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Composite Column Subjected to Non-Linear Time History Method in Comparison to Conventional RC Column

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Abstract – *Structural Steel-Concrete Composite structures are nowadays very popular owing to their advantages over conventional Concrete and Steel constructions. Concrete structures are bulky and impart more seismic weight and more deflection as compare to Composite Construction combines the better properties of both steel and concrete along with lesser cost , speedy construction, fire protection etc. Hence the aim of the present study is to evaluate and compare the seismic performance of G+15 structural model with composite frame and a R.C Frame model having spacing between columns as 5m and 10m is considered for the building models, these models are subjected to seismic zone* IV*, their corresponding behaviors and results are extracted and interpreted. Various parameters such as displacements, storey drifts, storey acceleration, storey force, storey stiffness, and base shear have been gathered. ETABS software is used and the results are compared; and it is found that composite structure is found to be more economical.*

Key Words: Steel-Concrete Composite structures, Time History Method, Base shear, Storey stiffness, displacement

1. INTRODUCTION

The design of structures for buildings and bridges is mainly concerned with the provision and support of horizontal surfaces. In buildings, the floors are usually made of concrete, reinforced by steel to resist tension. As spans increase though, it is cheaper to support the slab, for example by beams is in turn supported by columns. Both the beams and columns can be conveniently constructed using structural steel sections, normally hot-rolled I-sections and H-shapes respectively. It is used to be customary to design the bare steelwork to carry all the loads, it has become common to connect the concrete slabs to the supporting beams by mechanical devices. These eliminate, or at least reduce, slip at the steel-concrete interface, so that the slab and the steel beam section act together as a composite unit, commonly termed as “composite beam”. Use of composite or hybrid material is of particular interest, due to its significant potential in improving the overall performance through rather modest changes in manufacturing and constructional technologies.

In this work an attempt was made to analyze and study the performance of R.C.C and structural steel-concrete composite section with C/C spacing between columns as 5m and C/C spacing between columns as 10m w.r.t different parameters such as a story drift, story displacement, base shear, shear force.

1.1 Elements of composite construction

Composite slab

Composite slabs comprise reinforced concrete cast on top of profiled steel decking, which acts as formwork during construction and external reinforcement at the final stage. The decking may be either re-entrant or trapezoidal, as shown below. Trapezoidal decking may be over 200mm deep, in which case it is known as deck decking. Additional reinforcing bars maybe placed in the decking troughs, particularly for deep decking. They are sometimes required in shallow decking when heavy loads are combined with high periods of fire resistance. The steel is galvanized and maybe varying of thickness, although about1mm. The profiled decking is often designed to be continuous over two spans when acting as formwork. Composite slabs are normally designed to be simple spanning at room temperature.

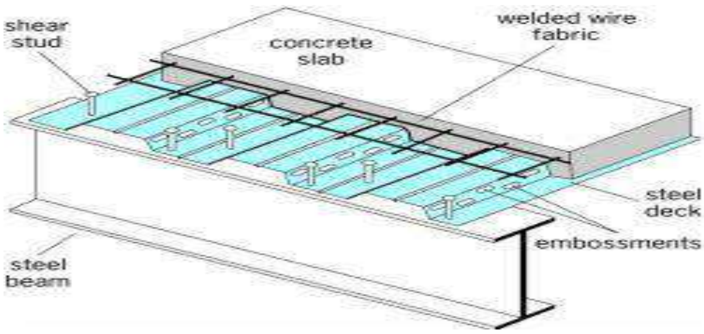


Figure 1.1: Composite beam and slab

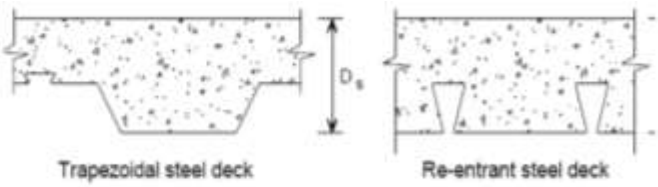


Figure 1.2: Typical Composite Beam Slab Details with shear connectors

Composite beams

The second element within the floor are the beams supporting the slabs and carrying the loads to the columns. Depending on the grid of beams the slabs therefore are spanning in one direction. Following the philosophy of mixed structures those beams can be realized in steel, concrete, steel-concrete composite or even other materials or their combination. In the following only steel-concrete composite floor beams will be treated in detail. In a composite beam within the sagging moment region the concrete slab is activated in compression by shear connectors. Headed studs dominate in practical application, the advantage is the combination of a relatively large stiffness with a very large deformation capacity.

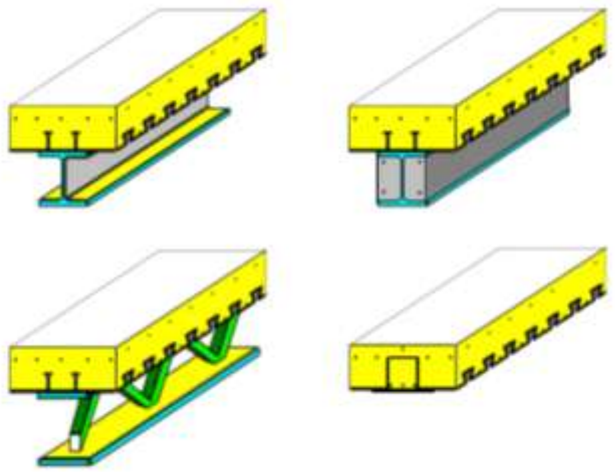


Figure 1.3: Conventional and innovative composite beams

Composite columns

Beside the possibility to realize pure steel or concrete columns the bearing behavior of composite columns mainly dominated by the structural steel part in it. They are commonly used where large normal forces are combined with the wish for small sections. As the composite columns maybe prefabricated the construction time can be drastically reduced compared to in-situ concrete. A decisive advantage over bare steel columns is the very high fire resistance of composite columns without any preventive measures.

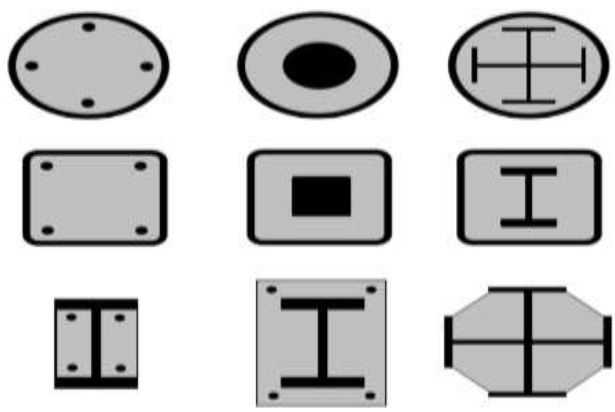


Fig 1.4: Examples of composite columns

1.2 Behavior of Tall Buildings

As earthquakes can happen almost anywhere, some measure of earthquake resistance in the form of reserve ductility and redundancy should be built into the design of all structures to prevent catastrophic failures. Moreover, during the life of a building in a seismically active zone, usually the building will be subjected to many earthquakes, including some moderate ones, one or more large ones, and possibly a very severe one. Building massing, shape and proportion, ground acceleration, and dynamic response of the structure, influences the magnitude and distribution of earthquake forces. When compared to the wind loads, earthquake loads have stronger intensity.

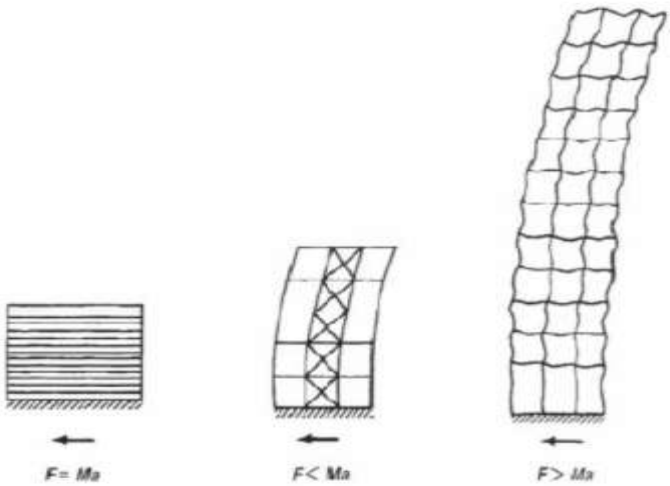


Fig 1.5: Schematic representation of seismic force

2. MODELLING AND BUILDING DATA

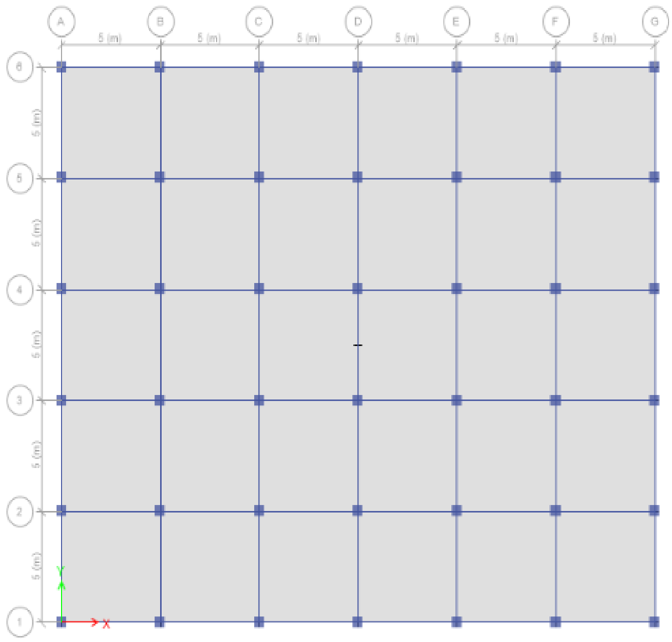


Fig 1.6 : Building plan

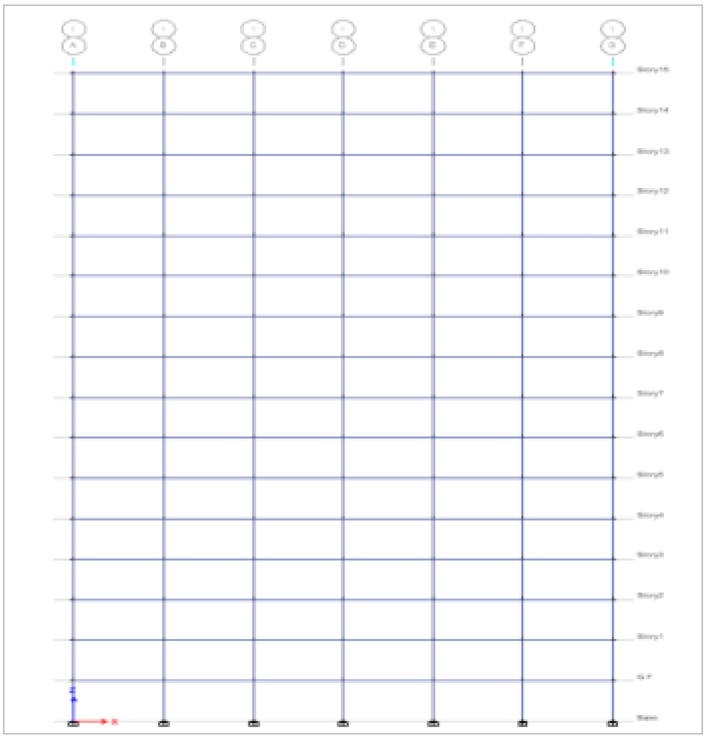


Fig 1.7: Building Elevation

Table-1: Building Data

Plan dimension	30mx30m
No of storey's	G+15
C/C distance between column in X-direction	5m & 10m
C/C distance between column in Y-direction	5m & 10m
Typical storey height	3m
Depth of foundation	3m
Thickness of wall	230mm
Thickness of slab	125mm
Floor finish	1kN/m^2
Live load on floors	4kN/m^2
Live load on roof	1.5kN/m^2
Density of concrete	25
Grade of concrete(fck)	M25 & M30
Grade of steel(fy)	Fe415; Fe550 & Fe345
Seismic zone IV	0.24
Soil zone	II

2.1 Analysis of Building

Time history method is used for the analysis of RCC and composite structures with composite column of spacing 5m and 10m. Time history method gives all possible forces which are generated, and there by displacement of structure, during entire duration of ground motion at equal interval, typically 0.05 to 0.1 sec. in this method the structural response is computed at a number of subsequent time instants during and after the application of a load. Base shear can be determined by multiplying total seismic weight of building to coefficient of acceleration spectrum value. Base displacement in this the structure forced through some varying displacement over time. The displacements can act independently in the global X, Y, and Z directions. Base acceleration is very similar to the base displacement and represents putting through some varying ground acceleration over time. Multiple modes of vibrations are considered where base shear of each mode can be calculated separately. It can be calculated by determining the modal mass and modal mass participation factor for each mode.

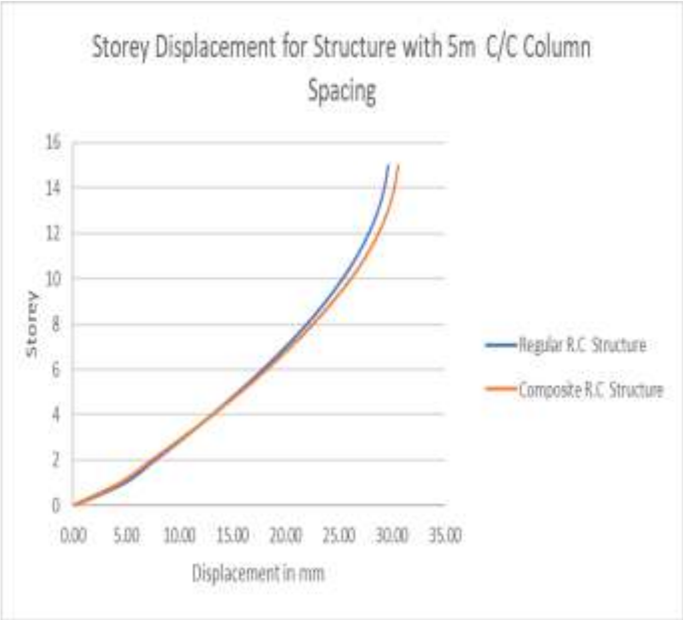
2.2 Results and Discussion

1. Storey Displacement

The floor level versus displacement graph is been plotted for all four models

Table 2: Storey Displacement for Structure with 5m C/C Column Spacing

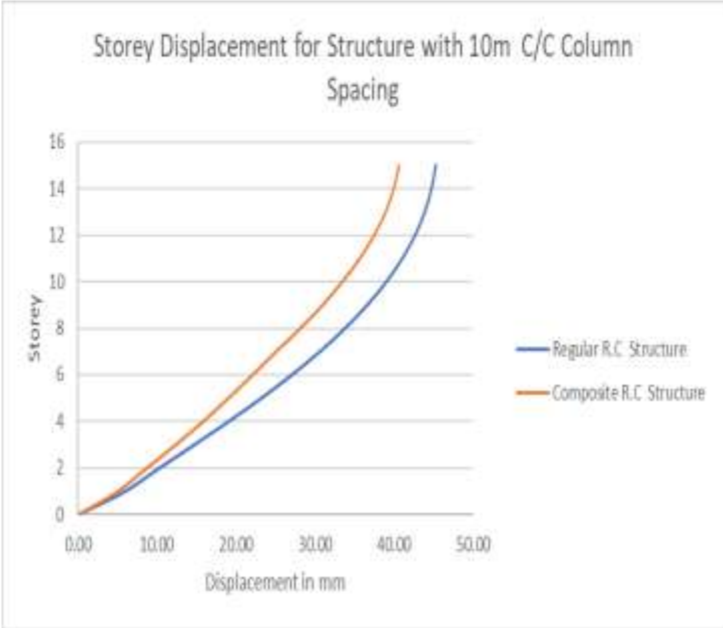
Storey	Regular R.C Structure	Composite R.C Structure
15	29.67	30.57
14	29.30	30.20
13	28.68	29.59
12	27.82	28.70
11	26.70	27.53
10	25.34	26.10
9	23.76	24.41
8	21.97	22.52
7	19.99	20.44
6	17.84	18.17
5	15.52	15.71
4	13.04	13.07
3	10.42	10.28
2	7.66	7.36
1	4.81	4.39
0	0.00	0.00



Graph 1: Storey Displacement for Structure with 5m C/C Column Spacing

Table 3: Storey Displacement for Structure with 10m C/C Column Spacing

Storey	Regular R.C Structure	Composite R.C Structure
15	45.21	40.54
14	44.66	39.89
13	43.80	38.86
12	42.58	37.42
11	40.96	35.58
10	38.94	33.39
9	36.53	30.87
8	33.72	28.06
7	30.53	25.00
6	26.98	22.02
5	23.11	18.97
4	18.99	15.77
3	14.66	12.31
2	10.23	8.65
1	5.89	4.97
0	0.00	0.00



Graph 2: Storey Displacement for Structure with 10m C/C Column Spacing

2. Storey Drift

The floor level versus drift graph is been plotted for all four models.

Table 4: Storey Drift for Structure with 5m C/C Column Spacing

Storey	Regular R.C Structure	Composite R.C Structure
15	0.000127	0.000134
14	0.000207	0.00022
13	0.00029	0.00031
12	0.000373	0.000392
11	0.000453	0.000478
10	0.000527	0.000561
9	0.000596	0.000637
8	0.000659	0.000704
7	0.000718	0.000765
6	0.000774	0.000822
5	0.000826	0.000878
4	0.000875	0.000931
3	0.000918	0.000973
2	0.000955	0.00099
1	0.000989	0.000928
0	0.000626	0.000539

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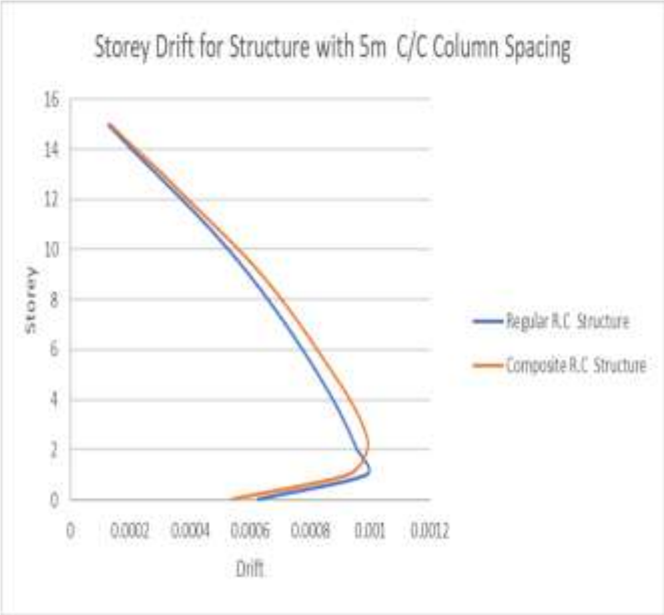
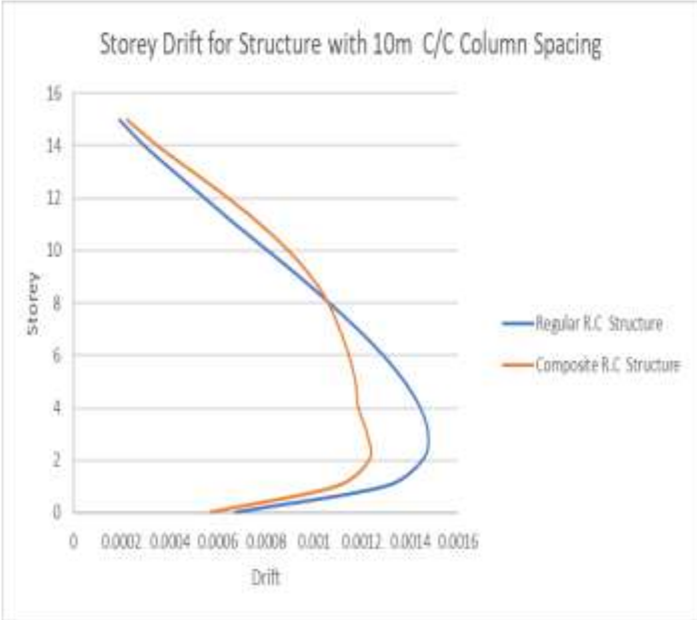


Graph 3: Storey Drift for Structure with 5m C/C Column Spacing

Table 5: Storey Drift for Structure with 10m C/C Column Spacing

Storey	Regular R.C Structure	Composite R.C Structure
15	0.000191	0.000221
14	0.000296	0.000349
13	0.00042	0.000497
12	0.000547	0.000643
11	0.000674	0.000776
10	0.000808	0.000892
9	0.00094	0.000987
8	0.001064	0.001058
7	0.001182	0.001105
6	0.001288	0.001144
5	0.001376	0.001171
4	0.001442	0.001183
3	0.001475	0.001219
2	0.001452	0.001228
1	0.001299	0.001094
0	0.000674	0.000567



Graph 4: Storey Drift for Structure with 10m C/C Column Spacing

3. Storey Forces

The floor level versus force graph is been plotted for all four models.

Table 6: Storey Force for Structure with 5m C/C Column Spacing

Storey	Regular R.C Structure	Composite R.C Structure
15	118.06	118.91
14	265.28	270.19
13	408.14	417.26
12	544.55	557.83
11	672.31	689.36
10	789.33	809.37
9	893.78	915.77
8	984.42	1007.27
7	1060.67	1083.50
6	1122.73	1145.03
5	1171.47	1193.13
4	1217.97	1229.43
3	1286.19	1255.59
2	1350.96	1297.88
1	1393.75	1336.26
0	1398.29	1340.64

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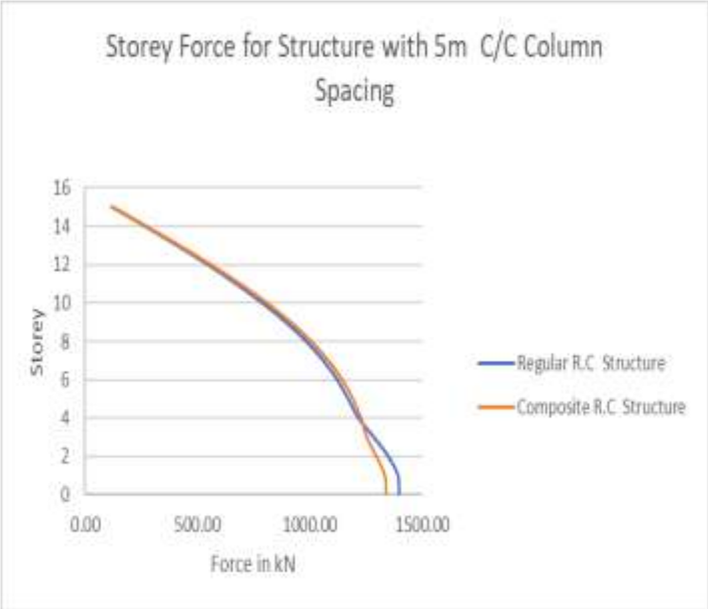
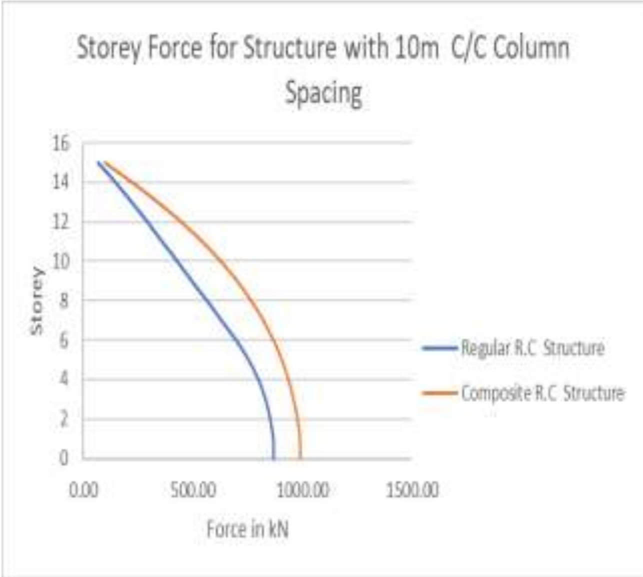


Graph 5: Storey Force for Structure with 5m C/C Column Spacing



Graph 6: Storey Force for Structure with 10m C/C Column Spacing

Table 7: Storey Force for Structure with 10m C/C Column Spacing

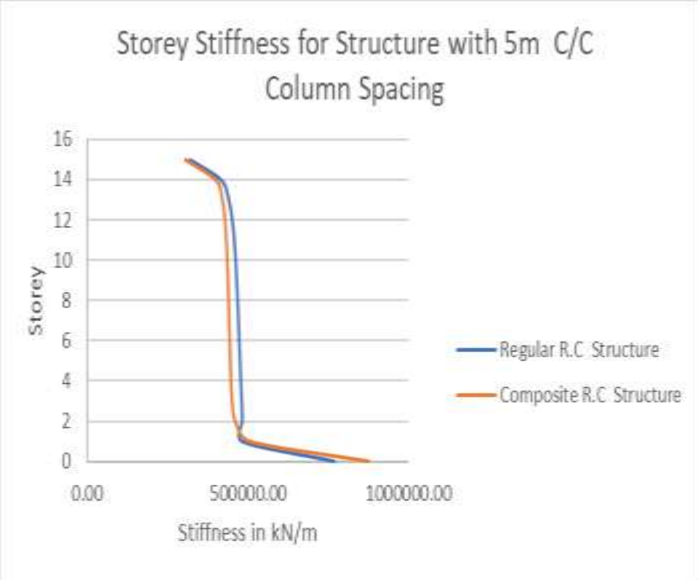
Storey	Regular R.C Structure	Composite R.C Structure
15	66.93	100.97
14	147.00	224.87
13	220.41	341.22
12	292.91	447.84
11	359.55	543.55
10	429.38	628.14
9	495.05	702.06
8	565.39	766.11
7	631.01	821.02
6	698.13	867.38
5	755.28	905.54
4	800.31	935.76
3	832.72	958.30
2	853.49	976.20
1	867.96	987.75
0	868.95	988.76

4. Storey Stiffness

The floor level versus stiffness graph is been plotted for all four models.

Table 8: Storey Stiffness for Structure with 5m C/C Column Spacing

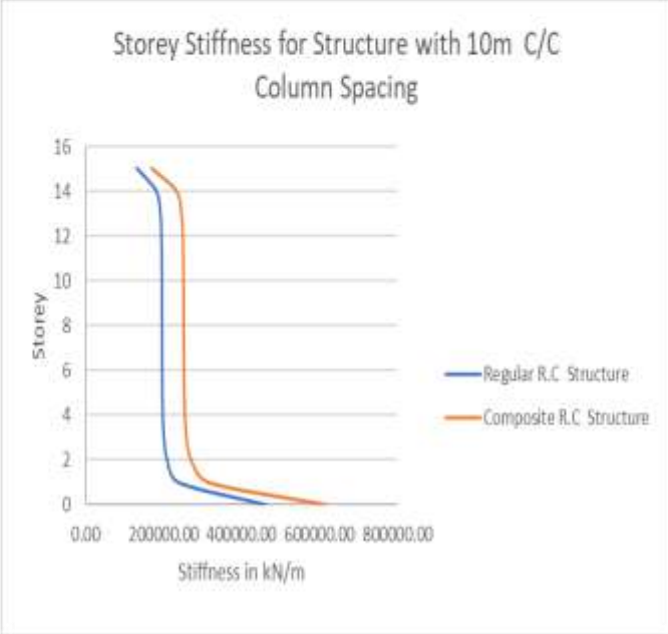
Storey	Regular R.C Structure	Composite R.C Structure
15	319128.33	303827.64
14	415791.46	398205.73
13	440210.37	419247.11
12	451035.20	427330.02
11	457361.00	431713.01
10	461706.93	434641.91
9	465027.40	436860.63
8	467800.70	438713.61
7	470304.02	440394.18
6	472718.73	442035.11
5	475174.93	443770.37
4	477754.91	445882.31
3	480490.94	449437.98
2	482478.85	459414.85
1	480609.31	502860.85
0	770006.70	874937.36



Graph 7: Storey Stiffness for Structure with 5m C/C Column Spacing

Table 9: Storey Stiffness for Structure with 10m C/C Column Spacing

Storey	Regular R.C Structure	Composite R.C Structure
15	130389.70	169244.14
14	180158.23	232132.22
13	191103.26	245707.68
12	193897.51	249296.57
11	194730.88	250497.96
10	195042.63	251043.52
9	195210.10	251388.18
8	195350.55	251679.56
7	195518.18	251989.61
6	195774.61	252400.02
5	196260.80	253095.70
4	197367.07	254608.73
3	200258.99	258596.86
2	208617.79	270645.72
1	237136.23	314313.84
0	462447.28	615718.61



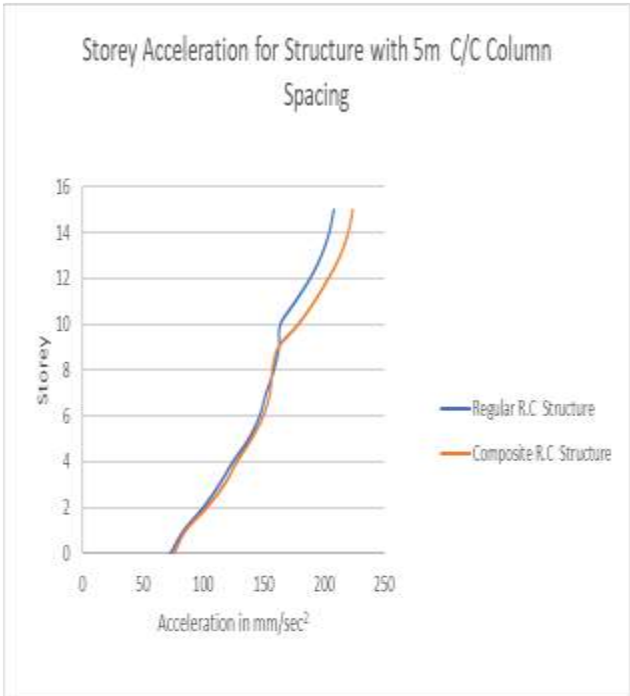
Graph 8: Storey Stiffness for Structure with 10m C/C Column Spacing

4. Storey Acceleration.

The floor level versus acceleration graph is been plotted for all four models.

Table 10: Storey Acceleration for Structure with 5m C/C Column Spacing

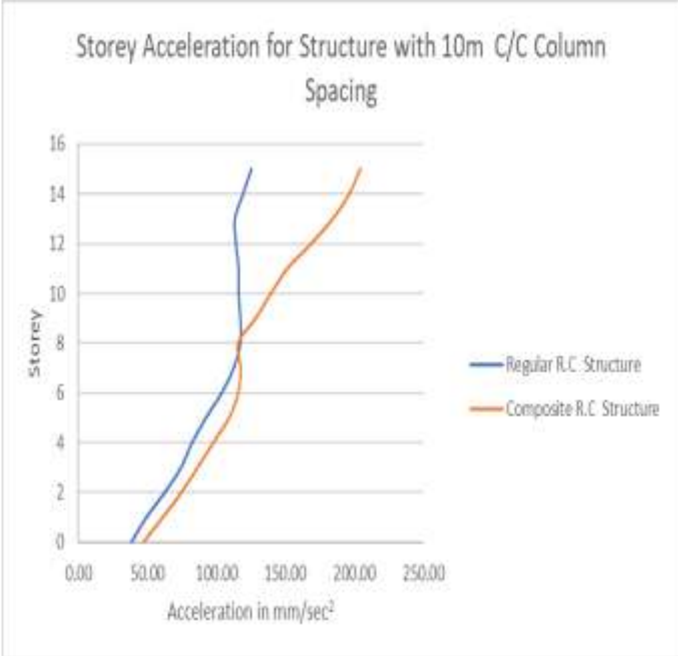
Storey	Regular R.C Structure	Composite R.C Structure
15	208.52	224.04
14	204.62	220.15
13	198.09	213.51
12	188.69	203.57
11	176.48	192.05
10	164.12	178.58
9	163.1	162.15
8	158.82	157.28
7	152.39	155.40
6	146.99	149.76
5	137.78	139.96
4	124.85	127.89
3	113.39	117.34
2	100.1	102.75
1	83.94	85.27
0	73.16	75.88



Graph 9: Storey Acceleration for Structure with 5m C/C Column Spacing

Table 11: Storey Acceleration for Structure with 10m C/C Column Spacing

Storey	Regular R.C Structure	Composite R.C Structure
15	125.34	204.28
14	119.21	196.38
13	113.30	184.37
12	114.04	168.90
11	115.97	151.51
10	115.96	139.76
9	117.20	128.63
8	117.26	115.94
7	112.41	117.72
6	103.82	115.94
5	92.39	109.40
4	82.34	97.94
3	74.38	86.58
2	62.62	74.98
1	49.34	61.49
0	38.50	47.48

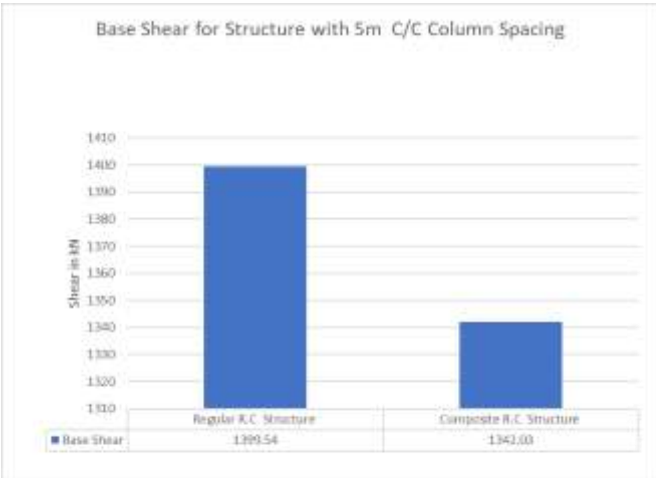


Graph 10: Storey Acceleration for Structure with 10m C/C Column Spacing

5. Base Shear

Table 12: Base Shear for Structure with 5m C/C Column Spacing

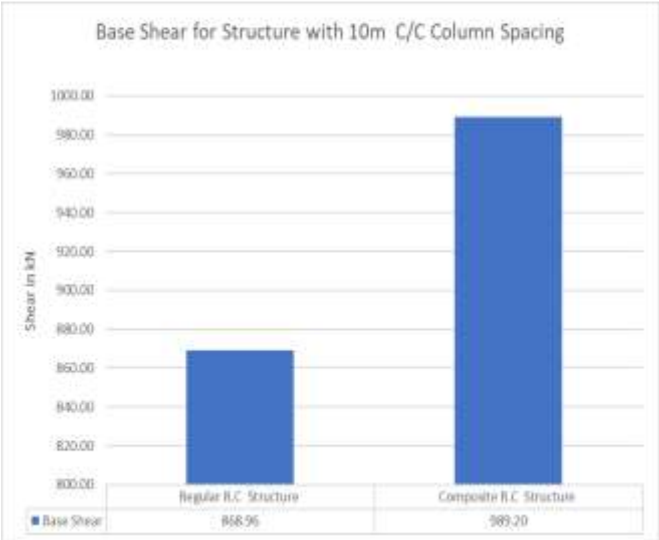
	Regular R.C Structure	Composite R.C Structure
Base Shear	1399.54	1342.03



Graph 11: Base Shear for Structure with 5m C/C Column Spacing

Table 13: Base Shear for Structure with 10m C/C Column Spacing

	Regular R.C Structure	Composite R.C Structure
Base Shear	868.96	989.20



Graph 12: Base Shear for Structure with 10m C/C Column Spacing

3. CONCLUSIONS

In the thesis a structural model with composite frame and a R.C Frame model have spacing between columns as 5m and 10m is considered for the building models, wherein these models are subjected to seismic zone IV, their corresponding behaviors and results are extracted and interpreted. Following are the broad conclusions

- The storey displacement in composite building models with 5m spacing between columns is found to be comparatively little higher than that of the R.C Frame model. Whereas in the case of 10m spacing between columns it was found to be lesser in composite model than for R.C frame model.
- The Storey Drift values in the case of the 5m and 10m spacing between columns is found to be comparatively higher than that of the R.C Frame model.
- The lateral displacement of structural steel-concrete composite frame is reduced as compared with RCC frame.
- The storey acceleration in composite building models with 5m and 10m spacing between columns is found to be comparatively less in R.C Frame model.
- Structural Steel-concrete composite frame has more lateral load capacity compare to R.C frame model.
- Composite structures are being more ductile, and so resist lateral load better than R.C frame structures.
- The base shear in composite building models with 5m spacing between columns is found to be comparatively less than that of the R.C Frame model. Whereas in the case of 10m spacing between columns it was found to be little higher in composite model than for R.C Frame model.
- Base shear for RCC frame is more than structural Steel-concrete composite because the weight of the RCC frame is more than the composite frame.
- Structural steel-concrete composite is light in weight as compared RCC which gives economical foundation design.
- Self-weight of composite structures reduces as compared to RCC which in turn reduces the foundation cost. Due to the reduction of self-weight of composite structures, it induces fewer amounts of lateral forces.
- Composite model is very easy, economical and speed construction is possible.

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