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Analysis of Composite Column Building with Lateral Load Resisting Systems using Etabs

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ABSTRACT: The present work seeks to research the seismic behavior of a high rise building with composite columns and building with shear walls & composite column and also with bracings and composite column, building with composite column, bracings, shear walls are examine the key style problems involved. The current study deals with unstable behavior of multi storied framed structure assessed through equivalent static technique of study as per IS: 1893-2002 for zone III & zone V in three soils (soil-I soil-II soil-III) by using ETABS software (2016 version). The analyses performed on a collection of two forms of standard moment resisting framed 3D area models with totally composite columns. The analysis is provided and therefore the results compared in terms of important earthquake response parameters like Base shear, storey displacements and lateral forces on building elevation.

KEYWORDS: Lateral Load resisting systems, Different types of Soils, Earthquake Zones, ETABS

I. INTRODUCTION

Composite columns are constructed using various combinations of structural steel and concrete in an attempt to utilize the beneficial properties of each material. The interactive and integral behavior of concrete and the structural steel elements makes the composite column a very stiff, more ductile, cost effective and consequently a structurally efficient member in building and bridge constructions.

Mainly three types of composite column sections are used in high-rise building construction.

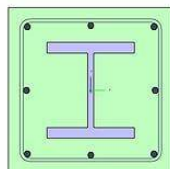


Fig 1.1 Showing Typical view of Composite column

In early 1900's, concrete was used to encase steel columns and beams, and as a filler material for floor systems. In 1907, the first experimental test was carried out by Emperger on built up composite columns under concentric load. Experimental investigations on concrete encased steel composite columns have been conducted by different researchers since long before. Analytical method was developed in early 1900 to investigate the behavior of FEC columns. On the other hand numerical simulations of reinforced concrete structures using finite element method, witnessed a remarkable advancement since 1990. Though, experimental research is costly and time consuming than numerical research, yet the

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progress in numerical studies are comparatively less. Recently, a nonlinear finite element models investigating the behavior of concentric and eccentric axial load of FEC columns was developed by different researchers. The design of composite columns has been addressed by a large number of design specifications.

Composite columns may take a range of forms, as shown in the figure below. As with all composite elements they are attractive because they play to the relative strengths of both steel and concrete. This can result in a high resistance for a relatively small cross sectional area, thereby maximising useable floor space. They also exhibit particularly good performance in fire conditions.

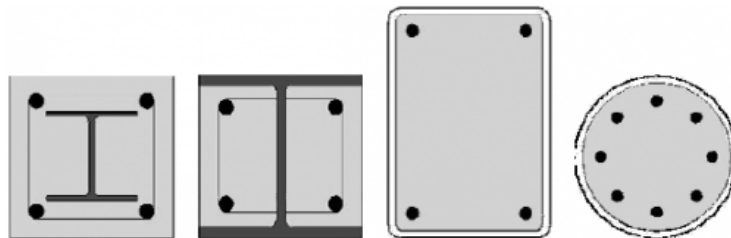


Fig 1.2 Typical composite column cross sections

Design rules for composite columns in structural frames are given in BS EN 1994-1-1[4]. This is the first time that guidance has been given in a code for use in the UK, which may explain why composite columns have been rarely used to date. Rules are provided for composite H sections, either fully or 'partially encased' (web infill only), and for concrete filled hollow sections. Typical cross sections are shown. Composite columns requiring formwork during execution tend not to be viewed as cost-effective in the UK.

Concrete filled hollow section compression members need no formwork and they use material more efficiently than an equivalent H section. Concrete infill adds significantly to the compression resistance of the bare steel section by sharing the load and preventing the steel from buckling locally. The gain in fire resistance may be at least as valuable, especially if it permits the column to be left unprotected or only lightly protected. Infill concrete retains free water which in other situations would be lost; its latent heat of evaporation significantly delays temperature rise.

Rectangular and circular hollow sections can be used. Rectangular sections have the advantage of flat faces for end plate beam-to-column connections (using Flow drill or Hollow connections). Ordinary fin plates can be employed with either shape.

A programmed, Fire Soft, for the design of concrete filled hollow sections in ambient and fire conditions has been developed.

Composite construction:

Composite construction dominates the non-residential multi-storey building sector. This has been the case for over twenty years. Its success is due to the strength and stiffness that can be achieved, with minimum use of materials.

The reason why composite construction is often so good can be expressed in one simple way - concrete is good in compression and steel is good in tension. By joining the two materials together structurally these strengths can be exploited to result in a highly efficient and lightweight design. The reduced self weight of composite elements has a knock-on effect by reducing the forces in those elements supporting them, including the foundations. Composite systems also offer benefits in terms of speed of construction. The floor depth reductions that can be achieved using composite construction can also provide significant benefits in terms of the costs of services and the building envelope.

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Benefits of Composite Construction

1. The benefits of composite construction include speed of construction, performance and value. Steel framing for a structure can be erected quickly and the pre-fabricated steel floor decks can be put in place immediately. When cured, the concrete provides additional stiffness to the structure.
2. Additionally, the concrete encasement protects the steel from buckling, corrosion and fire. Service integration within the channels on the composite decks is another advantage to composite construction.
3. Building quality standards can be adhered to easily by the use of pre-fabricated decks. Excessive deflections can be controlled by cambering the beams or by shoring the metal decks to limit deflection when concrete is poured.

Advantages Of Steel-Concrete Composite Construction

1. Most effective utilization of materials viz. concrete in compression and steel in tension.
2. High ductility of steel leads to better seismic resistance of the composite section. Steel component can be deformed in a ductile manner without premature failure and can withstand numerous loading cycles before fracture.
3. Steel component has the ability to absorb the energy released due to seismic forces through its unique property called ductility.
4. Ability to cover large column free area. This leads to more usable space. Area occupied by the composite column is less than the area occupied by the RCC column
5. Faster construction by utilizing rolled and/or pre-fabricated components. Also speedy construction facilitates quicker return on the invested capital.
6. Quality of steel is assured since it is produced under controlled environment in the factory under strict Quality Assurance Plan (QAP). More use of steel in composite construction compared to that in RCC structure ensures better quality control.
7. Cost effective, based on life cycle cost analysis since steel structures can be maintained easily and less frequent repairs are required for steel structure.
8. Steel is more durable, highly recyclable and hence environment friendly.
9. Keeping span/loading unaltered, smaller structural sections are required compared to non-composite construction. Therefore, reduction in overall weight of the composite structure compared to the RCC construction results lesser foundation costs.
10. Cost of formwork is lower compared to RCC construction.
11. Cost of handling and transportation is less because major part of structure is fabricated in workshop near the site

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12. The steel component and hence the steel-concrete composite construction is more resistant against accidental loads compared to RCC construction
13. Composite sections have higher stiffness compared to only steel construction and hence experience lesser deflection than the non-composite steel sections.

Shear wall structures:

Adequate stiffness is to be ensured in high rise buildings for resistance to lateral loads induced by wind or seismic events. Reinforced concrete shear walls are designed for buildings located in seismic areas, because of their high bearing capacity, high ductility and rigidity. In high rise buildings, beam and column sizes work out large and reinforcement at the beam-column junctions are quite heavy, so that, there is a lot of clogging at these joints and it is difficult to place and vibrate concrete at these places which does not contribute to the safety of buildings. These practical difficulties call for introduction of shear walls in High rise buildings.

Concrete or masonry continuous vertical walls may serve both architecturally as partitions and structurally to carry gravity and lateral loading. There will be no architectural difficulty in extending them through the height of the building; their very high in plane stiffness and strength had proved them to be ideally suited for resisting lateral loads. Compared to frame type structures, shear-wall structures offer less distortion and less damage to nonstructural elements. Care shall be taken to have symmetrical configuration of walls in the building so that torsion effect in plan could be avoided.

In a shear wall structure, shear walls are entirely responsible for the lateral load resistance of the building due to seismic and wind loadings. These shear walls act as vertical cantilevers in the form of separate planar walls, and also as non planar assemblies of connected walls around stair case, elevators and service shafts. Shear walls are much stiffer horizontally than rigid frames. Shear walls are much economical up to about 35 stories. In contrast to the rigid frames, the shear walls' solid form tends to restrict open internal spaces where required. However, they are well suited to hotels and residential buildings where the floor by floor repetitive planning allows the shear walls to be vertically continuous. They also serve excellent acoustic and fire insulators between rooms and apartments.

Use of bracing system in decreasing the effective length of the column

A new bracing system shaped like a diamond is incorporated in the main building frame and its applicability is evaluated by detailed calculations. It is also compared with the other known bracing system known as the cross bracing system. Both the bracing system has been shown below.

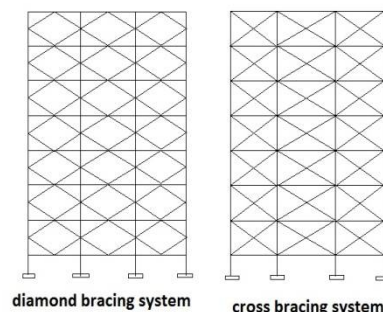


Fig-1.1 Showing different types of bracings

Bracing is a very effective global upgrading strategy to enhance the global stiffness and strength of steel and composite frames. It can increase the energy absorption of structures and/or decrease the demand imposed by earthquake loads. Structures with augmented energy dissipation may safely resist forces and deformations caused by strong ground motions. Generally, global modifications to the structural system are conceived such that the

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design demands, often denoted by target displacement, on the existing structural and non-structural components, are less than their capacities (Figure 1). Lower demands may reduce the risk of brittle failures in the structure and/or avoid the interruption of its functionality. The attainment of global structural ductility is achieved within the design capacity by forcing inelasticity to occur within dissipative zones and ensuring that all other members and connections behave linearly.

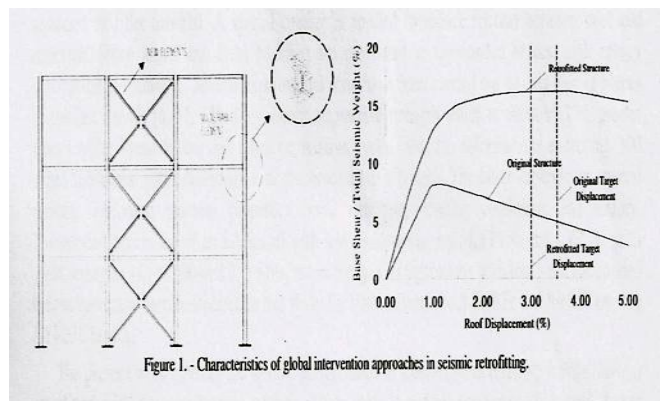


Figure 1. - Characteristics of global intervention approaches in seismic retrofitting.

Bracing may be inefficient if the braces are not adequately capacity-designed. Braces can be aesthetically unpleasant where they change the original architectural features of the building. In addition, braces transmit very high actions to connections and foundations and these frequently need to be strengthened.

III. NUMERICAL MODELLING

Building dimensions

The building is 24m x 24m in plan with columns spaced at 6m from center to center. A floor to floor height of 3.0m is assumed. The location of the building is assumed to be at zone-5 & soil-3.

Column size : 500mm X 650 mm

Beam size : 400mm X 450 mm

Shearwall Thickness 230 mm

Bracing size: 230mmx230mm,

Slab thickness: 120mm,

Live load: 3KN

Floor Finish: 1KN

Mix proportion: M30

Grade of steel : Fe 500

Load Combination: (DL+LL+EQX+WIND X) 1.2

Dead load - 1.2

Live load - 1.2

EQX - 1.2

WIND X -1.2

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Windward Coefficient : 0.8

Leeward coefficient : 0.5

5.5 Load Cases

5.5.1. Live Load

Live load is assumed as per IS 875(part 2-imposed loads) table 1. the building is analysed by assuming it to be a residential building the live load was taken as 2KN/m^2

5.5.2. Earth Quake Load

Earth Quake load in this analysis is accordance to IS 1893(part 1)-2002. The buildings models are prepared in all seismic zones i.e. in Z2, Z3, Z4 and Z5. Therefore the value of Z is taken as 0.1, 0.16, 0.24 and 0.36 respectively. And the models are made in all types of soils i.e., Hard/ Rocky (Type I), Medium soil (Type II) and in Loose soil (Type III).

5.5.3. Load combinations:

As per clause 6.3.1.2 of IS 1893 different load combinations are

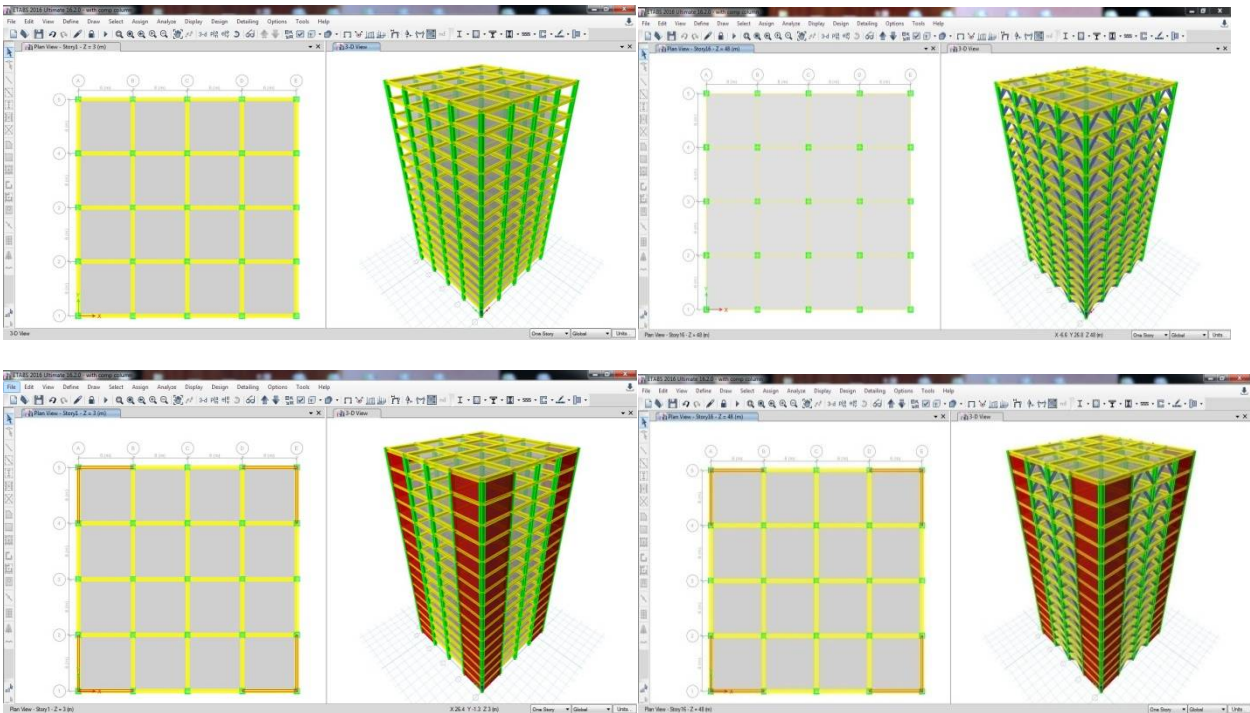
Static & dynamic Loading:

- 1.5(Dead load + Live load)
- 1.2(Dead load + Live load + Lateral load in X direction)
- 1.2(Dead load + Live load - Lateral load in X direction)
- 1.2(Dead load + Live load + Lateral load in Y direction)
- 1.2(Dead load + Live load - Lateral load in Y direction)
- 1.5(Dead load + Lateral load in X direction)
- 1.5(Dead load - Lateral load in X direction)
- 1.5(Dead load + Lateral load in Y direction)
- 1.5(Dead load - Lateral load in Y direction)
- 0.9(Dead load) + 1.5(Lateral load in X direction)
- 0.9(Dead load) - 1.5(Lateral load in X direction)
- 0.9(Dead load) + 1.5(Lateral load in Y direction)
- 0.9(Dead load) - 1.5(Lateral load in Y direction)

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IV. RESULTS

Table : 1 Comparative values of Displacement in Zone-3 Soil-1 in Linear Static Analysis.

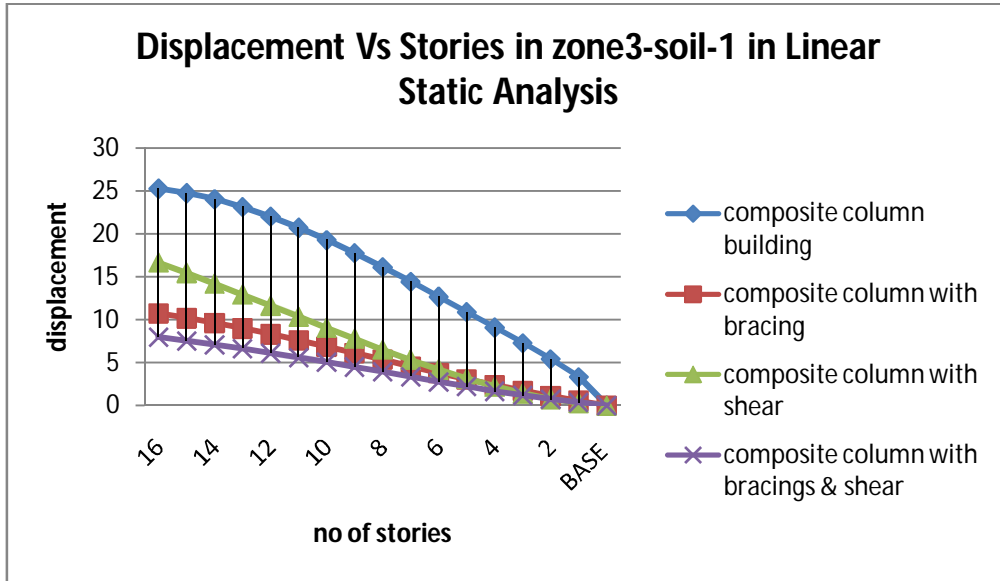
No. of stories	composite column building	composite column with bracing	composite column with shear	composite column with bracings & shear
16	25.26	10.737	16.655	7.98
15	24.746	10.186	15.431	7.52
14	24.034	9.605	14.186	7.102
13	23.115	8.985	12.926	6.636
12	21.999	8.319	11.645	6.137
11	20.714	7.612	10.35	5.616
10	19.289	6.873	9.054	5.073
9	17.75	6.113	7.778	4.509
8	16.12	5.343	6.53	3.932
7	14.422	4.574	5.329	3.351
6	12.675	3.816	4.195	2.774
5	10.896	3.08	3.147	2.211
4	9.097	2.377	2.21	1.674
3	7.283	1.715	1.406	1.174
2	5.419	1.106	0.762	0.726
1	3.317	0.552	0.306	0.353
BASE	0	0	0	0

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Graph : 1 Displacement variation along Zone-3 soil-1 in Linear Static Analysis

Table : 2 Comparative values of Displacement in Zone-3 Soil-2 in Linear Static Analysis.

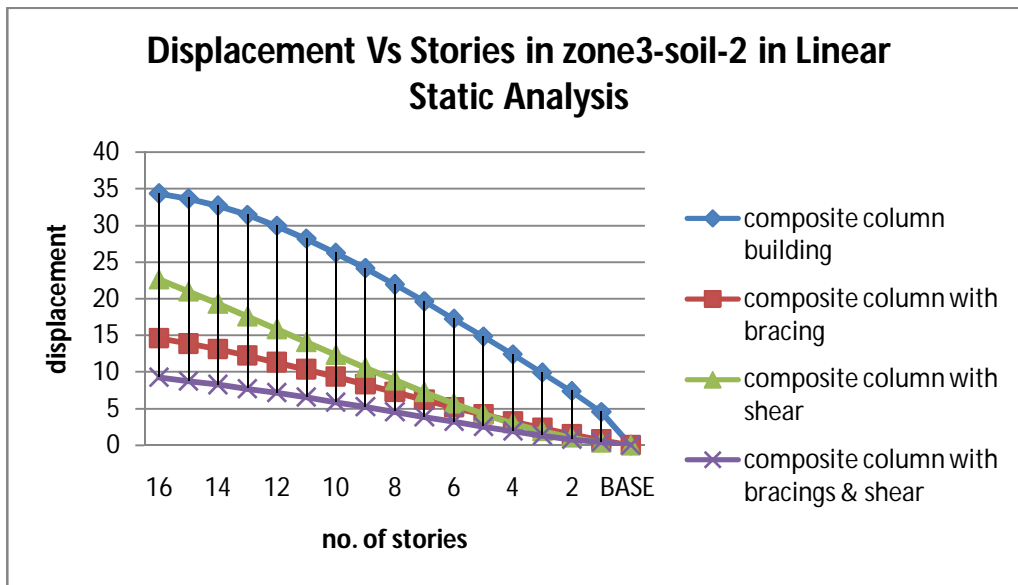
No. of stories	composite column building	composite column with bracing	composite column with shear	composite column with bracings & shear
16	34.33	14.576	22.619	9.265
15	33.648	13.846	20.98	8.746
14	32.686	13.063	19.292	8.26
13	31.436	12.219	17.578	7.719
12	29.918	11.302	15.836	7.139
11	28.171	10.34	14.075	6.526
10	26.233	9.334	12.312	5.893
9	24.139	8.3	10.566	5.236
8	21.922	7.252	8.865	4.564
7	19.613	6.205	7.229	3.887
6	17.237	5.174	5.684	3.214
5	14.817	4.173	4.258	2.559
4	12.371	3.215	2.981	1.933
3	9.904	2.314	1.886	1.351
2	7.369	1.485	1.009	0.829
1	4.504	0.733	0.388	0.395
BASE	0	0	0	0

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Graph : 2 Displacement variation along Zone-3 soil-2 in Linear Static Analysis

Table : 3 Comparative values of Displacement in Zone-3 Soil-3 in Linear Static Analysis.

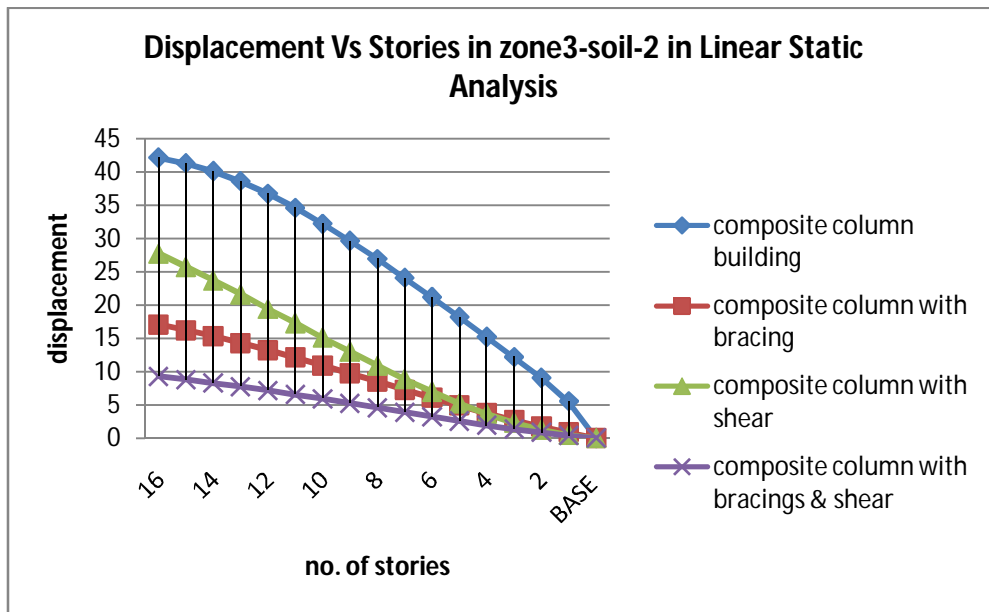
No. of stories	composite column building	composite column with bracing	composite column with shear	composite column with bracings & shear
16	42.14	17.081	27.755	9.265
15	41.313	16.235	25.759	8.746
14	40.136	15.319	23.688	8.26
13	38.602	14.329	21.585	7.719
12	36.738	13.252	19.446	7.139
11	34.592	12.12	17.283	6.526
10	32.212	10.94	15.118	5.893
9	29.641	9.727	12.974	5.236
8	26.919	8.498	10.88	4.564
7	24.083	7.27	8.866	3.887
6	21.165	6.06	6.967	3.214
5	18.194	4.885	5.215	2.559
4	15.191	3.761	3.645	1.933
3	12.161	2.704	2.3	1.351
2	9.049	1.732	1.221	0.829
1	5.526	0.851	0.466	0.395
BASE	0	0	0	0

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Graph : 3 Displacement variation along Zone-3 soil-3 in Linear Static Analysis

Table : 4 Comparative values of Displacement in Zone-5 Soil-1 in Linear Static Analysis.

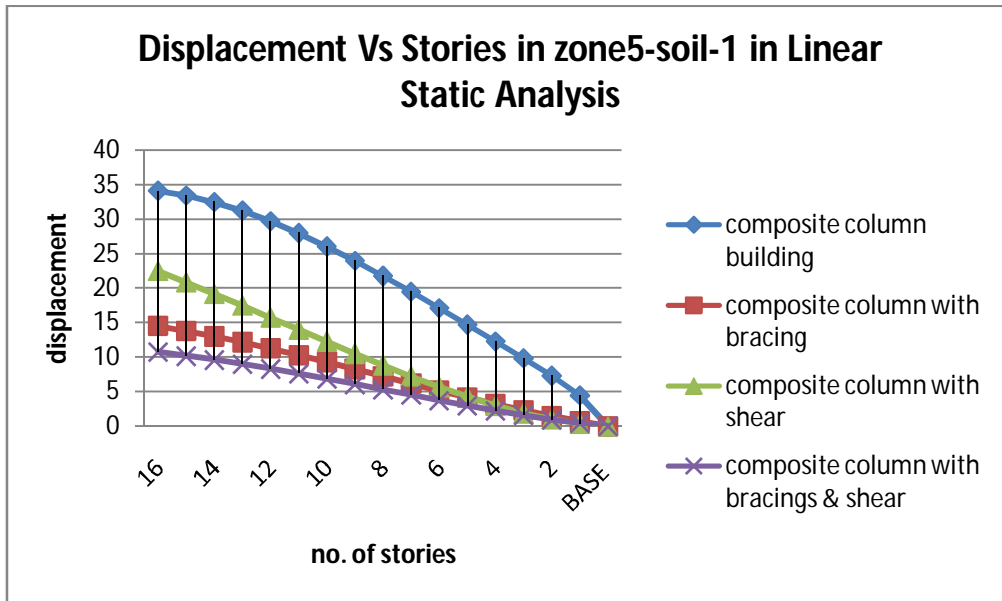
No. of stories	composite column building	composite column with bracing	composite column with shear	composite column with bracings & shear
16	34.078	14.469	22.454	10.733
15	33.4	13.745	20.826	10.148
14	32.446	12.967	19.15	9.584
13	31.205	12.129	17.449	8.957
12	29.698	11.219	15.72	8.284
11	27.964	10.264	13.972	7.567
10	26.04	9.266	12.221	6.831
9	23.962	8.239	10.488	6.067
8	21.761	7.199	8.8	5.286
7	19.469	6.16	7.177	4.499
6	17.11	5.136	5.643	3.718
5	14.708	4.142	4.227	2.956
4	12.281	3.191	2.96	2.229
3	9.831	2.297	1.873	1.552
2	7.315	1.474	1.002	0.947
1	4.471	0.728	0.386	0.444
BASE	0	0	0	0

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Graph : 4 Displacement variation along Zone-5 soil-1 in Linear Static Analysis

Table : 5 Comparative values of Displacement in Zone-5 Soil-2 in Linear Static Analysis.

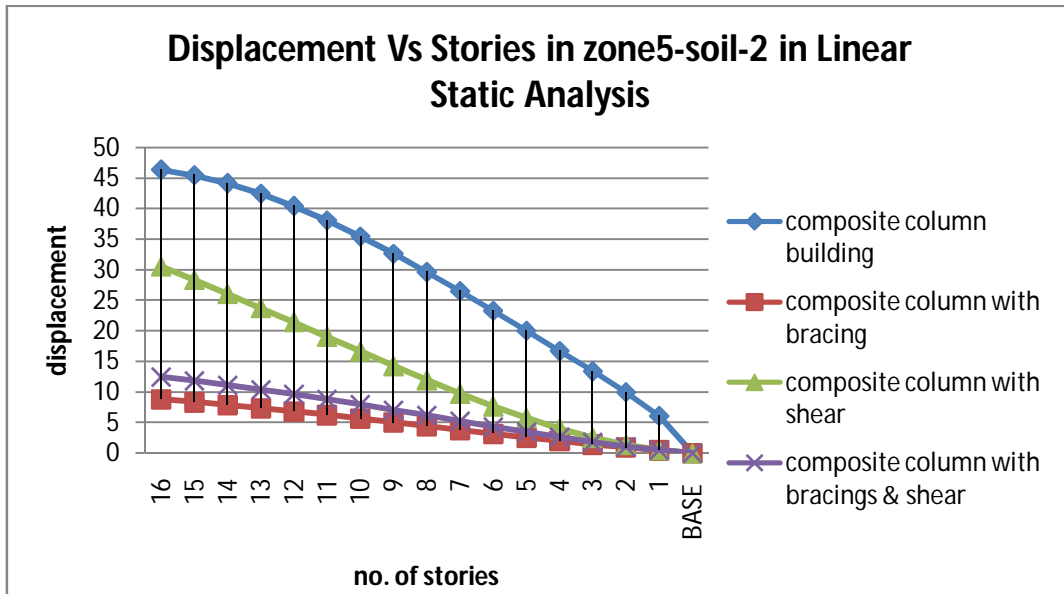
No. of stories	composite column building	composite column with bracing	composite column with shear	composite column with bracings & shear
16	46.322	8.774	30.505	12.468
15	45.417	8.316	28.318	11.804
14	44.126	7.838	26.043	11.147
13	42.439	7.337	23.73	10.419
12	40.39	6.795	21.379	9.637
11	38.031	6.218	19.001	8.802
10	35.414	5.615	16.62	7.938
9	32.587	4.995	14.264	7.049
8	29.595	4.367	11.961	6.14
7	26.477	3.74	9.744	5.223
6	23.269	3.122	7.654	4.313
5	20.002	2.522	5.727	3.426
4	16.701	1.948	4.001	2.579
3	13.369	1.409	2.521	1.79
2	9.948	0.912	1.335	1.086
1	6.073	0.459	0.51	0.501
BASE	0	0	0	0

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Graph : 5 Displacement variation along Zone-5 soil-2 in Linear Static Analysis.

Table : 6 Comparative values of Displacement in Zone-5 Soil-3 in Linear Static Analysis.

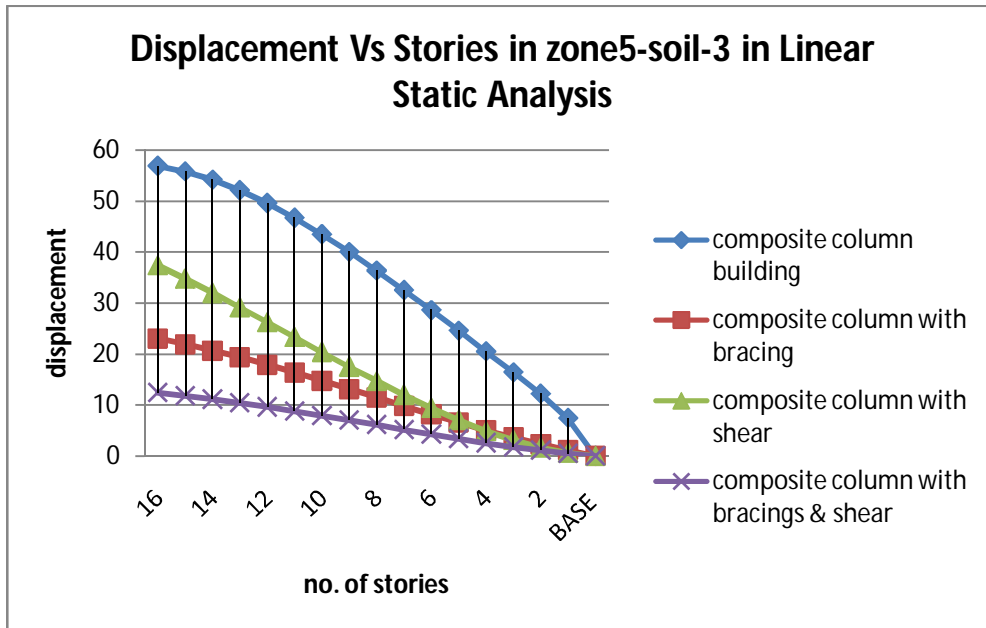
No. of stories	composite column building	composite column with bracing	composite column with shear	composite column with bracings & shear
16	56.866	23.034	37.437	12.468
15	55.765	21.91	34.769	11.804
14	54.183	20.681	31.978	11.147
13	52.112	19.343	29.139	10.419
12	49.596	17.889	26.252	9.637
11	46.699	16.349	23.332	8.802
10	43.486	14.756	20.408	7.938
9	40.015	13.117	17.515	7.049
8	36.34	11.457	14.687	6.14
7	32.512	9.799	11.965	5.223
6	28.572	8.165	9.394	4.313
5	24.561	6.578	7.022	3.426
4	20.507	5.06	4.898	2.579
3	16.416	3.633	3.079	1.79
2	12.216	2.319	1.622	1.086
1	7.453	1.133	0.62	0.501
BASE	0	0	0	0

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Graph : 6 Displacement variation along Zone-5 soil-3 in Linear Static Analysis.

V. CONCLUSION

1. Analysis carried out on two different heights of buildings i.e.. 45m in both static analysis and dynamic analysis with composite column and shear wall at optimum locations.
2. From the analysis Displacement is compared for all the models in zone 3 & zone 5 and it can be concluded that displacement is increasing with increase in height and the displacement can be reduced by providing shear walls at optimum locations.
3. When Displacement is analysed in linear static analysis it is observed that 40% of displacement is reduced when shear walls are provided at optimum locations.

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