

# Seismic Analysis of Irregular Composite Structures with Shear Connectors using ETABS

Muhammed Sabith K, Dr. Sabeena M. V.

Department of Civil Engineering, AWH Engineering College, Kozhikkode, Kerala, India

## 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.

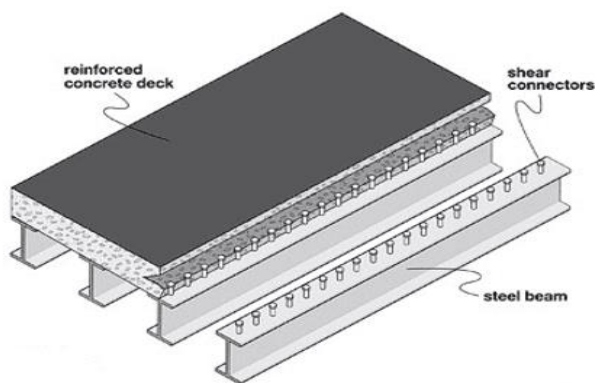


Figure 1: Composite deck slab [1]

### 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.

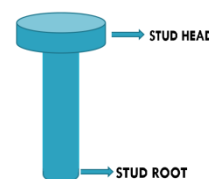


Figure 3: Shear connector

## 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<br>5m – ISMB200                          |
| Size of column        | ISHB250 embedded in<br>RCC column of<br>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

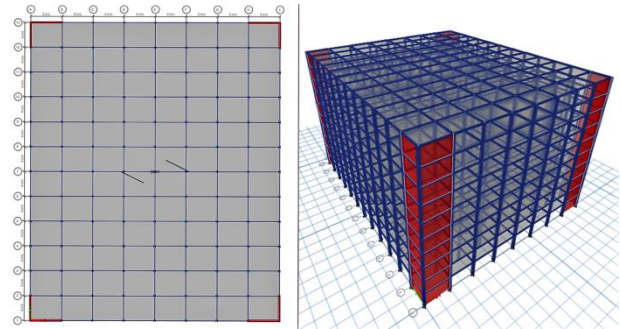
|                        |        |
|------------------------|--------|
| Thickness of deck slab | 125 mm |
| Height of the stud     | 100 mm |
| Diameter of the stud   | 25 mm  |
| Load per stud          | 86 kN  |

**Table 5.** Loads assigned

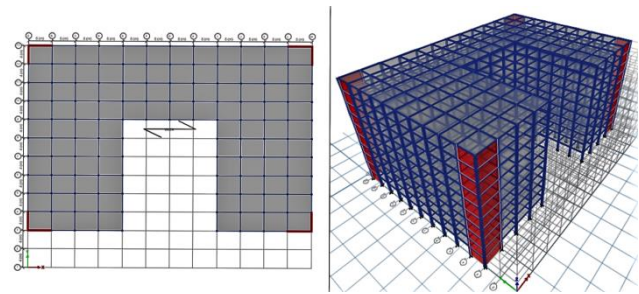
|              |                                                                  |
|--------------|------------------------------------------------------------------|
| Dead load    | As per structure                                                 |
| Wall load    | 10kN/m                                                           |
| Floor Finish | 1.5kN/m <sup>2</sup>                                             |
| Live load    | For roof – 1.5kN/m <sup>2</sup><br>For slab – 4kN/m <sup>2</sup> |

**Table 6:** Seismic data considered

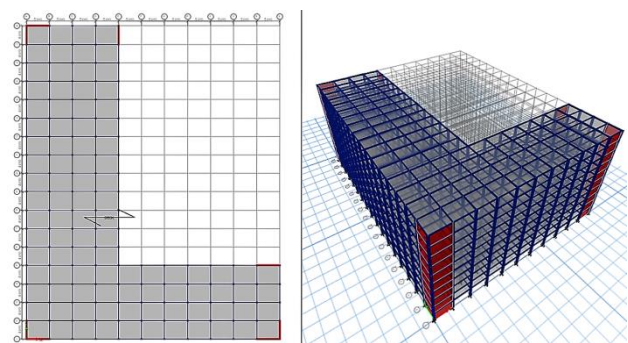
|                               |        |
|-------------------------------|--------|
| Seismic zone                  | V      |
| Zone factor, Z                | 0.36   |
| Type of soil                  | Medium |
| Damping                       | 5 %    |
| Response reduction factor (R) | 5      |
| 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 Displacement

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.

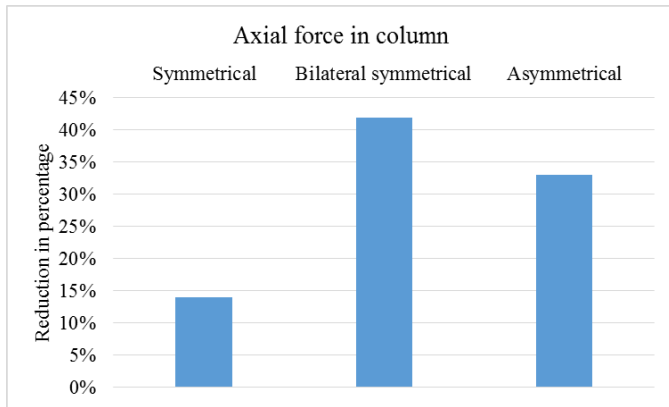
### D. Axial force in column

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   |

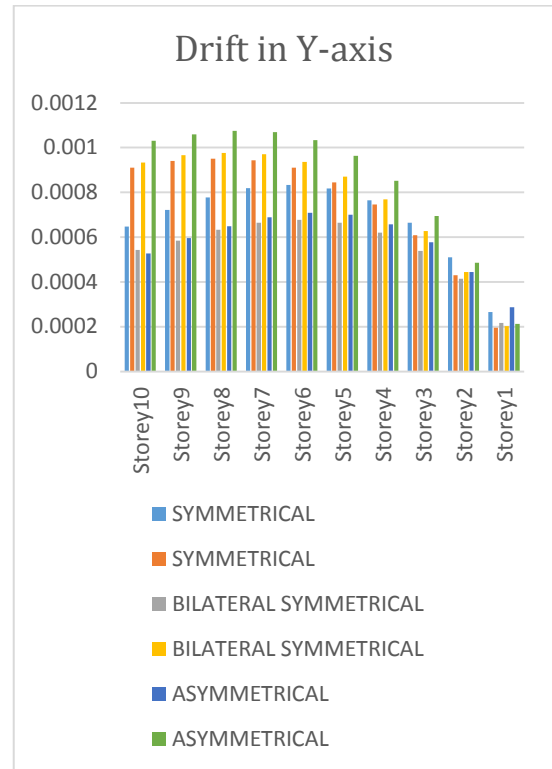
The variation shows that in composite structure the axial force is reduced to 14%-42% with respect to RCC structure.



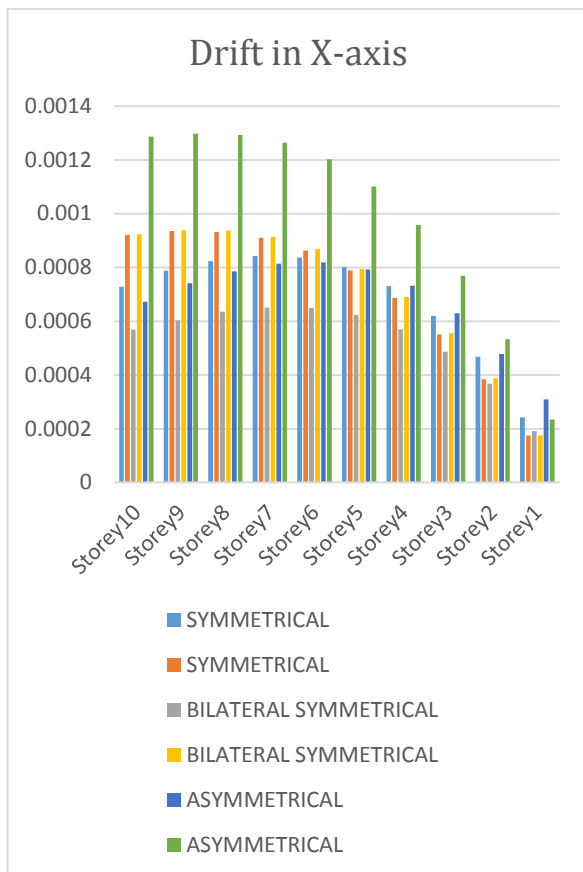
**Figure 7:** Reduction in axial force

### 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 9:** Drift along Y-direction



**Figure 8:** Drift along X-direction

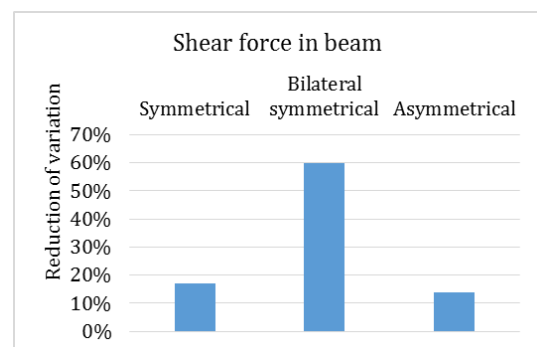
The drift value for composite structures is higher than RCC structures but, it is within the limit. Since the displacement value of composite structures is large, then its drift value also increases. Hence the composite structures shows larger variation than RCC structures

### 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

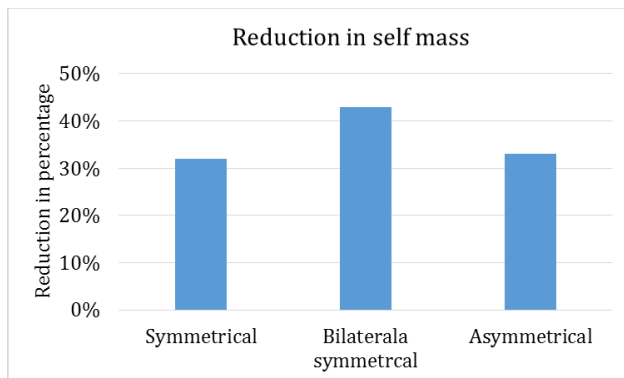
The shear force in beams is reduced by 14% to 60% shows that composite structure is safe from failure due to shear.

## 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.

## VI. REFERENCE

- [1] K. Mukesh Kumar and H. Sudarsana Rao, 2013, Seismic Analysis of Steel Concrete Composite System and its Contrast with RCC Structures, International Journal of Science and Research, 5, 2319-7064.
- [2] Mr. Nitish A. Mohite, Mr. P.K.Joshi, Dr. W. N. Deulkar, 2015, Comparative Analysis of RCC and Steel-Concrete Composite (B+G+ 11 Storey) Building, International Journal of Scientific and Research Publications, Vol 5, 10.
- [3] Harikrushna Kapadia, Gunvant Solanki And Hitesh Dhameliya, 2015, Comparison Between R.C.C And Composite Structure Of (G+3) Industrail Building , International Journal of Advance Engineering and Research Development , 12,116-150.
- [4] Nitin M. Warade and P. J. Salunke, 2013, Comparative study on analysis and design of composite structure, International Journal of Advance Research in Science and Engineering, 3, 12,166-172.
- [5] Panchal D. R and Marathe P. M. ,2013, Analysis, Design And Modelling Of The Seismic Behaviour Of R.C.C, Steel & Composite (G+30 Story) Building, 4th ECCOMAS Thematic Conference On Computational Methods In Structural Dynamics And Earthquake Engineering, Greece, 12-14 .
- [6] Shashikala. Koppad and Dr. S.V.Itti, 2013, Comparative study of rcc and composite multistoreyed buildings, International Journal Of Engineering And Innovative Technology , 3, 256-272.
- [7] Sattainathan.A and Nagarajan.N, 2015, Comparitive study on the behavior of R.C.C, Steel & Composite Structures (B+G+20 storeys),

- International Journal on Applications in Civil and Environmental Engineering , 3 ,21-26.
- [8] Umesh P. Patil and Suryanarayana M, 2015, Analysis of g+15 rcc and composite structure having a soft storey at ground level by response spectrum and equivalent static methods using etabs 2013 , International Research Journal of Engineering and Technology ,2, 2395-0072.
- [9] Abhishek Sanjay Mahajan and Laxman G. Kalurkar, 2016, Performance Analysis Of RCC And Steel Concrete Composite Structure Under Seismic Effect, International Journal of Research in Engineering and Technology, Vol 05 ,4.
- [10] M.Pavithra, Kiran Chavan Keraba and A.Arun Kumar,2015, Comparative Study of R.C.C, Steel Composite Structure with Mechanical Shear Connectors Under Seismic Loading , Vellore Institute of Technology,Vellore.
- [11] Khaja Rasool Thagaragunta and M. Helen Santhi, 2014, Analysis and Design of a G+7 storeyed Precast Building, Vellore Institute of Technology, Vellore.
- [12] Ali Shariati, N. H. RamliSulong, MeldiSuhatri and Mahdi Shariati, 2012, various types of shear connectors in composite structures: A review, International Journal of Physical Sciences, 22, 2876-2890.
- [13] Mohammad Makki Abbass ,Ayad S. Adi , B. S. Karkare, 2014, Strength Model for Shear Stud , International Journal of Application or Innovation in Engineering & Management , Vol 3, 6.
- [14] Vijaya Sarathy,R, Jose Ravindraraj,B, Geetha, Vijayakumar, 2015, Experimental Investigation on Effect of Shear Connector In Light Weight Concrete, International Journal of Civil Engineering and Technology, 6, 5.
- [15] Dr.D.Vijayalakshmi and Dr.D.Tensing, 2014, An Experimental Study on Steel Concrete Composite Beams with Shear Connectors under Pure Torsio, International Journal of Emerging Technology and Advanced Engineering ,4,3
- [16] Hozaif S. Vohra and Mazhar Dhankot, 2015, Shear Connectors and Composite Deck Slab Experimental Study – State of the Art Review , International Journal of Scientific Engineering and Research, 3, 2347-3878.
- [17] Sameera Wijesiri Pathirana, Brian Uya, Olivia Mirza , Xinqun Zhub, 2016, Strengthening of existing composite steel-concrete beams utilising bolted shear connectors and welded studs, Journal of Constructional Steel Research ,114 ,417– 430.
- [18] Prerana M Choradiya and Popat D Kumbhar, 2015, Behavior of Concrete Deck Slab Using Shear Connectors: A Review, International Journal of Innovative Research in Science, Engineering and Technology, Vol 4, 12.
- [19] Jorge Douglas Bonilla Rocha, Enrique Mirambell Arrizabalaga, Rafael Larrúa Quevedo , Carlos A. Recarey Morfa, 2012, Behavior and strength of welded stud shear connectors in composite beam, Rev. Fac. Ing. Univ. Antioquia, 63 , 93-104.
- [20] Jorge Douglas Bonilla Rocha , Luciano M. Bezerra , Rafael Larrúa Quevedo, 2015, Study of stud shear connectors behaviour in composite beams with profiled steel sheeting , Revista de la Construcción Journal of Construction , Vol 3 , 14.
- [21] Jae Yoon Kang, Jong Sup Park, Woo Tai Jung, Moon Suing Keum, 2014, Evaluation of the Shear Strength of Perfobond Rib Connectors in Ultra High Performance Concrete, Scientific Research Publishing , Vol.6 , 989-999 .
- [22] Ling-Zhu Chen, Gianluca Ranzi, Shou-Chao Jiang, Faham Tahmasebinia, Guo-Qiang Li, 2015, Behaviour and design of shear connectors in composite slabs at elevated temperatures ,Journal of constructional Steel Research, 115, 387–397.
- [23] Daniel de Lima Araújo, Marcel William Reis Sales, Silenio Marciano de Paulo, Ana Lúcia H. de Cresce El Debs, 2016, Headed steel stud connectors for composite steel beams with precast hollow-core slabs with structural topping, Engineering Structures ,107 ,135–150.
- [24] D. R. Panchal and P. M. Marathe, 2011, Comparative Study of R.C.C, Steel and Composite (G+30 Storey) Building , Institute Of Technology, Nirma University, Ahmedabad, 08-10.
- [25] Mustapha Muhammad Lawan ,Mahmood Md. Tahir, Jahangir Mirza, 2016, Bolted Shear Connectors Performance in Self-Compacting Concrete Integrated with Cold-Formed Steel Sectio , Latin American Journal of Solids and Structures ,13,731-749.
- [26] IS11384:1985 ,Code of practice for composite construction structural steel and concrete ,BIS, New Delhi
- [27] IS3935:1966, Indian code of practice for Composite construction, BIS, New Delhi.
- [28] IS456: 2000 ,Indian code of practice for plain and RCC, BIS, New Delhi.
- [29] IS800: 2007 ,Indian Code of Practice for General construction in steel, BIS, New Delhi.