Flexural Strengthening of RC Tee Beams using Ferrocement

P. Raghunathapandian, B. Palani, D. Elango

Abstract: One of the cost-effective and most widely used methods of strengthening is the use of ferrocement lamination in the distressed element. 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 B1 and S1. Similarly 70% as B2 and S2 and 80% as B3 and S3 set (3 beams in each set) of beams were strengthened along soffit only using ferrocement. S1, S2 and S3 set (3 beams in each set) of beams were strengthened along with the side faces of the web only using ferrocement. After proper curing, all the strengthened beams were tested for their flexural strength. The results were compared with corresponding control beams and presented. Based on this investigation it is concluded that the flexural strength capacities of Reinforced concrete Tee beams strengthened with ferrocement are significantly increased.

Keywords: Ferrocement, Strengthen, Wire Mesh, Damaged beam

I. INTRODUCTION

The repair and rehabilitation of the endowing structures have become one of the most challenging problems in building construction. The defects, failure and distress in the structure needs on the result of a structural deficiency, which is also caused by various parameters like erroneous design, poor workmanship or overloading of the structure. After several investigations, it was found that the ferrocement is a suitable material to rehabilitation and re-strengthening of structural elements because it helps to improve the crack resistance which is combined with high toughness, the ability to be cast into a different shape and rapid construction with small machinery, additionally lightweight imposed and low-cost construction.

II. LITERATURE REVIEW

In recent years many experimental studies have been conducted to strengthen flexural members by using several materials. Kaushik et.al. (1994) found that the addition of a thin layer of ferrocement to a concrete beam improves its ductility and cracking strength. Through this Composite beams reinforced with square mesh proves better performance than the composite beams reinforced with hexagonal mesh. The increase in the number of layers strengthens the cracking stiffness of the composite beams in both cases. Nassif et.al. (1998) in this Study ferrocement develops the flexural behaviour of reinforced cement concrete beams and there is an increase when moment carrying capacity is increased by 9% & 15% respectively. Fahmy et.al. (1997) found that the flexural behaviour of reinforced concrete T-beams strengthening with thin ferrocement laminate attached on the tension face using L-shaped mild steel round bars as shear connectors. From the experimental investigation, was found that the performance of the strengthened beams can be improved and substantially in terms of strength, flexural rigidity and first crack load, provided the connectors which are the surface is to receive the laminate roughened to ensure the sufficient bond strength for composite action.
III. MATERIAL PROPERTIES

Table 1 Summary of material properties used

| 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       |

Compressive strength of cement mortar cubes (N/mm²)

| Sl.no | Material Properties      | Experimental result | IS codes                  |
|-------|--------------------------|---------------------|---------------------------|
| 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 |

Material - Fine Aggregates

| Sl.no | Material Properties      | Experimental result | IS codes                  |
|-------|--------------------------|---------------------|---------------------------|
| 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     |

Material - Coarse Aggregates (10 – 20 mm)

| Sl.no | Material Properties      | Experimental result | IS codes                  |
|-------|--------------------------|---------------------|---------------------------|
| 14    | Water Absorption         | 0.5%                | IS: 2386(Part-3)2002.     |
| 15    | Specific Gravity         | 2.74                | IS: 2386(Part-3)2002.     |
| 16    | Impact test              | 46.53%              | IS:2386(Part-4)2002       |
| 17    | Specific Gravity         | 2.74                | IS: 2386(Part-3)2002.     |
| 18    | Fineness modulus         | 8.44                | IS: 2386(Part-1)2002.     |

Case i:-

i) Tee beams undamaged and strengthened along soffit were denoted as U₁₂.
ii) Tee beams pre-damaged and strengthened along soffit were denoted as B₁, B₂ and B₃.

Case ii:-

i) Tee beams undamaged and strengthened alongside faces of the web were denoted as U₃.
ii) Tee beams pre-damaged and strengthened alongside faces of the web were denoted as S₁, S₂ and S₃.

Table 2 Summary of Strengthening Plan

| Beam Group | Beam Code | Predamaged level (%) | Type of Strengthening |
|------------|-----------|----------------------|-----------------------|
| C          | C₁        | 100                  | Nil                   |
|            | C₂        | 100                  | Nil                   |
|            | C₃        | 100                  | Nil                   |
| Table 1 | | |
|---|---|
| **U_n** | **-** |
| B<sub>1</sub>  | 60 |
| B<sub>2</sub>  | 70 |
| B<sub>3</sub>  | 80 |

Cast-in-situ techniques used for undamaged and pre-damaged Tee beams strengthened with ferrocement under the soffit of the web (B)

| Table 2 | | |
|---|---|
| **U_n** | **-** |
| S<sub>1</sub>  | 60 |
| S<sub>2</sub>  | 70 |
| S<sub>3</sub>  | 80 |

Cast-in-situ techniques used for undamaged and pre-damaged Tee beams strengthened with ferrocement alongside faces of the web (S)

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**Fig 1.** Rebar with a strain gauge attached
**Fig 2.** Tee beam mould with rebar
**Fig 3.** Tee beam specimens
IV. METHODS OF STRENGTHENING OF TEE BEAMS

Ferrocement was applied to the Soffit of the web (B) in case (i) and alongside faces of the web (S) 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 the difference in diameter. 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.

V. TEST RESULTS & DISCUSSION

Experimental investigations were carried out on twenty-three No’s of Tee beams for their flexural behaviour under four-point bending. The investigation parameters recorded during the flexural test on Tee beams are load at first crack, deflection characteristics, ultimate load carrying capacity, mode of failure, ductility ratio and energy absorption. 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.
Conclusions were derived from the results of this experimental investigation:

1. All the strengthened Tee beams exhibit higher flexural strength when compared with control beams.
2. The undamaged & strengthened Tee beams $U_B$ exhibit an increase in ultimate flexural strength capacity of 37.48% when compared with control beams.
3. The undamaged & strengthened Tee beams $U_S$ exhibit an increase in ultimate flexural strength capacity of 42.55% when compared with control beams.

4. Pre-damaged & strengthened Tee beams $B$ exhibits an increase in ultimate load carrying capacity of 12.73 to 24.16% compared control beams.
5. Pre-damaged & strengthened Tee beams $S$ exhibits an increase in ultimate load carrying capacity of 21.56 to 23.68% compared control beams.

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