

Flexural and Shear Response of Concrete Encased Steel Beams

Neelima Khare¹, V. S. Shingade²PG Student, Department of Civil Engineering, Trinity College of Engineering and Research, Pune, India¹Assistant Professor, Department of Civil Engineering, Trinity College of Engineering and Research, Pune, India²

ABSTRACT: This study investigates the behavior of structural properties composite steel and concrete beams in which rolled steel sections are used as bottom reinforcement. Rolled steel sections are used as an alternative to normal tmt steel reinforcement. Such arrangement of composite beams are proving better alternative in high rise construction. Major parameters investigated are ultimate flexure and shear strength of beams. To predict the accuracy of proposed study experimental analysis was performed. The comparison between normal tmt steel as main reinforcement and rolled steel section as main reinforcement was carried out. The constant parameters included in this study are percentage of steel, cross sectional area of beam, grade of concrete – M20. The variable parameter included is spacing of stirrups. The effect of change in stirrups spacing was studied experimentally. From the load – deflection relationship it was found that, the performance of beams with rolled steel sections as main reinforcement was better as compared to beams with normal tmt steel as main reinforcement. Also concrete encased steel beams are effective in enhancing the load carrying capacity of beams. This increases the ductility and hence reduces the weight of structure. which in turn reduces lateral forces due to earthquake.

KEYWORDS: Composite beams, rolled steel sections – angle section and channel section, flexure and shear strength.

I. INTRODUCTION

When concrete and steel are combined together they form a composite member. The composite construction has gained importance due to its ability to combine the advantage of steel and concrete. Concrete is best utilized in compression and steel in tension. As concrete is incapable of resisting tensile load and steel section that are slender are most likely to undergo buckling under critical load. But when combined together to form composite member their individual weakness are overcome both their strength are utilized fully to increase the strength, stiffness and durability of the structure. The most widely used application of composite construction is in the construction of bridges and high rise construction. High rise structure in earthquake prone area are subjected to lateral loads along with gravity loads. Hence ductility of such structure plays important role. It can be achieved to some extent by reducing the self weight of the structure which in turn reduces loss or damage due to earthquake forces to great extent. Usually conventional practice is to use normal tmt steel as bottom reinforcement in beams. But if we replace the normal tmt steel with rolled steel angle section and channel sections then following advantages in composite beams can be achieved:

- The strength and load carrying capacity is increased for the same cross sectional area.
- Good fire resistance and corrosion protection can be achieved.
- It will be more economical for the same span and loading.
- Depth and weight of beam is reduced, hence giving more head room to the buildings.
- Large column free space can be covered.
- Deflection is less as stiffness is increased.
- Construction is faster.

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II. AIMS AND OBJECTIVE

Aim:

To study the effect of rolled steel section – angle section and channel sections as main reinforcement on beams under shear and flexure.

Objective:

- Study of confinement of concrete by stirrups in composite beam with rolled steel section and beams with normal tmt steel
- To study effect of Rolled steel angle section and channel section as main reinforcement on ultimate load carrying capacity and deflection.

The variables parameter included in this study is:

- Spacing of Stirrups i.e. confinement effect.

The Constant parameters included in this study are as follow:

- Percentage of steel
- Cross sectional area of member
- Grade of concrete – M20

Beams:

- Size of beam adopted: 150 mm x 150 mm x 700 mm.
- Breadth (b) = 150 mm
- Depth (D) = 150 mm
- Effective depth = $150 - 25 - (12/2) = 119$ mm

Nomenclature:

Following members are recognized for experimental investigation:

- **N Beams:** Members with Normal ie. Conventional tmt steel reinforcement.
- **A Beams:** Members with rolled steel Angle sections as reinforcement.
- **C Beams:** Members with rolled steel Channel sections as reinforcement.

III. EXPERIMENTAL WORK

In the present work, rolled steel angle sections are used in the members as bottom reinforcement. Also normal tmt steel is used as bottom reinforcement. The percentage of steel and the cross-sectional area are kept same in the composite section and in the conventional section.

1. First of all, cubes were casted and cured for 28 days and thereafter tested under compression testing machine to obtain required compressive strength of concrete.
2. Formwork was prepared for beams and cage of reinforcement was placed maintaining the clear cover as per design.
3. The spacing of stirrups ie confinement effect was maintained for 50 mm spacing and 100 mm spacing.
4. The concrete was mixed thoroughly as per the mix design, placed and compacted immediately after mixing.
5. Samples were kept for setting for 24 hrs.
6. After setting the samples were cured for 28 days.
7. Members were tested on universal testing machine. Their failure load and deflection are noted. For this purpose, the criteria included is maximum and minimum tension reinforcement in beams as per clause 25.6 of IS 456-2000.

IV. TESTING OF BEAMS

All types of beams were tested in UTM machine. The two point load was applied at the middle third portion of the beam. The load was applied gradually and crack pattern was observed. Load at first crack, yield load and failure load along with corresponding deflection were observed. Graph of load v/s deflection was plotted. Hence the load carrying

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capacity and their corresponding deflections were studied for beams with rolled steel sections as main reinforcement. Table 1 below shows various parameters considered for experimental programme

TABLE I

Type of Beam	N	A	C
Bottom Reinforcement	2 #12	2 # ISA 20 x 20 x 3	3 # Channels 20 x 7 x 3
Area of tension reinforcement (mm ²)	226	224	252
Top reinforcement	2 # 8	2 # 8	2 # 8
Stirrups	2 legged 8 mm dia	2 legged 8 mm dia	2 legged 8 mm dia
Stirrups Spacing(mm)	50 & 100	50 & 100	50 & 100
No. of samples casted	6 nos.	6 nos.	6 nos.

Comparison between N and A Beams:

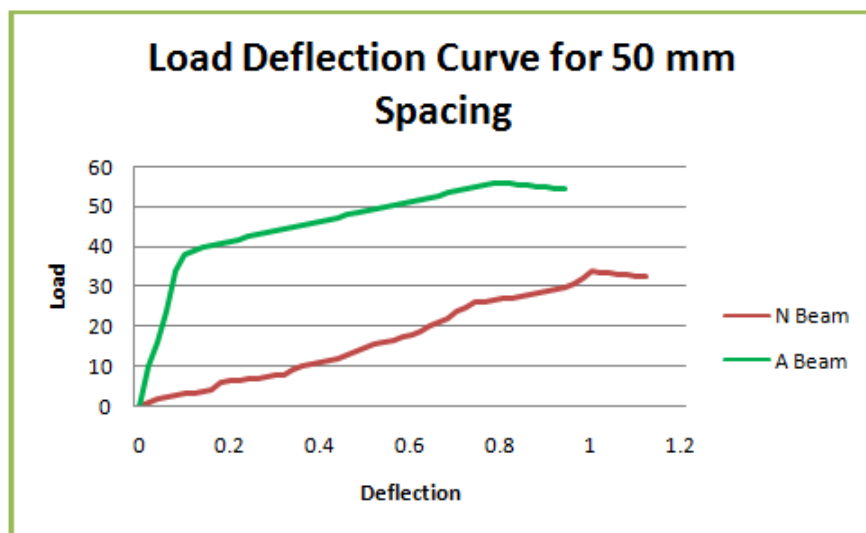


Fig. 1 Load – Deflection curve for N and A Beams for 50 MM spacing

For 50 mm spacing specimen, the N Beam failed at a load of 34 kN and first crack was developed at a load of 25 kN. The corresponding maximum deflection was 1.0 mm. The A Beam specimen failed at a load of 56 kN and first crack was developed at a load of 38 kN. The corresponding maximum deflection was 0.8 mm. The load carrying capacity is increased by 64.7 % and deflection is reduced by 20 % as compared to N Beam specimen.

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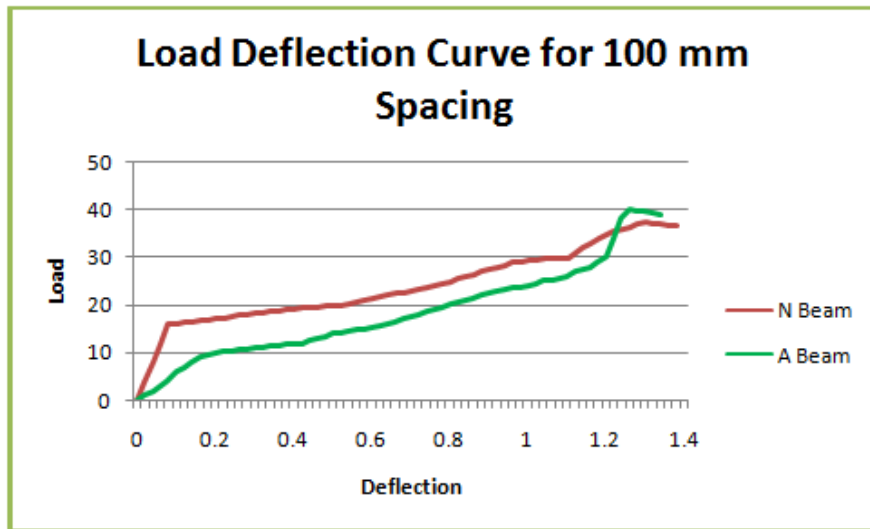


Fig. 2 Load – Deflection curve for N and A Beams for 100 MM spacing

For 100 mm spacing specimen, the N Beam failed at a load of 37.5kN and first crack was developed at a load of 16 kN. The corresponding maximum deflection was 1.3 mm. The A Beam specimen failed at a load of 40 kN and first crack was developed at a load of 20 kN. The corresponding maximum deflection was 1.26 mm. The load carrying capacity is increased by 6.67 % and deflection is reduced by 3 % as compared to N Beam specimen.

For the same percentage of steel and area of cross-section of beam, the deflection of A Beam is comparatively less as compared to N Beam specimen. The substantial increased load carrying capacity is attributed due to increase in flexure and shear strength of A Beams as compared to N Beam specimen which in turn indicates stiffness of beam is increased by the use of rolled steel angle sections.

Comparison between N Type and C Type Beams:

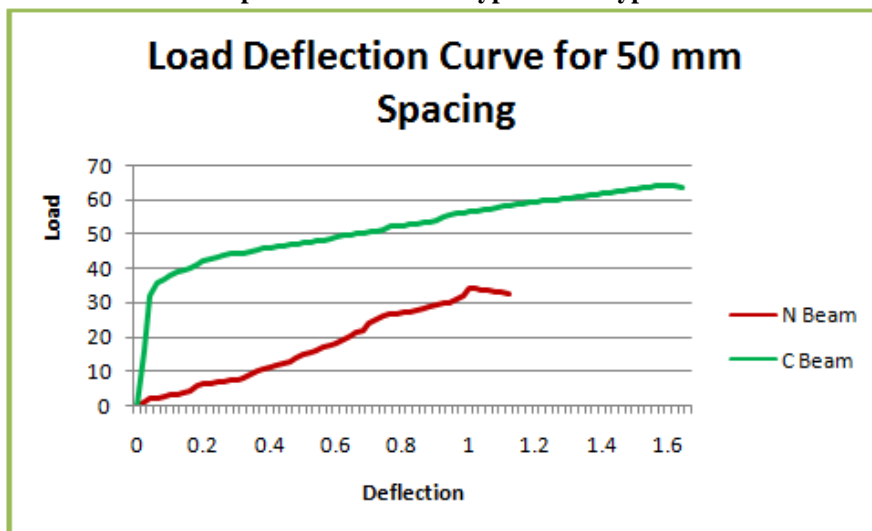


Fig. 3 Load – Deflection curve for N and C Beams for 50 MM spacing

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For 50 mm spacing specimen, the C Beam failed at a load of 64 kN and first crack was developed at a load of 36 kN. The corresponding maximum deflection was 1.58 mm. The load carrying capacity is increased by 88.2 % where as deflection is increased by 58 % as compared to N Type beam specimen.

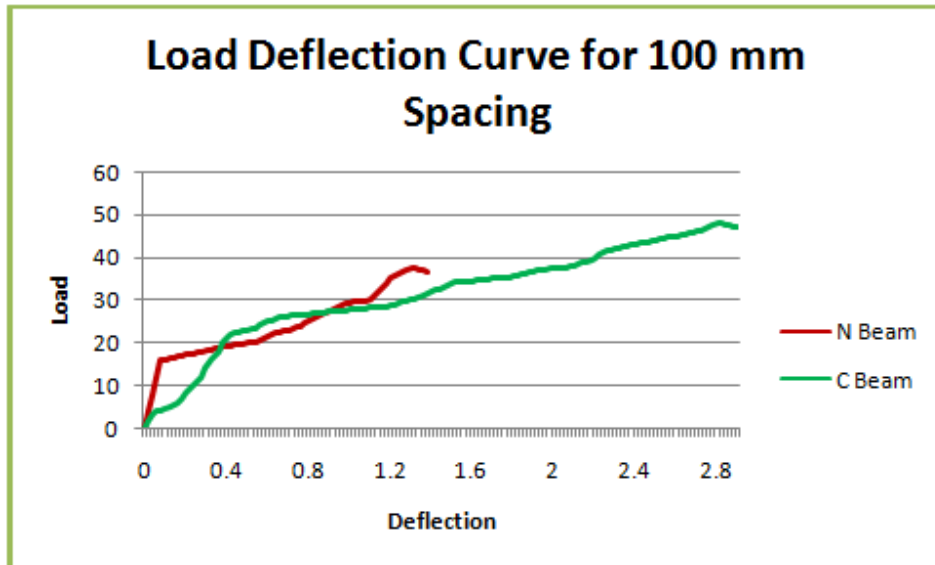


Fig. 4 Load – Deflection curve for N and C Beams for 100 MM spacing

For 100 mm spacing specimen, failed at a load of 48kN and first crack was developed at a load of 20 kN. The corresponding maximum deflection was 2.8 mm. The load carrying capacity is increased by 28 % where as deflection is increased by 153.8 % as compared to N Beam specimen.

For the same percentage of steel and area of cross-section of beam, the deflection of C Beam is more as compared to N Beam specimen. The substantial increased load carrying capacity is attributed due to increase in flexure and shear strength of C Beams as compared to N Beam specimen which in turn indicates stiffness of beam is increased by the use of rolled steel channel sections.

V. CRACK PATTERN

There are three different phases of beam response. In first phase, there is change in curvature with the development of flexure crack due to bending moment in beam reaching its cracking moment. The second phase leads to major diagonal cracks near the support due to diagonal tension exceeding the tensile strength of concrete. Third phase leads to diagonal crack yields and large deflection. Excessive cracking occurs giving warning of impending failure.

It is obvious from fig.6 and fig. 7 that A and C beams fail by diagonal cracks at support which indicates shear failure. Fig. 5 shows that N beam fail by flexure cracks on the tension face which extends more or less vertically in the beam. Shear failure is attributed to large shear force near the supports for A and C beams. Hence shear reinforcement near the support is of utmost importance in A and C beams. Hence sudden failure can be avoided by providing shear reinforcement. It was clear from above experiment that if shear reinforcement is provided the beam can carry additional load. Hence we can say that load carrying capacity is increased by provision of shear reinforcement.

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Fig. 5 Flexure and shear cracks for N beam



Fig. 6 Shear cracks for A beam



Fig. 7 Shear cracks for C beam

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VI. RESULT AND DISCUSSION

TABLE III

Spacing (mm)	First crack load (kN)					
	N beam		A beam		C Beam	
	Load	Def.	Load	Def.	Load	Def.
50	25.00	0.74	38.00	0.13	36.00	0.07
100	16.00	0.07	20.00	0.80	20.00	0.38

The Above table II shows the first crack load and their corresponding deflection for N Type, A Type and C Type beam specimen.

TABLE III

Spacing (mm)	Yield load (kN)					
	N beam		A beam		C Beam	
	Load	Def.	Load	Def.	Load	Def.
50	32.00	0.95	51.00	0.61	60.00	1.30
100	30.00	1.10	30.00	1.10	40.00	2.20

The Above table III shows the yield load and their corresponding deflection for N Type, A Type and C Type beam specimen.

TABLE IV

Spacing (mm)	Failure load (kN)					
	N beam		A beam		C Beam	
	Load	Def.	Load	Def.	Load	Def.
50	34.00	1.00	56.00	0.80	64.00	1.58
100	37.50	1.30	40.00	1.26	48.00	2.80

The Above table IV shows the failure load and their corresponding deflection for N Type, A Type and C Type beam specimen.

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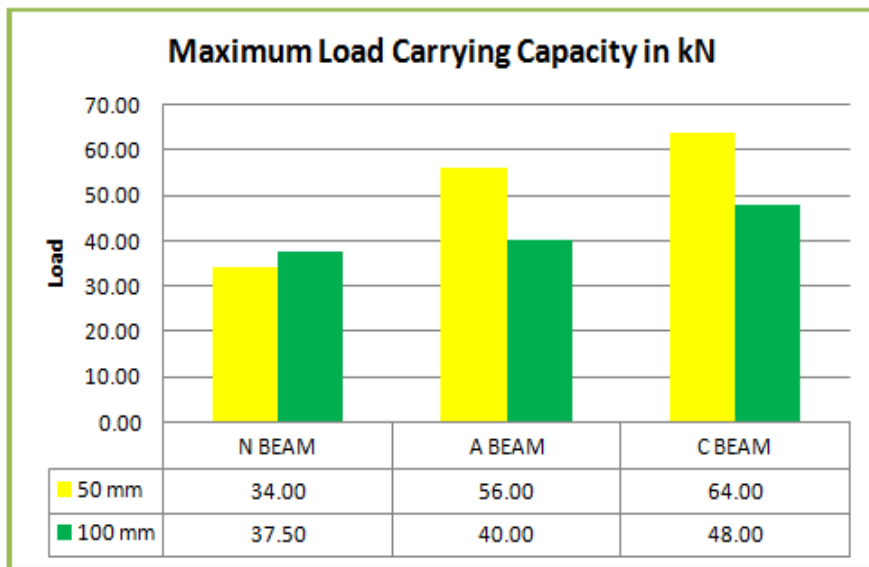


Fig. 8 Maximum load carrying capacity for N, A, C beams

The above fig. 8 shows maximum load carrying capacity for N type, A Type and C Type beams for 50 mm stirrups spacing and 100 mm stirrups spacing. It is clearly obvious that A Type and C Type beams has more load carrying capacity as compared to N Type beam.

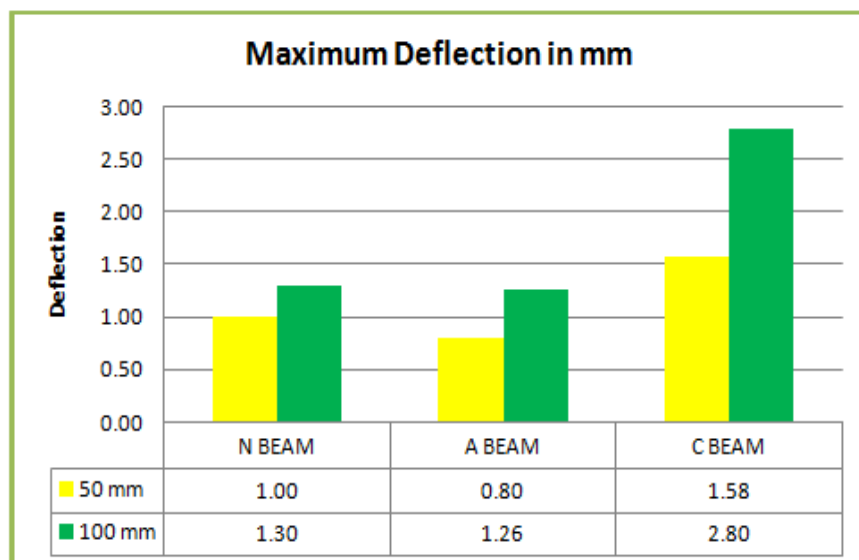


Fig. 9 Maximum Deflection for N, A, C beams

The above fig. 9 shows maximum deflection for N type, A Type and C Type beams for 50 mm stirrups spacing and 100 mm stirrups spacing. It is clearly obvious that deflection for A Type beams is less as compared with N Type and C Type beam. Hence angle sections as bottom reinforcement is more effective than C Type and N Type beams.

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1. There was increase in flexural strength of angle reinforced beams as compared to normal tmt steel beams.
2. Maximum permissible deflection is $(\text{span}/250) 700/250=2.8$ mm. Hence the deflection in both the types are within permissible limit (Clause 23.2 of IS 456).
3. The deflection of angle reinforced beam is reduced as compared to normal tmt steel reinforced beam. This shows that stiffness is increased due to use of angle section reinforcement.
4. There is increase in shear strength of beam encased with angle section and channel sections as compared to normal tmt steel reinforcement.
5. For normal tmt steel reinforcement diagonal as well as slight central cracks were observed indicating shear and flexure failure and for angle and channel reinforcement diagonal cracks were observed indicating shear failure.
6. As the spacing of stirrups are decreased the shear strength of beam is also increased and vice versa.
7. It is observed that as the spacing between the stirrups decreases, the deflection is less an vice- versa
8. Use of rolled steel Angle section as main reinforcement is economical as compared to normal tmt bars.
9. Also beams encased with angle section performs better as compared to beams encased with channel sections in terms of load carrying capacity and deflection.

VII. CONCLUSION

- It was observed that A type reinforcement has favorable effect under flexure and shear as compared to N type and C Type of reinforcement.
- Average percentage reduction in deflection for A type of reinforcement as compared to N type is 20% for 50 mm spacing; and 3.00 % for 100 mm spacing.
- Percentage increase in Shear Strength for A type of reinforcement as compared to N type is 64.71 % for 50 mm spacing and 6.67 % for 100 mm spacing
- Percentage increase in Shear Strength for C beam as compared to N type is 88.24 % for 50 mm spacing; 28 % for 100 mm spacing.
- Percentage increase in deflection for C beam as compared to N type 88% for 50 mm spacing and 153.8 % for 100 mm spacing.
- A type reinforcement is advisable as compared to N type and C Type reinforcement due to its improved performance under flexure, shear and deflection.

REFERENCES

- [1]. Mrs. V. S Sohoni, "Behaviour of Concrete Encased Steel Composite Members of Framed Structure, December 2012.
- [2]. CorradoChisari, Claudio Amadio, "An experimental, numerical and analytical study of hybrid RC-encased steel joist beams subjected to shear", Engineering Structures – ELSEVIER, 2014.
- [3]. Shun-ichi Nakamura, Naoya Narita, "Bending and shear strengths of partially encased composite I-girders", Journal of constructional steel research - ELSEVIER, 2003

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

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- [4]. Moataz Awry Mahmoud , Tamer Hassan Elafandy , Hussein Osama Okail ,Amr Ali Abdelrahman, “Interfacial shear behavior of composite flanged concrete beams”, HBRC Journal, 2013
- [5]. Daniel Lowe, Raj Dasa, Charles Clifton, “Characterization of the splitting behavior of steel-concrete composite beams with shear stud connection” ,Procedia Materials science ELSEVIER, 2014
- [6]. JianguoNie; Yan Xiao; and Lin Chen, “Experimental Studies on Shear Strength of Steel–Concrete Composite Beams”, Journal of structural Engineering, 2004.
- [7]. C. C. Weng; S. I. Yen; and M. H. Jiang, “Experimental Study on Shear Splitting Failure of Full-Scale Composite Concrete Encased Steel Beams”, Journal of structural Engineering, 2002.
- [8]. R.A. Barnes , P.S. Baglin , G.C. Mays , N.K. Subedi, “External steel plate systems for the shear strengthening of reinforced concrete beams”, Engineering Structures, ELSEVIER, 2000.
- [9]. Leopoldo Tesser, Roberto Scotta, “Flexural and shear capacity of composite steel truss and concrete beams with inferior precast concrete base”, Engineering Structures, ELSEVIER, 2012.
- [10]. V. Kvočák and L. Drab, “Partially-encased composite thin-walled steel beams”, Procedia Materials science ELSEVIER, 2012
- [11]. Chao Liu, “Research on Property of Steel-Encased Concrete Composite Beams with superior Performance”, International journal of computer trends and technology, 2013
- [12]. Jun He, Yuqing Liu, ZhaofeiLin ,Airon Chen , Teruhiko Yoda, “Shear behavior of partially encased composite I-girder with corrugated steel web: Numerical study”, Journal of constructional steel research ,ELSEVIER, 2014.
- [13]. By C. C. Weng, S. I. Yen, and C. C. Chen – “Shear strength of concrete encased - composite structural members”, Journal of structural Engineering, 2001.
- [14]. By Deric John Oehlers , “Splitting induced by shear connectors in composite beams”, Journal of structural Engineering, 1989
- [15]. Herbert K. Schilger (Canada), “US patent with design registration no.4905440”, and date of issue of Patent: march 6, 1990.
- [16]. Mr.Vincent, Mr.Richard (Canada), “US patent with design registration no.6061992”, and date of issue of Patent: march 16, 1998.
- [17]. Sherif-El-tawil, Gregory G.Deierlein, “Strength and Ductility of concrete encased Composite column”, Journal of Structural Engineering, Vol 125 no. 9 pp 1009 – 1019, September 1999.
- [18]. Roberto Leon and Larry Griffens, “Composite Column Design”, Journal of Mordern Steel Constuction, August 2005.