ISSN (online): 2349-6010

Experimental Studies on Steel-Concrete Composite Beams in Bending

P. Tejeshwara Kumar
PG Student
Department of Civil Engineering
Jogaiah Institute of Technology & Sciences, Kalagampudi, West Godavari District, AP-534268

Lotla Sandeep Reddy
Assistant Professor
Department of Civil Engineering
Jogaiah Institute of Technology & Sciences, Kalagampudi, West Godavari District, AP-534268

Abstract

The use of composite structures is increasingly present in civil construction works. The steel section located mainly in the tension region and a concrete section, located in the compression cross sectional area, both connected by metal devices known as shear connectors. The main functions of these connectors are to allow for the joint behavior of the beam-slab, to restrict longitudinal slipping and uplifting at the elements interface and to take shear forces. Experimental studies were carried out to study the behavior of steel-concrete composite beam with different spacing of shear connectors subjected to pure bending. Two point loading experimental setup were used for the study of composite beams. The behavior of beams with different shear connector spacing, 75mm, 100mm, 125mm and 150mm were analyzed under pure bending up to the failure. From the test results it is observed that the beam with 125mm spaced shear connector having more strength and toughness under loading. This paper presents a study of the behavior of steel-concrete composite beams and presenting the most effective section from the results. A comparison with the conventional concrete also carried out with composite construction.
Keywords: Bending, Steel-Concrete Composite Beams

LIST OF SYMBOLS AND ABBREVIATIONS

- A1 dimensions of the test specimen
- A_1B_1 beam ID with spacing of the bracing
- ASB Asymmetric beam
- A_1T_1 beam ID with thickness of the sheet
- B breadth of the test specimen
- D depth of the test specimen
- E modulus of elasticity
- f'_{ck} Target average compressive strength at 28 days
- f_{ck} Characteristic compressive strength at 28 days
- I moment of inertia
- L length of the test specimen
- OPC Ordinary Portland cement
- S Standard deviation
- t_s thickness of the sheet
- W ultimate load taken by the beam

I. INTRODUCTION

A. General:

Modern civilization relies upon the continuing performance of civil engineering infrastructure ranging from industrial building to power station and bridges. A structural member composed of two or more dissimilar materials joined together to act as a unit is referred as composite structure. It is a powerful construction concept in which compressive strength of concrete and the tensile strength of steel are almost effectively used.

Modern civilization relies upon the continuing performance of civil engineering infrastructure ranging from industrial building to power station and bridges. A structural member composed of two or more dissimilar materials joined together to act as a unit is referred as composite structure. It is a powerful construction concept in which compressive strength of concrete and the tensile strength of steel are almost effectively used.

Therefore, a first approach is to define the conditions under which composite beams with a wide variety of shear connectors may be designed using the rigid-ideal plastic design method

B. Definition for Composite Beams

Composite beams are flexural members made of two or more longitudinal members which are constrained in their relative longitudinal displacements at the interface by means of a shear connection of the members. In this report the term "composite beam" is also used synonymously for steel-concrete composite beams.

1) Composite Construction

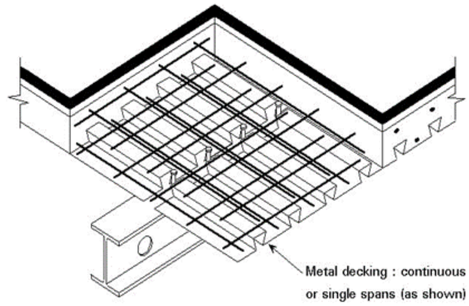

Fig. 1: Steel Fitch Beams

Composite construction refers to any members composed of more than one material. The parts of these composite members are rigidly connected such that no relative movement can occur. Examples are:

Composite construction aims to make each material perform the function it is best at, or to strengthen a given cross section of a weaker material.

2) Shear Connectors

One of the most important parts of a composite beam is the fixing points or shear connectors between the two materials. The correct connection of the two parts of the composite allows the materials to act as a unit and gives the composite beam its inherent strength. A composite beam is constructed generally by casting a reinforced concrete slab on the top of the steel beam.

3) Cold Formed Sheet

Cold-formed steel (CFS) is the common term for products made by rolling or pressing thin gauges of sheet steel into goods. Cold-formed steel goods are created by the working of sheet steel using stamping, rolling, or presses to deform the sheet into a usable product.

Some of the main properties of cold formed steel are as follows:

- Lightness in weight
- High strength and stiffness
- Ease of prefabrication and mass production
- Fast and easy erection and installation
- Substantial elimination of delays due to weather
- More accurate detailing
- Non shrinking and non-creeping at ambient temperatures
- No formwork needed
- Termite-proof and rot proof
- Uniform quality
- Economy in transportation and handling
- Non combustibility

II. METHODOLOGY

A. Aim of the Project

The following aspects are aimed in this thesis.

- To observe the behavior of steel-concrete composite beam subjected to pure bending, with particular regard to their behavior at failure.
- To study the effect of shear connectors on the ultimate strength of beam.
- To study the effect of spacing of bracing on the ultimate strength of beam.
- To compare the deflection of steel-concrete composite beams with conventional concrete.

All rights reserved by *www.ijirst.org*

B. Methodology

An approach is made to conduct number of experiments to observe the behavior of the beams under pure bending. The observations from the experiments will be compared with the results from the finite element analysis.

1) *Beam size: 2300x300x150mm*
- Number of beams: 4 nos. Phase I
- Literature review of composite beam.
  Literature review of analysis of steel-concrete composite beams on various parameters.
- Literature review on numerical analysis and experimental investigation of steel- concrete composite beams.
- Detailed study of the materials used and their properties.

III. RESULTS AND DISCUSSIONS

A. Importance of the Study

Tests on steel concrete composite beams were reported since early 19^{th} century itself. Many aspects of composite structural interaction between steel beams and concrete have been studied and reported in Canada and elsewhere as early 1922. These studies relate to the behavior of conventional concrete slab over steel I- beam. Such tests are not considered here for the review. The tests reported below include information on the composite beam and slabs which use stay-in-place from.

Concrete frame construction has until recently been traditionally undertaken using plywood formwork for all structural elements and so no inherent advantage have been achievable during the construction phase. This has been overcome by the development of composite profiled beams which employ a permanent formwork system consisting of profiled sheeting for concrete framed construction.

In order to conduct the analysis of confined steel concrete composite beam (CSCC Beam) the knowledge about the material properties, mix adopted and compressive strength is essential. Hence experiments were conducted on material, specimen of concrete cubes and cold formed sheet to understand the behavior of material under composite action

1) *Material Properties*
- Cement: The cement conforming to is 1489(part-1):1991, Ramco Premium composite 53 grade of cement is considered for the concrete mix
- Water: Locally available potable water is used for mixing the concrete.
- Fine Aggregate: The fine aggregate used for the entire specimen were natural river sand complying with the requirement of IS383:1970.
- Coarse Aggregate: A crushed granite stone of size 20mm are used for all the beams.
- Cold Formed Sheet: 1.2mm thickness of sheet adopted for making the beams. From sheet test coupons were cut and tested in a computerized UTM and the tensile properties were recorded
- Reinforcement Steel: Fe 415 grade of 8mm diameter steel rods were used as bottom longitudinal reinforcement to take care of temperature and shrinkage effects. The rod samples were tested in a computerized UTM and tensile properties were recorded.
- Headed Stud: The diameter of headed stud used in these beams is 6mm and shank diameter is 50mm having a flange width of 30mm which is T- shaped.
- Bracing: Could rolled sheet are made into pieces with the dimension 148X10mm with thickness of 1.2mm is welded in pure in bending region.

2) *Mixes Adopted*

Mix ratio as per IS method is adopted for the design mix. Plain concrete cubes cylinders; plain beams of standards size were cast, cured and tested in UTM. M30 Grade of Concrete is chosen and the design mix adopted for the Test Specimens is 1:1.6:2.8. Water cement ratio is 0.45

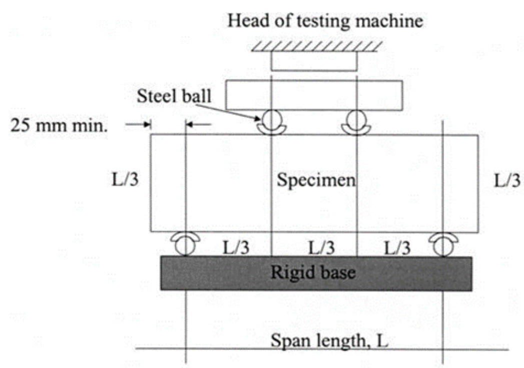

Fig. 1: Experimental Setup

B. Method of Construction

Four beams were constructed using a permanent formwork for the soffit and vertical sides of beam. They were fabricated in same cross section and interface connection with different spacing. The fabrication of beams has two stages. They are fabrication of trough and concreting.

1) Fabrication of Trough

The trough is fabricated using a permanent formwork for the soffit and vertical sides of the beam. It requires the fabrication of braced trough girder. The cold formed sheet of 610 mm width and 2.3 m length is bent in a plate bending machine to form a sheet outer skin of 2300 X 150 X 230 mm. The thickness of sheet varies is 1.2mm. To have good bonding condition shear connectors of 6mm diameter were welded at 75,100,125,150 mm c/c in the pure bending region along both sides as well as bottom of the sheet. Similarly same sheets are made into pieces to the dimension of 148 x10mm with the thickness of 1.5mm are used as braces. The spacing of the bracing varies as 100 mm and 150mm.Sectional view of trough section is shown in figure.

1) Concreting

a) Mixes Adopted:

M30 Grade of Concrete is chosen and the design mix adopted for the Test Specimens is 1:1.6:2.8. Water cement ratio is 0.45

b) Casting

All the materials were weighed and kept ready before mixing was started. The Fine aggregate and cement were mixed together, until a uniform colour was achieved. Then the coarse aggregate was added to this mixture and the dry materials were properly mixed. Water was added at this stage and the concrete was mixed manually for about 5 minutes and continued until the resulting concrete was uniform in appearance.

In the steel troughs packing pieces (precast mortar briquettes of thickness equal to the required thickness of cover) were placed in position at two or three points to give proper cover to the reinforcing bars. The concrete was placed in two to three layers; each layer was vibrated with a needle vibrator. The tops of the beams were floated off smoothly with a straight edge. The specimens were cured by providing wet gunny bags for 28 days and air dried for 1 day before testing. Once the concrete was poured and cured, the steel and concrete acted compositely with complete interaction until the bond was broken.

c) Safety Measures

As a precautionary measure the proving ring, loading jack, load distributing beam, the test specimen and the cantilever truss with brackets were tied to the top beam of the loading frame by means of cotton yarn ropes giving some sag while tying. Concrete cubes were also placed underneath the bracket as an additional precautionary measure.

d) Erection of Test specimen

The test specimen was erected on the supports by manually to a span length of 2.30m. After erection of beam, loading points were fixed at the middle third point of span. The load distributing beam was placed over these supports by proper centering and checking for verticality**.**

Then the proving ring was mounted on the center point of the load distributing beam with a rubber pad in between the flat surface of the load distributing beam and bottom flat surface of the ring. Then the ring was checked for verticality by plumb bob and the plane of the ring was adjusted by tilting so that it was exactly along the centerline of the load distributing beam and the test specimen.

IV. EXPERIMENTAL SETUP AND TESTING PROCEDURE FOR PURE BENDING

A. Testing Procedure

For pure bending a total number of four composite beams with an effective span of 2.3m were tested. The position of the supports and dial gauges points were marked on the beams. The beams were tested for two point loading. The failure started with the initial separation of sheet in the form of waves due to local buckling followed by yielding of the beams. The first crack was observed on the specimen followed by the appearance of several cracks which propagated in the inclined manner upon further increase of load.

At failure, crushing of compression concrete and failure of bracings and yielding of tension steel were observed. The load deflection curves of CSCC beams are linear up to yield load and have a long plateau beyond Variation of Load with deflection

B. Observation about the Behavior of Beams

S. No.	*Description*	*No. of beams*	*Beam ID*	*Dimension (mm)*				*Spacing (mm)*
				L	*B*	*D*	*ts*	
1	*GROUP A* *Beams subjected to pure bending with 0% torque.*	*4*	*A1T1*	*2300*	*150*	*230*	*1.2*	*75,100,125, 150*

The dial gauge at middle point shows higher deflections than the other two readings. Fig compares the load-deflection responses of CSCC beams under pure bending.

1) Variation of Load with Deflection

Table - 1
Load- Deflection Values for 75mm Shear Connector Spaced Beam.

All rights reserved by *www.ijirst.org*

Sl. No	Load(KN)	Left(mm)	middle(mm)	Right(mm)	Average (mm)
1	20	.65	.75	.72	.71
2	40	1.3	1.4	1.28	1.33
3	60	2.0	2.5	2.23	2.24
4	80	3.4	3.8	3.53	3.6
5	100	4.2	4.4	4.32	4.3
6	120	5	6.3	5.41	5.57
7	140	6	8	6.16	6.72

The dial gauge at middle point shows higher deflections than the other two readings. The first crack is formed with in a distance 10cm from the midpoint of the beam. The ultimate load taken by this beam is 120KN.

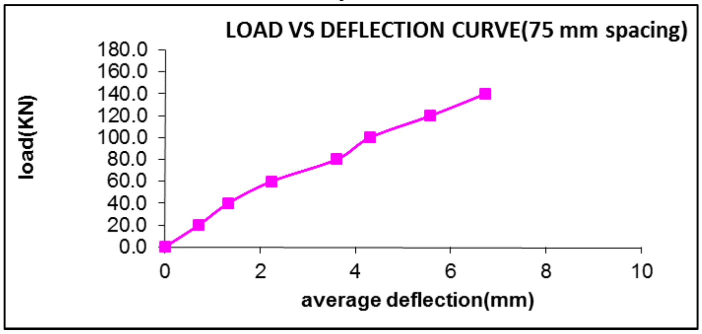

Fig. 2: Load Vs Deflection Curve for 75mm spaced shear connector beam

Table – 2
Load - Deflection Values for 100mm shear connector spaced beam

Sl.no	Load(KN)	Left(mm)	middle(mm)	Right(mm)	Average (mm)
1	20	.65	.8	.5	.65
2	40	1.25	1.5	1.1	1.28
3	60	3.12	5.8	2.1	3.67
4	80	6.5	8.15	6.4	7
5	100	8.20	9.15	8.7	8.68
6	120	9.00	11.07	9.7	9.92
7	140	12.00	14	11.8	12.6

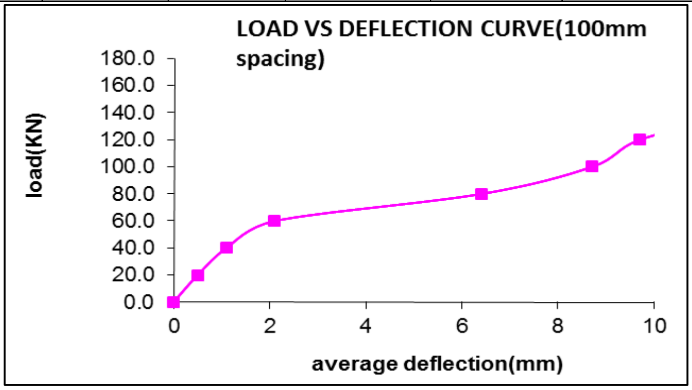

Fig. 3: Load Vs Deflection Curve for 100mm spaced shear connector beam

the figure shows linear variation of deflection with load. The ultimate load taken by this specimen is 170 KN.

Table – 3
Load- Deflection Values for 125 mm shear connector spaced beam

Sl.no	Load(KN)	Left(mm)	middle(mm)	Right(mm)	Average(mm)
1	20	.45	.50	.32	.42
2	40	1.1	1.15	.98	1.07
3	60	1.95	2.10	1.82	1.96
4	80	3.25	3.6	3.12	3.32
5	100	4.7	4.8	4.6	4.7
6	120	6.4	6.9	5.32	6.2
7	140	8.45	8.7	7.31	8.15
8	160	13.40	13.40	11.8	12.8
9	180	13.90	14.60	12.20	13.57

All rights reserved by www.ijirst.org

The average deflection of the test specimen with 125mm shear connector spacing is almost linear with increase in load. Ultimate load carried by this beam was 190KN. And the first cracks are formed at distance of 5cm from the midpoint

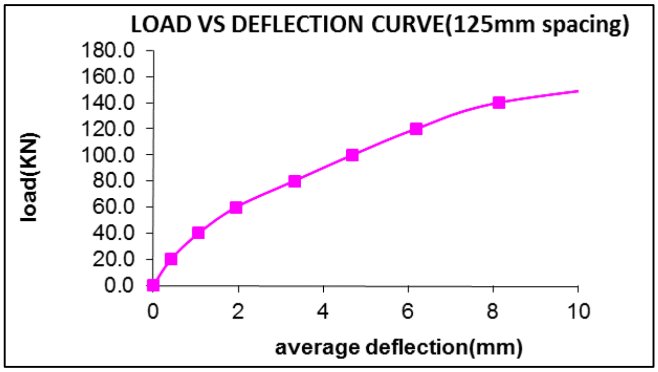

Fig. 4: Load Vs Deflection Curve for 125mm spaced shear connector beam

Table – 4
Load- Deflection Values for 150 mm shear connector spaced beam

Sl.no	*Load(KN)*	*Left(mm)*	*middle(mm)*	*Right(mm)*	*Average(mm)*
1	*20*	*.7*	*.85*	*.6*	*.72*
2	*40*	*1.75*	*1.9*	*1.1*	*1.58*
3	*60*	*2.3*	*3.8*	*2.4*	*2.8*
4	*80*	*3.5*	*4.9*	*3.6*	*4*
5	*100*	*4.6*	*7.25*	*4.5*	*5.45*
6	*120*	*5.8*	*9.40*	*5.4*	*6.9*
7	*140*	*7*	*10.50*	*6.5*	*8*

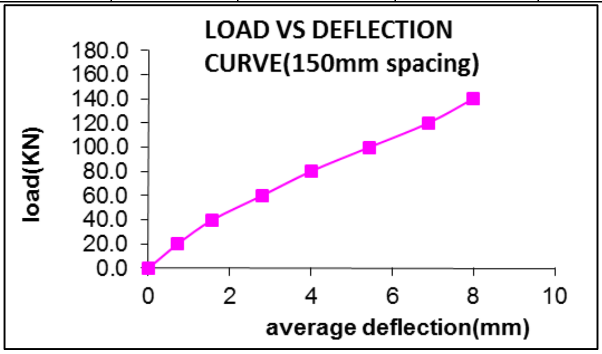

Fig. 5: load vs deflection curve for 150mm spaced shear connector beam

The ultimate load taken is 180KN. The cracks were first seen within 10cm from the midpoint of the beam.Since the ultimate load is maximum 125mm spacing, the same beam has the maximum ultimate moment.

C. Comparison of Ultimate Load With Spacing:

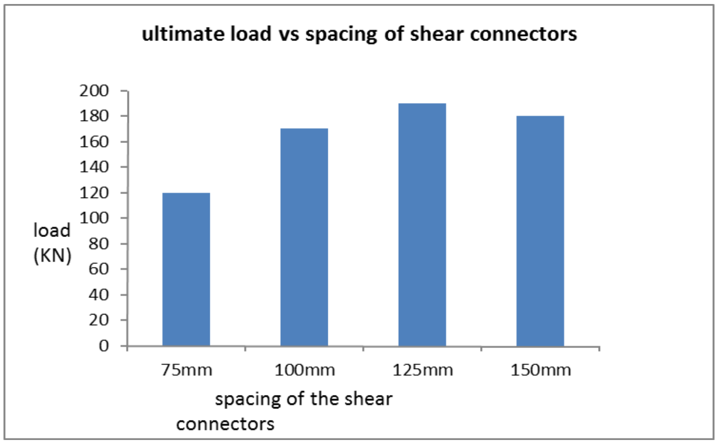

Fig. 6: Comparison of Ultimate Load With Spacing

All rights reserved by *www.ijirst.org*

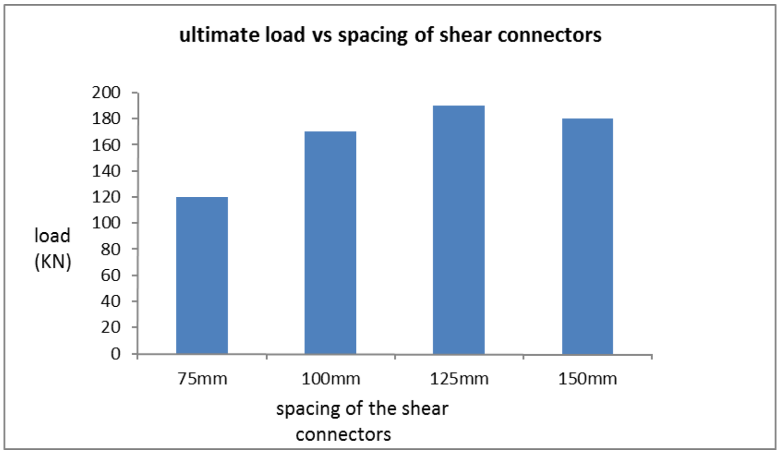

Fig. 7: Comparison of ultimate moment with spacing

D. Moment Vs Flexural Rigidity

The flexural rigidity was computed as the ratio of applied bending moment to the curvature in the constant bending moment zone. Flexural rigidity (EI) value was calculated as shown below:

$$EI = \frac{Moment}{Curvature}$$

$$Moment = \frac{WL}{6}$$

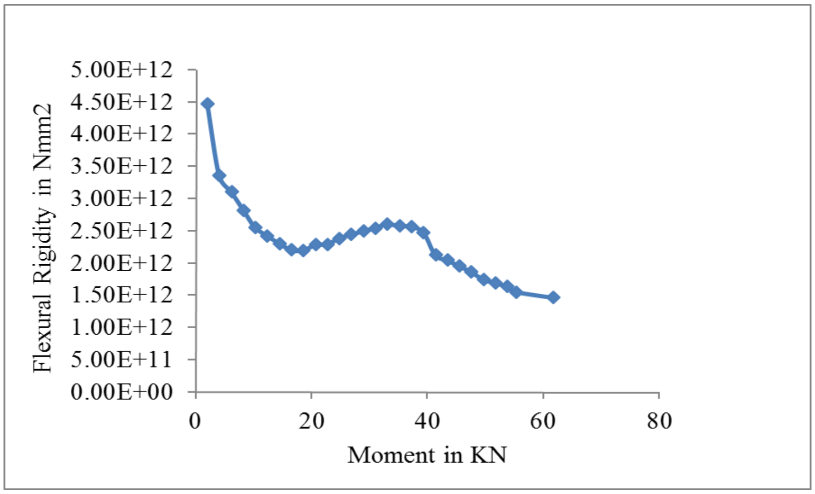

Fig. 8: Flexural Rigidity Vs Moment Graph

Figure shows the moment vs. flexural rigidity relationships for the CSCC beams under pure bending. The value of flexural rigidity decreases with the increase in moment. For beams with 125 mm spacing of shear connector the moment carrying capacity was found to be higher than the beams with 75mm, 100mm and 150mm spacing.

The reason for the enhancement in flexural stiffness is due to closely spaced shear connector which contributed additional confinement.

V. CONCLUSIONS AND DISCUSSION

A detailed investigation was carried out on steel-concrete composite beams subjected to pure bending. The major conclusions are drawn as follows:

- The ultimate load taken by the beams were comparatively higher in beam having 125mm shear connector spacing.
- The beam having 125mm spacing has higher ultimate bending moment.
- It was also found that beams with75mm, 100mm, 125mm and 150mm spacing of shear connector have shown higher values of toughness which is an indication of the energy absorption capability of the beams.
- The value of flexural rigidity decreases with the increase in moment. For beams with 125 mm spacing of shear connector the moment carrying capacity was found to be higher than the beams with 75mm, 125mm and 150mm spacing.
- The reason for the enhancement in flexural stiffness is due to closely spaced shear connector which contributed additional confinement.

All rights reserved by www.ijirst.org

- The failure of beams is caused by local buckling of sheet, formation of cracks and crushing of concrete followed by yielded of steel under flexure.
- The deflection varies linearly up to the yield point in pure bending.
- The enhancement in strength due to confinement was observed from earlier literature.
- The behavior of shear connectors was observed from push out tests from earlier literature.
- The load taken by the steel-concrete composite beam is more than the conventional concrete.

REFERENCES

[1] Alessandro Zona a,n, GianlucaRanzi (2010)“Finite element models for nonlinear analysis of steel–concrete composite beams with partial interaction in combined bending and shear”
[2] E.L. TAN, B. UY, M.A. BRADFORD(2008) “effects of partial shear connection on composite steel-concrete beam behaviour under combined flexure and torsion”
[3] G. Ranzi , M.A. Bradford (2005),“Analytical solutions for the time-dependent behavior of composite beams with partial interaction”
[4] Jianguo Nie; Jiansheng Fan; and C. S. Cai (2004),“Stiffness and Deflection of Steel– Concrete Composite Beams under Negative Bending”
[5] Jianguo Nie; Liang Tang; and C. S. Cai (2009) “Performance of Steel-Concrete Composite Beams underCombined Bending and Torsion”
[6] Jianguo Nie; Muxuan Tao; C. S. Cai; and Shaojing Li(2009) “Deformation
[7] Jun-Sik Kim, Maenghyo Cho, Edward C. Smith (2007) “An asymptotic analysis of composite beams with kinematically corrected end effects”
[8] Liang, QQ, Uy, B, Bradford, MA and ronagh, HR,(2005)” Strength Analysis of Steel–Concrete Composite Beams in Combined Bending and Shear”
[9] Liang, QQ, Uy, B, Bradford, MA & Ronagh, HR,(2007) Closure to “Strength Analysis of Steel-Concrete Composite Beams in Combined Bending and Shear”
[10] M.F.H. Wolff , V. Salikov , S. Antonyuk , S. Heinrich, G.A. Schneider (2013),” Three-dimensional discrete element modeling ofmicromechanical bending tests of ceramic–polymer composite materials”
[11] Namdeo Adkuji Hedaoo, Laxmikant Madanmanohar Gupta2 and Girish Narayanrao Ronghe (2012) ” Design of composite slabs with profiled steel decking: a comparison between experimental and analytical studies”
[12] P.S.Patil, M.G.Shaikh (2013)”A Study of Effect of Shear Connector in Composite Beam in Combined Bending and Shear by Ansys.”
[13] Subhankar Dasa,Pannalal Choudhurya, Sudipta Haldera, P Sriramb (2013)“Stress and free edge delamination analyses of delaminated composite structure using ANSYS”