Flexural Behavior of Concrete Beams with Composite Reinforcement

Bharathi.K.M[1], Abdul Hameed.A[2]

[1] *PG Student, Department of Civil Engineering, Nandha Engineering College, Erode-52. bharathi.structural@gmail.com, Mobile: 9965359849*

[2] *Assistant Professor, Department of Civil Engineering, Nandha Engineering College, Erode-52.*

Abstract: **This paper describes the properties and behavior of RC beams with composite reinforcement. This studies the comparative resulting advantages by the in-filled steel pipes. This also discuss about implementing of this reinforcement in construction and the forthcoming benefits of this project. The beams casted were tested for flexure, under two point loading condition. Different structural parameters were investigated.**

Keywords: **Composite reinforcement, flexure, in-filled pipes, structural parameters.**

1. Introduction

The main theme of this project is the composite reinforcement. The conventional reinforcement used for construction purposes is replaced by this composite reinforcement. This is aiming to check how effectively this composite reinforcement will behave and the areas this can be adopted to obtain the advantages of this composite reinforcement.

The use of composites in the form of concrete-in-filled tubes for the construction of new high-performance structural members will receive significant attention, with large numbers of studies reporting on the flexural behavior of beam and a few studies have reported on the flexural behavior of beams reinforced with steel bars. This composite system consists of an outer steel tube with cement mortar in-filled with the sieved crumb rubber mixture. The resulting beam combines the advantages of all three materials to achieve a high-performance structural member.

2. Research objectives

There are different perspectives in the literature on issues of confinement and analysis methods.

The next section will discuss the details of the experimental program, which will be followed by characterization of the measured responses and will discuss how effectively this composite reinforcement can be used.

3. Past research

Literature on the subject of CRBs is vast and dates back to the 1950. The focus of past research can be divided into the following broad categories: (1) Impact of confinement (including the effect of multi-axial stresses on response); (2) Issues related to composite action and strain compatibility under flexural response; (3) Member level response (including flexural strength and stiffness, shear strength, and ductility) as effected by geometric variables including internal steel.

Lengthy literature reviews in all these areas are to be found elsewhere and is outside the scope of this research. Summarized in this paper is the new work on the usage of in-filled steel tube as reinforcement.

3.1. Truss

Concrete filled steel tubular (CFST) chord to hollow tubular brace truss (referred to as CFST truss for short) is a type of truss which uses CFST members as its chords and hollow tubes as its braces. A concrete slab can be provided on the CFST truss to form a hybrid CFST truss. The main parameters investigated were the shear span ratio, the angle between the brace and chord, profile of the bottom chord, the existence of the infill concrete and the concrete slab. On comparing the influences of these parameters on the flexural behaviour and failure modes of the trusses were investigated and the results showed that both the infill concrete and concrete slab improved the flexural performance.

3.2. Steel tube-reinforced concrete

Concrete (STRC) composite wall, with steel tubes embedded at the wall boundary elements and fully anchored within the foundation. This arrangement is supposed to enhance the wall's seismic performance. The area ratios of steel tube and of concrete filled steel tube (CFST) (i.e. the ratios of the cross-sectional areas of steel tubes over that of the wall boundary element, respectively), axial force ratio, and cross-sectional shape of walls were taken as major test variables. The test results showed that the composite walls had larger load-carrying and deformation capacities relative to the RC wall counterpart.

3.3. Concrete filled steel tubes

Concrete filled steel tubes are used in a variety of structures including bridges, high rise buildings, and power plants. They provide several possible advantages over conventional reinforced concrete or hollow steel tube construction including simplified construction (steel tubes can serve as permanent formwork) and improved seismic behavior.

Reinforced concrete filled steel tubes are commonly used for bridge sub structures in high seismic regions where the steel tube is used as a permanent casing which eases construction. Concrete confinement is provided by the steel tube, increasing the compressive strength and strain capacity.

4. Composite reinforcement

The composite reinforcement here used is the in-filled mild steel pipe. Mild steel pipe of required size can be adopted. This steel pipe is in-filled with the mixture of the cement slurry and the sieved crumb rubber with ratio of 1:2 parts of the cement and the rubber. The thickness of the mild steel pipe can be 1mm to 2 mm.

The pipe can be in-filled with injector or manually. For high requirements it can be in-filled using the injectors. Thus the pipe can be in-filled in-situ or ex-situ. The in-filled pipe is allowed to set for a minimum of 24hours. Then the pipe can be cut or bent and used for the requirements.

4.1. Nurling Process

The mild steel pipes of the required sizes were made to undergo nurling process in the laboratory to make impressions on the smooth pipe. This nurling process was done by considering the importance of the binding of concrete material with the reinforcement, since plain pipes will lack bonding equivalent to the TMT bars. Thus this innovative composite reinforcement will eradicate the negative issues on the strength comparision and physical behavior conforming to the conventional bars.

Fig.1 Nurled pipes

4.2. Weight of pipe

The weight of the empty mild steel pipe, weight of the in-filled mild steel pipe and also the weight of the same size conventional reinforcement rod is taken and compared.

This comparative weight results show that, the weight of the in-filled mild steel pipe is very less to the conventional rod. Also due to the less weight these types of in-filled mild steel pipes are easy to handle and transport.

4.3. Properties and behavior

The properties of the conventional reinforcement rod and the composite reinforcement are studied comparatively. The study result shows that the composite reinforcement is strong enough to be compared with the conventional reinforcement rod and also surely can be replace the conventional rod and very hardly exceptional to use in few areas.

The conventional reinforcement rod and the composite reinforcement are taken under the same kind of tests to obtain the comparative results. This test result also shows that the composite reinforcement proposed is well and good to be replaced for the conventional reinforcement rod.

4.4. Crumb rubber

Crumb rubber is obtained from the used tyres. These rubbers are soft and very light in weight. The increasing amount of waste tyres worldwide makes the disposition of tyres a relevant problem to be solved. In the last years over three million tons of waste tyres were generated. Most of them were disposed into landfills. To significantly reduce the landfill disposal of waste tyres, the development of new markets for the tyre becomes fundamental.

Fig.2 Crumb rubber

Recently some research has been devoted to the use of granulated rubber and steel fibres recovered from waste tyres in concrete. As a consequence RSFRC (recycled steel fibres reinforced concrete) appears a promising candidate for both structural and non-structural applications. In the present experiment has done to make use of waste tyres obtained from tyre retreading centres in structural applications.

Fig.3 Mild steel pipe

Fig.4 In-filled pipe

5. Experimental program

5.1. Test specimen details

Impact test for the in-filled mild steel tube and conventional reinforcement rod were taken out. The impact test result shows that, it will be safe and permissible to use the in-filled steel tube as reinforcement in concrete members.

Fig.5 Casted beams

The test specimens of size 150mm × 150mm × 700mm are casted and cured for 28 days. The beams were casted using both the conventional rods and also the in-filled steel tube for the assistance of comparative results.

5.2. Test setup & instrumentation

The test setup consisted of two point loads, one-third from both sides, in the center of the specimen to create a constant moment region. The actuators which applied the loads were pushed. The load will be applied gradually and will be checked out for the strength, crack spacing and crack width.

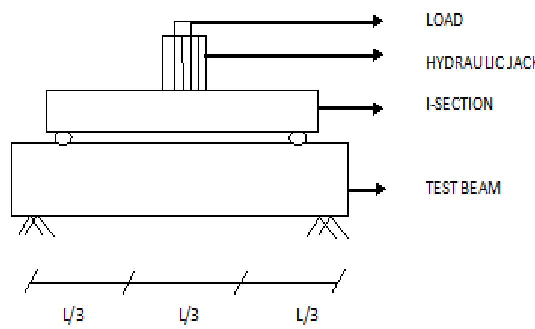

Fig.6 Test Setup

5.3. Loading history

Before yield, the loading of each test was force-controlled and separated into four increments: (1) quarter yield force (2) half yield force (3) three-quarter yield force and (4) yield force. One complete cycle was conducted at each loading level.

6. Flexural behavior

Flexural behavior of concrete beams reinforced with in-filled steel tube is studied in this paper. Tensile test, standard pull-out test and static flexural experiment for concrete beams were made.

6.1. Flexural Tensile Strength

Flexural strength is defined as a materials ability to resist deformation under load. The modulus of rupture is calculated based on the distance of the crack from the nearer support "a" measured on the centre line of the tensile face of the specimen are recorded.

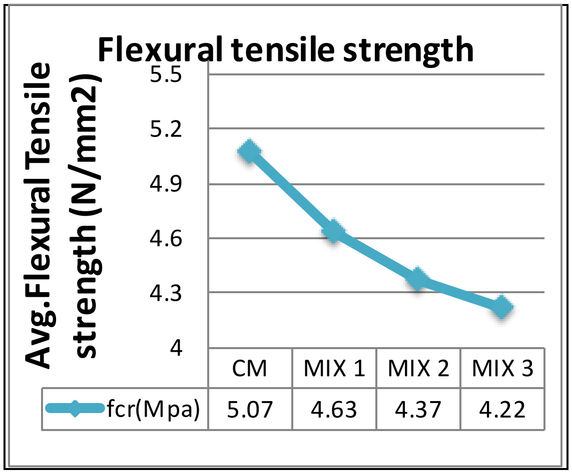

Fig.7 Flexural tensile strength

6.2. Crack Patterns

All the beams were failed in flexural mode, as the load increases the flexure cracks initiates in the pure bending zone and the first cracks appears almost in the mid span. As the load increases, existing cracks propagated and new cracks developed along the span. The cracks at the mid-span opened widely near failure, the beams deflected significantly, thus indicating that the tensile steel must have yielded at failure.

Fig.8 Crack pattern

6.3. Experimental Results

All the test beams were studied for pure bending. Structural parameters like cracking load, service load and ultimate load with their respective deflections are investigated. Also, the experimental values are compared with the theoretical values conforming to IS: 456-2000.

6.3.1 Cracking Moment

The load at which the first crack was observed was calculated as the cracking moment. As the tensile reinforcement is increased the cracking moment also increases. The theoretical cracking moment was calculated as per the IS: 456-2000 recommendations and compared with the experimental values for the varying tensile reinforcement.

Table 1: Cracking moment

EXPERIMENTAL RESULTS AND THEORETICAL RESULTS OF CRACKING MOMENT				
Beam designation	Ast (%)	Experimental cracking momentMc(kNm)	Theoretic-al cracking moment Mr(kNm)	Ratio Mc/Mr (IS:456-2000)
TB -1	0.72	5.0	3.837	1.25
TB -2	0.72	5.2	3.837	1.30

6.3.2 Flexural Capacity

The ultimate moment carrying capacities of the beams are calculated theoretically conforming to IS: 456-2000 and compared it with the experimental results.

Table 2: Ultimate moment

EXPERIMENTAL RESULTS AND THEORETICAL RESULTS OF ULTIMATE MOMENT				
Beam designation	Ast (%)	Experimental ultimate moment, (kNm)	Theoretical ultimate moment (kNm)	Ratio Mu(E)/ Mu(t) (IS:456-2000)
TB - 1	0.72	16.54	10.60	1.56
TB - 2	0.72	17.2	10.60	1.62

6.3.3 Deflection

The deflection of the beam were measured at an interval of 2kN at the mid span and 1/3rd span from both the sides of support till the failure of the beams. The deflections recorded are compared with the theoretical values conforming to the IS: 456-2000 at all the loads.

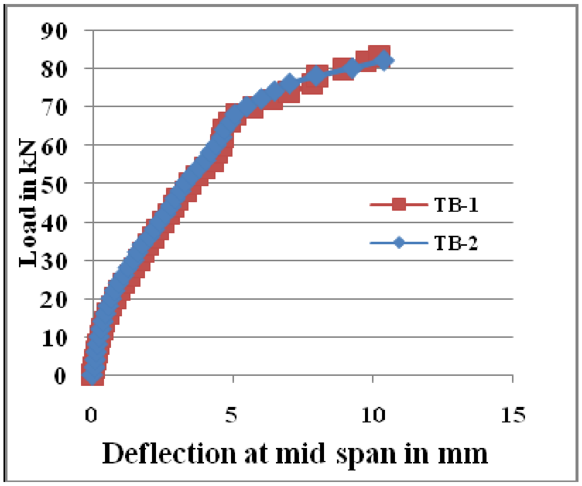

Fig.9 Deflection at mid span

6.3.4 Crack Width

Crack width is an important factor from the durability point of view and cracks formed were < 0.3mm conforming to the IS: 456-2000. The cracks formed propagated towards the compression zone from the tension zone and the observations were made.

6.3.5 Surface Strain

Surface strains were measured using DEMEC gauges. The strains were measured at every 2kN load increments.

7. Conclusion

The main aim of this project is to provide light weight and economical structures. The study shows that steel tubes have high tensile strength and low elastic modulus compared with steel bars. The bond strength between tubes and concrete shows good bond performance. By controlling the reinforcement ratio the ductility of steel tube reinforced beams can meet the requirements of normal service conditions. Low cost residents can be constructed using this composite reinforcement and with some improved properties this can also be adopted for seismic resistance.

References

[1] Abdelrahim Dessouki.K Ahmed Yousef.H ,Mona Fawzy .M (2015) "Investigation of in-plane moment connections of I-beams to square gravity loads" HBRC Journal Vol.no 11, PP (43–56)

[2] Aiello. M. A, Leuzzi. F, Centonze. G, Maffezzoli. A (2009) "Use of steel fibres recovered from waste tyres as reinforcement in concrete: Pull-out behaviour, compressive and flexural strength" Waste Management Vol.no 29, PP (1960–1970)

[3] Ayman Moustafa, Mohamed ElGawady.A (2015) "Mechanical properties of high strength concrete with scrap tire rubber" Construction and Building Materials Vol.no 93, PP (249–256)

[4] Brown. N. K, Kowalsky. M. J, Nau. J .M (2015) "Impact of D/t on seismic behavior of reinforced concrete filled steel tubes" Journal of Constructional Steel Research Vol .no 107, PP (111–123)

[5] Esmaeel Esmaeeli, Joaquim Barros.A.O (2015) "Flexural strengthening of RC beams using Hybrid Composite Plate (HCP): Experimental and analytical study" Composites Vol.no 79, PP (604-620)

[6] Fabiana Maria da Silva, Luisa Andréia Gachet Barbosa, Rosa Cristina Cecche Lintz, Ana Elisabete Jacintho(2015) "Investigation on the properties of concrete tactile paving blocks made with recycled tire rubber" Construction and Building Materials Vol.no 91, PP (71–79)

[7] Haolin Su , Jian Yang, Tung-Chai Ling , Gurmel S. Ghataora , Samir Dirar (2014) "Properties of concrete prepared with waste tyre rubber particles of uniform and varying sizes" Journal of Cleaner Production Vol.no 19, PP (1-9)

[8] Huiyong Ban, Brian Uy, Sameera Wijesiri Pathirana, Ian Henderson, Olivia Mirza, Xinqun Zhu (2015) "Time-dependent behaviour of composite beams with blind bolts under sustained loads" Journal of Constructional Steel Research Vol. no 112 , PP (196–207) 39

[9] Jia-Bao Yan, Richard Liew.J.Y, Xudong Qian, Jun-YanWang(2015) "Ultimate strength behavior of curved steel–concrete–steel sandwich composite beams" Journal of Constructional Steel Research Vol.no 115, PP (316–328)

[10] Jiaru Qian, Zao Jiang, Xiaodong Ji (2012) "Behavior of steel tube-reinforced concrete composite walls subjected to high axial force and cyclic loading" Engineering Structures Vol.no 36, PP (173–184)

[11] Ligang Yua, Qijun Yub, Lan Liub (2012) "Hybrid modified wasted rubber powder and its hydration reaction in the cement-based material" Procedia Engineering Vol.no 27, PP (394 – 404)

[12] Lin-Hai Han , Wu Xua, Shan-Hu He , Zhong Tao(2015) "Flexural behaviour of concrete filled steel tubular chord to hollow tubular brace truss: experiments" Journal of Constructional Steel Research Vol.no 109, PP (137–151)

[13] Madiha Ammari Z.J, Moayyad Al-Nasra.M, Abdelqader Najmi "Effective use of U-Link in Concrete Filled Steel Tubes Beams" International Journal of Engineering Science Invention Vol.no 21, PP (59-66)

[14] Marques.A.M, J.R.Correia.J.R, DeBrito.J (2013) "Post-fire residual mechanical properties of concrete made with recycled rubber aggregate" Fire Safety Journal Vol.no 58, PP (49–57)

[15] Mehmet Gesog lu, Erhan Guneyisi, Ganjeena Khoshnaw, Suleyman Ipek (2014) "Abrasion and freezing–thawing resistance of pervious concretes containing waste rubber" Construction and Building Materials Vol.no 73, PP (19–24)

[16] Si Larbi. A, Ferrier. E, Jurkiewiez,. B, Hamelin. P (2007) "Static behaviour of steel concrete beam connected

by bonding" Engineering Structures Vol.no 29, PP (1034–1042) 40

[17] Shiming Chen , Toi Limazie, Jianyao Tan, (2015) "Flexural behavior of shallow cellular composite floor beams with innovative shear connections" Journal of Constructional Steel Research Vol.no 106, PP (329–346)

[18] Taek Hee Han , Ki Yong Yoon , Young Jong Kang(2010) "Compressive strength of circular hollow reinforced concrete confined by an internal steel tube"Construction and Building Materials Vol.no 24, PP (1690–1699)

[19] Vasdravellis.G, Uyb.B, Tanc.E.L, Kirklandb.B (2015) "Behaviour and design of composite beams subjected to sagging bending and axial compression" Journal of Constructional Steel Research Vol.no 110, PP (29–39)

[20] Wei-Hua Wang, Lin-Hai Han, Wei Li b, Yi-Hai Jia (2014) "Behavior of concrete-filled steel tubular stub columns and beams using dune sand as part of fine aggregate" Construction and Building Materials Vol.no 51, PP (352–363)

[21] Wenjie Ge, Jiwen Zhang, Dafu Cao, Yongming Tu (2015) "Flexural behaviors of hybrid concrete beams reinforced with BFRP bars and steel bars" Construction and Building Materials Vol.no 87, PP (28–37)

[22] Weidong Lu, Zhibin Ling, Qifan Geng, Weiqing Liu, Huifeng Yang, Kong Yue (2015) "Study on flexural behaviour of glulam beams reinforced by Near Surface Mounted CFRP laminates" Construction and Building Materials Vol.no 91, PP (23–31)

[23] Yu-Bing Leng, Xiao-Bing Song, Hai-LinWang (2015) "Failure mechanism and shear strength of steel–concrete–steel sandwich deep beams" Journal of Constructional Steel Research Vol.no 106, PP (89–98) 41

[24] Yunita Idris, Togay Ozbakkaloglu (2014) "Flexural behavior of FRP-HSC-steel composite beams" Thin-WalledStructures Vol.no 80, PP (207–216)

[25] Yu Wang, Xudong Qian, Richard LiewJ.Y, Min-Hong Zhang (2014) "Experimental behavior of cement filled pipe-in-pipe composite structures under transverse impact" International Journal of Impact Engineering Vol.no 72, PP (1-16)

