

# Flexural Response of R.C. Tee Beams Strengthened with Ferrocement



P. Raghunathapandian, B.Palani, D. Elango

**Abstract:** Ferrocement is the composite of Ferro (Iron) and cement (cement mortar). Ferrocement can be considered as a type of thin-walled reinforced concrete construction in which small-diameter wire meshes are used uniformly throughout the cross-section instead of discretely placed reinforcing bars and in which Portland cement mortar is used instead of concrete. In this investigation, 23 reinforced concrete Tee beams were tested for their flexural strength. Three sets of Tee beams were pre-damaged up to 60, 70, and 80 percent of the ultimate load level of control beams respectively. Beams pre-damaged up to 60% are designated as  $W_1$  and  $F_1$ . Similarly 70% as  $W_2$  and  $F_2$  and 80% as  $W_3$  and  $F_3$ . Two beams are undamaged, but they are strengthened are designated  $U_W$  and  $U_F$ .  $U_W$ ,  $W_1$ ,  $W_2$  and  $W_3$  set (3 beams in each set) of beams were strengthened with three faces of the web using ferrocement.  $U_F$ ,  $F_1$ ,  $F_2$  and  $F_3$  set (3 beams in each set) of beams were strengthened with three side faces of the web + bottom of the flange using ferrocement. After proper curing, all the strengthened beam specimens were tested for their flexural strength. The results were compared with corresponding control beams and presented.

From the experimental investigation, it is seen that the ultimate Flexural strength capacity of Reinforced concrete Tee beams strengthened with ferrocement is significantly increased.

**Keywords:** Ferrocement, Wire mesh, undamaged, pre-damaged

## I. INTRODUCTION

Ferrocement is the composite of Ferro (Iron) and cement (cement mortar). Ferrocement can be considered as a type of thin-walled reinforced concrete construction in which small-diameter wire meshes are used uniformly throughout the cross-section instead of discretely placed reinforcing bars and in which Portland cement mortar is used instead of concrete. In ferrocement, wire-meshes are filled in with cement mortar. It is a composite, formed with closely-knit wire mesh; tightly wound round skeletal steel and impregnated with rich cement mortar. Ferrocement it is possible to fabricate a variety of structural elements, may be used in foundations, walls, floors, roofs, shells etc. They are thin-walled, lightweight, durable and have a high degree of impermeability. It combines the properties of thin sections and the high strength of steel.

In addition, it needs no formwork or shuttering for casting. In Construction Field ferrocement has used all fields of construction, including water storage structures and soil retaining structures, building structural components, space structures of large size, bridges, domes, dams, boats, conduits, bunkers, silos, water treatment plants and sewage treatment plants.

## II. METHODOLOGY

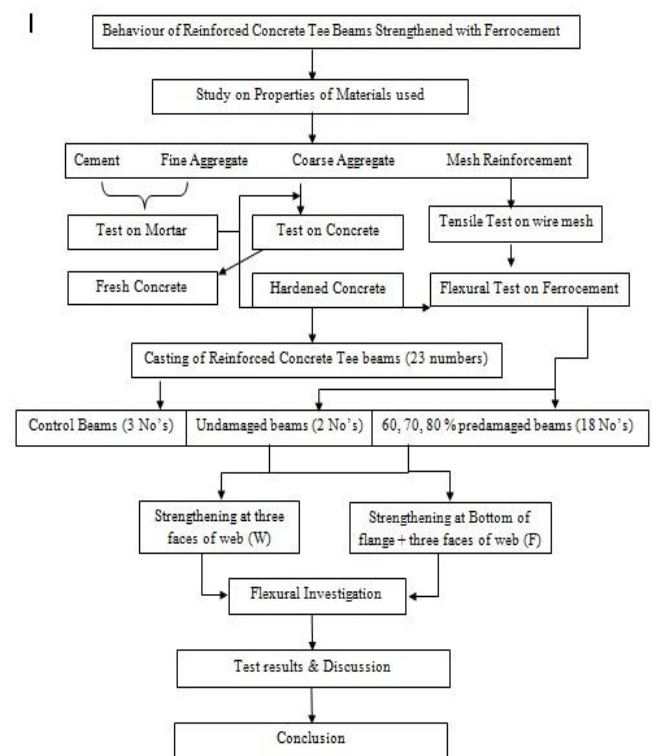


Fig 1. Methodology

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## III. MATERIAL PROPERTIES

**Table 1 Summary of material properties used**

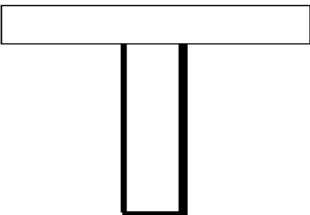
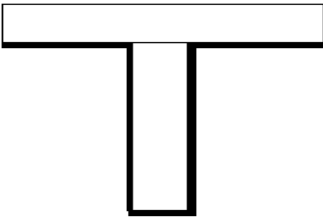
Material - Cement			
Sl.no	Material Properties	Experimental result	IS codes
1	Grade of cement	OPC - 53	IS:12269 – 2013
2	Soundness Test	2mm	IS:4031 (Part-3)2005
3	Fineness of Cement	8%	IS:4031 2005
4	Consistency of Cement	30%	
5	Setting Time - Initial	45mins	IS:12269:2013 Clause 6
6	Setting Time - Final	230mins	
7	Specific gravity	3.15	IS:4031(Part-3)2005
<b>Compressive strength of cement mortar cubes (<math>\text{N/mm}^2</math>)</b>			
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
<b>Material - Fine Aggregates</b>			
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
<b>Material - Coarse Aggregates (10 – 20 mm)</b>			
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

### Wire mesh Properties:

Mesh type	In Longitudinal direction	In Transverse direction
Weldmesh	6 Numbers of 1.3 mm dia. wires @ 16mm c/c in each layer	32 Numbers of 1.3 mm dia. wires @ 16 mm c/c in each layer
Woven mesh	22 Numbers of 0.78mm dia. wires@ 4.5 mm c/c in each layer	152 Numbers of 0.78 mm dia. wires @ 4.5 mm c/c in each layer
Specific surface area	0.064 $\text{mm}^2$	0.409 $\text{mm}^2$

- i) Tee beam undamaged and strengthened three faces of the web denoted as  $U_w$ .
- ii) Tee beams pre-damaged and strengthened three faces of web denoted as  $W_{1-3}$ .
- iii) Tee beam undamaged and strengthened three faces of web cum bottom of flange denoted as  $U_F$ .
- iv) Tee beams pre-damaged and strengthened three faces of web cum bottom of flange denoted as  $F_{1-3}$ .

**Table 2: Summary of Strengthening Plan**

Beam Group	Beam Code	Predamaged level (%)	Type of Strengthening
C	C <sub>1</sub>	100	Nil
	C <sub>2</sub>		
	C <sub>3</sub>		
W	U <sub>w</sub>	0	Cast - in – situ techniques used for undamaged and pre-damaged Tee beams strengthened with ferrocement three faces of the web (W) 
	W <sub>1-1</sub>	60	
	W <sub>1-2</sub>		
	W <sub>1-3</sub>		
	W <sub>2-1</sub>	70	
	W <sub>2-2</sub>		
	W <sub>2-3</sub>		
	W <sub>3-1</sub>	80	
	W <sub>3-2</sub>		
	W <sub>3-3</sub>		
F	U <sub>F</sub>	0	Cast - in – situ techniques used for undamaged and pre-damaged Tee beams strengthened with ferrocement three faces of web cum bottom of the flange (F)
	F <sub>1-1</sub>	60	
	F <sub>1-2</sub>		
	F <sub>1-3</sub>		
	F <sub>2-1</sub>	70	
	F <sub>2-2</sub>		
	F <sub>2-3</sub>		
	F <sub>3-1</sub>	80	
	F <sub>3-2</sub>		
	F <sub>3-3</sub>		

#### IV. EXPERIMENTAL INVESTIGATION

To carry out the Experimental investigation, materials used and their Properties are tabulated. M<sub>25</sub> Grade of the concrete mix was used for the preparation of Tee beams specimens and 23 numbers of RC Tee beam specimens were cast. The Tee beams Specimens are designed as under reinforce beam. The beam consists of the flange of size 500\*100 mm and web of 150 mm\*300 mm reinforced with conventional steel bars. The effective span of the beam is 2700 mm. Main reinforcements of Tee beams specimens were high yield strength deformed steel bars of 3 - 10mm diameter bars are used. The cross-sectional geometries and longitudinal reinforcements were the same for all the specimens.





**Fig 1. Tee beam mould with reinforcement bars**

On these 23 numbers of Tee beam, three were used as control beam specimens and tested for failure to find out the safe load carrying capacity and also the ultimate flexural strength corresponding to the allowable deflection as per IS 456 - 2007. The end conditions were steel rocker bearings on supporting piers resting on the loading frame. Loads were applied with a hydraulic jack. The load was distributed to the specimen by pin-connected steel distribution beam which apply loads at one-third span. The beams were loaded up to the flexural failure of Tee beam specimens.



**Fig 2. Beam mould after pouring of concrete**



**Fig 3. Beam specimens before testing**



**Fig 4. Flexural Testing on Tee beam Specimen**

### V. METHODS OF STRENGTHENING OF TEE BEAMS

Ferrocement was applied on the three faces of the web (W) in Case (i) and three faces of web + bottom of the flange (F) in case (ii). Weldmesh & woven mesh were used in ferrocement to strengthen the Tee beams. The cages were prepared by tying the woven mesh layer to the weld mesh layer at regular intervals by using binding wire. There were two kinds of galvanized iron mesh, which have a difference in diameter.





**Fig 5. Tee beam attached with wire cages**



**Fig 6 Strengthened Tee beams**

One layer of weld mesh of diameter 1.0mm with a spacing of 16mm centre-to-centre in both directions and one layer of a woven mesh of wire diameter 0.8mm with a spacing of 5mm centre-to-centre in both directions was cut to the required size and tied with each other.

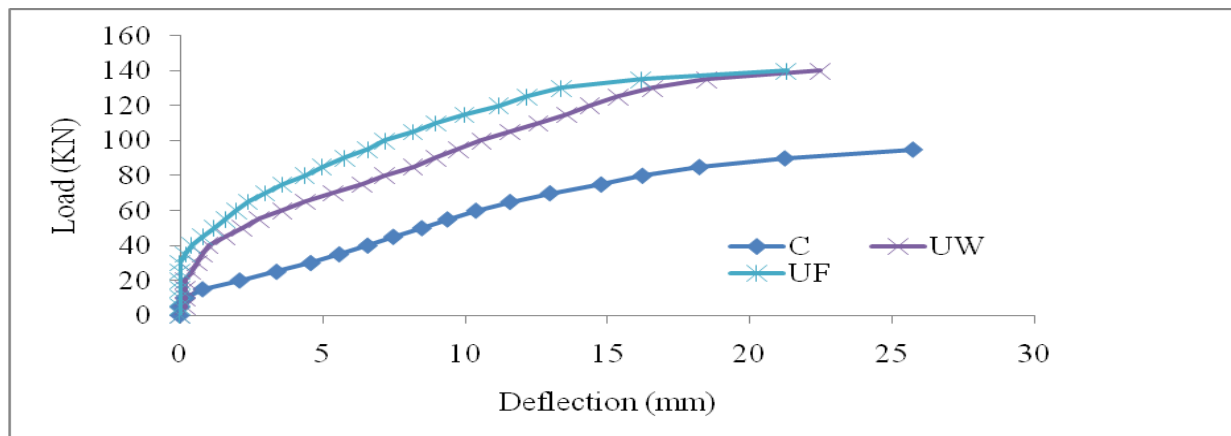
## VI. TEST RESULT & DISCUSSION

Experimental investigations were carried out on 23 No's of Tee beam specimens for their flexural behaviour

under four-point bending. The experimental investigation parameters recorded during the flexural test on Tee beams are load at first crack, deflection characteristics, ultimate load carrying capacity, mode of failure. The test results of the strength and deformation properties of the control specimens, undamaged & strengthened Tee beams and pre-damaged & strengthened Tee beams were presented in the following graphs.

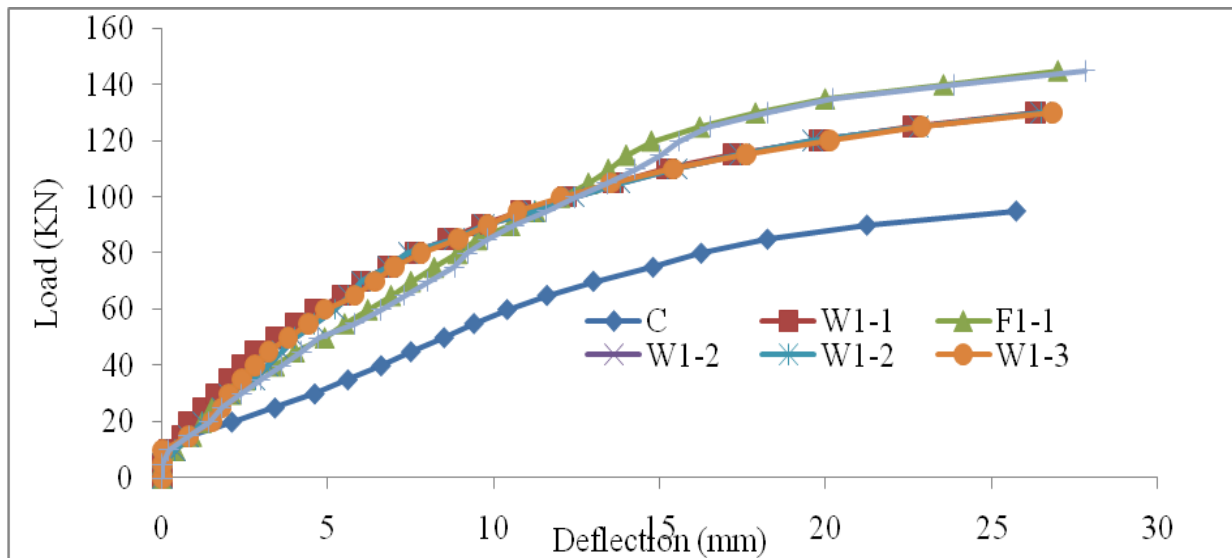


**Fig 7. Flexural Testing on Strengthened Tee Beams**

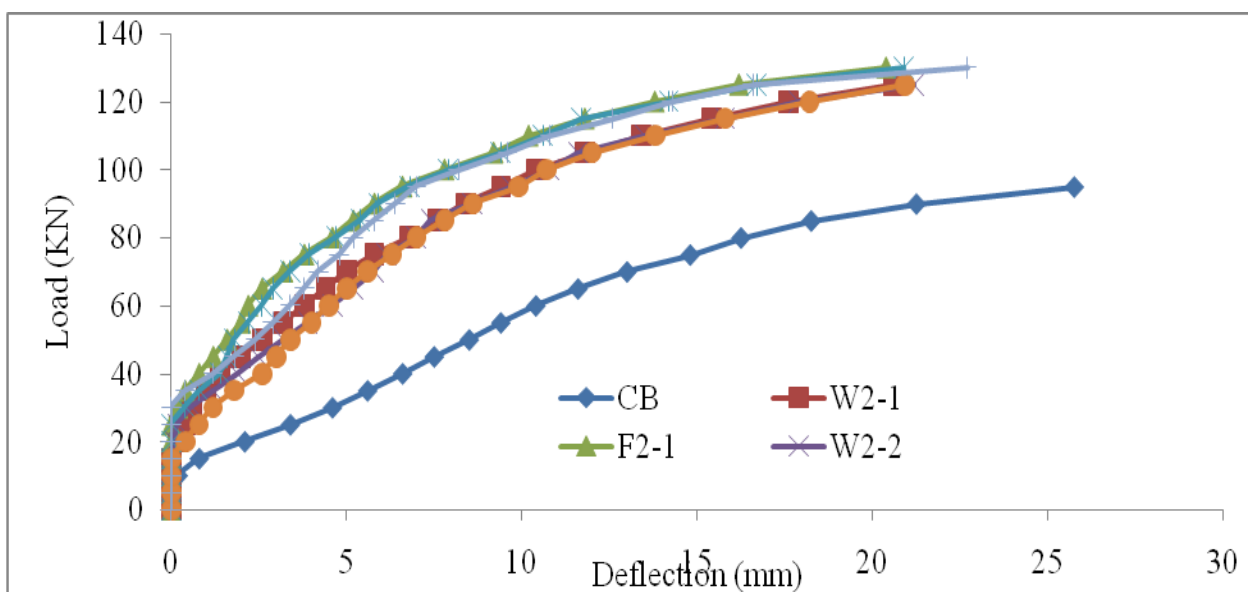


**Fig 8. Load – Deflection Relationships of undamaged & Strengthened Tee Beams**

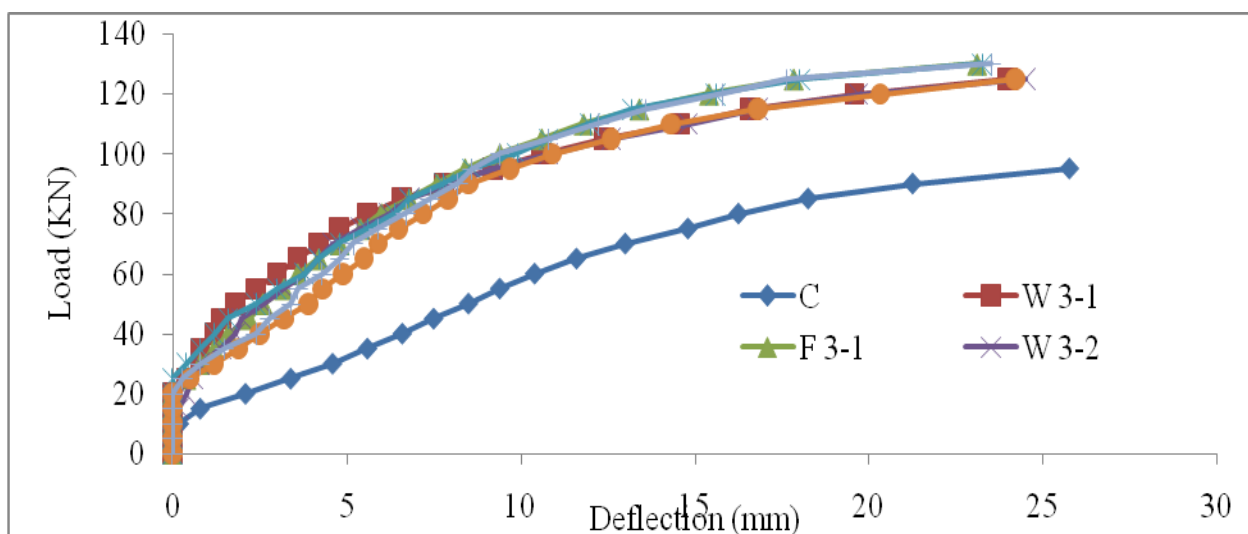
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**Fig 9. Load – Deflection Relationships of 60% pre-damaged & Strengthened Tee Beams**



**Fig 10. Load – Deflection Relationships of 70% pre-damaged & Strengthened Tee Beams**



**Fig 11. Load – Deflection Relationships of 80% pre-damaged & Strengthened Tee Beams**

## VII. CONCLUSION

1. Ferrocement strengthening (Cast in situ) techniques have been used in this investigation.
2. The undamaged & strengthened Tee beams  $U_W$  exhibit an increase in ultimate load-carrying capacity of 57.33 % when compared with control beams.
3. The undamaged & strengthened Tee beams  $U_F$  exhibit an increase in ultimate load-carrying capacity of 74.36 % when compared with control beams.
4. Pre-damaged & strengthened Tee beams  $W$  exhibits an increase in ultimate load-carrying capacity of 32 to 37 % compared with control beams.
5. Pre-damaged & strengthened Tee beams  $F$  exhibits an increase in ultimate load-carrying capacity of 30 to 53.08 % compared with control beams.

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