IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 5, Issue 4, April 2018

Experimental Investigation of Cold-Formed Steel Composite Beams with Shear Connectors

Sudharsan S[1], Vinoth Kumar N[2]

PG, Valliammai Engineering College, Kancheepuram, Tamilnadu, India[1]

Assistant Professor, Valliammai Engineering College, Kancheepuram, Tamilnadu, India[2]

Abstract: A structural member composed of two or more dissimilar materials joined together to act as a unit is known to be a composite member. Cold- formed steel members are extensively used in the building construction industry, especially in residential, commercial and industrial buildings. In recent times, the use of cold- formed high strength steel members has rapidly increased. In this the flexural behavior of cold formed steel with M30 grade of concrete is investigated by conducting analytical and experimental study. Totally six simply supported composite beam specimen are tested under two point loading to determine the flexural strength. There are six composite beams and it is provided with different configuration of shear connectors. The cross section of beam were kept such that span to depth ratio varied from 8 to 12. The cold formed steel of Channel section with lip facing at compression side is used. To avoid slip and to transfer horizontal shear between cold formed steel and concrete, the shear connectors are provided. The Channel shear connectors and T – shear connectors were used. The beam specimens were tested by subjecting them to two point loading. The load- deflection behavior, ultimate flexural load and failure pattern of beam had studied. The experimental results indicate that, the load carrying capacity of the composite beams with Channel connector is more than the composite beams with T shear connector. The experimental results have also indicated that, the span to depth ratio have an influence on the increase in the load carrying capacity of the composite beams. The mid-span deflection at ultimate load for the composite beams was reduced in case of Channel shear connector. It was observed that, the steel-concrete composite beams failed due to flexural and shear-compression failure.

Keywords: Cold Formed Steel, Shear Connector, Composite Beam, Flexural behavior.

1. INTRODUCTION

In thin walled or cold formed steel sections, width to thickness ratio of plate elements is always large and the flexural failure occurs by buckling and not by yielding which limits its load carrying capacity. Instead, if the section is filled with concrete, not only is the premature buckling of thin plates prevented, but also steel section provides confinement to concrete thereby increasing the flexural capacity brought about by composite action. One of the most important developments in steel-concrete composite construction is the use of composite slabs in which cold formed thin walled steel sheeting has been utilized successfully throughout the world. However thin walled composite sections as cross section for beams is a relatively new concept and can serve as a suitable replacement for hot-rolled steel or reinforced concrete beam for small to medium, both spans and loading. Steel acts as formwork in the construction stage and later on it takes-up load in the service stage resulting in reduction in construction cost to some extent. Research work has been carried out on the behavior of steel concrete composite beams in several ways such as cold formed steel elements as soffits of the beam composite beam with profiled section composite beam with various interface connections composite thin walled closed flexural members with in-filled concrete, modular composite profile beams and RCC beam provided with cold formed plain sheet, and unstiffened and stiffened Channel in the tension zone. Recently studies on prefabricated cage reinforced steel concrete composite beam have been carried out. Earlier an experimental study was conducted on flexural behavior of empty cold formed steel Channel sections with lip on compression side and lip on tension side. It was shown that lip on tension side has more flexural strength than that of lip on compression side. The study is now extended to composite section to quantify the composite behavior. This paper discusses the flexural behavior of thin walled composite beams by means of an experimental study conducted mainly on two types of cross sections namely, Channel section with lip Behavior of composite section with Channel type shear connector and T type shear connector is included in this study.

1.1 Scope

The local buckling of cold formed steel is prevented by confinement of concrete therefore the load carrying capacity can be increased. The safety and serviceability condition of beam section is improved by a composite action. The cross sectional dimension of the composite beam can be reduced than conventional beam. The form work for the composite beam specimen can be avoided.

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 5, Issue 4, April 2018

1.2 Objective

- To determine the flexural behaviour of cold formed steel composite with shear connectors.
- To evaluate the performance of composite beam analytically in Ansys workbench 18.2.
- To evaluate the performance of composite beams experimentally.
- To compare the behavior of cold formed steel composite beam with different depths.
- To study the load deflection behavior of composite beam.

2. EXPERIMENTAL INVESTIGATION

In order to investigate the effectiveness of proposed method for improving the ultimate strength, six composite beams were welded with T and Channel shear connectors were used. The composite beam with shear connector is shown in Figure 3. The Longitudinal views of the beams with T and Channel connectors are shown in Figures 1 & 2. The 6 specimens consisting of T and C seies ,each having 3 specimens of composite Channel sections were tested. Cross sectional dimensions of Channel sections considered was 100x100mm, 100x125mm, 100x150mm.

Table 1: Beam Designation

Series	Beam Designation	Term explanation
T	CBT1	CB= Composite Beam T = T Connector C = Channel connector “1”= 100x100mm “2”= 100x125mm “3”= 100x150mm
	CBT2	
	CBT3	
C	CBC1	
	CBC2	
	CBC3	

Figure 1 – Beam with T connectors

Figure 2 – Beam with Channel Connector

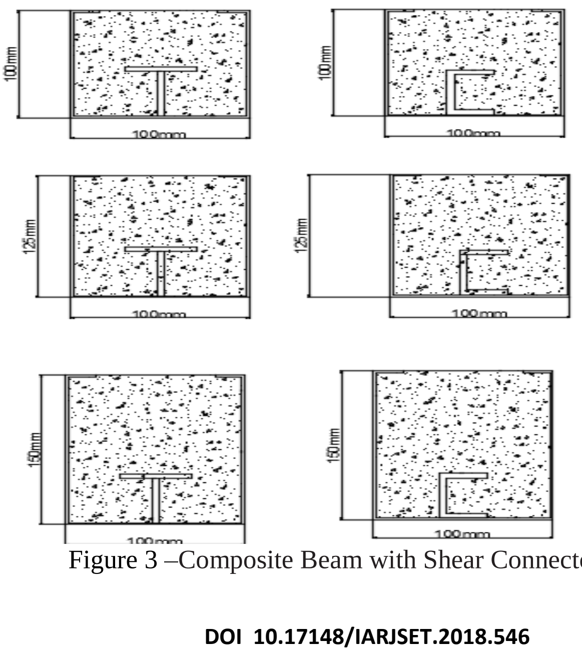

Figure 3 –Composite Beam with Shear Connectors

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 5, Issue 4, April 2018

2.1 Materials used and Mix Proportion

A. Concrete

Ordinary Portland cement of 43 grade conforming to IS: 1269-1987 was used. Locally available manufactured sand free from silt, organic matter and passing through 4.75mm sieve conforming to zone II of IS: 383-1970 was used as Fine aggregate. The tests on fine aggregate were conducted to determine the specific gravity and fineness modulus. Locally available crushed granite aggregate passing through 20mm sieve and retaining on 4.75mm sieve was used as Coarse aggregate. The aggregate was conforming to IS:383-1970.The tests on coarse aggregate was conducted in accordance with IS:2386-1963 to determine specific gravity.

Table 2: Material characterization

Test	Results
Cement	
Specific gravity	3.15
Fine aggregate	
Specific gravity	2.54
Coarse aggregate	
Specific gravity	2.7

Based on the properties of the materials obtained and the specifications as per IS: 10262-2009 the mix proportion for M30 grade of concrete was obtained as 1 : 1.35 : 2.87 with a W/C ratio of 0.45. The obtained mix proportion is shown in Table-3.

Table 3: Mix Proportion

Csement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Water (Kg/m^3)
438	592	1257	197

B. Cold Formed Steel

Cold formed steel is a type of steel manufactured, processed, fabricated by processing the steel at ambient temperature. Cold rolled sheets (Plate 1) are widely used in all fields of construction industry, mechanical industry, electrical industry etc. The manufacturing process of the cold formed steel products will be done at room temperatures and manufacturing process includes pressing and rolling. Cold formed steel sheet of 2.5mm thickness was used. The cold formed steel sheets fabricated in the form of Channel section by press break method. The width of 100mm is kept constant for all specimens and depth varies as 100mm, 125mm, 150mm.

C. Shear Connectors

Shear connectors are designed to transfer the longitudinal shear along the interface and also to help in resisting the separation of concrete particles from the steel beams at the interface. The T and Channel shape shear connectors were used and the cross sectional dimension of the shear connector is shown in figure 4. The shear connectors are welded by shop welding to the cold formed steel beam at spacing of 275mm.

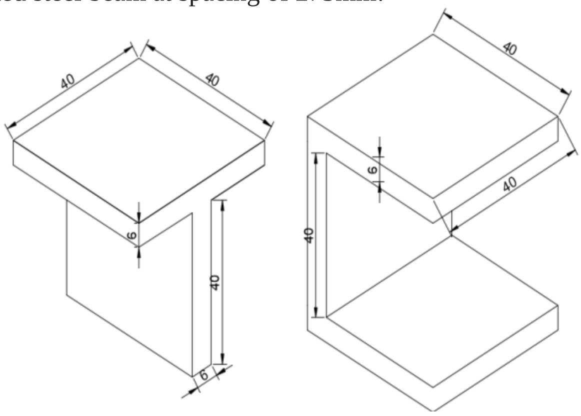

Figure 4 -Cross Section of T And Channel Shear Connectors

2.2 Casting of Beams

After the fabrication of Channels sections with shear connectors, the specimens were painted with primer paint only to the exteriors of the Channel sections and kept for drying. Concrete was mixed by hand as shown in figure 5 and Concrete was poured to the open section of the beam and at the ends sheets were kept as form work as shown in figure 6. After 24 hours of casting, Channel sections were covered with gunny bags and curing was done for 28 days. The M30 grade concrete cubes of 3 numbers were casted and tested for 28 days to determine the compressive strength. The average values of 28 days compressive strength of cubes obtained are 38 N/mm^2 .

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 5, Issue 4, April 2018

Figure 5 – Mixing of Concrete Manually

Figure 6 – Casting of Concrete

Figure 7– Compressive Testing of Cubes

2.3 Testing Procedure

A precession loading frame of 50 tonnes capacity was used in testing the beams. The loading jack which is used was 30 tonnes capacity. Two roller supports were provided 100mm apart from the ends of the beam. Two point loads was applied transversely for composite beam sections at distance of L/3 from the both supports as shown in figure 7.

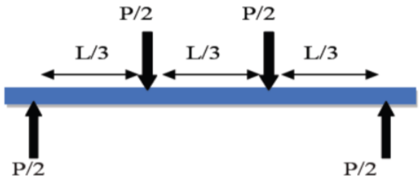

Figure 7- Loading arrangements

Load was applied gradually using Hydraulic jack in increment till failure of the specimens. The behaviour of the beams was observed throughout the loading range till the specimen failed. The deflection of beam was obtained by using dial

DOI 10.17148/IARJSET.2018.546

gauge. Load Deflection curves for each beam was obtained manually for each loading. Also the appearance of separation, propagation of cracks and slip were observed and recorded.

Figure 8 – Experimental Loading Setup

3. ANALYTICAL STUDY

Considering the cost involved and the time consumed for fabrication and testing of physical models, FEA is as an economical alternative to many engineering problems. The process of FEA starts with the creation of a geometric model of the structure, which is then divided into smaller shapes connected at specific nodal points. In this manner, stress-strain relationships are more easily approximated. Finally the material behaviour and boundary conditions are incorporated to each element and the analysis is to be performed. The FEA is performed using the finite element software called ANSYS Workbench 18.2 student version, through static structural analysis. Using the mathematical modelling the load versus deflection behaviour and failure loads under loading conditions have been studied and compared with the experimental results.

3.1 Modelling of Composite Beam

Initially the material type used in beam was added and its material property is assigned. The structural steel and concrete material is added and its property was assigned in engineering data. Then the geometric model should be created. The specimen will be drawn using the polyline and the dimension will be assigned in XY plane and it will be extruded for 1200 mm. The cold formed steel beam with T type shear connectors and Channel type shear connector was done as shown in figure 9, 10. Then the concrete portion was drawn along with the steel as shown in figure 11.

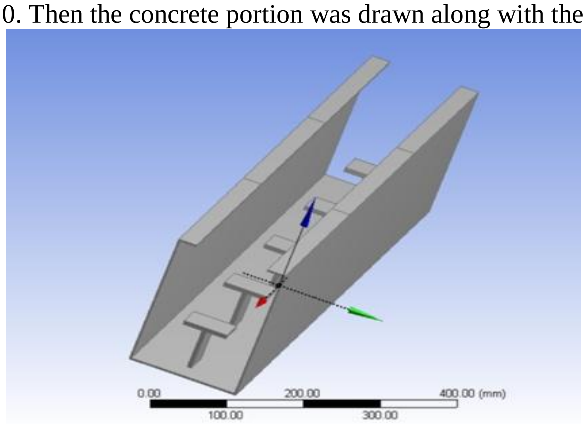

Figure 9 – CFS Beam with T Connectors

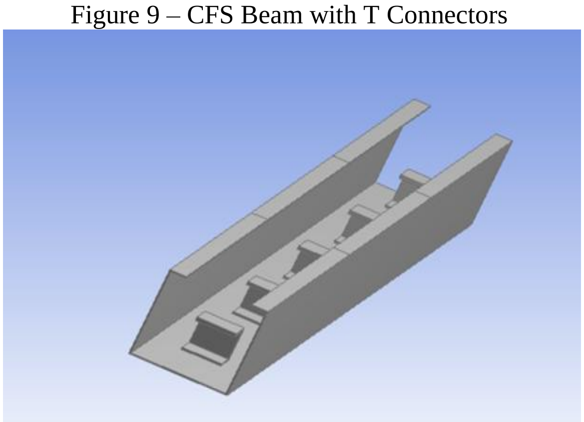

Figure 10 – CFS Beam with Channel Connectors

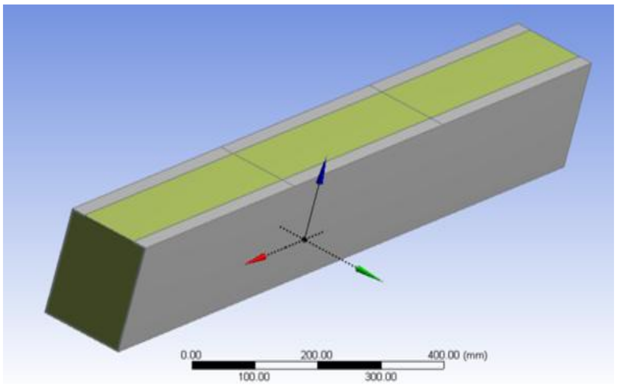

Figure 11 – Composite Beam Specimen

Then under the model the structural steel and concrete material was assigned to the geometry and the meshing was generated. The coarse mesh is provided in the model as shown in figure 12. The loading arrangements are given vertically downwards as two point load at L/3 distance from supports as shown is figure 13. Then the deformation results were obtained for each loads as shown in figure 14.

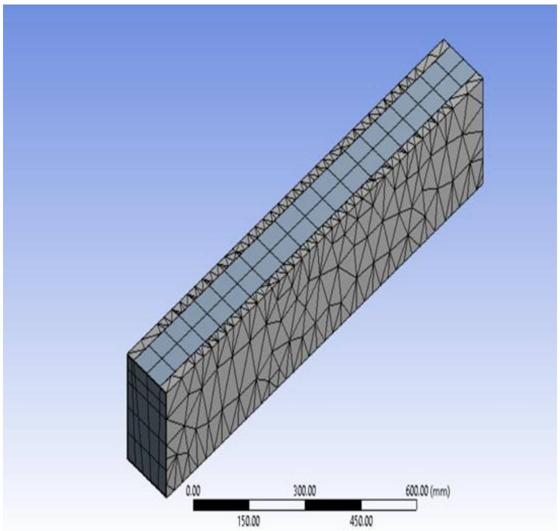

Figure 12 – Meshing Of Composite Beam

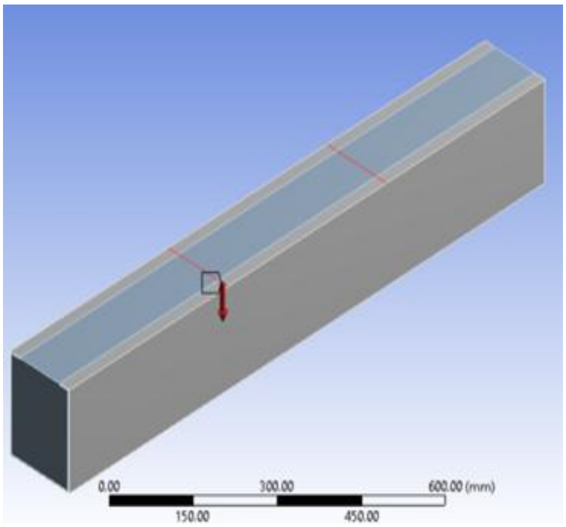

Figure 13 – Two Point Loading Setup

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 5, Issue 4, April 2018

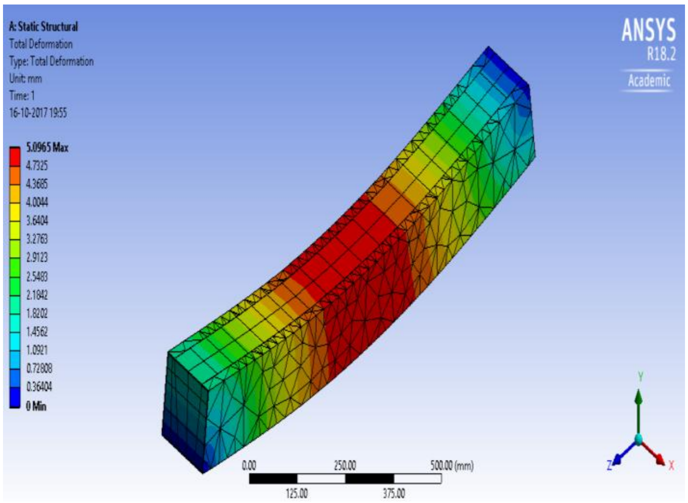

Figure 14 – Deformation Results

4. RESULTS AND DISCUSSION

4.1 Load-Deflection Behaviour of Beams

Load-deflection behavior is the principle constituent of the flexural behavior of the beams. Load-deflection curve serves as the basis for calculating deflection ductility . Figure 15 shows the loads – deflection behaviour of beams with Channel shear connectors and figure 16 shows the load – deflection behaviour of beams with T shear connectors. The figure 17 and figure 18 shows the analytical load deflection curve of C series and T series of beam.

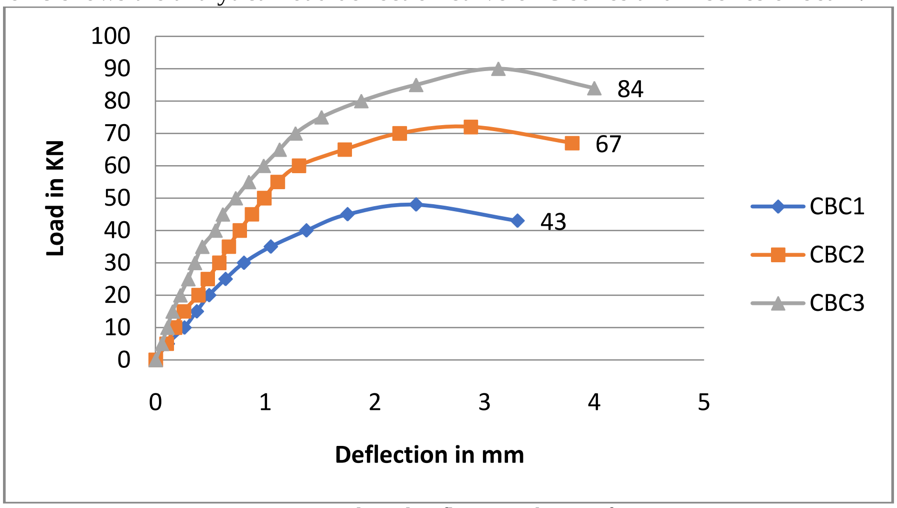

Figure 15 – Experimental Load Deflection Behavior of C Series Beams

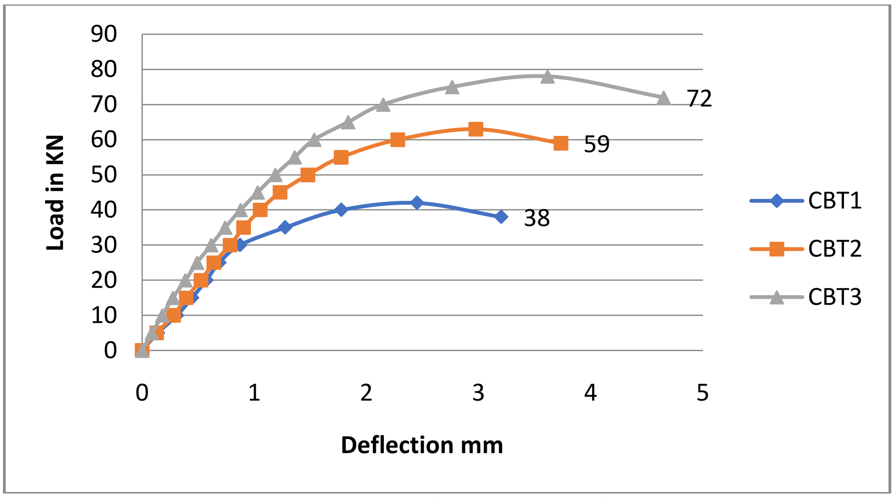

Figure 16 - Experimental Load Deflection Behavior of T Series Beams

DOI 10.17148/IARJSET.2018.546

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 5, Issue 4, April 2018

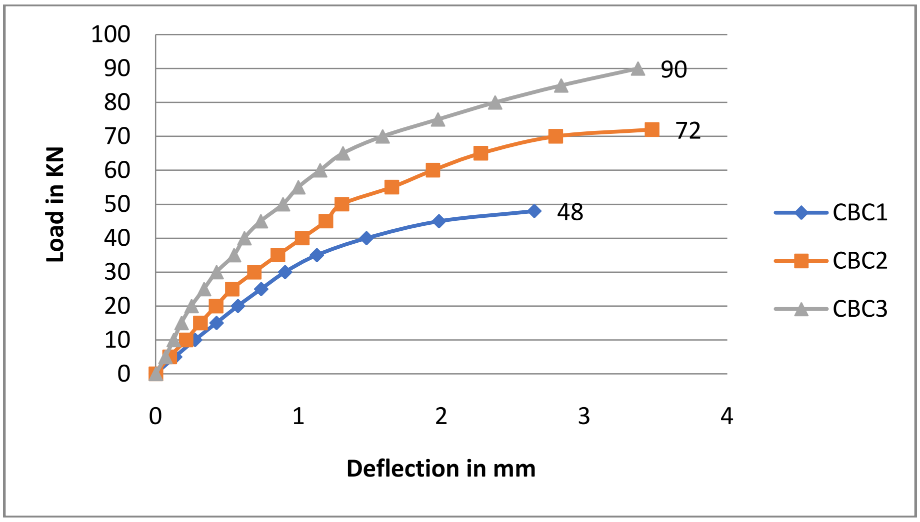

Figure 17 – Analytical Load Deflection Behavior of C Series Beams

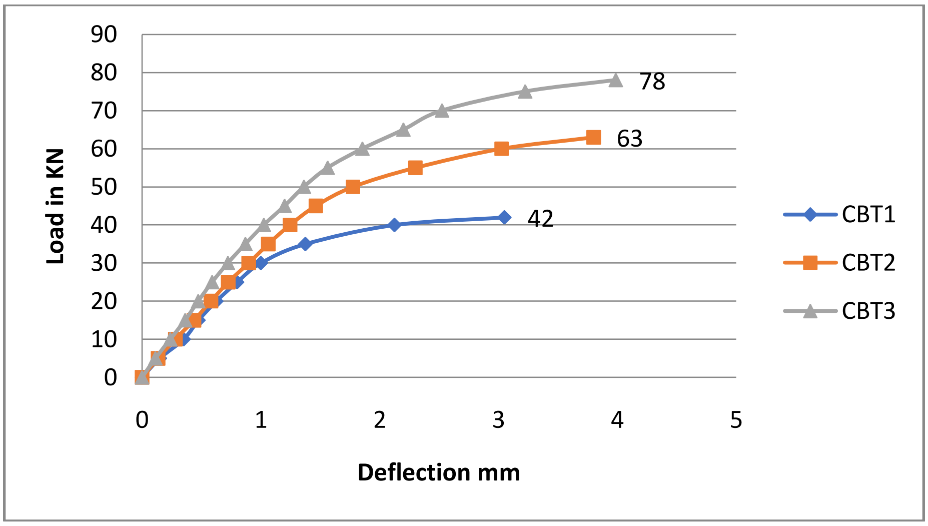

Figure 18 - Analytical Load Deflection Behavior of T Series Beams

4.2 Ductility index

Ductility index is the ratio of ultimate deflection to the deflection at the yield. Composite beam of cross section 100*100mm with Channel shear connectors has greater ductility index when compared when compared with other beams. Composite beam of cross section 100*125 mm with Channel shear connectors has lesser ductility index as shown in figure 19 and table 4.

Table 4 – Ductility Index of cold formed steel composite beam

Beam designation	Ultimate deflection (mm)	Deflection at yield (mm)	Ductility index
CBT1	2.45	0.87	2.81
CBT2	2.97	1.23	2.42
CBT3	3.12	1.13	2.77
CBC1	2.4	0.8	2.95
CBC2	2.87	1.3	2.20
CBC3	3.12	1.27	2.45

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 5, Issue 4, April 2018

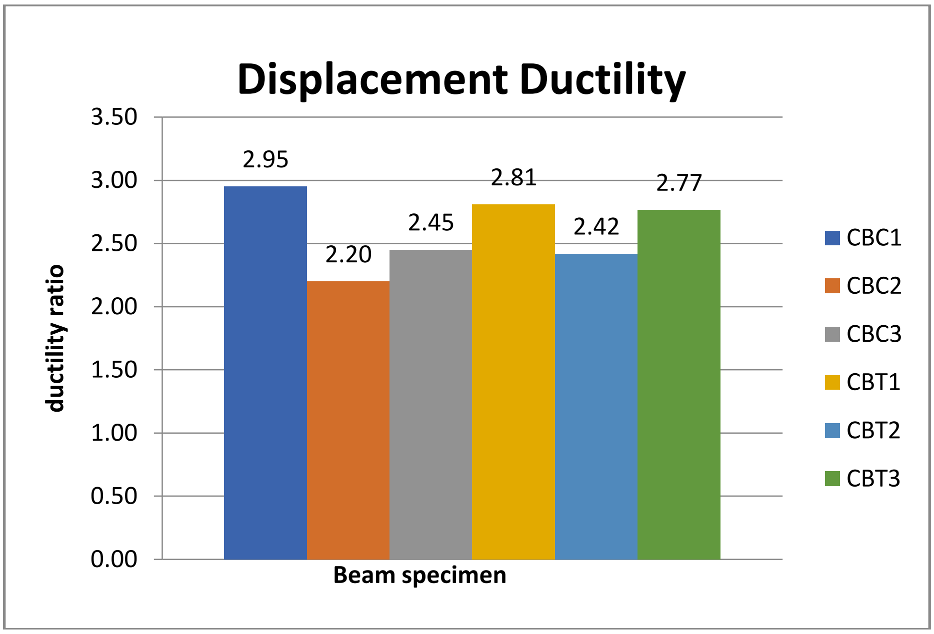

Figure 19 – Ductility Index Value

4.3 Ultimate Load

The load at which the beam is unable to carry any further load is termed as ultimate load. The ultimate load is concerned with the strength or load carrying capacity aspect of the structural behavior of the beams. The ultimate load of beams with Channel and T shear connector tested experimentally are shown in figure 20. The beam with Channel type shear connector carries more load than the beam of same cross section with T type shear connectors with increase in load is from 14% to 25% with respect to T series of beams.

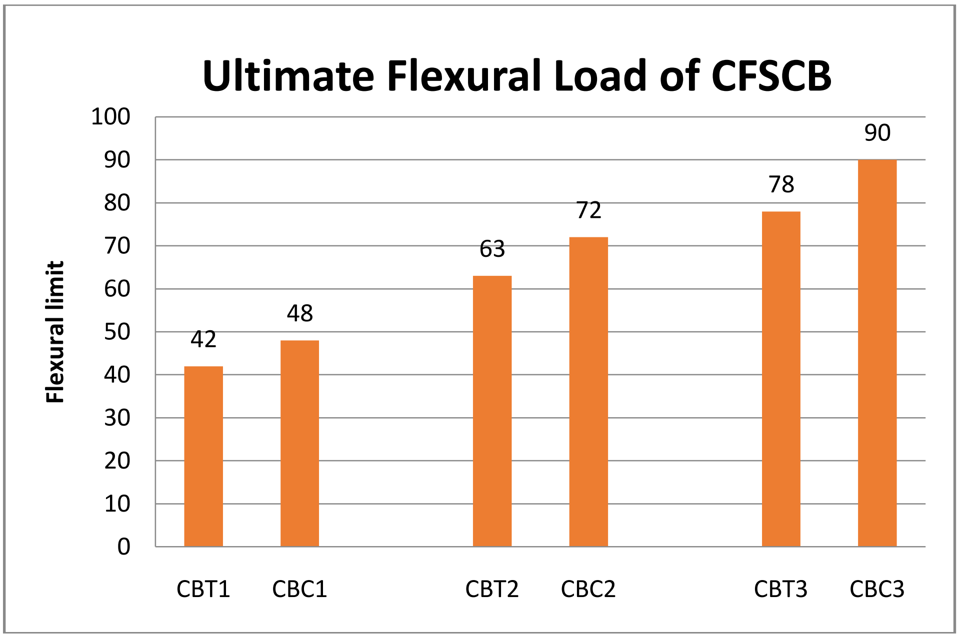

Figure 20 – Ultimate Load of Beams

5. FAILURE PATTERNS

It is observed that the failure takes place mostly as shear failure and flexural failure. The beam of CBT1 and CBC1 was failed in flexure .The flexural cracks are visible at compression face as shown in figure 21.The figure 22 shows the crack and separation of concrete from steel.

Figure 21- Flexural Crack of Beam CBT1

Figure 22- Crack and Separation of Steel from Concrete in CBT2

Figure 23 – Shear Failure from Supports

Table 5 – Failure Types

Beam designation	Type of failure
CBT1	Flexural failure
CBT2	Shear failure at tension face
CBT3	Shear at compression face
CBC1	Flexural failure
CBC2	Shear failure at compression face
CBC3	Shear failure at compression face

6. CONCLUSION

1) The flexural capacity of composite beams with Channel shear connectors is more than the beams with T shear connectors.
2) The rate of increase in load for C series of beam is from 14% to 25% with respect to T series of beams.
3) The deflection of C series beam at ultimate load is less than the T series of beam.
4) The displacement ductility index value is larger for the beam with channel shear connector of depth of 100mm and lesser for the beam with channel shear connector for a depth of 150mm.
5) The rate of increase in ultimate load for t series of beam CBT1 to CBT2 is 50% and CBT2 TO CBT3 is 23% .
6) The rate of increase in ultimate load for c series of beam CBC1 to CBC2 is 50%, and CBC2 to CBC3 is 25%.
7) The CBT1 and CBC1 were has flexural failure and other beams are failed in shear.
8) Deflection value of composite beam obtained from analytical method is slightly higher than the deflection value obtained from experimental analysis.

REFERENCES

1) Vinod hkumar P. Sattainathan Sharma A. (2016), "*Experimental Study on Flexural Behaviour Of Composite Beam with Shear Studs", International Journal of Science And Innovative Engineering and Technology*,Vol.1, e-ISBN : 978-81-904760-8-9.
2) Ahn, H.J. and Ryu, S.H. (2007), "*Experimental study on flexural strength of modular composite profile beams*", Steel. Compos. Struct.[
3) Anwar Hossain, K.M. (2003), "*Experimental and theoretical behavior of thin walled composite filled beams*", Electronic *J. Struct. Eng.*, 3, 117-138.
4) Anwar Hossain, K.M. (2005), "*Designing thin-walled composite-filled beams*", Proceedings of the institution of Civil Engineers, Structures and Building 158 issue SB4, 267-278.

5) AS/NZS 4600 (2005), "*Cold Formed Steel Structures*", Australia Standard / New Zealand Standards, Sydney, Australia.
6) Chitra, R. and Thenmozhi, R. (2011), "*Studies on prefabricated cage reinforced steel-concrete composite beams*", Asian J. Civil Eng. (Building and Housing), 12(1), 27-37.
7) Chitra, R., Thenmozhi, R. and Revathi, M.C. (2011), "*Flexural ductility of prefabricated cage reinforced steel-concrete composite beams*", Asian J. Civil Eng. (Building and Housing), 12(6), 719-729.
8) Valsa Ipe T. Sharada Bai H. Manjula Vani K. (2013), '*Flexural Behavior of Cold Formed Steel Concrete Composite Beams*', Korea Science, Vol.14, No.2, pp.105-120. Vinay N. Harish M.L. Prabhakara R. (2015), '*Experimental Investigation on the Flexural Behavior of the Steel Concrete Composite Beams*', International Research Journal Of Engineering And Technology, Vol.02, No.07, e-ISSN: 2395-0056.
9) Jyothi k.n. Valsa Ipe T. (2015), '*Performance of Infilled Cold Formed Steel Channel Section Beams*', International Journal Of Engineering Research And Technology, Vol.04, No.12, ISSN: 2278-0181.
10) Tensing D. Malathy R. Thivya J. (2016), '*Experimental Investigation of Confined Steel Concrete Composite Beam Under Bending*', International Journal of Advanced Engineering Technology, Vol.8, No.1, e-ISSN: 0976-3945.
11) Naveen R.K. Valsa Ipe T. (2016), '*Experimental Study on the Behavior of Concrete Infilled Light Gauge Steel Beams*', International Journal of Research in Engineering and Technology, Vol.04, No.20, E-ISSN: 2319-1163.