International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-7, Issue-6C2, April 2019

Behavior of Composite Cellular Beam Under Flexure

Nanduri Sai Tejaswi, P.Poluraju

Abstract: Construction technology is looking forward to recycling the material for ensuring the safe environment by applying new technologies like cellular beams. The cellular beam comprises of web openings. These types of beams are currently in use. These are flexible and elegant in nature. When a beam consists of I-section girder which is encased with concrete is known as encased beam. The composite cellular beam consists of I-section cellular girder which is wrapped with concrete. These composite cellular beams are free from corrosion and are fire resistant. These beams are more economical and ensure more structural integrity when compared with encased beams. This research mainly concentrates on flexural behavior of composite cellular beams. The experimental work is carried out by testing the specimens under three point bending test by varying various parameters such as circular web openings and spacing. Experimental data is characterized by Load vs. Deflection cure. It is been observed that composite cellular beam acquires more flexural strength and they are light in weight when compared to encased beam.

Index Terms: cellular beam, circular web openings, encased beam, three point bending test.

I. INTRODUCTION

A Structure is a combination of elements like beams, columns, cables, slabs, retaining walls. The beam is a flexural member used to transfer load by resisting the bending moment .The beams are classified based on the support conditions, materials used, shape and equilibrium conditions. The adequate cross sections are I and H section which is made up of steel. The steel has immense load carrying capacity at low weight. In beams instated of steel reinforcement an I-Section steel girder is placed which is known as encased beam (EB) as shown in Fig.1. The ultimate strength of encased beam is more than the designed strength and the present design of EB is considered as a reference from [1]. India is the 3rd largest manufacture of steel around the world some of the major steel plants in India located at Jharkhand, Chhattisgarh, Tamil Nadu, Andhra Pradesh, Karnataka, Orissa, and West Bengal. Steel and Iron are different based on their carbon percentage. If the carbon is having 0-0.08% it is wrought iron, 0.08-2% it is steel and rest from 2-4% is cast iron. The steel is manufacturing by a process of mixing raw materials like iron ore, coal, lime stone these are heated in an oven then steel is obtained. To produce one tonne of crude steel it requires 1400 kgs of iron ore, 800 kgs of coal, 300 kgs of lime stone and 120 kgs are of recycle steel. By using recyclable steel material, it can reduce 60 kgs of coal and 280 kgs of lime stone to produce one tonne of steel. From the steel industries the gases are released into the air and chemicals into lakes and rivers. By the research of W.H.O in 2018 the most heavily populated cities are Hyderabad, Mumbai, Pune, Chennai, Delhi, Punjab, etc. To decrease the pollution India is stepping into many techniques one of this is recycling of materials. As a structural engineer this can be achieved by saving the material like steel concrete. Then composite cellular beam is considered as shown in Fig. 2. These are incorporated with concrete and I-section steel girder. A contemporary form of castellated beams is cellular beam. The concrete is a brittle material and low tensile strength, where as the reinforcement is a steel material which is a ductile material and having low compressive strength when these materials combine they overcome the many failures. The circular web openings are made in I-section steel girder is cellular beam whereas the hexagonal, square openings are made it is castellated beam. The anatomical performance of cellular beam under flexure is consequently higher than the I-shaped beams [2].

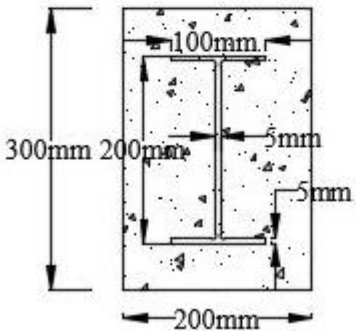

Fig. 1: Cross section of Encased Beam

The identical collapse mode of cellular beam is similar to the regular beams [3]. The stress to protect the cellular beam from fire, corrosion and to save the steel material in the encased beam the composite cellular beam is adopted. The cellular beam design is scrutinized from [4] and composite cellular beam design is accomplished.

I. RESEARCH SIGNIFICANCE

The essential investigation of the research work is to examine and to assess the experimental work which results in the construction field. This study is mainly concentrated on the flexural behavior of composite cellular beam (CCB) which is correlated with plain cement concrete beam (PCCB)

Revised Manuscript Received on April 09, 2019.

NANDURI SAI TEJASWI, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation (Deemed to be University), Vaddeswaram, Guntur District, Andhra Pradesh, India.

P. POLURAJU, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation (Deemed to be University), Vaddeswaram, Guntur District, Andhra Pradesh, India.

and encased beam (EB). For this M30 grade concrete is used by varying parameters like spacing and web openings.

This investigation concluded that the flexural strength or the modulus of rupture is more for the composite cellular beam with three web openings (CCB-3W) than composite cellular beam accompanying four web openings (CCB-4W) and PCCB. There is a slight variation in the flexural strength for EB and CCB-3W. By using CCB-3W the modulus of rupture is more, the steel material can be saved by 10.61% by weight and it can curse more deflection.

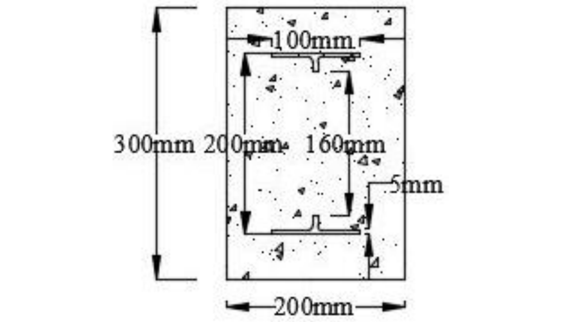

Fig. 2: Cross section of at the Web openings in Composite Cellular Beam

Fig. 3: Cellular beam with three web openings

Fig. 4: Cellular beam with four web openings

II. SPECIFICATIONS OF COMPOSITE CELLULAR BEAM

The detail investigation is done by using four beams (PCCB, EB, CCB-3W and CCB-4W) to find the flexural behavior. These specimens were cast under 1000 mm length, 200 mm width and 300 mm depth. The I –section steel girder with dimension 900 mm lengths, 100 mm width and 200 mm depth was considered.

Theses cellular beams (CB) are fabricated by using laceration process which is done by oxy-fuel cutting. This is easier and cheaper than other. The circular web opening is made from standardization [5]. Specification for the CCB-3W and CCB-4W respectively are shown below

Diameter of Web opening (D_o) = 160 mm
Spacing between Web opening (S) = 192 mm and
Diameter of Web opening (D_o) = 160 mm
Spacing between Web openings (S) = 272 mm
They detailed view is shown in Fig. 3 and Fig. 4.

A. Specimen Establishment

For the preparation of the CCB specimens the minimum grade of concrete is M30 for the severe condition IS 456: 2000[6] by the inclusion of super plasticizer PC-20 to the concrete mix. The minimum cover should be is given by [b_o +100 mm]. According to the code b_o is width of steel flange in mm. So, the concrete cover is 50 mm as per the older version of IS: 800 (1984). The cover blocks are adjusted into the mould and the concrete is layered by four times by investing the cellular beams into it. The same procedure is followed for EB. To avoid voids, honey combs vibration is essential by needle vibrator. Then smooth finishing should be given to the beam at top surface.

These are cured for 28 days using wet covering through gunny bags. This curing helps to avoid micro cracks and to maintain optimum moisture content and flexure strength has been examined.

III. THREE POINT BENDING TEST

The four beams were tested under three point bending test by using loading frame, it is load controller. The simply supported conditions are considered to find the flexural behavior. The specimens are placed consequently on the frame by abolishing 100 mm from the supports. Concentrated load is applied at centre of the beam by constitute meshing with a size of 50×50 mm to all the faces. The LVDTs (Linear Variable Deflection Transducers) is used to measure slippage and deformation of the beam. The LVDT is placed at mid span of the beam in vertical position as shown in the Fig. 5. Load is applied gradually with varying time the load and deflection increases. The results are obtained in the system in specified format. It is observed that when wing support is detached there is no further deflection.

IV. RESULTS AND DISCUSSIONS

To determine the flexural strength for three point bending test by using [7].

$$\sigma \equiv \frac{3PL}{2bd^2}$$

Where,
σ = Flexural strength (N/mm^2)
P = centre point load
L = length of the beam
b = width of the beam
d = depth of the beam

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Fig. 5: Three Point Bending Test

The test results are obtained for the specimens. The ultimate load obtained for PCC beam was 53.8 kN with deflection of 0.64 mm. It is observed that the experimental load is more than the designed load. The load vs. deflection graph is drawn for the PCC beam as shown in Fig. 6. The flexural strength obtained for PCC beam was 4.48 N/mm^2. There is sudden failure of specimen after ultimate load is reached.

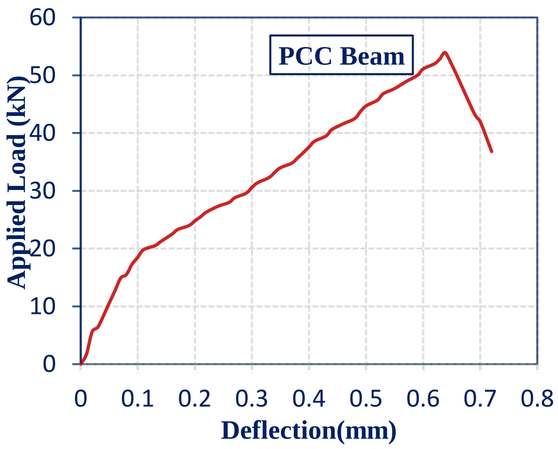

Fig. 6: Load *vs.* deflection for PCC Beam

In the similar manner encased beams are also tested under three point bending test, the ultimate load obtained was 366.8 kN with deflection 5.92 mm and flexural strength of 30.56 N/mm^2 observed from the test data. From load vs. deflection graph due to the I-section steel girder which is wrapped in the concrete. After the ultimate point the steel girder subjects to more deflection as shown in Fig. 7.

Flexural strength of 29.03 N/mm^2 from flexural strength formula is observed for composite cellular beam accompanying three web openings is tested and obtained ultimate load was 348.4 kN and deflection was 14.42 mm as shown in Fig.8.

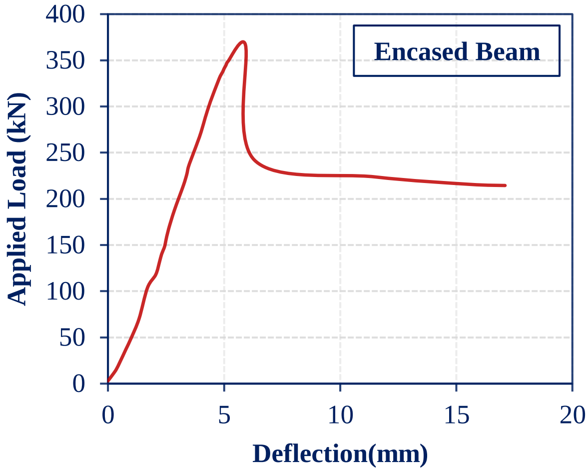

Fig.7: Load vs. deflection for Encased Beam

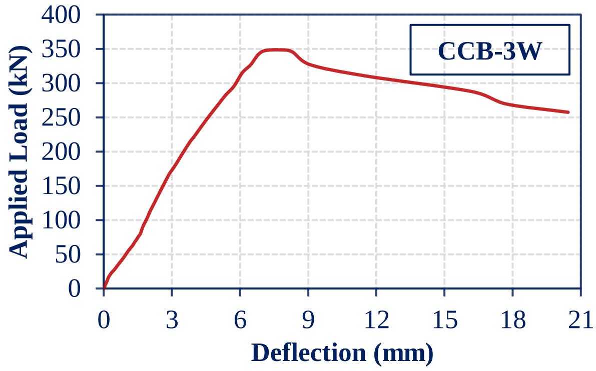

Fig. 8: Load *vs.* deflection for Composite Cellular Beam with 3-Web openings Beam

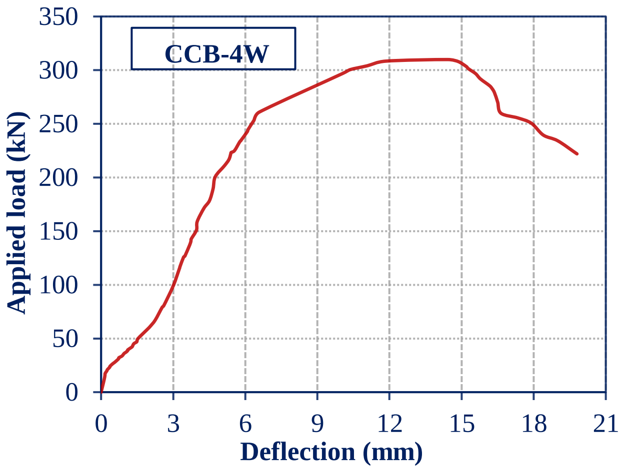

Fig. 9: Load *vs.* deflection for composite cellular beam with four web openings beam

Composite cellular beam accompanying four web openings is tested and obtained ultimate load was 309.9 kN and deflection was 7.73 mm as shown in Fig. 9. Flexural strength 25.82 N/mm^2 was observed from the formula given by the code.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

V. CONCLUSIONS

The beams were tested under three point bending. The results are tabulated and graphs are drawn on the results. The conclusions are given using obtained graphs. The flexural strength is observed from the specimens by testing are as:

1. Flexural strength of Encased Beam is 14.67 % more than Plain Cement Concrete Beam.
2. When CCB-3W is compared with CCB-4W the Flexural strength is 88.95% higher.
3. The modulus of rupture is similar with slight variation of 5.01% when compared CCB-3W with EB.
4. Concentration of stress at neutral axis is zero depending on Stress diagram. To find the flexural behavior where steel material is removed at neutral axis it can save the material up to 10.60% for CCB-3W and 16.85% for CCB-4W.
5. The EB can resist more deflection than PCCB by 10.81%.
6. The deflection for CCB-3W is 53.60% more than CCB-4W.
7. The composite cellular beams are lighter than encased Beams.
8. The cellular beams are protected from corrosion and fire resistance by cast as composite cellular beam
9. Both the steel and concrete materials can be saved in CCB when compared with encased beams.
10. These composite cellular beams are economical than Encased beams.

The Further investigation should be done to observe failure mechanism of composite cellular beam.

REFERENCES

1. Ammar A.Ali, Saad N.Sadik, Wael S.Abdul-Shaib, "Strength and Ductility of Concrete Encased Composite Beams", Engineering and Technology Journal (Eng. Tech. journal), Vol.30, No. 3, 2012, pp. 2701-2714.
2. Lucas Figueiredo Grilo, Richard Hallal Fakury, Ana Lydia Reis de Castro e Silva, Gustavo de Souza Vetissimo, "Design procedure for the web-post buckling of steel cellular beams", *Journal of Constructional Steel Research,* ELSEVIER, Vol.148, 2018, pp.525-541.
3. Delphine Snock, Jan Belis, "Lateral-Torsional Buckling Resistance of Castellated Beams", *Journal of Structural Engineering (J. Struct. Eng.)* , ASCE, Vol.143, No.3, 2017, pp.1-9.
4. AISC 31 Steel Design Guide, Castellated and Cellular Beam Design.
5. Constructalia ArcelorMittal Cellular Beams ACB, 2018, "ArcelorMittal Europe- Long products Sections and Merchant Bars. [Brochure].
6. IS: 456-2000, Plain and Reinforced Concrete-Code of Practice.
7. ASTM C 293-02, Stranded Test Method for Flexure Strength of Concrete(Using Simple Bean with Center point Load)
8. Richard Redwood, Sevak Demirdjian, "Castellated Beam Web Buckling in Shear", *Journal of Structural Engineering (J. Struct. Eng.)* , ASCE, Vol. 124, No. 10, 1998, pp. 1202-1207.
9. Ali nadjai, Klelia Petrou, Sanghoon Han, Faris Ali, "Performance of unprotected and protected cellular beams in fire conditions", *Construction and Building Materials,* ELSEVIER, Vol. 105, 2016, pp. 579-588.
10. Ajim S.Shaikh, Shahrukh K.Kazee, Vishal R, Vitnor, Sanket S.Desai, "Comparison of Steel Beams", *International Research Journal of Engineering and Technology (IRJET),* Vol. 2, No. 4, 2015, pp.1387-1390.
11. Aparna C Manoharan, R.K.Tripathi, "Analysis of Steel Beams with Circular openings", *International Journal of Civil Engineering and Technology (IJCIET),* Scopus, Vol. 8, No. 3, 2017, pp.411-422.
12. Ehab Ellobody, "Behavior of normal and high-strength castellated beams", *Structures and Buildings*, Vol.165, No. SB10, 2012, pp.529-542.
13. Benyagoub Djebli, Djamel Elddine Kerdal, "The total Deflection of Composite Cellular Beams under Transverse Loading", *Arabian Journal for Science and Engineering (Arab J Sci Eng)* Springer, Vol.39, No.10, 2014, pp.6815-6824.
14. Oliver Hechler, bChristian Muller, Gerhard Sedlacek, "Investigation on Beams with Multiple regular Web openings*", Composite Construction in Steel and Concrete V*, ASCE, 2006, pp. 270-281.
15. T.Okubo, D.A.Nethercot, "Web post strength in castellated steel beams", *Structural Engineering Group, Proc.Instn Civ.Engrs*, 1985, pp. 533-557.
16. Shiming Chen, Toi Limazie, Jianyao Tan, "Flexural behavior of shallow cellular composite floor beams with innovative shear connections", *Journal of Constructional Steel Research,* ELSEVIER, 2015, pp. 329-346,
17. R.P.Smoke, D.W.Dinehart, S.P.Gross, J.R .Yost, "Seismic Performance of Connections for cellular Beams in Steel Moment frames, *Structures congress,* ASCE, 2010, pp.967-978.
18. IS: 10262-2009, Concrete Mix Proportioning – Guidelines.
19. Eurocode 4: Design of Composite Steel and Concrete Structures - Part 1-1: General rules and rules for buildings.
20. AISC 360-16: Specifications for Structural Steel Building.
21. AISC 303-10: Code of Standard Practice for steel Buildings and Bridges.

AUTHORS PROFILE

NANDURI SAI TEJASWI received the Bachelor Degree in Civil Engineering from JNTUKAKINADA, Dhanekula Institute of Engineering and Technology, Ganguru, Vijayawada, Krishna District, Andhra Pradesh, India in 2017.She is pursuing Master of Technology in Structural Engineering at Koneru Lakshmaiah Education Foundation (Deemed to be University), Vaddeswaram, Guntur District, Andhra Pradesh, India. She actively participated in Workshops in and around the University. She did her Internship at CECON Consultants Private Limited and Architectural and Structural Services in Bhilai, Chhattisgarh, India. She is a member of IAENG (International Associate of Engineers).

Dr.P.POLURAJU is working as Associate Professor and HoD in Department of Civil Engineering at Koneru Lakshmaiah Education Foundation (Deemed to be University), Vaddeswaram, Guntur District, Andhra Pradesh, India. He has completed Master of Technology in Structural Engineering from IIT Madras in 2017. His research interest include Sandwich Panels.

*Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication*

Rehabilitation and Retrofitting of RC structures. He has published 32 research papers in international journals and conferences and guiding 8 numbers of Ph.D. scholars, guided 20 numbers of P.G. dissertation works and 10 numbers of U.G. project works. He is a lifetime member of ICI (Indian Concrete Institute) and ISRD.