804.18kN	408.08kN

C. Irregular shaped building (changing beam and column size) with irregular shaped building (same beam and column size)

Table 9 Comparison of Drift in X and Y direction

Storey	Irregular Shaped Building (Changing beam and column sizes)		Irregular Shaped Building (Same beam and column sizes)	
	Drift in x-direction mm	Drift in y-direction mm	Drift in x-direction mm	Drift in y-direction mm
20	2.608	1.21	2.02	0.78
19	3.611	1.94	2.375	1.051
18	4.694	2.729	2.87	1.363
17	5.706	3.474	3.387	1.681
16	6.413	4.002	3.891	1.993
15	6.053	3.636	4.375	2.296
14	6.616	4.054	4.838	2.588
13	7.171	4.467	5.277	2.868
12	7.624	4.82	5.691	3.134
11	7.697	4.899	6.078	3.387
10	6.952	4.269	6.435	3.624
9	7.149	4.443	6.762	3.845
8	7.349	4.622	7.057	4.05
7	7.445	4.741	7.318	4.236
6	7.183	4.597	7.544	4.404
5	6.406	3.98	7.736	4.522
4	6.36	4.0	7.904	4.685
3	6.327	4.025	8.114	4.826
2	6.226	3.984	8.64	5.123
1	6.035	3.769	10.573	6.53
0	0	0	0	0

Table 10 Comparison of Base Shears

Load Cases	Irregular Shaped Building (Changing beam and column sizes)	Irregular Shaped Building (Same beam and column sizes)
	Base Shears	Base Shears
EQx	2440.78kN	1889.62kN
EQy	2440.78kN	1889.62kN
RSx	2495.64kN	1938.47kN
RSy	2489.80kN	1921.27kN

D. Regular shaped building with irregular shaped building (same beam and column size)

Table 11 Comparison of Drift in X and Y direction

Storey	Regular Shaped Building		Irregular Shaped Building	
	Drift in x-direction mm	Drift in y-direction mm	Drift in x-direction mm	Drift in y-direction mm
20	0.279	0.248	2.02	0.78
19	0.321	0.378	2.375	1.051
18	0.363	0.504	2.87	1.363
17	0.404	0.625	3.387	1.681
16	0.442	0.74	3.891	1.993
15	0.476	0.849	4.375	2.296
14	0.507	0.952	4.838	2.588
13	0.534	1.048	5.277	2.868
12	0.557	1.137	5.691	3.134
11	0.577	1.22	6.078	3.387
10	0.593	1.295	6.435	3.624
9	0.604	1.362	6.762	3.845
8	0.611	1.422	7.057	4.05

7	0.614	1.474	7.318	4.236
6	0.613	1.517	7.544	4.404
5	0.607	1.552	7.736	4.522
4	0.596	1.576	7.904	4.685
3	0.584	1.591	8.114	4.826
2	0.596	1.595	8.64	5.123
1	0.841	1.781	10.573	6.53
0	0	0	0	0

Table 12 Comparison of Base Shears

Load Cases	Regular Shaped Building	Irregular Shaped Building
	Base Shears	Base Shears
EQx	925.43kN	1889.62kN
EQy	401.07kN	1889.62kN
RSx	942.66kN	1938.47kN
RSy	408.08kN	1921.27kN

IV. CONCLUSIONS

Above four models were compared for storey drift and base shear to carry out feasibility analysis of steel-concrete composite building in near future for tall buildings. Conclusions from this is summarized below:

1. Reduced dimensions of columns and beams leads to lesser dead weight of composite structures than regular RCC or steel structures, thus lowering the foundation cost.
2. The composite structures are less susceptible against seismic forces acting on the structure due to their less weight.
3. Composite structures have maximum displacement but within certain limits as they are more flexible as compared to RCC structures.
4. Storey drift is found to be maximum between base and storey 2 for each model analysed.
5. Regular shaped building with changing beam and column size have same base shear as irregular shaped building with same beam and column size.
6. For regular shaped building with same beam and column size have lowest base shears and irregular shaped building with changing beam and column size have highest base shears.

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