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Evaluation of RC, Composite and RC + Composite Structure under the Seismic Loading - A Comparative Study

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***Abstract* - Constructing high-rise structures in vulnerable land is always a major concern for structural engineers. The failure of many multi-storied and low-rise reinforced cement concrete and masonry buildings due to seismic forces has put structural engineers to look into different methods of construction practices to adopt, coming out from traditional methods to the new evolutionary designs. Since the RCC structure is bulky and has huge weight, composite structure could be the alternative solution to overcome these problems.**

To understand the behaviour of composite structure and its response during earthquakes, comparative study is done between conventional special moment resisting frame (SMRF) structure and composite structure. And for the better comparison, five different models of conventional SMRF frame, composite and semi rigid or semi composite structure were modelled and analysed. Further two more models were added in order to come out of different problems in the proposed models.

Modelling and analysis is carried out in ETABS-16. To know at what height composite structures are effective, analysis was done on 3 different storey levels i.e 7, 15 and 30 storeys. The building is presumed to be in critical seismic prone zone i.e Zone IV and soil type as medium soil Type-II. For the dynamic analysis, Response Spectrum Method is used.

Comparative study of all the different Models of same storey level in terms of storey drift, base shear, storey stiffness, maximum displacement, shear force & time period is discussed and shown.

Key Words: Composite structure, RC structure, RC + Composite, Dynamic response, Dynamic Analysis, Comparative study

1. INTRODUCTION

Over the past thirty-forty years, composite construction has been used in the US, UK, Australia and Japan as a cost-effective alternative to traditional structural steel or RC Structures and has become the most common form of floor system for steel framed office buildings.

Compared to high-rise steel structures, composite systems offer more effective and efficient use of materials, a reduction in overall construction time and many other advantages. The use of steel in construction industry is very low in India compared to many developing countries and limiting the use of steel as an alternative construction material where it can be economical is a heavy loss for the Nation.

Nowadays, composite construction is dominating the multi-storey building sector. It's due to the strength & stiffness as well as ductility that can be achieved with the minimum use of construction materials. Compressive and Tensile strengths can be utilised in a highly efficient and light weight design when steel and concrete materials are combined together effectively, as concrete is efficient in compression and the steel in tension. Also the reduction in self-weight reduces the forces in those structural elements which are supported on them, including foundations and also benefits in terms of speedy construction time.

Composite construction was first used in both buildings and bridges in U.S. over a century ago. Steel–concrete composite beams was the earliest form of method in composite construction. A composite tubular column was adopted as they provide permanent and integral formwork for compression member & also reduces construction time and cost.

The application of profiled steel deck slab (Steel sheet & RC slab) was adopted as it works for dual purposes i.e permanent formwork and reinforcement to concrete slab.

1.1 RESEARCH SIGNIFICANCE

- The Indian Standard Codal provision IS 3935-1966 says – "Though composite construction is not a very new technique, its importance in structural construction is of *recent realization* in this country". Thus researchers should also realise the research work on this topic.
- This research is carried out to know the structural behaviour of the steel-concrete composite structure under seismic loadings.
- Comparing different models i.e reinforced concrete cement & steel concrete composite structure will give a better idea between two different structural configurations.

2. METHODOLOGY

- In the design of high rise structures, reinforced cement concrete structure is found to be bulky and has huge weight whereas composite structure has less self-weight compared to rcc structure

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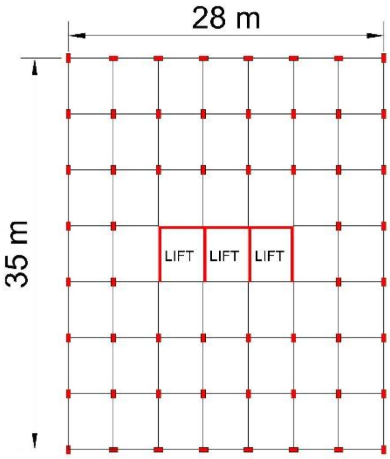
- As in steel sections, ductility and high tensile strength are key properties, while stiffness and high compressive strength is the best property of concrete members. Thus combining the duo steel-concrete composite structures, strength and stiffness can be achieved with minimum use of materials.
- In view of incorporating the above observations, the present study was carried out focusing on RC + Composite structures which can be constructed where the lower half stories will be of RCC and the remaining above half stories will be constructed as composite. With this overall reduction in self-weight of structure, stiffness on bottom floors and flexibility on top floors can be attained.
  - It is presumed that when seismic forces hit the RC + Composite structure, vibrations due to seismic energy will dissipate properly from the structure without any structural damage.
  - Also when the wind hits the structure, the top stories will dissipate the wind energy easily as the top stories is more flexible due to composite structure.

2.1 Description of Structural Model

Analysis was carried out considering **seismic zone-IV** and soil type was considered as Medium i.e. **soil type-II.** Response reduction factor, **R=5** & Importance factor, **I=1**.

This project is analyzed considering different storey levels **G+7, G+15, G+30** and each storey level has five different models i.e. **M-1, M-2, M-3, M-4, M-5** with architectural plan dimensions **28 m x 35 m** has seven bays in X and Y direction regular building. Total height of the building is 25m, 53m & 105.5m for G+7, G+15 & G+30 respectively. Keeping height of ground floor 4 m and typical storey height 3.5m which is maintained throughout the building. All the modelling and analysis was done in Etabs 16.



Following are the models considered for the analysis. Details of each model is described below:

Model no.1 (M-1): An RCC bare frame structure in which all the beams and columns are modelled as line elements, including core shear wall for lift at the centre of building having weight of masonry walls of 230mm thick on all the beams. Core wall or shear wall and floor slabs are modelled as thin Shell element.

Model no.2 (M-2): Model same as model no.1(M1) including L-shaped shear walls at extreme corners of building.

Model no.3 (M-3): Model same as model no.1(M1) but

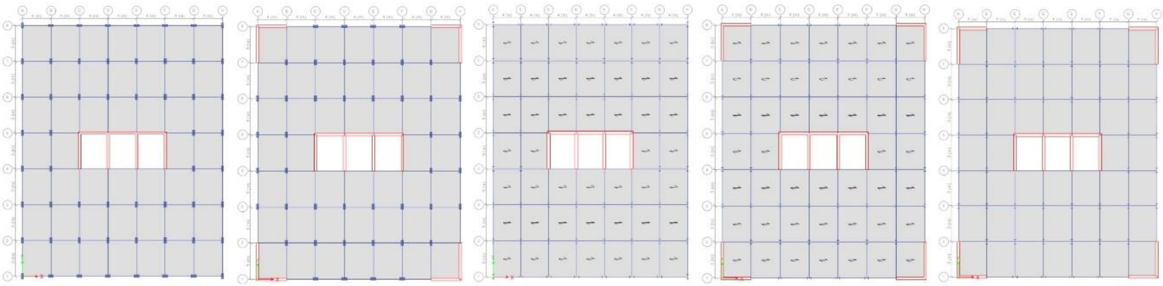
- All the reinforced concrete columns are encased with ishb and iswb section with minimum percentage of steel in column (composite columns).
- All the slabs are made as Deck slab and all the beams are made ISHB sections (Composite floor).

Model no.4 (M-4): Model same as Model no.3(M-3) including L- shaped shear walls at extreme corners of building.

Model no.5 (M-5): This Model has two parts, 1st part is lower portion of the structure and the above remaining half of the structure is 2nd part. i.e for (i) G+30 Storey Building, till G+16 is 1st half and 2nd half is above 16th storey to top storey (ii) G+15 Storey Building, till G+8 is 1st half and 2nd half is above 8th storey to Top storey (iii) G+7 Storey, till G+4 is 1st half and 2nd half is above 4th Storey to the Top storey.

- 1st Half part consists of RC beams and RC slabs.
- 2nd Half portion consists of composite floor i.e All the slabs are made as Deck slab and all the beams as ISHB steel sections.
- All the RC columns are encased with ISHB and ISWB section with min percentage of steel in column (composite columns) throughout the structure.
- Shear walls are considered at core and exterior corner edges as L-shaped

Note: Column sizes in composite Models kept same to the RC column. The main reason was to increase ductility in composite columns keeping stiffness and rigidity same as RC column where we can reduce lateral displacement upto some extent in Composite structure.



MODEL 1 **MODEL 2** **MODEL 3** **MODEL 4** **MODEL 5**

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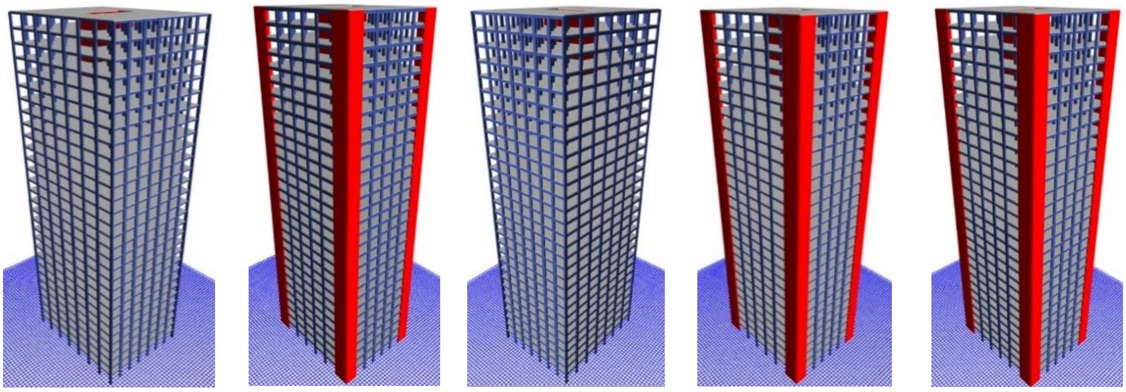

Fig -2.2: Top view and Rendered View of different Models

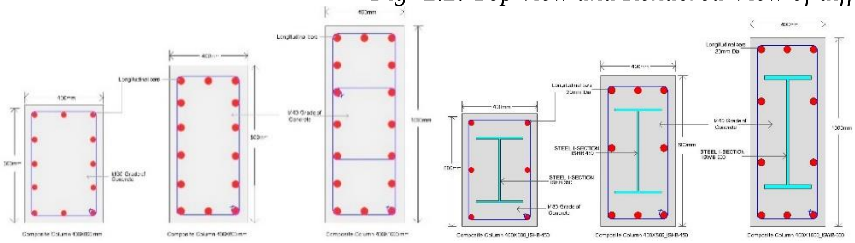

Fig -2.3: Different Column sizes considered for RC and Composite Structure

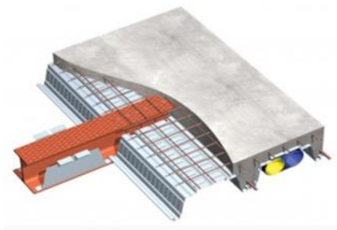

Fig - 2.4: Representative image of Profiled Decking Floors system

Table -2.1: Building Details

Sr. No.	Building Parameters	Descriptions
1	Type of the Building	Commercial
2	No. of Storeys	G+7, G+15, G+30
3	No. of Models	5 in each Storey levels
4	Seismic zone	Zone 4 (0.24)
5	Soil Type	Medium (Type-II)
6	Importance factor	1
7	Response Reduction Factor	5
8	Analysis	Response Spectrum Method
9	Grade of Rebar Steel for G+7, G+15, G+30	Fe 500
10	Grade of Concrete For	
	G+7	M30
	G+15, G+30	M40
11	Grade of Steel Sections	Fe250
12	Building Height	
	G+7	25m
	G+15	53m
	G+30	105.5m

Table -2.2: Column and Beam Details

Storey No.s	Model No.s	Column Size in mm	Beam	Grade
		Sizes in mm	Sizes in mm	
G+7	M-1-7	Col-400 x 600	500x300	M30
	M-2-7			
	M-3-7	Col-400x600-ISHB350	ISHB-400	
	M-4-7			
	M-5-7			
G+15	M-1-15	Col-400x800	600x300	M40
	M-2-15			
	M-3-15	Col-400x800-ISHB400	ISHB-400	
	M-4-15			
	M-5-15			
G+30	M-1-30	Col-400x1000 upto G+15, Col-400x800 above 15 Storey	600x300 & 750x300	M40
	M-2-30			
	M-3-30	Col-400x1000-ISWB600 upto G+15, Col-400x800-ISHB-450 above 15 Storey	ISHB-400 & ISWB-600	
	M-4-30			
	M-5-30		ISHB-400, ISWB-500 & ISWB-600	

3. RESULTS AND DISCUSSIONS

Study was carried out considering different parameters like lateral displacements, storey drifts, storey shear force, storey stiffness and time period for the different building models with graphical representation.

Note: (i) Results are shown only for 30 stories but conclusions will be given for other story level (G+15 & G+7) also.

(ii) For the values of Displacement, Drift, Storey Shear Force and Storey Stiffness, refer Table 3.1–3.4 at the end.

(iii) Result Values are shown in Appendix Tables.

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3.1 LATERAL DISPLCEMENT

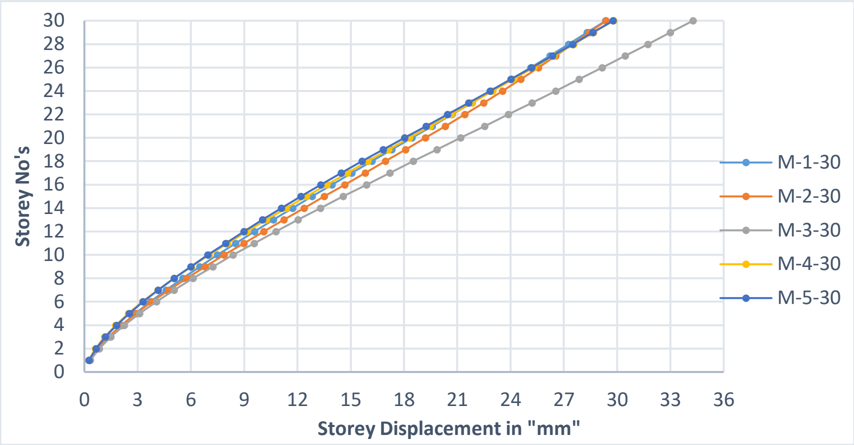

Chart -3.1: Displacements in X-direction

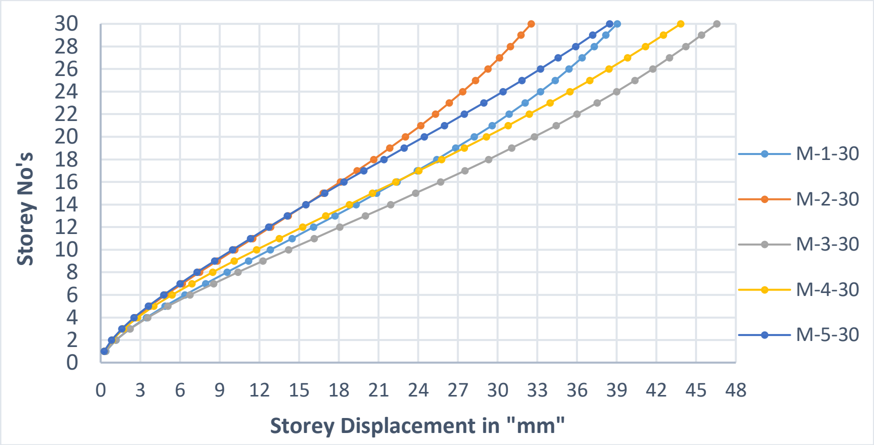

Chart -3.2: Displacements in Y-direction

- From table 3.1 and chart 3.1 & 3.2, Model 3 i.e composite structure with shear wall at core only, shows the highest displacement value at top floor level when compared with all the other building model, it shows that, this model is more flexible among all other building models in both longitudinal and transverse directions.
- Semi rigid or semi composite i.e Model 5 is showing similar results when compared with Model 1 & 2 in both the directions.
- Percentage differences when Model 3 is compared with Model 1, 2, 4 & 5 are **16.3%, 30.2%, 6% & 17.4%** respt in Transverse direction.

3.2 STOREY DRIFT

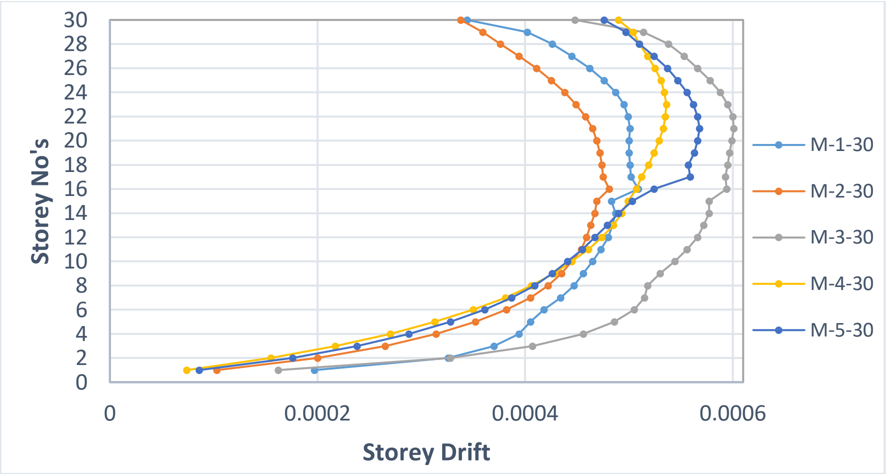

Chart -3.3: Drift in X-direction

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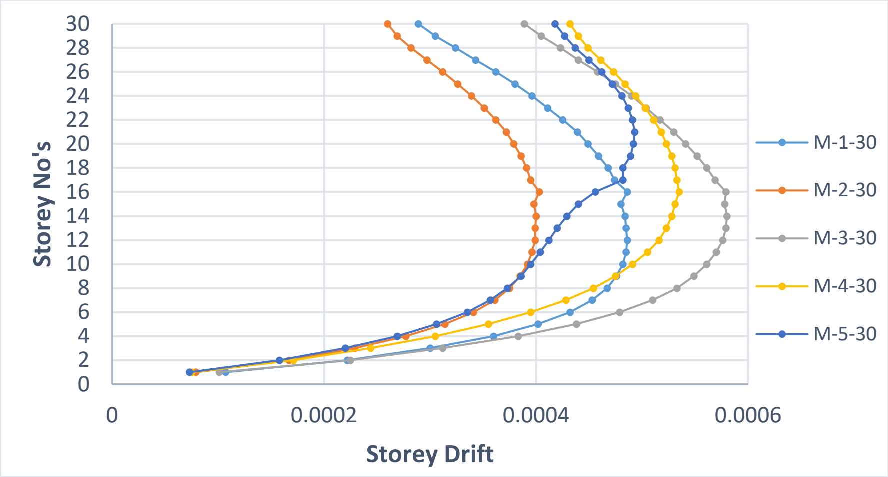

Chart -3.4: Drift in Y-direction

- All the drift ratios are within the permissible limit specified by the IS-1893-2002.
- Model 2 shows the least and Model 3 shows the highest amount of drift ratio when compared with all other models.
- Combination of RCC and composite building i.e Model 5, the drift initially was very much low in transition zone (16th and 17th storey) and then the drift drastically increased due to the flexibility in upper stories.
- Model 5 must be given due concentration during designing and construction in transition zone

3.3 STOREY SHEAR FORCE

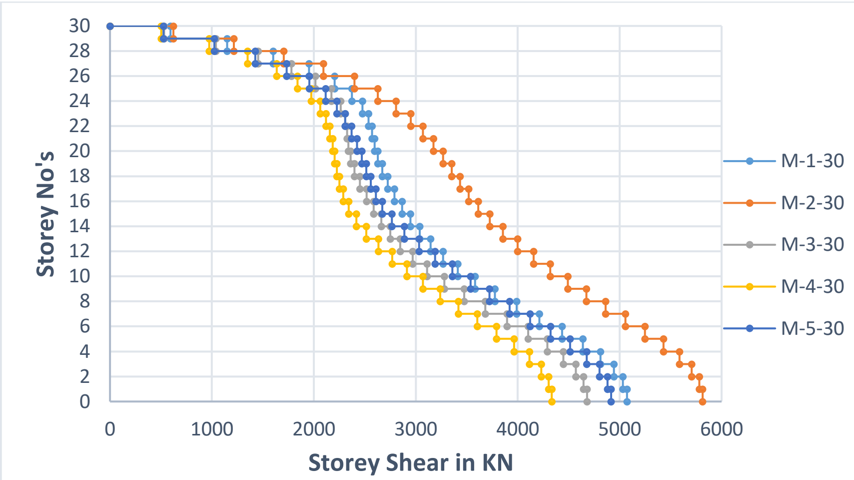

Chart -3.5: Storey Shear in X-direction

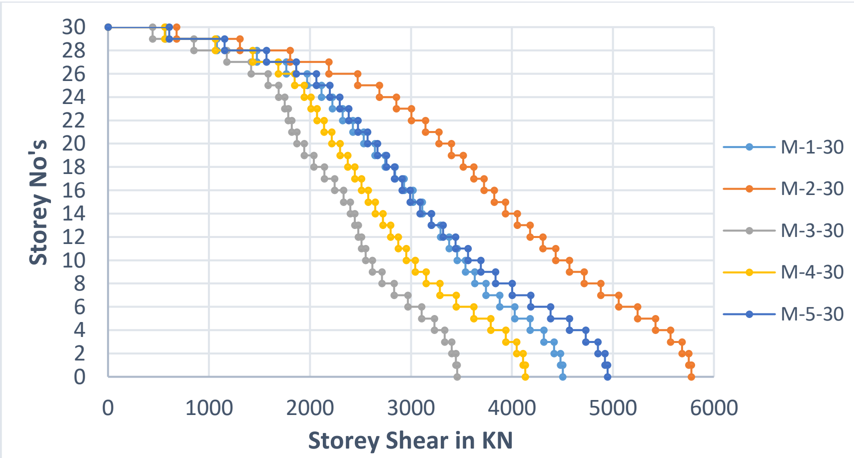

Chart -3.6: Storey Shear in Y-direction

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- Max storey shear is seen in Model 2, since it has higher seismic weight when compared to other Models.
- Composite structure shows minimum storey shear, as its self-weight is lesser then RC structures.
- Model 5 is showing closer values to Model 2.
- Percentage differences when Model 4 is compared with Model 1, 2, 3 & 5 in X-direction are **14.5%, 25.4%, 7.4% & 11.86%** respectively. And in Y-direction when Model 3 is compared with Model 1, 2, 4 & 5 are **23.2%, 40.15%, 16.32% & 30.11%** respectively.

3.4 STOREY STIFFNESS

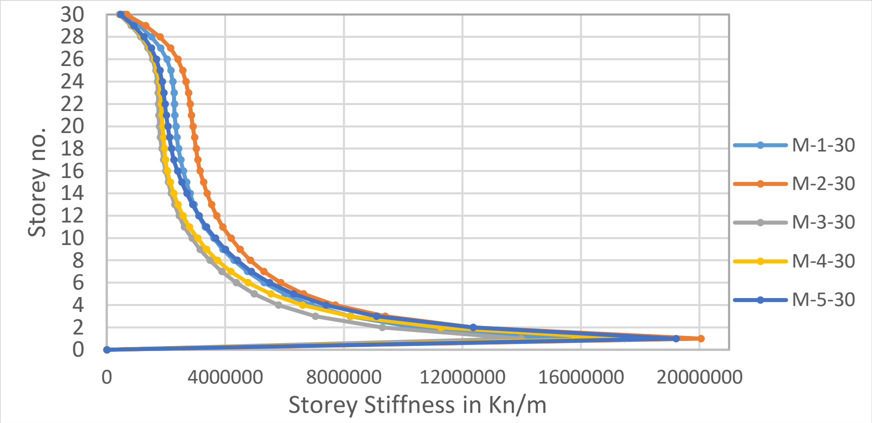

Chart -3.7: Storey Stiffness in X-direction

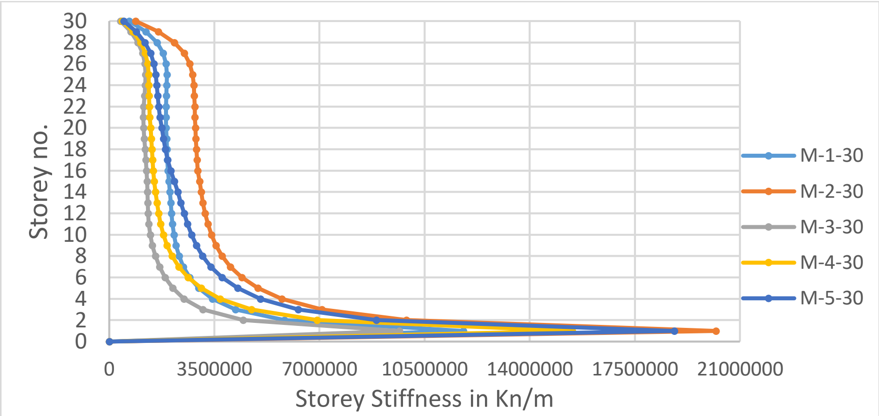

Chart -3.8: Storey Stiffness in Y-direction

- **No soft storey found** at any level storey even at Transition of RCC and composite Structure of Model 5.
- Models with **shear walls at periphery and core** are showing highest amount of Stiffness values.
- Stiffness differences when Model 3 is compared to Model 1, 2, 4 & 5 are **10%, 30%, 20% & 27%** in X-direction and **18%, 52%, 37% & 49%** in Y-direction.
- Stiffness attained in RC + Composite structure i.e Model 5 is almost similar to Model 2 which is complete RC model with shear wall at core and periphery.

3.5 TIME PERIOD

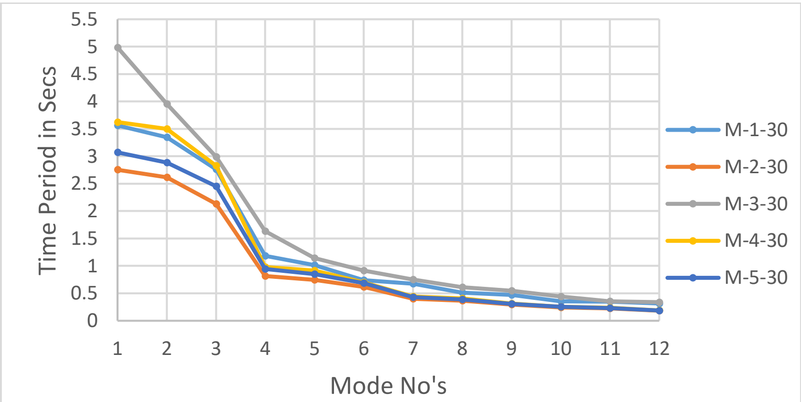

Chart -3.9: Time Period for 30 Storey Models

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- Model 3 shows the highest time period among all the Models in all storey level.
- The time period of Model 2 & 5 is nearly same and showing least time period in comparison with other Models.
- In 30 storey, composite Models showing max time period even after incorporation with shear wall at core and periphery but in 15 storey it was showing somewhat reduction after incorporation of Shear wall.
- For 7 Storey level, models with shear wall at core and periphery was showing least and same time period compared to models with shear wall at core only.

3.6 JOINT REACTIONS

Maximum reaction by gravity loads (D. L+L.L+SIDL) were only considered. Maximum value in every Model was occurring near the Center of the building and it was on Shear wall which is shown in the Fig.3.1 for all the models of different storey level.

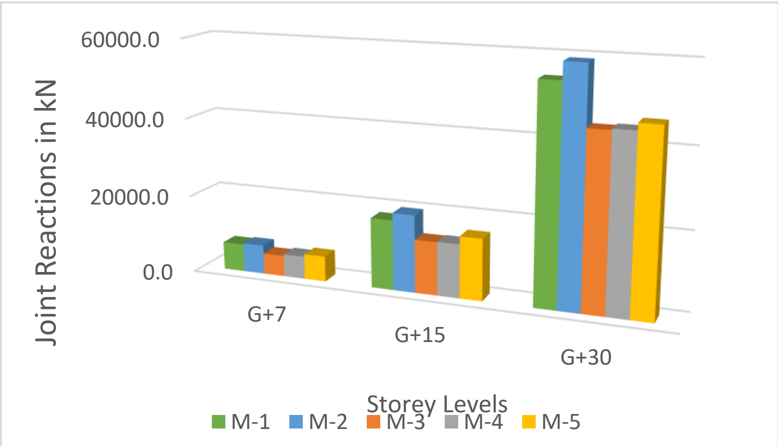

Chart -3.12: Maximum Joint Reactions

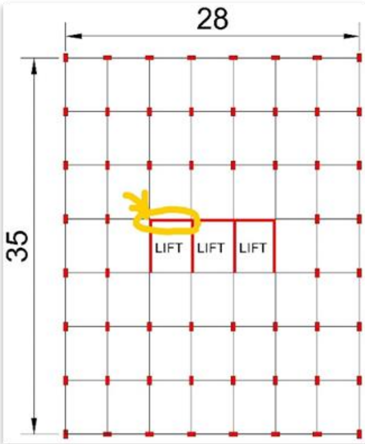

Fig -3.1: Max. Loads acting on shear wall

- Minimum reaction was seen in Model 3 and maximum reaction in Model 2
- In 30 storey models, the percentage difference when Model 3 is compared with Model 1, 2, 4 & 5 are 19%, 25%, 1% & 4% respt.
- More than 21% reduction in self weight is attained when Model 5 is compared with Model 2.
- Model 5 which has half of the structure RC and half of the structure composite then also the self-weight of the building can be reduced drastically.

4. CONCLUSIONS

▪ **Time Period**

- Maximum time period is observed in models with shear wall at core only which is Model 1 & 3. Least time period was seen in models with shear wall at core and periphery edges irrespective of RC and composite structure. Thus it can be said that additional shear walls at periphery edges is playing vital role in reducing time period.
- In 7 storey building, Model 2, 4 & 5 were showing similar and the minimum time period over Model 1 & 3. With this it can be said that going for low rise structure, providing Shear wall at periphery edges will effectively work irrespective of its structural configuration.

- **Displacement**

- For 30 Storey building, In RC Structure Model 2, **15%** of reduction was seen compared to Model 1. But in composite models, only **6%** reduction was seen between Model 3 & 4. This shows that shear wall is not effectively working in G+30 storey for composite structures. Thus, it need some additional lateral resisting frame like bracings or outriggers etc. **[see sec 4.2-a]**
- For 15 Storey, providing shear wall at periphery edges in composite Model is showing considerable reduction in storey displacement i.e about **15%**. Thus it shows that shear wall effectively working till 15 Storey level in composite structure.
- By going half RC half composite model, the displacement was similar to the Model with complete RC structure for all the storey levels.

▪ **DRIFT RATIO**

- Model 2 shows the minimum amount of drift ratio and Model 3 maximum. Thus it can be said that Model 2 is stiffer than all other models and in Model 3 flexibility prevails.
- Although, in composite models, drift ratios where fallen within the specified limit of IS-Codal provisions. Deflections must be limited during earthquakes for many different reasons, and hence provision of adequate stiffness is important, peculiarly in composite models.
- In Model 5, average drift at transitional zones are quite high in comparison with other storey levels. Thus greater concentration must be given during analysis and design of two different structural configurations when combined together. **[see sec 4.2-a]**

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- **SHEAR FORCE**

- Maximum shear force was seen in RC Model with shear wall at core and periphery (Model 2) and the minimum was found in Model 3 i.e composite model with shear wall at core only. This shows that Model 2 has higher capacity to resist lateral loads during seismic events.
- For Model 5, base shear is similar to Model 2, with this it can be concluded that even going for half of the structure as composite, we can get shear force similar to fully RC structure.

- **STIFFNESS**

- Stiffness is higher in RC models compared to composite models. This shows that Composite models has a lesser storey stiffness compared to RC structure despite of keeping same column sizes as of RC columns in composite models and even inducing with I-Sections. Thus it can be said that storey stiffness will not only depend on column properties and sizes but the floor system considered in the models will also matter.
- Percentage differences when Model 4 & 5 is compared was **10 %** and between Model 2 and 5, only **3%** is seen. This shows that stiffness similar to RC structure can be attained by making half of the building as RC and other half as Composite
- In 7 Storey, stiffness is same in the models with shear wall at periphery and core as well. Thus any one of the structure configuration Model can be adopted for 7 storey building.

4.1 Concluding Remarks:

- **Its seen that RC + Composite structure is showing overall best results compared to complete RC or composite Models. As in bottom stories of Model 5, stiffness is similar to RC structure and ductility is similar to composite structure.**
- **During seismic excitation, building should be stiffer at bottom as well as ductile to transfer the seismic vibrations safely and at the same time when the upper stories get displaced, there will be P-delta effects. Thus, "P" i.e Gravity loads should be minimized to reduce P-Delta effects. This can be achieved by adopting composite or steel structure which will reduce self-weight.**
- **Both the parameters, that is ductility & stiffness at bottom stories and reducing self-weight in upper stories can be achieved by combining duo structural configuration together which is Model 5 – RC + Composite Structure.**

4.2 Further Additional work

4.2-a: Observations

a. In 30 storey models, when the shear walls were introduced to the composite structure i.e Model 3 at periphery edges, result shows that it was not effective in reducing displacement and drift.

b. In RC + Composite model (model 5), average drift at transitional zones is quite high in comparison with other storey levels.

4.2-b: Alternate Solution

a. Instead of providing shear walls at periphery edges, bracings found to be more effective compared to shear walls in composite structure. [see 4.2-d Results]

b. Near the transition zone in Model 5, providing bracings will reduce the sudden drift change. [see 4.2-d Results]

4.2-c: Models Descriptions

Model 6 – Same as RC + Composite structure (Model 5) with additional X-bracings from transition zone (15 Storey) to the top storey.

Model 7 – Composite Structure (Model 3) with additional X-bracings at periphery of the Model.

Note: Angle Bracings are adopted with dimensions 150x150x25 in mm.

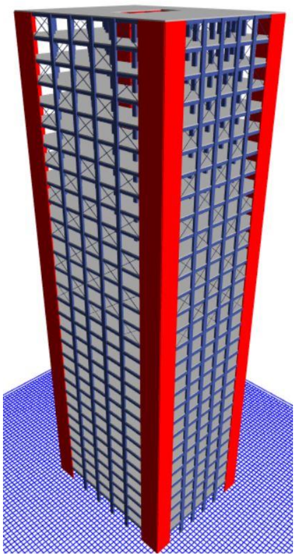

Fig-4.1: Model 6

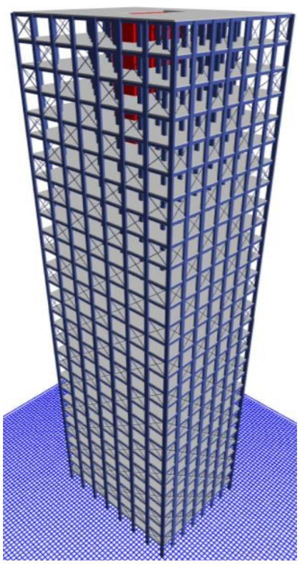

Fig-4.2: Model 7

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4.2-d: Results

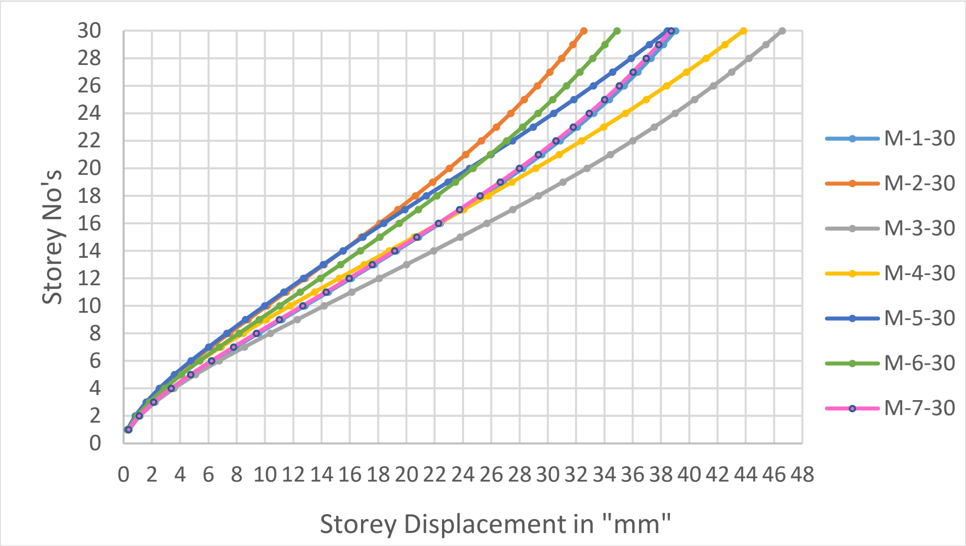

Chart - 4.1: Storey displacement of 30 Storey Models

From the Chart 4.1, it can be said that for 30 storey composite model, Bracings are the better option when compared to shear walls. As when Model 3 is compared with Model 4 (shear wall at periphery edges) only 6% of reduction is seen. And when Model 3 is compared with Model7 (Bracings at periphery) around 17% of reduction was seen. Hence we can conclude that dual resisting frames (core shear walls with external bracings) are better option instead of core Shear wall in addition to shear wall at edges.

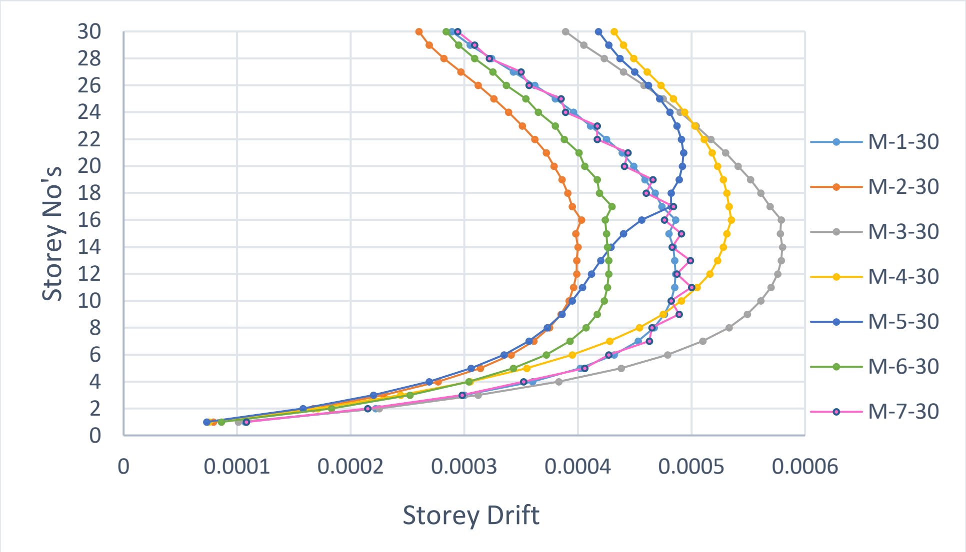

Chart - 4.2: Storey Drift of 30 Storey Models

From chart 4.2, it can be observed that Drift was drastically reduced when bracings were introduced at transition zone in Model 5 RC + composite structure which is Model 6. And it's showing similar results when compared with model 2.
Drift in composite Model 3 reduced more when bracings (Model 7) were provided at periphery instead of shear walls (Model 4).

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[12] “Composite Steel Core to speed up Seattle High-Rise”, Article by Katy Tomasulo

APPENDIX

Table: A.1 Displacement values for 30 Storey Models

Storey no.	Model 1-30		Model 2-30		Model 3-30		Model 4-30		Model 5-30	
	Ux	Uy	Ux	Uy	Ux	Uy	Ux	Uy	Ux	Uy
30	29.4	39.0	29.4	32.5	34.3	46.6	29.8	43.8	29.8	38.5
29	28.3	38.2	28.4	31.8	33.0	45.4	28.7	42.5	28.6	37.2
28	27.3	37.3	27.5	31.0	31.7	44.2	27.6	41.2	27.5	35.9
27	26.2	36.4	26.6	30.1	30.5	43.0	26.4	39.8	26.4	34.6
26	25.1	35.4	25.6	29.3	29.2	41.7	25.3	38.4	25.2	33.2
25	24.0	34.3	24.6	28.3	27.9	40.4	24.1	37.0	24.0	31.8
24	22.9	33.2	23.5	27.4	26.5	39.0	23.0	35.5	22.8	30.4
23	21.8	32.1	22.5	26.4	25.2	37.5	21.8	34.0	21.6	29.0
22	20.7	30.9	21.4	25.3	23.9	36.0	20.7	32.4	20.4	27.5
21	19.6	29.6	20.3	24.2	22.5	34.4	19.5	30.8	19.2	26.0
20	18.5	28.2	19.2	23.0	21.2	32.8	18.3	29.1	18.0	24.5
19	17.3	26.8	18.1	21.9	19.9	31.1	17.1	27.5	16.8	22.9
18	16.2	25.4	17.0	20.6	18.5	29.3	16.0	25.8	15.6	21.4
17	15.1	23.9	15.8	19.4	17.2	27.5	14.8	24.1	14.5	19.9
16	13.9	22.4	14.7	18.1	15.9	25.7	13.7	22.3	13.3	18.4
15	12.8	20.9	13.5	16.8	14.6	23.8	12.5	20.5	12.2	16.9
14	11.7	19.3	12.4	15.5	13.3	21.9	11.4	18.8	11.1	15.5
13	10.6	17.7	11.2	14.2	12.0	20.0	10.3	17.0	10.0	14.1
12	9.6	16.1	10.1	12.8	10.8	18.1	9.2	15.3	9.0	12.7
11	8.5	14.5	9.0	11.5	9.6	16.1	8.1	13.5	8.0	11.3
10	7.5	12.8	7.9	10.1	8.4	14.2	7.0	11.8	7.0	10.0
9	6.5	11.2	6.8	8.8	7.2	12.3	6.0	10.1	6.0	8.6
8	5.5	9.5	5.8	7.5	6.1	10.4	5.1	8.5	5.1	7.3
7	4.6	7.9	4.8	6.2	5.1	8.5	4.1	6.9	4.2	6.0
6	3.7	6.4	3.8	4.9	4.1	6.8	3.3	5.4	3.3	4.8
5	2.9	4.9	2.9	3.7	3.1	5.1	2.5	4.0	2.5	3.6
4	2.1	3.5	2.1	2.6	2.3	3.6	1.8	2.8	1.8	2.5
3	1.4	2.2	1.4	1.7	1.5	2.2	1.1	1.7	1.2	1.6
2	0.8	1.2	0.8	0.9	0.8	1.1	0.6	0.9	0.7	0.8
1	0.3	0.4	0.3	0.3	0.3	0.4	0.2	0.3	0.3	0.3

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Table: A.2 Drift Ratios for 30 Storey Models

Storey	Model 1-30		Model 2-30		Model 3-30		Model 4-30		Model 5-30	
No.	RSA-x	RSA-y	RSA-x	RSA-y	RSA-x	RSA-y	RSA-x	RSA-y	RSA-x	RSA-y
30	0.000344	0.000289	0.000338	0.00026	0.000448	0.000389	0.00049	0.000432	0.000476	0.000418
29	0.000402	0.000305	0.000359	0.000269	0.000514	0.000405	0.000504	0.00044	0.000497	0.000427
28	0.000426	0.000324	0.000376	0.000282	0.000538	0.000423	0.00051	0.000449	0.00051	0.000437
27	0.000445	0.000343	0.000394	0.000297	0.000553	0.00044	0.000518	0.000461	0.000524	0.00045
26	0.000462	0.000362	0.000411	0.000312	0.000566	0.000458	0.000525	0.000473	0.000537	0.000462
25	0.000476	0.00038	0.000425	0.000326	0.000578	0.000475	0.000531	0.000484	0.000547	0.000472
24	0.000487	0.000396	0.000438	0.000339	0.000588	0.00049	0.000534	0.000494	0.000556	0.000481
23	0.000495	0.000411	0.000449	0.000351	0.000595	0.000504	0.000536	0.000503	0.000562	0.000487
22	0.000499	0.000425	0.000458	0.000362	0.0006	0.000517	0.000535	0.000511	0.000566	0.000491
21	0.000501	0.000439	0.000465	0.000372	0.000601	0.00053	0.000533	0.000518	0.000568	0.000493
20	0.0005	0.000449	0.000469	0.000379	0.000599	0.000541	0.000529	0.000523	0.000566	0.000492
19	0.0005	0.000459	0.000472	0.000386	0.000597	0.000552	0.000524	0.000528	0.000563	0.000489
18	0.000501	0.000468	0.000474	0.000391	0.000595	0.000561	0.000519	0.000531	0.000557	0.000482
17	0.000502	0.000474	0.000475	0.000395	0.000593	0.000569	0.000512	0.000533	0.000559	0.000482
16	0.000509	0.000486	0.000481	0.000403	0.000594	0.000579	0.000507	0.000535	0.000524	0.000456
15	0.000483	0.00048	0.000469	0.000398	0.000577	0.000578	0.000499	0.000531	0.000503	0.00044
14	0.000487	0.000484	0.000467	0.0004	0.000577	0.00058	0.000493	0.000528	0.00049	0.000429
13	0.000484	0.000485	0.000463	0.000399	0.000572	0.000579	0.000485	0.000523	0.000479	0.00042
12	0.00048	0.000486	0.000459	0.000399	0.000566	0.000576	0.000474	0.000516	0.000467	0.000412
11	0.000473	0.000485	0.000454	0.000396	0.000556	0.00057	0.000461	0.000505	0.000455	0.000404
10	0.000465	0.000482	0.000445	0.000392	0.000544	0.000561	0.000445	0.000491	0.000441	0.000395
9	0.000456	0.000476	0.000435	0.000385	0.00053	0.000549	0.000428	0.000475	0.000426	0.000386
8	0.000447	0.000467	0.000422	0.000375	0.000518	0.000533	0.000406	0.000454	0.000409	0.000373
7	0.000434	0.000453	0.000405	0.000361	0.000515	0.00051	0.000381	0.000428	0.000387	0.000357
6	0.000418	0.000432	0.000382	0.000341	0.000505	0.000479	0.00035	0.000395	0.000361	0.000335
5	0.000405	0.000402	0.000352	0.000314	0.000486	0.000438	0.000313	0.000355	0.000328	0.000306
4	0.000394	0.00036	0.000314	0.000277	0.000456	0.000383	0.00027	0.000305	0.000288	0.000269
3	0.00037	0.0003	0.000265	0.000229	0.000407	0.000312	0.000217	0.000244	0.000238	0.00022
2	0.000326	0.000222	0.0002	0.000167	0.000328	0.000225	0.000155	0.000171	0.000176	0.000158
1	0.000197	0.000107	0.000103	0.000079	0.000162	0.000101	0.000074	0.000075	0.000086	0.000073

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Table: A.3 Storey Shear Force for 30 Storey Models

Storey no.	Model 1-30		Model 2-30		Model 3-30		Model 4-30		Model 5-30	
	Vx	Vy	Vx	Vy	Vx	Vy	Vx	Vy	Vx	Vy
30	593.8	567.8	622.7	678.9	531.7	442.8	501.3	561.3	525.2	605.1
29	593.8	567.8	622.7	678.9	531.7	442.8	501.3	561.3	525.2	605.1
28	1602.3	1473.6	1703.9	1804.5	1454.2	1174.9	1351.4	1433.4	1424.8	1567.8
27	1951.2	1765.4	2094.3	2187.3	1778.8	1417.4	1635.9	1686.9	1731.7	1862.8
26	2203.7	1970.3	2396.9	2472.8	2015.5	1585.0	1838.8	1846.7	1956.6	2061.9
25	2372.9	2113.5	2628.1	2686.9	2172.6	1689.8	1975.3	1943.3	2115.4	2195.3
24	2372.9	2113.5	2628.1	2686.9	2172.6	1689.8	1975.3	1943.3	2115.4	2195.3
23	2536.0	2322.1	2949.8	3004.8	2307.4	1785.2	2119.2	2069.2	2307.5	2383.2
22	2570.4	2424.8	3069.7	3143.4	2325.2	1819.5	2156.5	2138.0	2370.6	2475.4
21	2597.1	2532.9	3173.7	3275.9	2337.6	1869.5	2183.4	2215.9	2423.3	2571.6
20	2628.3	2641.8	3266.3	3400.8	2359.8	1943.6	2205.3	2296.6	2469.9	2667.2
19	2670.5	2745.8	3351.6	3516.2	2398.6	2038.9	2226.6	2373.7	2513.7	2756.6
18	2725.0	2842.3	3433.6	3622.0	2452.8	2144.0	2252.2	2443.9	2558.0	2837.8
17	2790.6	2932.9	3518.7	3723.0	2517.2	2245.5	2288.2	2509.6	2608.2	2913.9
16	2864.8	3021.5	3613.9	3825.7	2587.2	2332.1	2341.1	2575.5	2670.8	2991.1
15	2864.8	3021.5	3613.9	3825.7	2587.2	2332.1	2341.1	2575.5	2670.8	2991.1
14	3039.9	3203.3	3854.1	4054.0	2748.6	2445.1	2515.1	2721.0	2887.4	3200.1
13	3145.2	3293.0	3999.1	4178.5	2848.4	2477.9	2634.2	2797.9	3031.5	3319.3
12	3145.2	3293.0	3999.1	4178.5	2848.4	2477.9	2634.2	2797.9	3031.5	3319.3
11	3267.4	3377.3	4155.5	4305.4	2968.1	2508.6	2768.3	2874.6	3190.7	3441.0
10	3580.3	3538.2	4491.6	4568.7	3281.3	2617.7	3069.5	3042.0	3536.5	3693.0
9	3580.3	3538.2	4491.6	4568.7	3281.3	2617.7	3069.5	3042.0	3536.5	3693.0
8	3989.2	3743.1	4861.3	4879.2	3681.7	2833.7	3417.3	3286.6	3919.7	4002.3
7	4213.2	3877.7	5055.4	5057.6	3894.9	2969.8	3604.0	3447.0	4122.1	4187.0
6	4213.2	3877.7	5055.4	5057.6	3894.9	2969.8	3604.0	3447.0	4122.1	4187.0
5	4638.0	4180.3	5429.3	5420.1	4290.1	3232.0	3966.0	3791.4	4513.5	4569.8
4	4811.5	4315.4	5585.6	5572.0	4448.9	3332.9	4116.7	3937.9	4677.2	4731.2
3	4944.5	4417.9	5705.2	5684.5	4569.3	3403.5	4231.1	4045.6	4802.5	4850.3
2	4944.5	4417.9	5705.2	5684.5	4569.3	3403.5	4231.1	4045.6	4802.5	4850.3
1	5031.5	4479.8	5780.9	5751.2	4646.4	3443.2	4302.7	4108.5	4881.7	4920.4

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Table: A.4 Storey Stiffness Values for 30 Storey Models

Storey no.	Model 1-30		Model 2-30		Model 3-30		Model 4-30		Model 5-30	
	Kx	Ky	Kx	Ky	Kx	Ky	Kx	Ky	Kx	Ky
30	569357	664906	661004	881687	417037	380426	444834	426200	460289	477967
29	1101175	1218581	1306180	1637746	821903	715615	874314	793206	904133	894817
28	1510140	1589625	1789853	2163662	1136968	956777	1200169	1045481	1245429	1188601
27	1813389	1797770	2143625	2494050	1375693	1108184	1440041	1199782	1495465	1375769
26	2025432	1892715	2394472	2682020	1543231	1186360	1605928	1278022	1668001	1485547
25	2153287	1917861	2559000	2775768	1649644	1210472	1708778	1309528	1786673	1543838
24	2227414	1911318	2670532	2817414	1705894	1199855	1774043	1318984	1861814	1579996
23	2260232	1895622	2746557	2832018	1728413	1173718	1811277	1323855	1919753	1611353
22	2278700	1888460	2803405	2844714	1735244	1147926	1836854	1334611	1965673	1649156
21	2290220	1885979	2848918	2851053	1741905	1134429	1856669	1350329	2004415	1691865
20	2325890	1895109	2905995	2869912	1767620	1141304	1884861	1373584	2061699	1746677
19	2365342	1910812	2958207	2884495	1799384	1163750	1906362	1397111	2114093	1805260
18	2417966	1921738	3009321	2902208	1849747	1192435	1936551	1417569	2178848	1869402
17	2489346	1935884	3067784	2919971	1911288	1222381	1977715	1439836	2258208	1941276
16	2573965	1951878	3142489	2945083	1987101	1245131	2042807	1464211	2380419	2048711
15	2686450	1988044	3258637	3008563	2069128	1265697	2130573	1499844	2529996	2167583
14	2801770	2015928	3383781	3057344	2171109	1275495	2249675	1539005	2698473	2279243
13	2939439	2045340	3529684	3120606	2287864	1283196	2394753	1587002	2892688	2384539
12	3102901	2074530	3706958	3193888	2434858	1293776	2572785	1643564	3109858	2493446
11	3311765	2106629	3912705	3281958	2615003	1317147	2782583	1713020	3359255	2605018
10	3601917	2156133	4193813	3404375	2870820	1363363	3060331	1804285	3664741	2737574
9	3911881	2222030	4488494	3553823	3140944	1433912	3355462	1924982	3995323	2898351
8	4289423	2322009	4841908	3758999	3473296	1535896	3722499	2090741	4389319	3104932
7	4744583	2468319	5288066	4036397	3871628	1675006	4176117	2319657	4872416	3384800
6	5304036	2676636	5864020	4413167	4358899	1860618	4762208	2629841	5487079	3758075
5	5999984	2979546	6629214	4949833	4965430	2113812	5531406	3062561	6294921	4274859
4	6893215	3433110	7704266	5750303	5792820	2487261	6597300	3690660	7388979	5033175
3	8213451	4203548	9383510	7079105	7029679	3119660	8231786	4731745	9095625	6290891
2	10417199	5833051	12352249	9898726	9292780	4454379	11263662	6916623	12358739	8897661
1	15558846	11790339	20048652	20199197	13971262	9657903	17473163	15417718	19204879	18810740

Note: What we Justified at the time was, we wanted to increase the ductility of the structure keeping stiffness of the structure same as RC.

If we were concerned about reducing self wt, then equivalent section method would have been adopted to select the composite element sizes. But this could lead to reduction of stiffness and increase in displacement.