International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 7 Issue 1|| January 2018 || PP. 20-25

Experimenatal Investigation on Reinforced Concrete Tee- Beams Strengthen with Ferrocement

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Abstract: *This strengthening and enhancement of the performance of such deficient structural elements in a structure or a structure as a whole is referred to as retrofitting. All the important issue to be addressed in retrofitting is for life safety. Ferrocement is most commonly used as retrofitting material due to their easy availability, economy, durability, and their property of being cast to any shape without needing significant formwork. Ferrocement as a retrofitting material can be pretty useful because it can be applied quickly to the surface of the damaged element without the requirement of any special bonding material and also it requires less skilled labour, as compared to other retrofitting solutions presently existing. The Ferrocement construction has an edge over the conventional reinforced concrete material because of its lighter weight, ease of construction, low self weight, thinner section as compared to RCC and a high tensile strength which makes it a favorable material for prefabrication also.*

The present investigation on Preloaded Reinforced Concrete Tee Beams is retrofitted using Ferrocement to increase the strength at faces of web, by placing the wire mesh along the longitudinal axis of the beam. From the study it is seen that the ultimate load carrying capacity of Reinforced concrete Tee beam elements retrofitted by Ferrocement is significantly increased when Welded Wire mesh are used for retrofitting.

Keywords: *Ferrocement, Retrofitting, Wire Mesh,*

Date of Submission: -01-2018 Date of acceptance: 17-01-2018

I. Introduction

The Reinforced Cement Concrete structures constructed in the developed area are often found to exhibit distress and suffer changes, even before their service period that is often due to several causes such as improper design, faulty construction, change of usage of the building, change in codal provisions, over loading, earthquakes, explosion, corrosion, wear and tear, flood, fire etc. such unserviceable structures require immediate attention and enquiry into cause of distress and suitable remedial measures, for bringing the structure into its functional use again. In the last few decades several attempts have been made in India and abroad to study these problems and to increase the life of the structures by suitable retrofitting and strengthening techniques. Among the plate bonding techniques FRP plate are quite popular now a days. But it is observed that the use of FRP is restricted is many developed countries and urban areas of the developing countries due to higher initial cost and requirement of skilled labour for their application. Thus there is a need to develop an alternative technique, which is economical and can be executed at site even with less skilled labour available at site.

II. Experimental Programme

Table 1 Properties of Materials

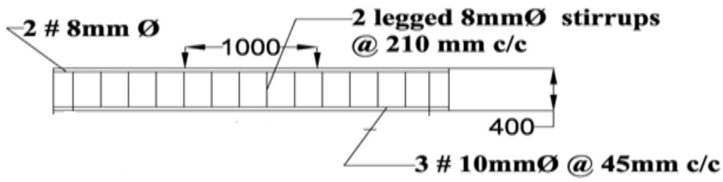
Properties of Cement			
Sl.no	**Property**	**Experimental Value**	**Indian Standards**
1	Grade	53	IS:12269 - 2013
2	Soundness Test	2mm	IS:4031 (Part-3)2005
3	Fineness of Cement	8%	IS:4031 (Part-2)2005
4	Consistency of Cement	30%	IS:4031(Part-4)2005
5	Initial Setting Time	45mins	IS : 12269:2013 Clause 6
6	Final Setting Time	230mins	IS : 12269:2013 Clause 6
7	Specific gravity	3.15	IS:4031(Part-3)2005

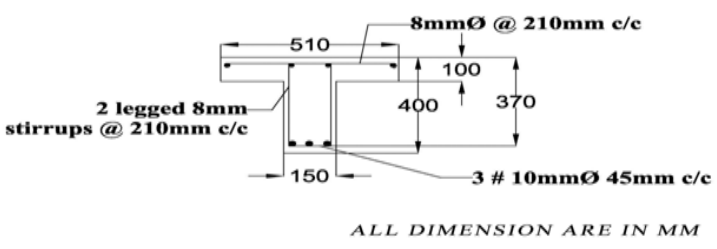
Compressive strength of cement mortar cubes (N/mm^2)			
8	3 Days	29.31	IS : 12269:2013 Clause 6
9	7 Days	38.12	IS : 12269:2013 Clause 6
10	28 Days	54.36	IS : 12269:2013 Clause 6
Properties of Fine Aggregates			
11	Fineness modulus	2.9	IS:2386(Part-1)2002
12	Specific Gravity	2.59	IS: 2386 (Part-3)2002
13	Water Absorption	1%	IS: 2386 (Part-3)2002
Properties of Coarse Aggregates (10 – 20 mm)			
14	Water Absorption	0.5%	IS: 2386(Part-3)2002.
14	Specific Gravity	2.74	IS: 2386(Part-3)2002.
15	Impact test	46.53%	IS:2386(Part-4)2002
16	Specific Gravity	2.74	IS: 2386(Part-3)2002.
17	Fineness modulus	8.44	IS: 2386(Part-1)2002

Table 2: Summary of Strengthening Plan

Sl. No	Beam Group	Beam Code	Pre – Loading Level (%)	Type of Strengthening	Steel Ratio (%)	Volume fraction of Ferrocement (%)
1	B_C	B_{C-1}	100	Nil	0.425	1.61
2		B_{C-2}	100		0.425	1.61
3		B_{C-3}	100		0.425	1.61
4	B_{RW}	$B_{RW\ 1-1}$	60	All Faces of Web	0.425	1.61
5		$B_{RW\ 1-2}$		All Faces of Web	0.425	1.61
6		$B_{RW\ 1-3}$		All Faces of Web	0.425	1.61
7		$B_{RW\ 2-1}$	70	All Faces of Web	0.425	1.61
8		$B_{RW\ 2-2}$		All Faces of Web	0.425	1.61
9		$B_{RW\ 2-3}$		All Faces of Web	0.425	1.61
10		$B_{RW\ 3-1}$	80	All Faces of Web	0.425	1.61
11		$B_{RW\ 3-2}$		All Faces of Web	0.425	1.61
12		$B_{RW\ 3-3}$		All Faces of Web	0.425	1.61

To carry out the investigation, Material used and its Properties are tabulated M25 Grade of concrete mix was used for preparation of specimen and 12 Reinforced Concrete Tee beams are casted. The specimens of reinforced under reinforced, balanced flanged concrete beam. The specimen consists of flange of size 510*100 mm and web of 150 mm*300 mm reinforced with conventional steel and the length of the beam is 3000 mm. Main reinforcements of Tee beams were high yield strength deformed steel bars of 3 numbers of 10mm diameter bars and four number 8mm diameter bars are used for stirrups. Out of these fourteen beams, three were used as control beams and tested for failure to find out the safe load carrying capacity and also ultimate load carrying capacity corresponding to the allowable deflection as per IS 456 - 2007. The cross sectional geometries and longitudinal reinforcements were the same for all the specimens. Longitudinal reinforcement consist of three 10 mm diameter steel rebar's in the bottom of the beam. Strengthening was not applied to control beam.





Section Details of RC T beams

Compaction is done with the help of needle vibrator in all the specimens and care is taken to avoid displacement of the reinforcement inside the form work. Then the top surface of the concrete is leveled and smoothened by metal trowel and wooden float. Remaining beams were stressed to 60%, 70%, and 80% of the ultimate load obtained from the testing of the control beams and were then retrofitted with 15mm thick ferrocement made with 1:2 cement sand mortar and w/c ratio 0.40.

The Ferrocement was reinforced with one layer of weld mesh Totally Nine Numbers of Preloaded Level (60%, 70%, and 80%) respectively were used with strengthen at all faces of web beams (B_{RW}) and also Control beam were designated as $\mathbf{B_C}$.

Fig 1: Preparation of Steel Reinforcement for Beams.

Fig 2: Tee beam mould before casting

Fig 3: Pouring of Concrete on Tee Beam Mould

Fig 4: Concreting of Tee beam mould

Fig 5: Demoulded RC Tee Beams

Fig 6: RC Tee Beams under Curing

All the beams were tested with an effective span of 2.8 m. Two concentrated loads were applied at 1m spacing from both supports (Fig 6). The beams were tested using hydraulically operated Jacks connected to a data acquisition system through the load cells with an increase in load

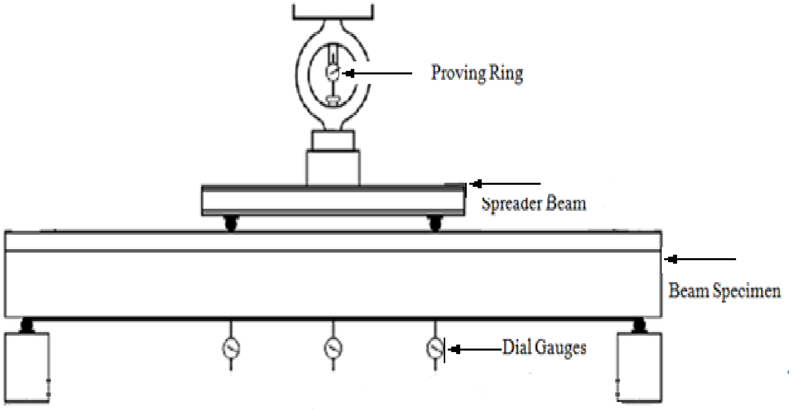


Fig 7: Schematic Diagram for Testing Arrangement

Fig 8: Flexural Tested on Tee Beam

The deflections in the beams were noted using three dial gauges placed at the quarter span points. The load is applied almost at a uniform rate load and deflections were recorded at regular intervals for each step.

III. Process Of Retrofitting On Pre Loaded Beam

The beams were stressed up to a specified limit as above and then retrofitted by applying weld mesh and then plastering it with cement mortar up to the thickness of 30 mm for all 9 beams. Effect of three different stress levels of 60%, 70% and 80% has been studied. First of all surface of beams were cleaned by sand blasting techniques. One layer of weld mesh stretched and attached along the all faces of web beams. The nail and visor used for bonding between beam and mesh. Then 15mm plaster in the form of 1:2 Cement mortars is applied on faces of beams. After remolding the beam were subjected to curing for 28days.

Fig 9: Pre – loaded Beams are retrofitting all faces of web T Beams (B_{RW})

IV. Test Results And Discussion

The control beams were tested up to failure. The remaining 9 beams were stressed to various levels i.e., 60%, 70% and 80% of the average ultimate load of control beams. Subsequently the retrofitting of beams using orientations of weld mesh in the ferrocement was carried out. These retrofitted beams were then loaded to failure and the data was recorded in the form of load and deflection. Fig 11, 12 and 13 shows the load deflection behaviors at the mid span points of the control as well as beams retrofitted with welded wire mesh orientations. It is observed from the curves in fig 11, 12 and 13 shows that with an increase in load there is a considerable increase in deflection for all the beams. It was also noted that the Maximum ultimate load carrying capacity of Retrofitted beams with 60% Pre Loaded levels achieved higher values.

Table 3: Ductility of Tested Beams

Beam Group	Beam Code	Ductility ratio	Average Ductility ratio	Increase in ductility %
BC	BC – 1	8.08	7.95	-
	BC – 2	7.63		
	BC - 3	8.13		
BRW	BRW 1- 1	4.57	4.53	42.99
	BRW1 – 2	4.61		
	BRW 1 – 3	4.41		
	BRW2 – 1	6.08	6.10	25.96
	BRW 2 – 2	5.74		
	BRW 2 – 3	6.47		
	BRW 3 – 1	5.94	5.88	23.26
	BRW3 - 2	5.60		
	BRW3 – 3	6.12		

Table 4: Energy Absorption of Tested Beams

Beam group	Beam code	Energy absorption N-m	Average Energy absorption	Increase in E.a %
BC	BC – 1	2980	2903.33	-
	BC – 2	2840		
	BC - 3	2890		
BRW	BRW 1- 1	3940	38733.33	33.41
	BRW1 – 2	3870		
	BRW 1 – 3	3810		
	BRW2 – 1	3290	3260.00	12.29
	BRW 2 – 2	3260		
	BRW 2 – 3	3230		
	BRW 3 – 1	2800	2606.67	10.21
	BRW3 - 2	2970		
	BRW3 – 3	2950		

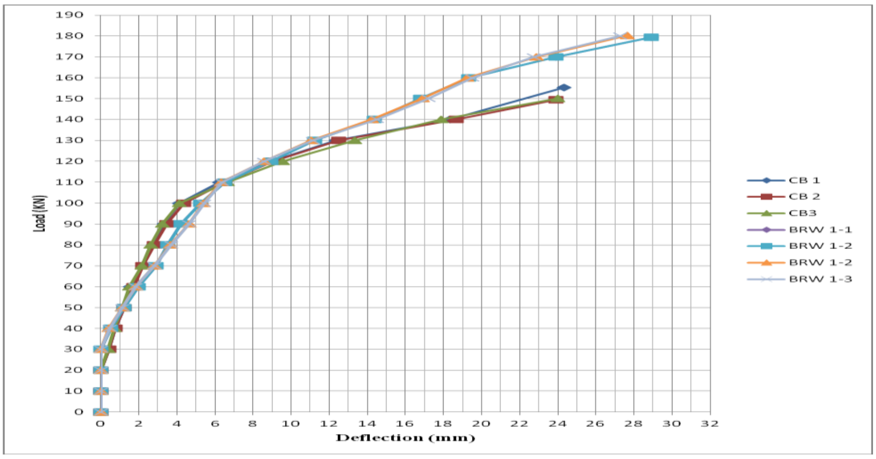


Fig 11 Load – Deflection Relationships of C_B, B_{RW} on 60% Pre-loaded Beams

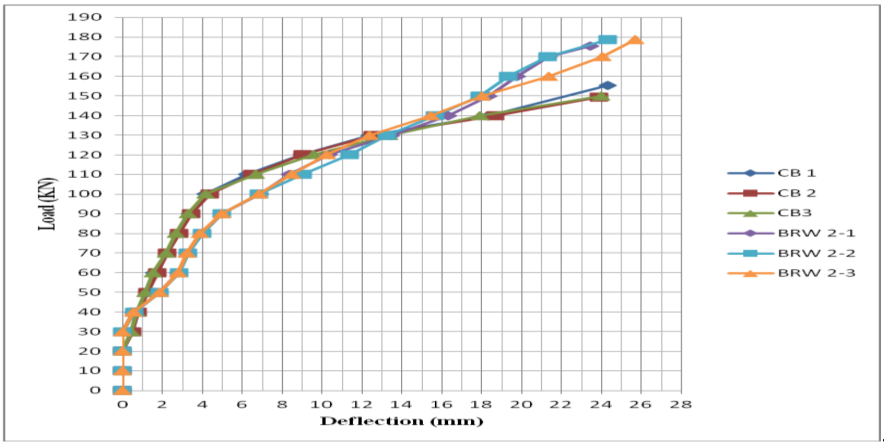


Fig 12 Load – Deflection Relationships of C_B, B_{RW} on 70% Pre-loaded Beams.

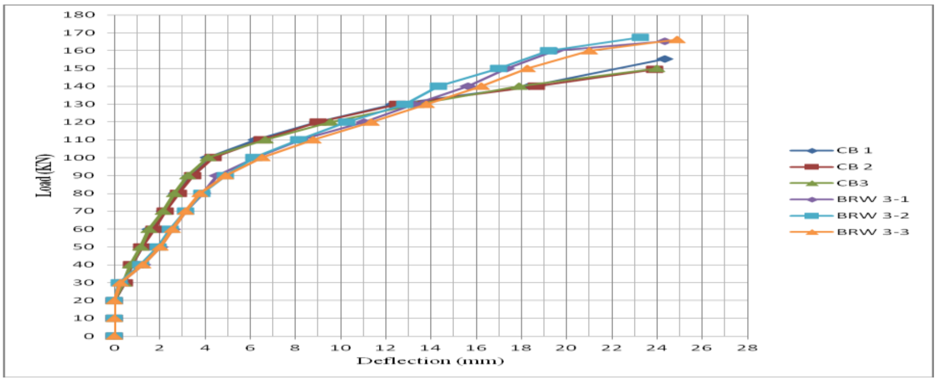


Fig 13 Load – Deflection Relationships of C_B, B_{RW} on 80% Pre-loaded Beams.

V. Conclusions

Based upon the test results of the experimental study undertaken, the following conclusions were drawn:

1. The failure of the composite is characterized by development of flexural cracks over the tension zone.
2. All the beams retrofitted using ferrocement exhibit higher flexural strength when compared with control beams.
3. Beams pre-loaded up to 60% of their ultimate load and retrofitted using ferrocement achieved higher ultimate load levels when compared with beams pre-loaded up to 70% and 80%.
4. In flexure, the beams Strengthen with all the faces of web more strength when compared to the Control Beams..
5. Beams Strengthen with ferrocement at all the faces of web, achieved on ultimate load which is 42.99 % higher than that of control beams.
6. All the retrofitted beams showed significant increase in ductility ratio and considerable increase in energy absorption.

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International Journal of Engineering Science Invention (IJESI) is UGC approved Journal with Sl. No. 3822, Journal no. 43302.j

International Journal of Engineering Science Invention(IJESI)P.Raghunathapandian*. "Experimenatal Investigation on Reinforced Concrete Tee- Beams Strengthen with Ferrocement." International Journal of Engineering Science Invention(IJESI), vol. 7 no. 1, 2018, pp. 20-25.