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Comparative study on CEC and CIC in composite buildings

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ABSTRACT

Construction of steel building is booming in many parts of the world. Composite building consist of steel deck slab, steel beam and composite column. In case of high rise composite buildings, Composite Encased Columns (CEC) or Composite Infilled Columns (CIC) are used. To determine the optimal column from CEC and CIC based on the seismic response and quantity of the material when used in a G+14 composite building is the objective of study. Models of composite building with infilled and encased columns are analyzed and designed using ETABs. Seismic analysis is done by Response spectrum method based on Indian code. Wind analysis is also carried out as per Indian Codes. The software results are analyzed for seismic behavior and the quantity of the material used for CEC and CIC are compared.

Keywords: *Composite infilled column, Composite encased column, Base shear and Lateral displacement.*

1. INTRODUCTION

Dawn of steel in construction industry has optimized the construction process completely. Composite buildings have a complex design and installation process but worth it from economic point of view. In composite buildings, steel deck infilled with concrete is the slab material and the deck slab acts compositely with steel beam. Composite behavior of deck slab and beam is stimulated by shear studs which connects both. Composite columns are used both in case of low-rise and high-rise buildings. For low-rise types, such as warehouses, parking garages, and so on. Composite columns are used in case of high rise buildings due to their load-bearing capacity and seismic and fire resistance. Composite columns are either infilled or encased type.

To understand the behavior of the building with CEC and CIC, ETABs model of composite building is created for each of a column. Composite building of 45m in height is considered to be located in zone 3. Steel bracing is provided for lateral stability. The building is analyzed for seismic effect by response spectrum method and wind loads, both are based on Indian standard codes. Composite columns are designed based on AISC 360:10 as there is no Indian code for design of same.

1.1 Composite Encased Column (CEC)

The Wide flange I-sections encased in concrete and reinforced with rebar are called composite encased columns as shown in fig: 1. Concrete part of the column can have square, rectangle or circular shape.
Advantages:

- Fire resistance because of concrete cover.
- Effective slenderness of steel member is reduced by encasing. This also increases the axial load carrying capacity of the member.
- Corrosion resistance of encased steel section.
- Local buckling of steel section is totally eliminated.
- Composite column will have plastic behavior which increases the load carrying capacity of section.

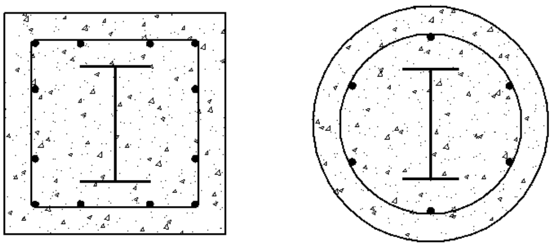

Fig 1: Composite encased column

1.2 Composite Infilled Column (CIC)

Concrete infilled in steel hollow tubes are called composite infilled columns as shown in the fig: 2. Hollow square and hollow circular steel are available for this type of column. They can also be reinforced if required. High strength concrete with low water cement ratio has to be used. These are widely used in Japan. The tubes are painted with fire and corrosion resistant paints.

Advantages:

- Local buckling of steel section is restrained by concrete and concrete strength is increased by confining effect of steel tube.
- Infill columns combine the advantages of stiffness of the concrete structures with the ductility of steel structures.
- No form work is required for the construction of columns.

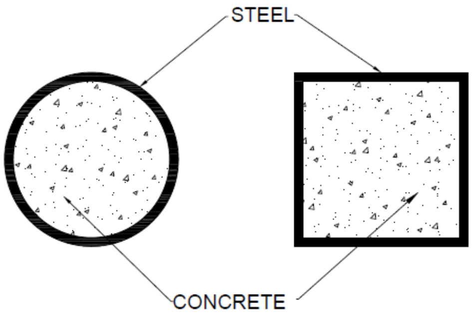

Fig 2: Composite Infilled Column

2. OBJECTIVE

- To study the behavior of composite building with composite encased and infilled column.
- To determine the effective composite building with respect to seismic behavior and quantity when CEC and CIC are used.

3. METHODOLOGY

Study is carried out to understand the behavior of composite building of 45m height (G+14) with composite encased and infilled column. A standard grid of 8m×11m is used. Seismic analysis is carried out by response spectrum method based on IS 1893-2016. Wind analysis is also carried out by IS 875:2015. Model-1 of composite building is created with encased column and Model-2 with infilled column. The lateral stability of the building is achieved by providing lateral steel bracings. Infilled columns were given same square dimensions as that of encased columns i.e. 600mm×600mm and 700mm×700mm. But they could not meet the strength requirement of the building. Thus, the dimensions were increased.

Table 1: Structural Data of building

Plan Dimensions	40m×33m
Height of building	45m
Floor Height	3m
Grade of concrete	Slab-M30; Column-M50
Steel Grade	Rebar-Fe500; I-sections – S350
Deck Slab	Total depth – 130mm Deck depth – 60mm (S350)
Beam (UB sections)	**B1**-UB 452×152×82 **B2**-UB 533×210×92 **B3**-UB 610×229×113 **B4**-UB 533×210×122 **B5**-UB 457×152×52
Bracing (UC Sections)	**D1**-UC 305×305×137 GF to 8th Floor **D2**-UC 254×254×89 8th to 14th Floor
Composite Encased Column	**C1**-600mm×600mm Encased with UC-254×254×167 **C2**-700mm×700mm Encased with UC-305×305×283
Composite Infilled Column	**C1**-700mm×700mm; Tube-13mm all sides **C2**-800mm×800mm; Tube-15mm all sides

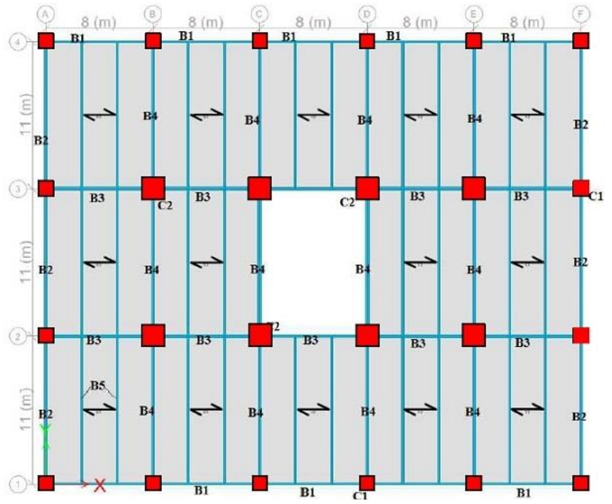

Fig 3: Floor layout of composite building

Table 2: Load data

Seismic Zone	3
Zone Factor	0.16
Reduction Factor	5
Importance Factor	1
Soil Condition	Medium
Wind Speed	50m/s
Damping	5%
Floor Finish	1kN/m^2
Screed	1.1kN/m^2
Partition	1kN/m^2
Live Load	4kN/m^2

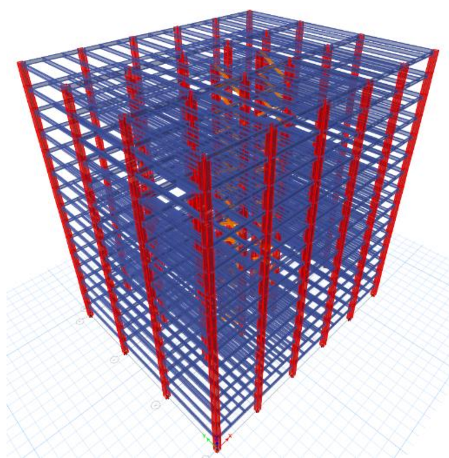

Fig 4: 3D model of building.

4. COMPARISON OF RESULTS

Two models are analyzed and designed using ETABs. Designs are verified by manual calculations. Software and manual calculations of design are on par with each other. The results are analyzed and compared to determine better model.

Table 3: Results

	Model-1	Model-2
Maximum Base Shear (kN)	6756.654	5798.939
Maximum Story Displacement (Seismic Case) (mm)	110	83
Maximum Story Displacement (Wind Load) (mm)	61	54
Fundamental Time Period	3.395	3.208
Storey Stiffness (kN/m)	216511.329	233995.163
Utilization Factor	0.486	0.379

4.1 Maximum Base Shear

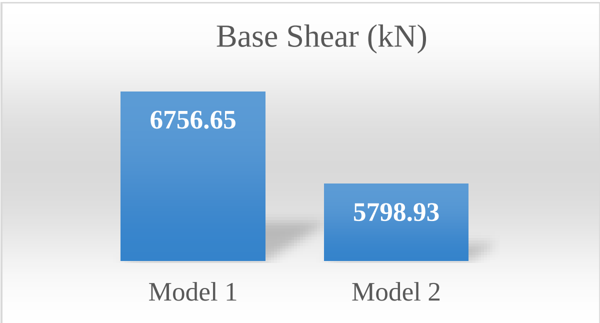

Fig 5: Comparison of Base shear

Base shear of Model-2 is 16.5% lesser when compared to Model-1.

4.2 Lateral Displacement

Permissible limits for the lateral displacement of the building are:

$$Permissible\ Limit = \frac{H}{250} = 180mm\ (Seismic) \ldots (1)$$

$$Permissible\ Limits = \frac{H}{500} = 90mm\ (Wind) \ldots \ldots (2)$$

Based on (1) and (2) it is clear that both models are within the permissible limits in case of lateral displacements. Displacement in seismic case for Model-2 is 32.5% less than Model-1. And in wind load case Model-2 is 13% less than Model-1.

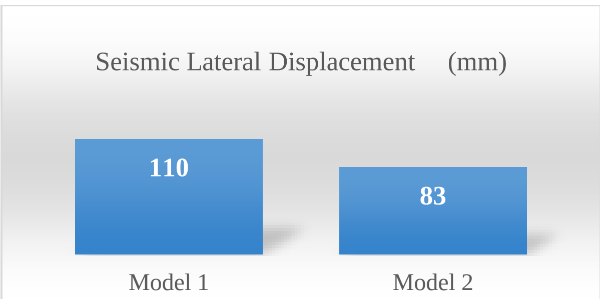

Fig 6: Comparison of Seismic lateral displacement

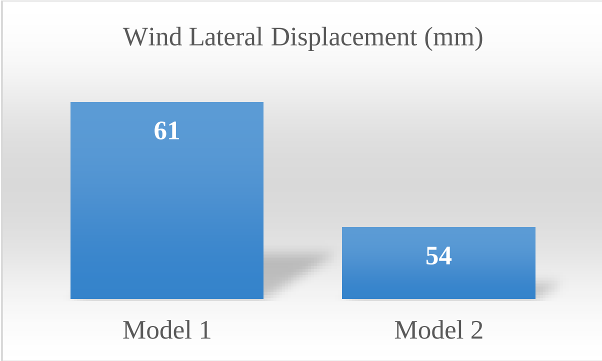

Fig 7: Comparison of lateral displacement due to wind load

4.3 Fundamental Time Period

Model-1 has higher fundamental time period compared to Model-2. They differ by 0.187 seconds. Higher the fundamental time period higher flexibility of structure. So Model-1 is flexible than Model-2.

4.4 Storey Stiffness

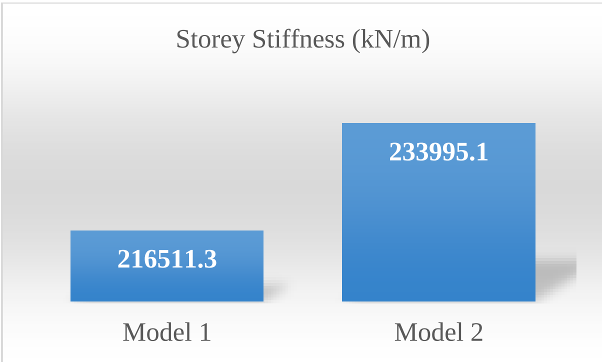

Fig 8: Comparison of storey stiffness

From the graph, it is clear that Model-2 is much stiffer than Model-1.

4.5 Utilization Factor

Utilization factor is weighted average of PMM ratio of all the members of an element. This indicates the factor of the material strength utilized. The utilization factor of encased column is more than that of the infilled column (From table-3).

4.6 Quantity Comparison

Table 4: Estimation of Quantity

Column Type	Material	Quantity
Composite Encased Column (CEC)	Concrete (m^3)	428.86
	Steel I-section (tons)	237.15
	Rebar (tons)	70.03
Composite Infilled Column (CIC)	Concrete (m^3)	580.536
	Steel tube (tons)	367.09

From table 4, it can be stated that the quantity of steel and concrete in case of composite infilled column is more compared to composite encased columns.

5. CONCLUSION

The conclusions of study conducted on composite building with CEC and CIC designed and analyses using ETABs software are:

- Base shear and lateral displacement of a building with encased column is higher than that of same building with infilled column. So with respect to lateral loads composite building with infilled columns will have a better behavior.
- The stiffness of composite building with infilled column is higher.
- Composite building with infilled columns are rigid compared to buildings with encased column.
- Smaller dimensions of encased columns can provide the required resistance compared to infilled column.
- Quantity of the material of steel and concrete is higher in case of infilled columns.
- Construction time for CIC is comparatively less as no shuttering and rebar arrangement is required.

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