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A Study on Repair Materials and Mesh Bonding Techniques Used To Repair Concrete Beams Failed In Flexure

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ABSTRACT
In this work it is proposed to study the behavior of repaired concrete beams. The effectiveness of various repair materials was studied. Also different repair techniques were tried and results were compared. Plain concrete beams of dimensions 150mm x 150mm x 700mm were casted. The beams were failed in flexure with two point loading. The failed beams were repaired using various methods and techniques. The repair technique adopted was external bonding of steel meshes of various types with various repair materials. Beams repaired with Epoxy + SBR + Cement (RESC) without any mesh bonding giving better results. Almost all the mesh bonding repair techniques adopted were giving more than 100% regain of load carrying capacity of the original beams.
Keywords **–** Plain Concrete Beams, Repair, Epoxy, Latex, Wire Mesh

I. INTRODUCTION

In recent days, repair and rehabilitation of structures has got importance due to damage of many structures because of various reasons. Evaluation of repair materials and repair techniques are to be understood well before attempting to rehabilitate a structure. Many researchers tried to understand the repaired structural elements behavior by varying the repair materials and/or repair techniques. Singh et al (1992) [1] given that the epoxy injection by pump and epoxy bonded steel plate are quite effective in repair of beams. It was concluded that at low amplitude the repaired beams were slightly less stiff than original beams. As per Emmanuelle Davi1 et al. (1998) [2] External bonding of composite plates to reinforced concrete structures represents an interesting alternative to steel as it can avoid the corrosion of the plate. Shash (2005) [3] repaired the cracks with epoxy injection, The deflection under the externally applied load was less than the allowable value indicating that the repaired beams can safely carry the expected loads. Kothandaraman and Vasudevan (2010). [4] report that bonded steel plating, external post-tensioning and FRP composites wrapping are some of the techniques widely followed to retrofit various structural elements. Vasconcelos et al. (2011). [5] presented results about the use of metakaolin based geo polymers mortars for retrofitting purposes. Ahmad et al. (2012). [6] proposed technique consist of applying locally available polymer modified mortar in cracked beams to increase the load carrying capacity. Samir et al. (2013). [7] investigated the use of various cementitious repair materials in terms of restoring the flexural capacities of pre-cracked reinforced concrete shallow beams. Hyun –Do Yun (2013). [8] dealt with the flexural and cracking behavior experimentally in the plain concrete beams with a hybrid polyvinyl alcohol (PVA) and polyethylene (PE) fiber reinforced strain-hardening cement composite (SHCC) layer before and after repeated freeze–thaw exposure. Ismail et al. (2014). [9] experimented on plain concrete beams externally bonded with wire mesh–epoxy composite using one to five wire mesh layers. In this paper various repair techniques which are economical, effective and convenient in practical were studied and presented.

II. MATERIALS FOR REPAIR

Ordinary Portland cement (OPC 53 grade) conforming to IS 12269-1987, River sand with specific gravity 2.62 conforming to zone- II as per IS 383-1970, locally available granite crushed stone aggregate of size 10mm and down confirming to IS 383: 1970 with specific gravity 2.7, Potable Water from the local source used for mixing and curing, Epoxy resin, S.B.R (Styrene Butadiene Rubber) Latex were used in this study. Concrete mix used was of 1:2.24:2.95 with 0.5 water cement ratio and meshes used for repair are shown in Fig. 1,2 and described in Table.1

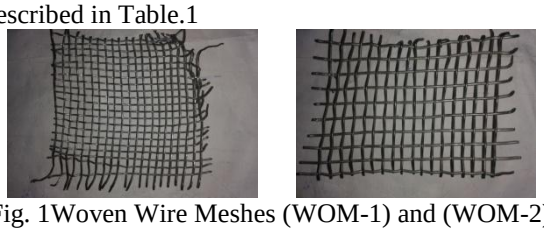

Fig. 1Woven Wire Meshes (WOM-1) and (WOM-2)

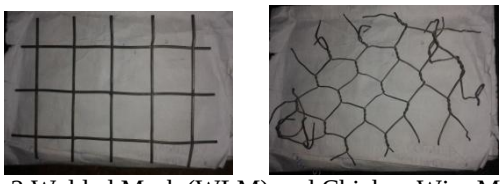

Fig. 2 Welded Mesh (WLM) and Chicken Wire Mesh (CWM)

Table 1 Description of the Meshes Used for Repair

Description Of The Mesh	Woven wire mesh (wom-1)	Woven wire mesh (wom-2)	Welded wire mesh (wlm)	Chicken wire mesh(cwm)
Shape of wire grid	Square	square	square	hexagonal
Diameter of wire	0.3mm	0.76mm	0.9mm	0.3mm
Spacing of wires/rods	1.5mm	3mm	16.5mm	13.5mm

III. REPAIR TECHNIQUES ADOPTED

The failed original beams were then repaired (Fig.3) using various techniques mentioned below and cured for 14 days with wet gunny bags, then tested again with same two point loading on UTM (Fig.4). The failure load was noted which was flexural capacity of the repaired beam and compared with original beam failure load. The failed pieces were glued together with

1. Cement+Water **(RC)**.
2. S.B.R Latex (Styrene Butadiene Rubber) modified Cement **(RSC)** Paste.
3. Epoxy resin + SBR modified Cement Paste **(RESC)**.
4. Epoxy Resin + Cement Paste **(REC)**.

The failed pieces were repaired by using

5. Epoxy + SBR latex modified Cement Paste with externally bonded Woven Wire Mesh (WOM-1) **(RESC- WOM-1)**.
6. Epoxy + SBR latex modified Cement with externally bonded Woven Wire Mesh (WOM-2) **(RESC- WOM-2)**.
7. Epoxy + SBR latex modified Cement with externally bonded Welded Wire Mesh (RESC-WLM).
8. Epoxy + SBR- Cement modified latex with externally bonded Chicken wire mesh **(RESC - CWM)**.
9. Epoxy + Cement paste with externally bonded Chicken wire mesh **(REC –WOM-1)**.
10. Epoxy resin + Cement with externally Stitched 4mm rods **(REC – 4mm RODS)**.

Fig.3 Joining with SBR modified cement paste, Attached Chicken Wire Mesh on Epoxy coating and Plastered with SBR modified cement mortar

Fig. 4 Testing of Beam Repaired with Epoxy, SBR + Cement Modified Latex and Welded Mesh (RESC-WLM

IV. TEST RESULTS

The test results were presented in Table 2 and Table 3. The results were divided into two parts as without and with meshes.

Table 2 Load Taken by the Beams Repaired with Various Repair Materials (without meshes)

Sl. No	**Description**	**Average Load Taken by Original Beam (kN)**	**Average Load Taken by Repaired Beam (kN)**	**%ge of Load Taken by Repaired Beams Compared to Original Beam**
1	RC	27.25	14.75	54.12
2	RSC	26.10	8.85	33.90
3	RESC	25.20	26.15	103.76
4	REC	26.0	4.85	18.65

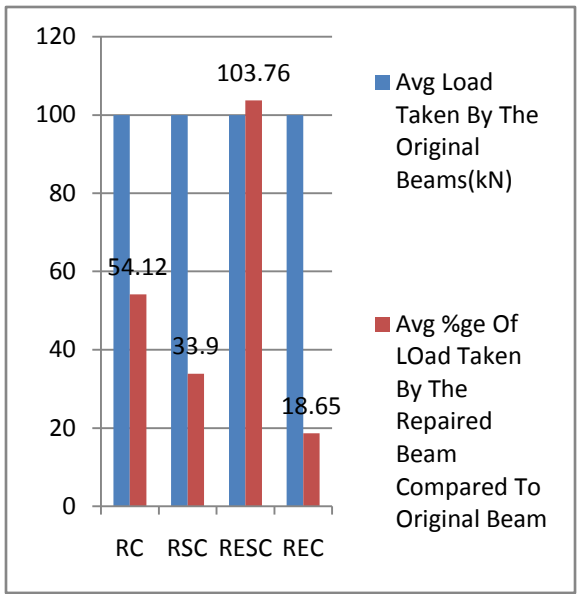

Fig.5 %ge of Load Taken by Repaired Beams Compared to Original Beam (Without meshes)

Table 3 Load Taken by the Beams Repaired with Various Repair Techniques (With meshes)

Sl. No.	Designation	Average Load Taken by Original Beam (kN)	Average Load Taken by Repaired Beam (kN)	%ge of Load Taken by Repaired Beams Compared to Original Beam
1	RESC - WOM-1	23.45	26.80	114.28
2	RESC - WOM-2	29.50	31.50	106.77
3	RESC – WLM	24.40	39.00	159.83
4	RESC – CWM	26.75	30.50	114.00
5	REC - WOM-1	25.00	13.75	55.00
6	REC-4mm RODS	26.00	36.00	138.46

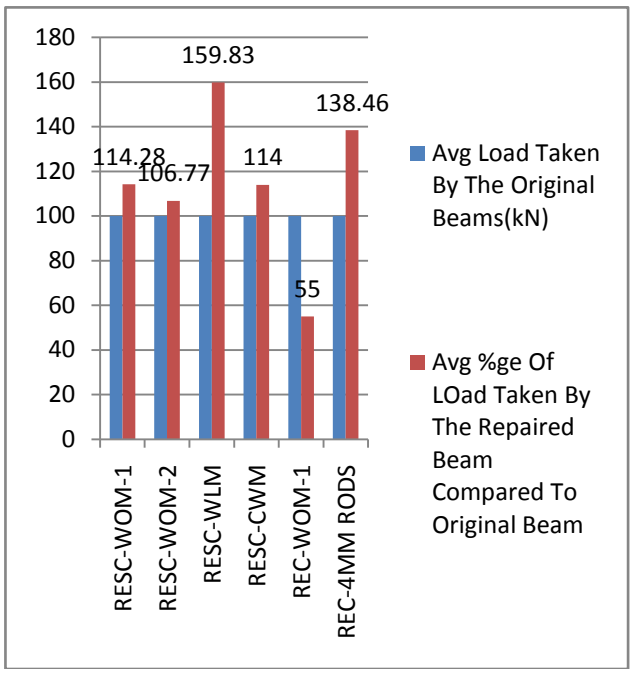

Fig.6 %ge of Load Taken by Repaired Beams Compared to Original (With meshes)

V. CONCLUSION

This study was aimed to arrive a better combination of repair materials and also to find better repair techniques. The test results were compared using Fig. 5 and Fig.6

The following were the conclusions from the study,

1. If combination of repair materials only considered then Epoxy + SBR + Cement (RESC) without any mesh bonding giving better results. With this combination the repaired beam load carrying capacity (flexural capacity) regained up to 103.76% compared to original beam.
2. The repaired beams have regained only 54.12% with Cement + water (RC) and 33.9% with Cement + SBR + Water (RSC) combination.
3. Almost all the repaired techniques adopted, Except Woven mesh bonded with epoxy and cement paste (REC-WOM-1), were shown more than 100% regain of load carrying capacity of the original beams.
4. The beam repaired with welded mesh glued with Epoxy, SBR, Cement combination (RESC-WLM) showed 159.83% regain in load carrying capacity.
5. The beam repaired with woven wire mesh glued with Epoxy, SBR, Cement combination (RESC-WOM-1) showed 114.28 % regain in load carrying capacity.
6. The beam repaired with woven wire mesh glued with Epoxy, SBR, Cement combination (RESC-WOM-2) showed 106.77 % regain in load carrying capacity.
7. The beam repaired with chicken wire mesh glued with Epoxy, SBR, Cement combination (RESC-

CWM) showed 114 % regain in load carrying capacity.

8. The beam repaired with woven wire mesh glued with Epoxy, Cement combination (REC-WOM-1) showed 55 % regain in load carrying capacity.
9. The beam repaired with Epoxy, Cement combination and externally stitched 4mm rods (REC- 4mm RODS) showed 138.46% regain in load carrying capacity.
10. Bonding of woven wire mesh with only cement paste was giving poor results. If the cement paste was modified with latex then results obtained were better and adoptable.
11. Among mesh bonding techniques, welded mesh bonded using Epoxy, SBR and cement paste (RESC-WLM) was giving good result.
12. Stitching with 4mm rods on tension face also were giving adoptable result.

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