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Seismic Analysis of Irregular Composite Structures with Shear Connectors using ETABS

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ABSTRACT

In this paper, an attempt is made to study the effect of stud shear connector in composite structures and is compared with the conventional RCC structure. RCC and steel constructions have made incredible developments in India for the last decades. These concrete and steel constructions may undergo certain deteriorations due to some defect in material properties, weaker bond strength or subjected to overloading if years pass by. Here is where the shear connectors plays a major role in composite structures. This study is carried out on plan irregular structures with medium rise building of 10-storey. Modelling and analysis has been done to estimate the behavior of shear connector in plan irregular structures and is compared with RCC structures. Its variation with respect to RCC structure is found to choose a best construction method. The parameters considered are storey displacement, base shear, storey drift, stiffness, axial force in columns, shear force in beams and mass of the structure. The provisions of IS-11384 1985 is considered. The seismic behavior of these structures is evaluated by Response spectrum analysis with the help ETABS V 16. The result shows that the composite structures have bright future in India in the area of construction of any plan irregular structures.

Keywords: Headed stud connector, Composite construction, irregular structures, response spectrum analysis, ETABS

I. INTRODUCTION

Steel-Concrete Composite construction is a well-established construction method for some decades which is an alternative method to steel and concrete constructions. While comparing to other developing countries, the use of steel in construction is very low due to its cost. But the steel has many good properties that it can be provided for large spans, high strength/weight ratio, high tensile strength and ductility. These properties of steel is mixed with the good properties of concrete such as the resistance to heat, corrosion, buckling and its high compressive strength makes the Composite Construction to be accepted by the world. In order to increase the ductility the stiffness should be reduced then only it will become flexible. The stiffness is directly proportional to the mass (according to Newtons Law and Hooke's Law). So the mass is reduced by using composite construction. In addition to that lesser cost and speedy construction are also provided by them. Steel-concrete composite systems for buildings are formed by connecting the steel beam to the concrete slab with the help of mechanical shear connectors (Headed Stud Connector) so that they act as a single unit. In the present work, Steel-Concrete composite construction is compared with RCC construction for a symmetrical, bilateral symmetrical and asymmetrical commercial building based on IS-11384 1985.

In this study symmetrical, bilateral symmetrical and asymmetrical plans of building having same floor area with 10-storey were considered. The variation of parameters of composite structure with respect to RCC structure are recorded with the help of finite element analysis in ETABS software. Thus the suitability of composite construction method in low rise, medium rise and high rise building can be verified.

II. COMPOSITE CONSTRUCTION

For making a single unit, the steel member and concrete member is combined with the help of shear connector. So the higher compressive strength of concrete and higher tensile strength of steel is combined. Hence the property of the composite member is enhanced by utilizing the properties of steel and concrete. The main elements of composite constructions are composite deck slab, composite column and shear connector.

1. Composite Deck Slab

Composite deck slab comprises of steel beams, shear connector and concrete slab. In general a steel beam (I section) is coupled with concrete slab by using shear connector. This composite deck slab acts as a rigid diaphragm providing solidity to the structure in addition to that it distributes wind loads, earthquake loads and horizontal shear to the composite frame system. An example for composite deck slab is shown in figure 1.

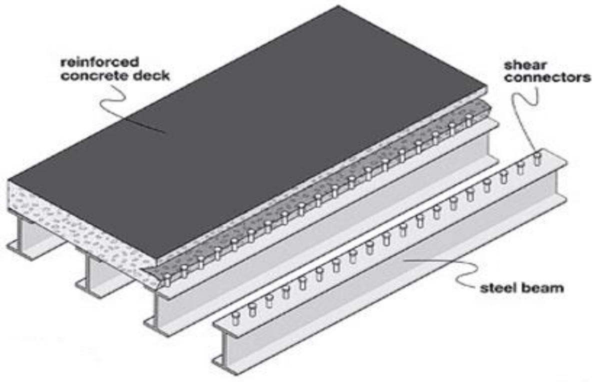

Figure 1: Composite deck slab [1]

2. Composite Column

A member consisting of both steel and concrete elements can be termed as steel-concrete composite columns. In composite columns, friction and bond are the two parameters makes the steel and concrete elements to act as a single unit. While compared with RCC columns, the composite columns have less cross sectional area and light weight. Due to this the usable floor area is increased and the foundation cost decreased. The composite column can be classified as concrete encased, concrete filled, battered section. The type of composite columns are shown in figure 2.

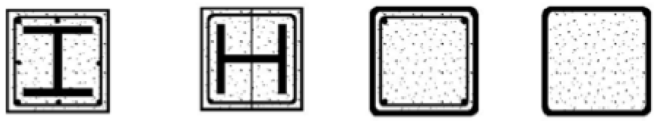

Figure 2: Types of composite column [1]

2. Shear Connector

Shear connector is defined as welded stud, spiral bar, short length of channel or any other similar connector that resists horizontal shear between the components. Thus incorporating shear connectors at the joints (i.e. Beam to beam connection or at beam to column connection or slab to beam connection) ensures that the composite structure acts monolithically in taking up loads. Shear connectors makes the joints stable to take up horizontal loads. So providing of shear connectors helps the structure to take up both vertical load and horizontal shear thus reduces the probability to fail due to seismic forces. The most preferably used connector is the headed stud connector which is shown in figure 3. Headed stud connectors are also termed as “Nelson stud connectors”. They have shown a good shear resisting property and flexural property under seismic loading. The anchoring property of headed stud connectors is comparatively good. Placing of transverse reinforcement is so easy when comparing with other type of shear connectors. This is the reason why the headed stud connectors are preferred than other type of shear connectors. IS-11384 provides the codal provisions for stud shear connector.

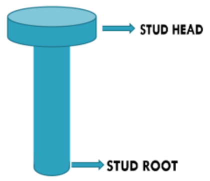

Figure 3: Shear connector

III. METHODS AND MATERIAL

A. Modelling and Analysis

A 10-storeyed composite structure with shear connector having irregular plan such as bilateral symmetrical and asymmetrical is compared with symmetrical structure and its variations for considered parameters with respect to RCC structure in Seismic Zone V has been considered for the study. The models are shown in figure 4 to figure 6. The three structural plan of same area is considered with bay size of 5m in X-direction and 4m in Y-direction. The building configuration for RCC structure is shown in Table 1 and for composite structure is shown in Table 2. The stud used for composite used for symmetrical and bilateral symmetrical structure is not suitable for asymmetric structure since it fails due to shear. The specifications for deck slab used for symmetric and bilateral symmetric structure is shown in Table 3 and for symmetrical structure is shown in Table 4. The load assigned and seismic data's considered for this study is shown in Table 5 and Table 6.

Table 1: Building configuration for RCC structure

Size of beam	500mm x 500mm
Size of column	250mm x 450mm
Thickness of slab	125mm
No. of storey	10
Height of each storey	3m
Grade of steel	Fe415
Grade of concrete	M30
Shear wall thickness	230mm

Table 2: Building configuration for composite structure

Size of beam	4m – ISMB250 5m – ISMB200
Size of column	ISHB250 embedded in RCC column of 400mm x 400mm
Type of slab	Deck Slab
No. of storey	10
Height of each storey	3m
Grade of steel	Fe415
Grade of concrete	M30
Shear wall thickness	230mm

Table 3: Properties of Deck slab for symmetrical and bilateral symmetrical structure

Thickness of deck slab	120 mm
Height of the stud	62 mm
Diameter of the stud	12 mm
Load per stud	23 kN

Table 4: Properties of Deck slab for asymmetrical structure

Thickness of deck slab	125 mm
Height of the stud	100 mm
Diameter of the stud	25 mm
Load per stud	86 kN

Table 5. Loads assigned

Dead load	As per structure
Wall load	10kN/m
Floor Finish	1.5kN/m^2
Live load	For roof – 1.5kN/m^2 For slab – 4kN/m^2

Table 6: Seismic data considered

Seismic zone	V
Zone factor, Z	0.36
Type of soil	Medium
Damping	5 %
Response reduction factor (R)	5
Importance factor (I)	1.5

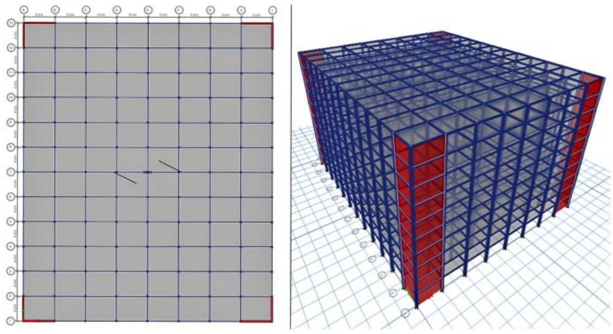

Figure 4: Plan and 3D view of the symmetrical structure

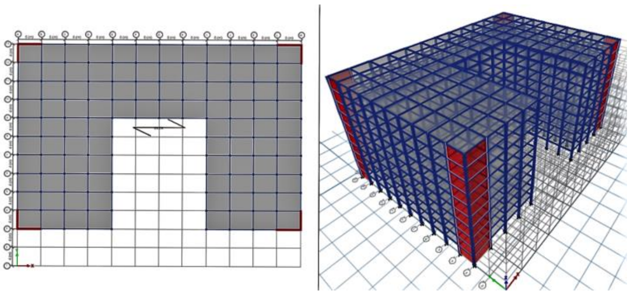

Figure 5: Plan and 3D view of the bilateral symmetrical structure (C-shaped structure)

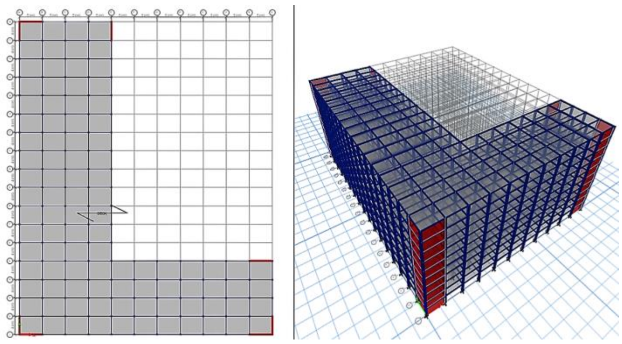

Figure 6: Plan and 3D view of the symmetrical structure(L shaped structure)

IV. RESULTS AND DISCUSSION

A. Storey Dispacement

Lateral movement of the structure due to the lateral force is said to be storey displacement. Flexible structures experiences only less acceleration under earth quake. The maximum displacement at the top storey for composite and RCC in X-direction is given in Table 7 and in Y-direction is given in Table 8.

Table 7: Storey displacement along X-direction

	RCC	Composite
Symmetrical	20.30mm	29.82mm
Bilateral Symmetrical	16.02mm	21.54mm
Asymmetrical	18.90mm	27.90mm

Table 8: Storey displacement along Y-direction

	RCC	Composite
Symmetrical	17.50mm	25.43mm
Bilateral Symmetrical	16.67mm	23.09mm
Asymmetrical	17.50mm	22.70mm

The variation of displacement in composite structure with respect to RCC structure is 26% to 32% more in X-direction and 23% to 31% more in Y-direction shows composite structures are more flexible than RCC structures.

B. Storey Stiffness

The flexible structures should have less stiffness then only it can bear more lateral displacement. So the stiffness should be reduced. The max stiffness at the bottom storey is tabulated in Table 9 for X-direction and Table 10 for Y-direction.

Table 9: Storey stiffness along X-direction

	Stiffness in kN/m	
	RCC	Composite
Symmetrical	902260.5	366465.8
Bilateral Symmetrical	9141477	5386504
Asymmetrical	9034210	6557604

Table 10: Storey stiffness along Y-direction

	Stiffness in kN/m	
	RCC	Composite
Symmetrical	952102	346012
Bilateral Symmetrical	9613590	5825494
Asymmetrical	8051594	5712628

The variation of stiffness in composite structure with respect to RCC structure is 27% to 59% less in X-direction and 29% to 64% less in Y-direction shows composite structures are more flexible than RCC structures.

C. Storey Shear

It is the total lateral force expected at the base at the time of earthquake. So the good earthquake resistant construction should have less storey shear. The maximum storey shear for RCC and composite structure are tabulated in Table 11 along X-direction and Table 12 along Y-direction.

Table 11: Storey shear along X-direction

	Storey shear in kN	
	RCC	Composite
Symmetrical	5936.68	3392.17
Bilateral Symmetrical	6024.95	3435.66
Asymmetrical	8889.14	3109.96

Table 12: Storey shear along Y-direction

	Storey shear in kN	
	RCC	Composite
Symmetrical	5723.46	3165.84
Bilateral Symmetrical	5812.88	3226.20
Asymmetrical	9110.65	3042.83

The variation of storey shear in composite structure with respect to RCC structure is 43% to 65% less along X-direction and 44% to 67% less along Y-direction shows composite structures are suitable for earthquake resistant construction than RCC structures.

D. Axial force in column

A column is designed based on the total axial force acting on the column. The size of the column can be reduced by reducing axial force and hence the materials is also saved. The axial force for an exterior column having max. Axial force in composite structure is compared with the same column in RCC structure and is Tabulated in Table 13 and its variation is plotted in Figure 7.

Table 13: Axial force in column

	Axial force in kN	
	RCC	Composite
Symmetrical	1970.00	1704.00
Bilateral Symmetrical	1597.63	932.97
Asymmetrical	2130.36	1419.06

The variation shows that in composite structure the axial force is reduced to 14%-42% with respect to RCC structure.

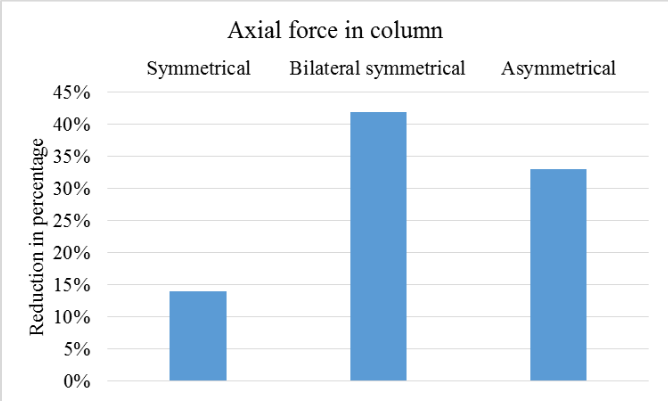

Figure 7: Reduction in axial force

E. Storey Drift

It is the relative displacement of two adjacent storeys. Drift depends upon the displacement. The drift in X-axis is plotted in Figure 8 and Y-axis in Figure 9.

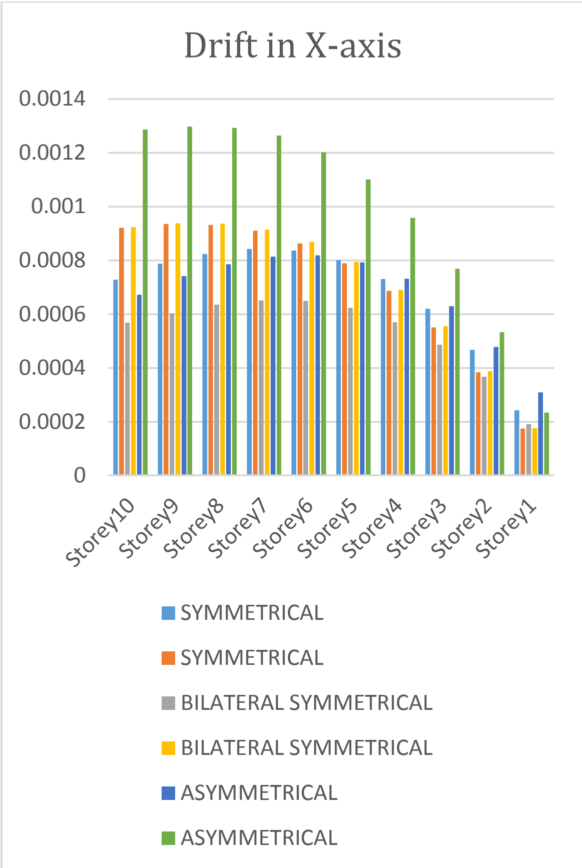

Figure 8: Drift along X-direction

The drift value for composite structures is higher than RCC structures but, it is within the limit. Since the displacement value of composite structures is large, then its drift value also increases. Hence the composite structures shows larger variation than RCC structures

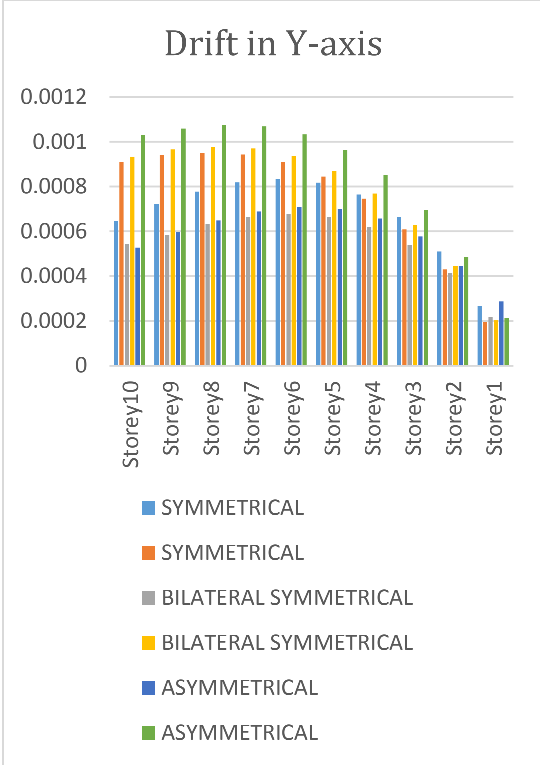

Figure 9: Drift along Y-direction

F. Shear force in beams

The main objective of providing shear connector is to reduce the horizontal shear acting on the beam and to save the beam from shear failure. The shear force for an exterior beam having maximum shear force in composite structure is compared with the same beam in RCC structure and its value is tabulated in Table 14 and is plotted in figure 10.

Table 14: Shear force in beam

	Shear force in kN	
	RCC	Composite
Symmetrical	56.16	46.58
Bilateral Symmetrical	49.29	19.51
Asymmetrical	38.63	33.19

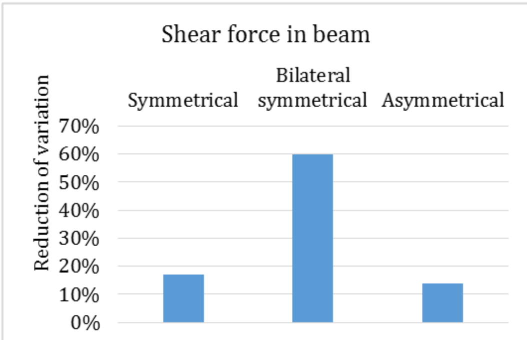

Figure 10: Reduction in shear force

The shear force in beams is reduced by 14% to 60% shows that composite structure is safe from failure due to shear.

G. **Self-mass of structure**

In order to reduce stiffness and base shear the mass should be reduced. By reducing mass the construction should become economical. The self-mass for RCC and Composite are tabulated in Table: 14 and is plotted in Figure 11.

Table 15: Self mass of structure

	Self-mass in kg	
	RCC	Composite
Symmetrical	11411459.8	8322489.8
Bilateral Symmetrical	14892125	8438591
Asymmetrical	12641448	8438767

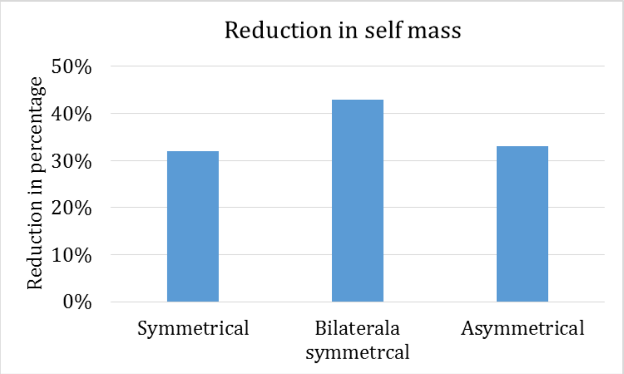

Figure 11: Reduction in self-mass

The variation in mass for composite structure with respect to RCC structure shows that the possibility to reduce the mass by 27% to 43%.

V. CONCLUSION

From this study the following conclusions were made:

1. The composite structures have large lateral displacement than RCC structure which is around 23% to 32% shows that it is more flexible.
2. Composite structure has reduced stiffness to make the structure flexible. The reduction of about 27% - 64% with respect to RCC structure.
3. The storey shear is reduced by 43% to 67% with respect to RCC structure shows composite structure is suitable for earthquake resistant constructions.
4. The drift is large in composite due to large displacement but it is within the limit.
5. Axial force in the column is reduced by 14% to 42% shows that the usable floor area can be increased, due to reduction in column size.
6. The shear force in the beam is reduced by 14% to 60% shows that composite structure is safe from shear failure.
7. The self-mass of the composite structure is reduced by 27% to 43%. Hence the stiffness and base shear is reduced and made the structure more flexible and economical.
8. The effect of shear connector in composite structure made composite structure more advantageous than RCC structure. Hence it is clear that the composite construction is an alternative method for construction industry and it has a bright future in India.

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