A Comparative Study of Seismic Behaviour of G+10 Storey Building With RCC and Composite Columns for Different Configurations

***Sarmili Swain*[1] *and P. K. Parhi*[*2]**

Abstract

In India, RCC structures are most commonly used as these are very much convenient for multistorey buildings. Steel concrete composite construction is not preferred because of its complexity in its analysis and design. It has unique characteristics of both the materials which results in greater economy and safety. In the present investigation, ETABS 2018 software is used for the analysis of a G+10 multistorey building of three different geometrical shapes of same plan area of 225m^2. Comparison of seismic behaviour is done for all the three different plan areas consisting of RCC columns and composite columns. The various parameters considered in the study are storey displacement, storey drift, storey stiffness, and base shear. Comparison is done for four parameters for different cases and the best of the configuration is found out. Study of the above parameters is done by adopting response spectrum method for Zone III and Zone V.

Keywords : **Base Shear, Equivalent Static Method, Response Spectrum Method, Storey Drift, Storey Displacement, Storey Stiffness**

I. INTRODUCTION

A. *General*

To overcome the major problem of increasing population and urbanization, there is a huge requirement to accommodate the population under a single roof for which, high rise structures are opted. These type of skyscrapers are generally affected by wind and earthquake loads. Earthquake loads are especially most dangerous as they cause huge damage to the structure as well as huge loss of life and property. The tall structures are designed considering safety, stiffness, economy, durability, ductility, seismic resistance parameters under various seismic zones. The use of composite construction for buildings and bridges is more advantageous than structures of steel and concrete used independently. The composite type of structures are more advantageous as compared to RCC structures as they have high fire resistance rating, speed of construction, flexibility, etc.

The present investigation aims to study the following objectives:

- Study of buildings of square shape, L shape, and triangular shape for same plan area of 225 m^2 and comparison [1].
- To study various parameters like storey displacement, storey drift, storey stiffness, and base shear under seismic zone III and zone V.
- To understand the benefits of use of composite columns.

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B. Reinforced Concrete

RC possesses high compressive strength to withstand a huge amount of load. It is durable, fire-resistant, can be easily handled and requires little maintenance but it has disadvantages as it needs proper mixing, casting, and curing which affects the member for its final strength. It has low tensile strength which demands for large sections of columns and beams in high rise buildings.

C. Composite Columns

Steel concrete composite columns are the compression load-bearing members of encased hot-rolled steel section or a concrete filled tubular section used in a composite framed structure. Composite columns are advantageous as they are fire resistant and are strengthened by reinforcing bars in the concrete cover [2]. Concrete' filled steel tubes are filled with high strength concrete, with a minimum cube strength of 45 to 55 N/mm^2. In order to meet the required 'fire resistance' rating, the concrete core must be longitudinally reinforced.

II. LITERATURE REVIEW

Before proceeding to the seismic analysis of the RC framed and composite framed buildings, a wide range of literature reviews were carried out to understand the concept and find out the gap in the research.

Kumar and Sen [3] investigated a G+10 storey building considering seismic, dead, and live loads using ETABS 2017. The parameters studied were moments, shear force, base shear, axial force, maximum displacement, and tensile forces on structural system' and comparison was done under seismic zones III, IV, and V. The paper concluded that the lateral displacements, base shear, and storey drifts are more in zone V as compared to zones IV and III.

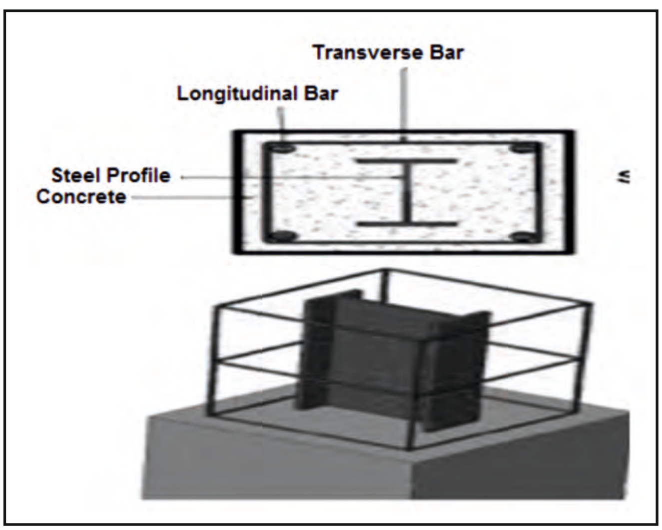

Fig. 1. Composite Column

Anargha and Mithulraj [4] analyzed the behavior of RC, steel, and composite structure under seismic loading using ETABS. Base shear, storey drift, and storey shear were compared for RCC and composite structures. Displacement was less for ISMB 225 when used as beam element than ISHB 150 when used as column section. Storey shear of composite column is less as compared to RCC column as the building weight is decreased when composite column is used.

Vedha and Pash [5] investigated G+18 multistory framed structure by equivalent static and response spectrum approach in Zone IV is compared for R.C.C., Steel, and Composite. It is assumed that the building frame is an OMRF. Base shear, storey drifts, storey overturning moments, and roof displacements are only a few of the variables that are compared. The outcome demonstrates that using composite beams reduces forces since the section is smaller and composite buildings are more cost-effective.

Dheekshith and Kumar [6] investigated the seismic assessment of an RC structure with vertical abnormalities and mass irregularities in seismic Zones II and IV method employed by linear static method. The comparison of several metrics included lateral displacement, storey drift, and storey shear. The study came to the conclusion that vertical uneven buildings exhibit increased lateral displacement. When the structure experiences mass irregularity, the percentage of steel increased.

Alwani [7] used comparable static analysis in STAAD Pro to evaluate a G+15 building situated in seismic zones III and IV. The appropriate member capacity is estimated along with the seismic force demand for each individual member for the design base shear. The response reduction considers values of OMRF and SMRF with deflection diagrams. The study came to the conclusion that axial force changes linearly with storey height and that storey height increases the bending moment caused by seismic load in the column and footing.

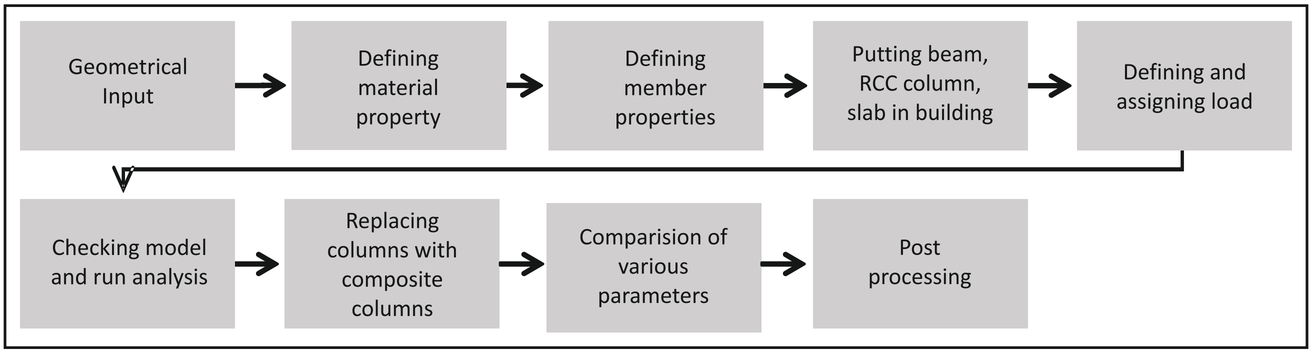

Fig. 2. Flowchart

III. METHODOLOGY

Steps used to analyze G+10 building in ETABS 2018 are described in the flow chart (Fig. 2).

A. Mathematical Formulation

The seismic analysis of the structure mainly considers the external load, structural behavior, and the types of materials used for the construction of the model. In this investigation of seismic analysis, both ESM and RSM are used as classified in IS 1893 : 2016 Codal Provision.

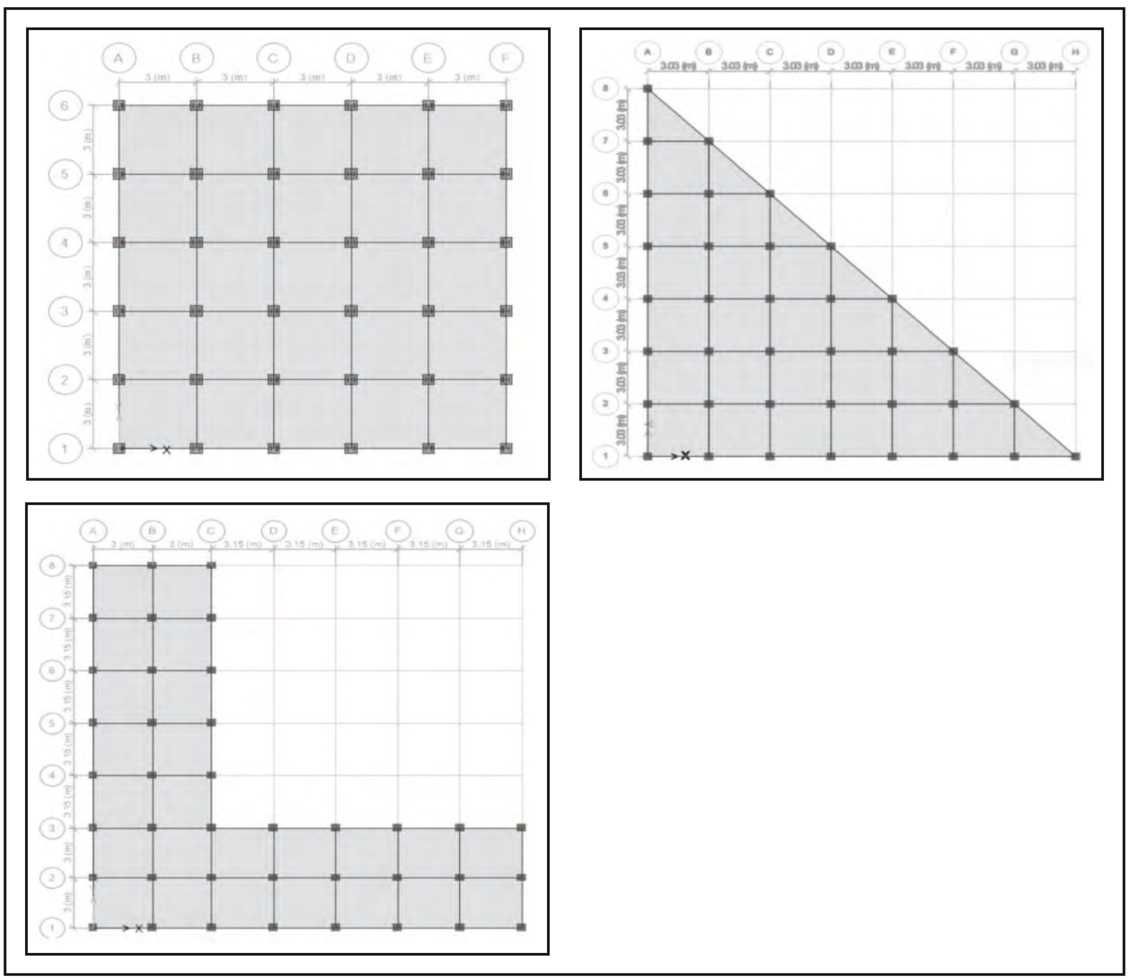

Fig. 3. Plan of square, L shape and triangular G+10 building

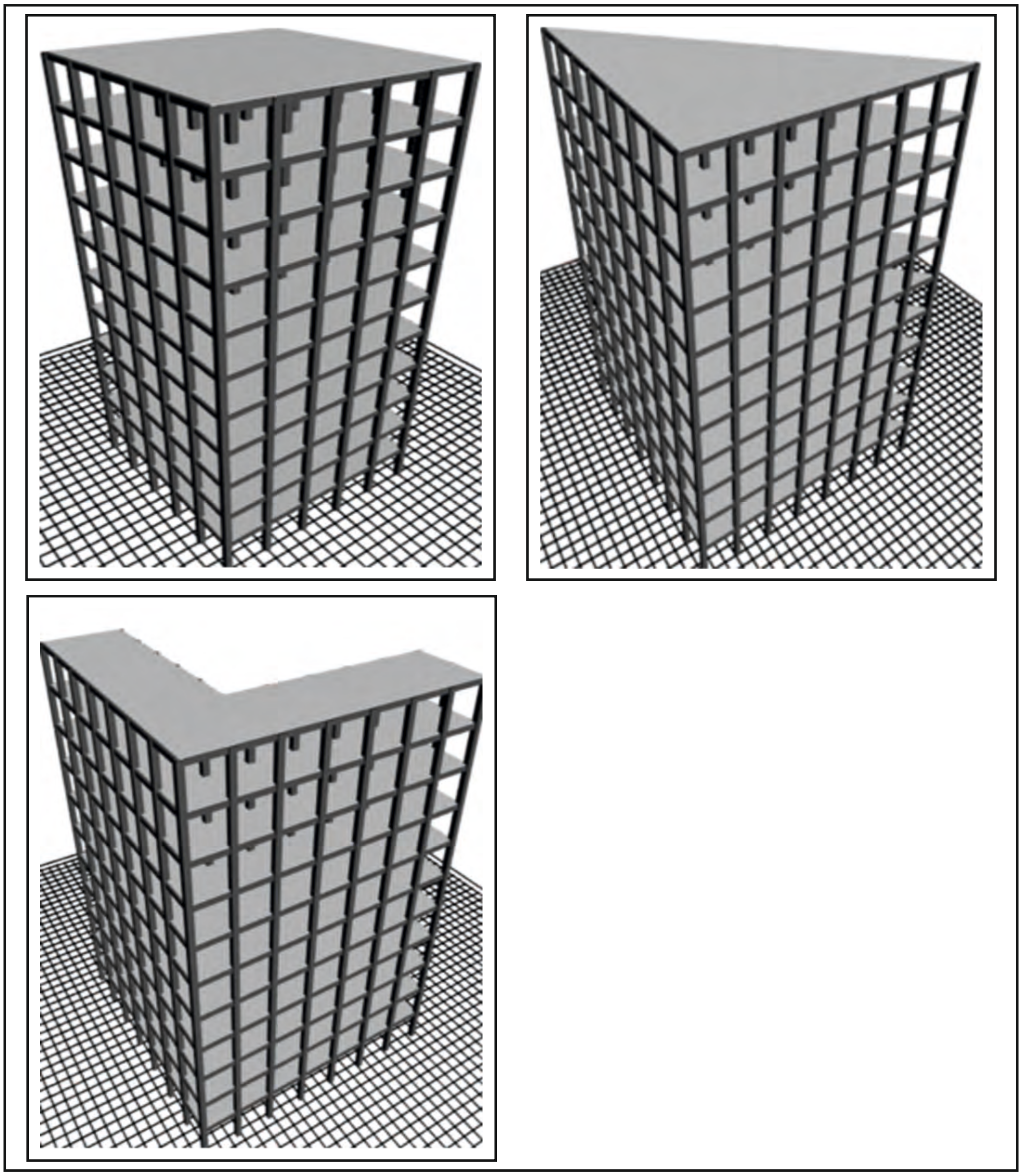

Fig. 4. 3D plan of square, L shape, and triangular building

Storey shear force in each mode by response spectrum method (RSM):

Storey shear force can be calculated in storey i in mode k and the peak lateral force *(Q_{ik})* is determined by the expression,

$$V_{ik} = \sum_{j=i+1}^{n} Q_{ik}$$

Limitation of Storey Drift

Storey drift should not exceed 0.004 times the storey height as per IS1893: 2016.In this analysis, the storey height is taken as 3 m. So, the limited value of storey drift for this investigation is 0.012 m [8].

B. System Development

In this investigation, a plan area of 225 m^2 is taken. Different shapes of building like square shape, L shaped,

TABLE I.
SPECIFICATIONS OF THE BUILDING

Plan Area	225 m^2
No. of Storeys	11
Storey Height	3 m
Beam Size	(230*360) mm
Column Size	(450*450) mm
Slab Thickness	150 mm

TABLE II.
MATERIAL DETAILS

Grade of Concrete	M30
Grade Of Steel	Fe 415
Steel Section Used [10]	ISHB 250

TABLE III.
SEISMIC DATA AND LOADING DETAILS

Dumping Ratio	5%
Building Type	SMRF
Importance Factor	1
Response Reduction Factor	5
Soil type	Medium
Seismic Zone	III and V
Dead Load	Default values to be calculated by ETABS 2018
Live load on floor and roof	2.5 kN/m^2
Floor Finish	1kN/m^2

and triangular shape are considered. The structural dimension and its properties are described next in brief. Fig. 2 shows the plan of three different buildings. Fig. 3 shows the 3D view of the three different G+10 buildings. In addition, the building is provided with both RCC columns and composite columns. Various parameters like storey displacement, storey drift, store stiffness, and base shear are studied in both zone III and Zone V. Further details of the building are provided in Tables I to III [9].

IV. RESULTS AND DISCUSSIONS

Response spectrum method is used to analyze three different models using both RCC columns and composite columns in zone III and zone V. Various parameters such

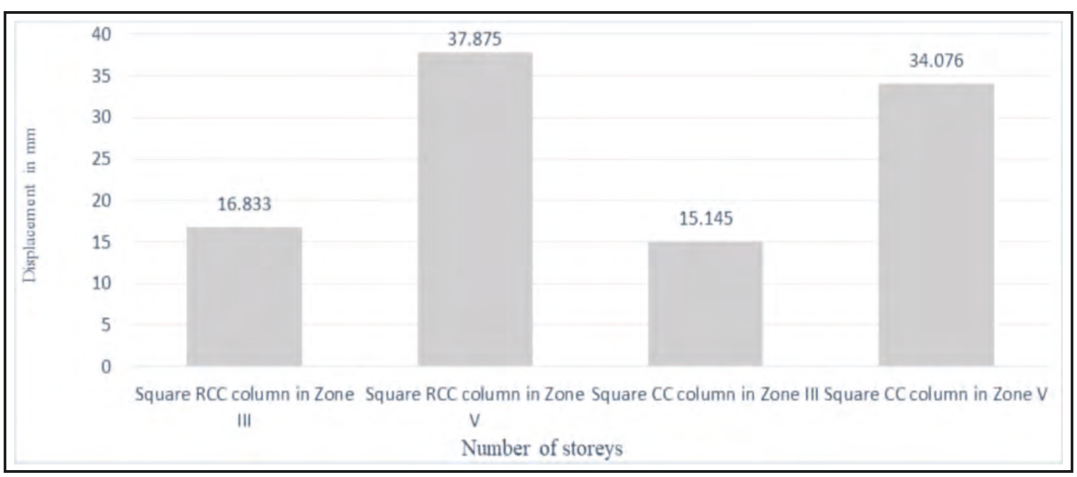

Fig. 5. Maximum storey displacement of square plan

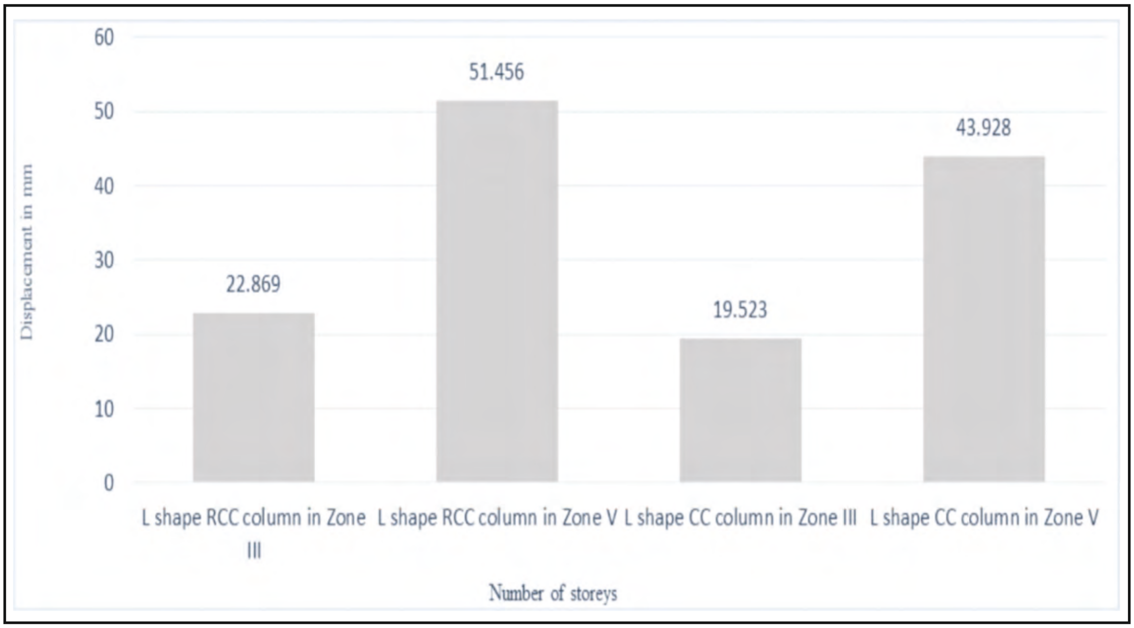

Fig. 6. Maximum storey displacement of L shape plan

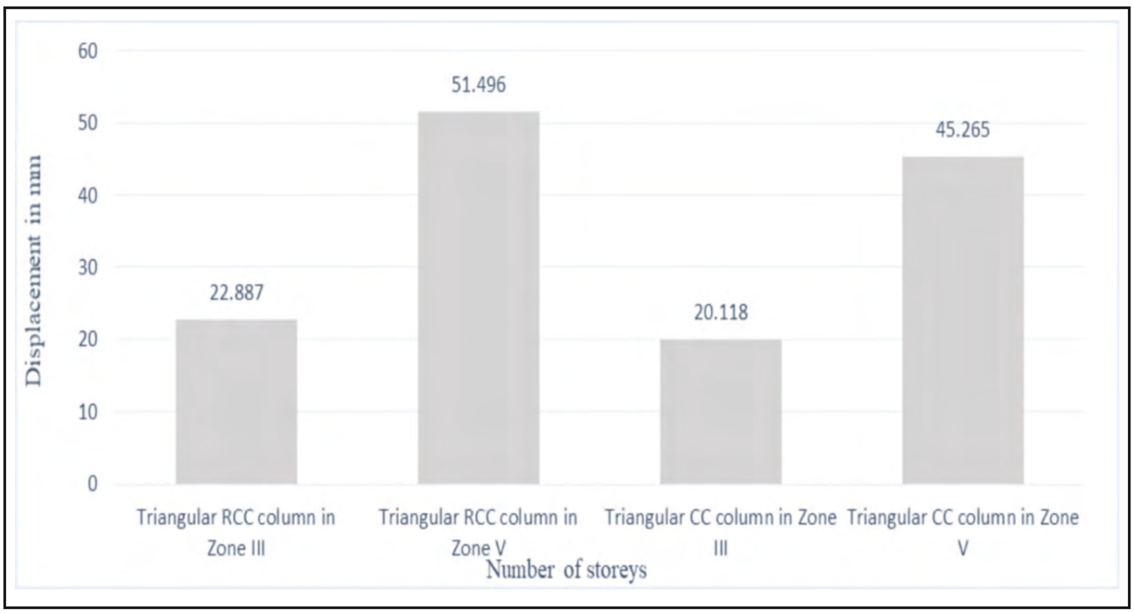

Fig. 7. Maximum storey displacement of triangular building plan

as maximum storey displacement, storey drift, maximum storey stiffness, and base shear are considered in the study. Graphs are plotted for various parameters and conclusion is drawn for the best configuration.

A. Storey Displacement

Storey displacement is the lateral displacement of the storey relative to its base. The storey displacements for different models are presented next.

Fig. 5, 6, and 7 show the maximum storey displacement of G+10 building for three different plans. Maximum storey displacement occurs at the top most floor in the 11^{th} floor. From the graph, it clearly indicates that when the composite columns are replaced with RCC columns, the displacement values are reduced for square plan, L shape, and triangular plans by 10.03%, 14.629%,

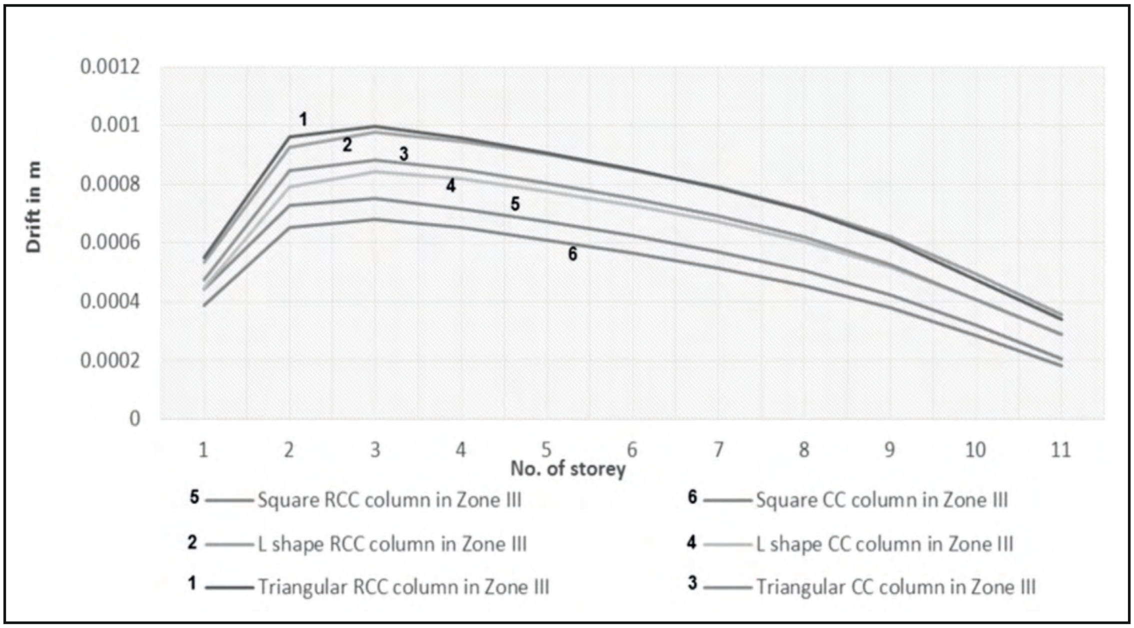

Fig. 8. Storey Drift for Zone III

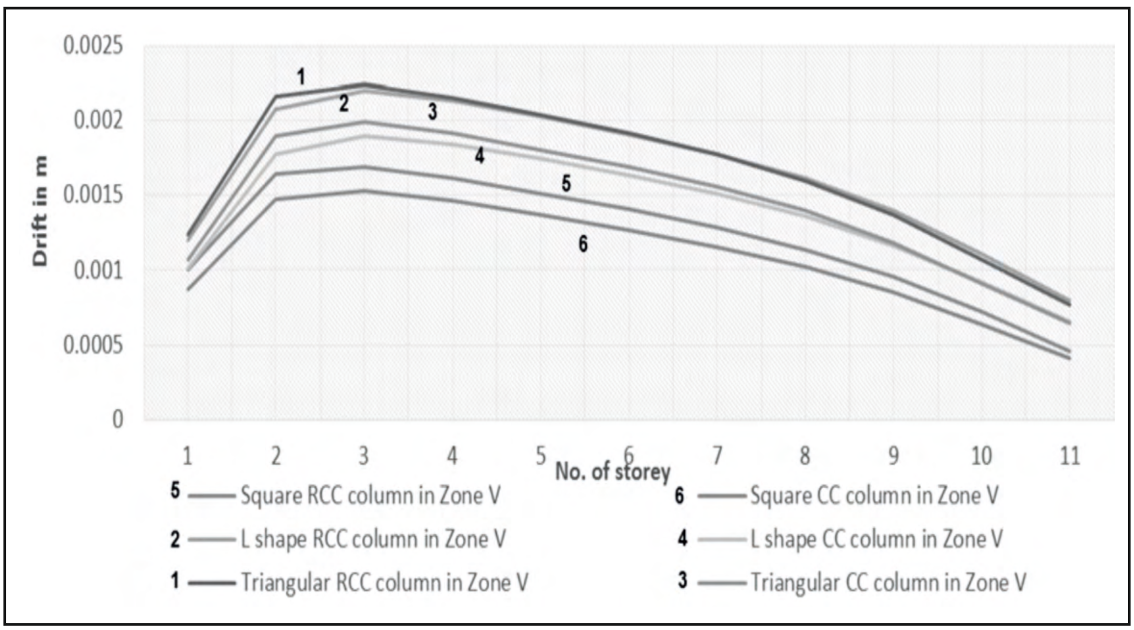

Fig. 9. Storey drift in Zone V

and 12.098% respectively in zone III. Similarly, in zone V the displacement is reduced for square plan, L shape, and triangular plan by 10.03%,14.629%, and 12.098% respectively. It is seen that the percentage of decrease of maximum storey displacement is almost similar for both the zones.

B. Storey Drift

Storey drift is the relative displacement of one storey relative to the other. Here, the storey drifts for Zone III and Zone V are shown in Fig. 8 and Fig. 9.

From these figures, it is clearly observed that the square composite column for both zone III and zone V shows the least value with respect to the storey drift. All the storey drift lies within the permissible limit, i.e. within 0.012m. It is seen that the storey drift occurs maximum at storey 3. Maximum storey drift occurs for triangular plan using RCC column that indicates the structure is the least stable among all the models. Maximum storey drift increases by 57.28% when the building zone is changed from zone III to zone V. In case of zone III, when composite columns are used, the maximum storey drift is decreased by 9.33%, 14.28%, and 12% for square, L shape and triangular plan respectively Similarly, in case of zone V maximum storey drift for third storey when composite columns are replaced by RCC columns are reduced by 9.47%, 13.69%, and 11.16% for square, L shape, and triangular plan respectively. From this trend it is seen that the percentage of change of maximum storey displacement for 11th storey and maximum storey drift for 3rd storey is almost similar.

C. Storey Stiffness

Storey stiffness is the measure of the amount of force required to displace a building by certain amount. Fig. 9 shows the storey stiffness of three different types of

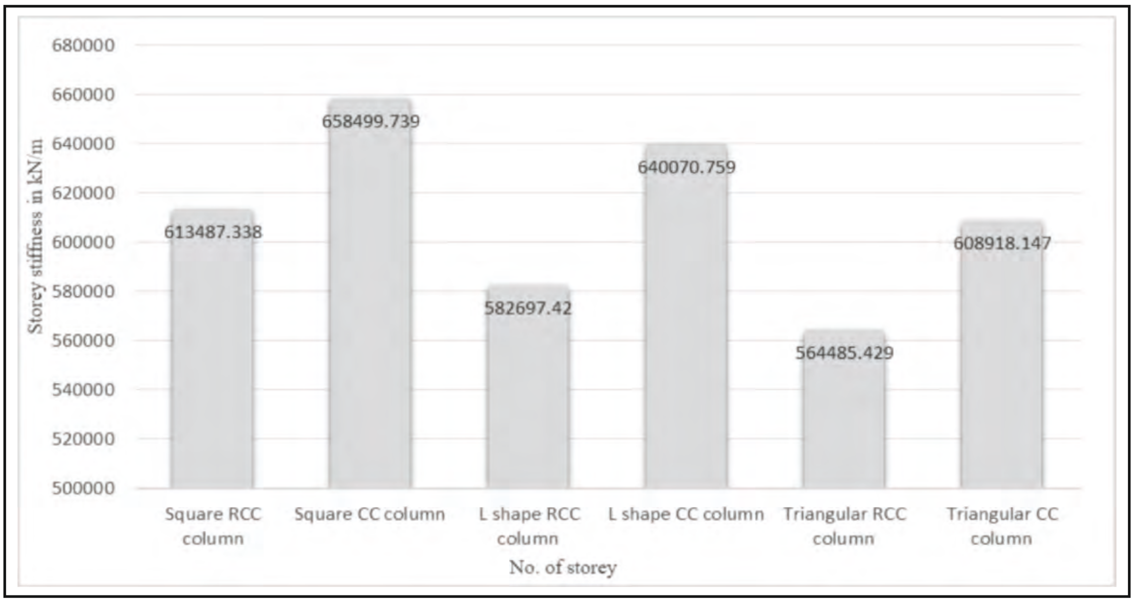

Fig. 10. Storey Stiffness

TABLE IV.
BASE SHEAR FOR DIFFERENT CONFIGURATIONS

Different Conditions	BASE SHEAR(kN)
Square RCC column in Zone III	794.4655
Square CC column in Zone III	752.1235
Square RCC column in Zone V	1787.5473
Square CC column in Zone V	1682.2272
L shape RCC column in Zone III	824.2706
L shape CC column in Zone III	773.6467
L shape RCC column in Zone V	1854.609
L shape CC column in Zone V	1740.7052
Triangular RCC column in Zone III	816.5575
Triangular CC column in Zone III	767.0201
Triangular RCC column in Zone V	1837.2545
Triangular CC column in Zone V	1725.7952

building plan using both RCC columns and composite columns differently.

From Fig. 10 it is seen that the storey stiffness is maximum for square plan using composite columns, hence it is the best combination among all. The storey stiffness is least for triangular plan with RCC columns, so is the least preferable. When composite columns are replaced by RCC columns the percentage of increase in stiffness is 7.34%, 9.84%, and 7.87% for square plan, L shape, and triangular plan respectively.

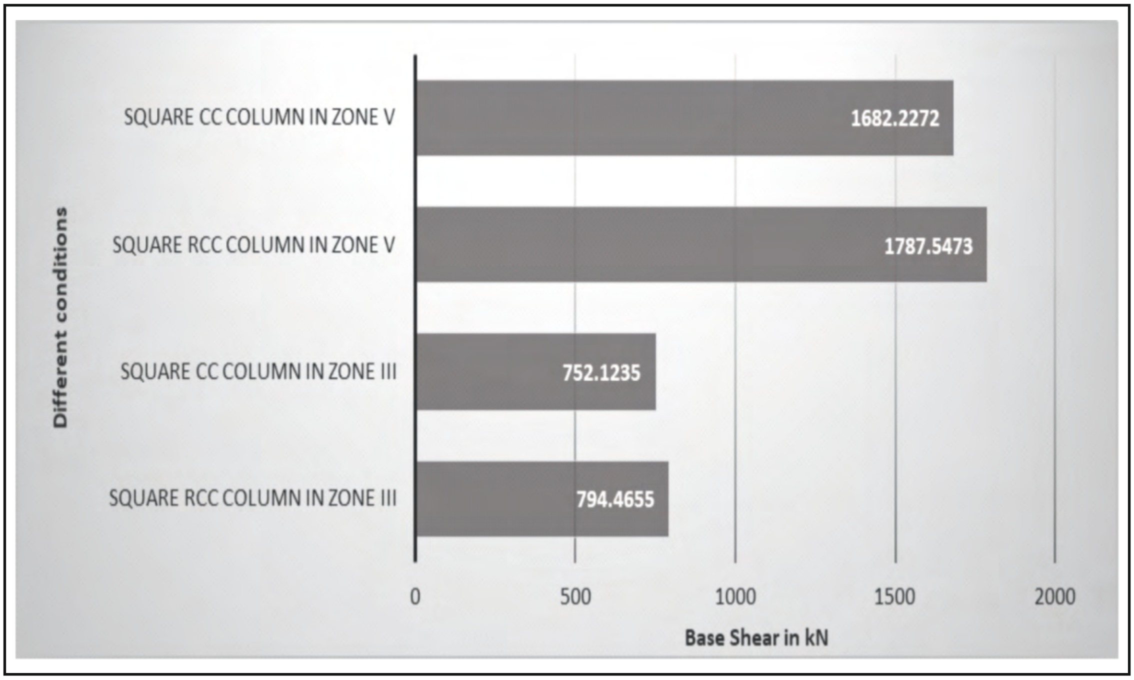

Fig. 11. Base Shear of Square Plan

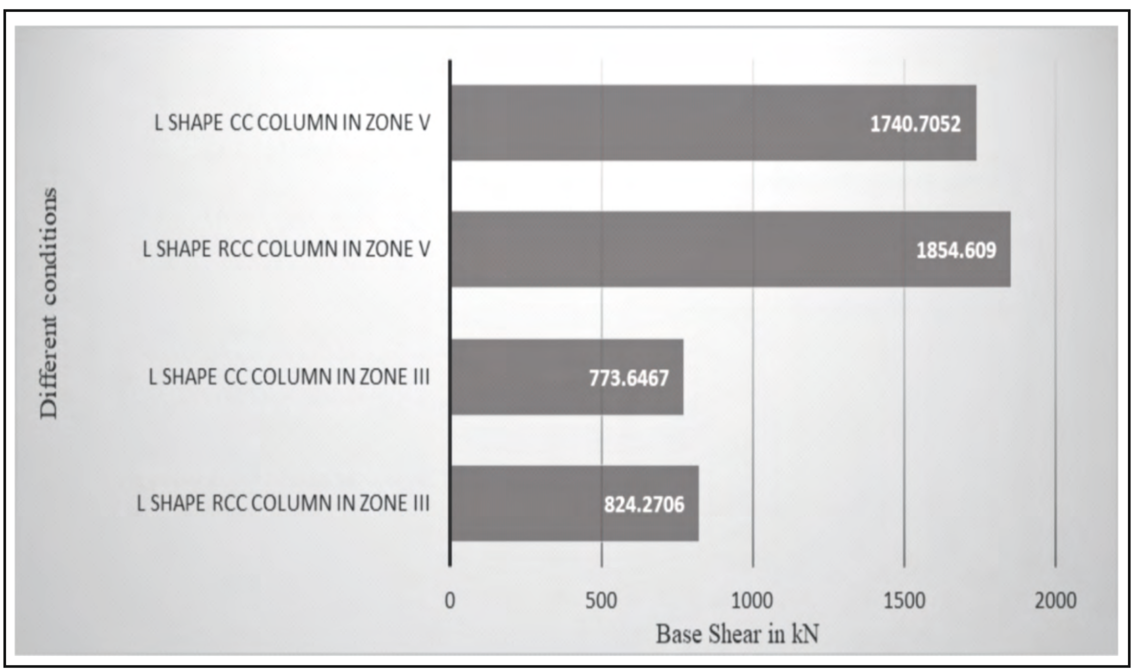

Fig. 12. Base Shear for L Shape Building Plan

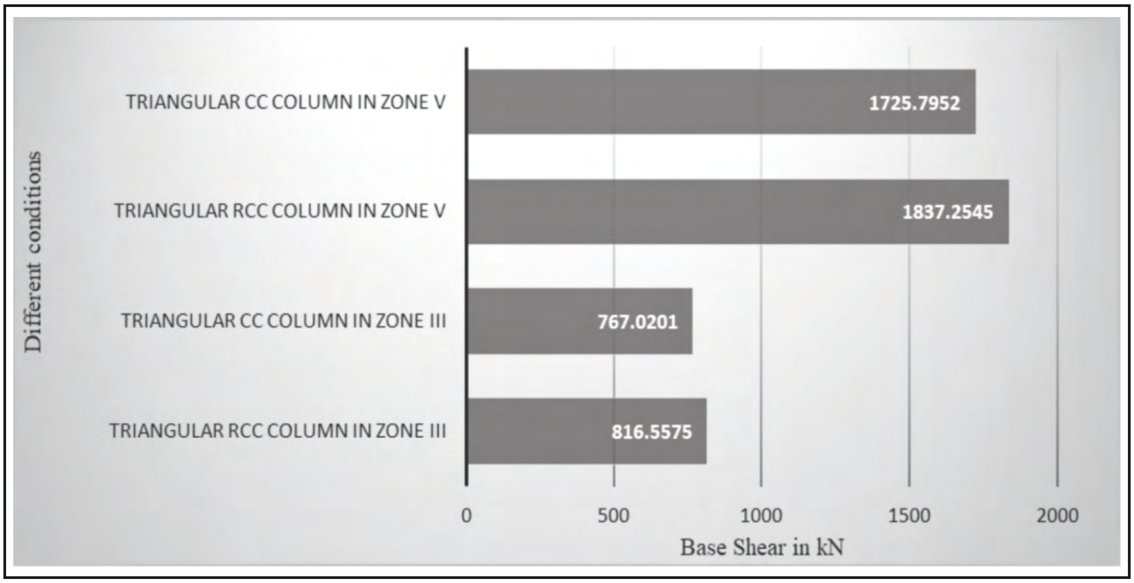

Fig. 13. Base Shear for Triangular Plan

D. Base Shear

Base shear is the maximum expected lateral force that occurs due to seismic ground motion at the base of the structure. It generally depends upon the soil condition at the site. Table IV and Fig. 9 show the base shear of three different building plans using RCC column and composite column.

Fig. 11 to 13 show the variation of base shear in square, L shape, and triangular plan. It is seen the L shape building with RCC column in Zone III is least stable while the best configuration is the square shape building with composite column. Similarly, in case of Zone V the L shape building with RCC column shows maximum base shear. Hence, it is least stable. It is clearly observed from the graph that when composite columns are replaced by RCC column, the base shear is reduced both in zone III and zone V.

V. CONCLUSION

- In all different conditions it is seen that the storey displacements are within permissible limits according to IS code.
- All the storey drifts are within permissible limits, hence the building is safe.
- The use of composite column for multistory building gives better results when compared with RCC columns.
- Storey displacement values for composite columns are almost 20% less when compared with high rise building with RCC column.
- Storey drift values for composite column are 20% less when compared with building using RCC columns.
- Storey shear values for composite column are increased by 10% than the building with RCC columns. Hence, composite columns are giving better results, hence should be much preferred.
- Composite columns are light weight which reduces the dead load of the structure ultimately reducing the weight of the body on foundation. So, from this study it is concluded that composite columns are light in weight, are more economical, and quick in construction.
- From these results, it is seen that square shape plan with composite columns gives least displacement, drift, base shear, and provides maximum stiffness, hence it is the best plan for zone III and zone V when compared with other two plans.

AUTHORS' CONTRIBUTION

Sarmili Swain carried out all the computational investigation under the supervision of Prof. Parhi who helped her by providing the idea about the research topic and helped in review of literature and correction of the manuscript.

CONFLICT OF INTEREST

The authors certify that they have no affiliation with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter, or materials discussed in this manuscript.

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