Sci.Int.(Lahore),28(3), 3001-3005,2016 ISSN 1013-5316;CODEN: SINTE 8

RETROFITTING OF REINFORCED CONCRETE IN FLEXURE BY CRACK SEALING USING INJECTABLE MATERIALS: APPLICATION TO BEAMS

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ABSTRACT: *Retrofitting of damaged beams in flexure through crack sealing by three different materials was carried out and results of flexure test performed on same retrofitted beams are presented and discussed in this paper. A total of six RC beams of cross section 75×150mm with length of 1350mm were cast and loaded in flexure to developed flexural cracks of approximately 1.5 mm to 2mm width. Cracked beams were retrofitted by crack sealing by the use of externally applied and/or injected materials which include locally available epoxy resin, epoxy mortar and synthetic rubber emulsion. The results of 3PBT on retrofitted RC beams in flexure showed that by the use of all three materials/techniques employed in this study not only flexural strength is restored but also enhanced. Among the three materials/techniques, the maximum benefits in terms of flexural strength regain and improvement was exhibited by epoxy mortar chemdur-31.*

Keywords: RC beams; retrofitting; Chemdur-31; Chemdur-52; SBR Latex; flexure behaviour

1. INTRODUCTION

After the earthquake of 8th October 2005 in Pakistan, an increasing demand of strengthening / retrofitting of the existing undamaged and moderately damaged structures has been observed. Practical situations arise where existing concrete structures or some of their components may, for a variety of reasons, be found to be inadequate in carrying expected load and in need of repair and/or strengthening. Different repair techniques have been successfully developed to strengthen a given structure or part of it to restore its serviceability and strength limit states. Technical methods used for repair of reinforced concrete structures are epoxy injection and cement grouting techniques, CFRP strips, post tensioning, ferrocement layering, and section enlargement [1,2]. These techniques are widely used to treat cracking problem in concrete.

The purpose of repair is to improve the function and performance of the structure, restore and increase the strength and stiffness, improve appearance of the concrete surface, provide water tightness, prevent access of corrosive materials to the reinforcement, and to improve the durability performance of the structure [3,4]. Epoxy resins find wide application as grouting materials. The filling of cracks, either to seal them from the entrance of moisture or to restore the integrity of a structural member is one of the most frequent applications. Cracks of 6mm or less are most effectively filled with a pourable or pump able epoxy compound [5,6].

The final selection of a suitable and most effective method of retrofitting generally depends on simplicity, speed of application, structural performance, availability of material and total cost. In present study three different materials which are locally available have been used to retrofit pre-cracked beams by crack sealing methods. The purpose of using three different materials was to explore which material gives maximum positive results in terms of regain and improvement of flexural strength of RC beams to suggest /recommend for practicing engineers work in the field of repair and maintenance. This research study was carried out to investigate the structural response of damaged RC beams retrofitted using following materials/ techniques:

(1) Epoxy mortar
(2) Epoxy injection
(3) Synthetic rubber emulsion

The selected three techniques are easy to apply even by unskilled labour with minimal guidance.

2. EXPERIMENTAL PROGRAM

2.1 Test Specimens

Eight beam specimens of cross section 75mm × 150mm and length 1350mm length having same properties and material ratio were cast for the experimental program of this study. All the specimens were having same steel reinforcement; 2-10mm diameter bars were used as tension reinforcement, 2-6mm diameter bars were used at top as hanger bars. To avoid shear failure 6mm diameter bars (shear stirrups) at 75mm c/c spacing were used. Reinforcement detail of test specimens is shown in Figure-1. In addition to beams, cylindrical specimens were also prepared to determine the compressive strength of concrete used in this study. Both beams and cylinders were cured for 28 days before testing.

2.2 Materials and Concrete Composition

The present study focused on following three methods of retrofitting (crack sealing) using locally available materials:

a) Epoxy mortar commercially named as Chemdur–31.

b) Inject-ale low viscosity epoxy commercially named as Chemdur–52.

c) Synthetic rubber emulsion: SBR-Latex a high performance water resistant bonding agent.

All the specimens were cast with 0.6 water cement ratio and 1:2:4 material ratio. Ordinary Portland cement, Margala crush as coarse aggregates, and Lawrencepur sand as fine aggregates were used in preparation of concrete. Specimens were divided in four groups. Grouping of beam specimens and their technical data is presented in Table-1 and Table-2, respectively. Pictorial presentation of step-by-step procedure starting from casting of specimens to curing is given in Figure-2.

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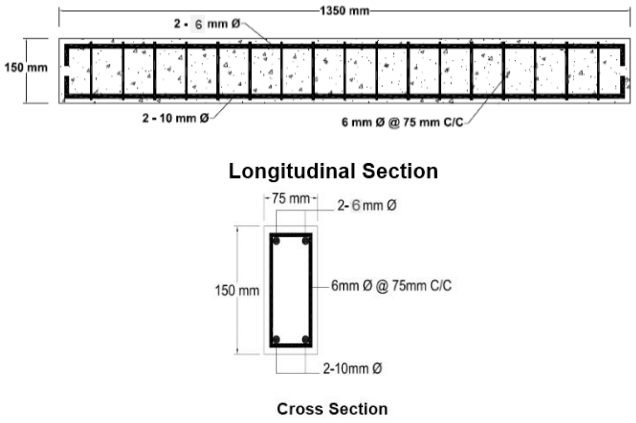

Figure-1 Reinforcement details of beam specimens.

Table 1: Grouping of beams

Description	Material	No. of Specimens
RFB-CH31	Chemdur-31	2
RFB-CH52	Chemdur-52	2
RFB-SBR	SBR-Latex	2

Regarding the nomenclature of test specimen in Table-1 RFB stands for retrofitted beam and CH31 stands for Chendur-31, which is name of epoxy mortar. Similarly CH52 stands for Chemdur-52 which is epoxy resin. SBR stands for styrene butadiene rubber which is high performance water resistant bonding agent and mortar improver.

Figure-2 Specimen casting and curing

Table 2: Technical data of used chemicals

Technical Data from Vendor:		
Chemdur-31	**Chemdur-52**	**SBR-Latex**
Properties :		
Density: 1.65kg/lit. E : 4300 N/mm^2 Coeff. of thermal expansion : 50x10^6 / ºC Comp. Strength : 35-40 N/mm^2 Flexural strength : 30-40 N/mm^2 Tensile Strength : 15-20 N/mm^2 Bond Strength To Concrete : 3.5 N/mm^2 Bond Strength To Steel : 15 N/mm^2	Density: 1.1kg/lit. Viscosity : 250 @30ºC Coeff. of thermal expansion : 89x10^{-6} / ºC Comp. Strength : 55 N/mm^2 Flexural strength : 50-40 N/mm^2 Tensile Strength : 25 N/mm^2 Bond Strength To Concrete : 4.0 N/mm^2 Bond Strength To Steel : 12 N/mm^2	Density: 1.0kg/lit. SBR Latex is synthetic rubber emulsion which is added to cement mortars and concrete where good adhesion, water resistance are improved strength characteristics are required.

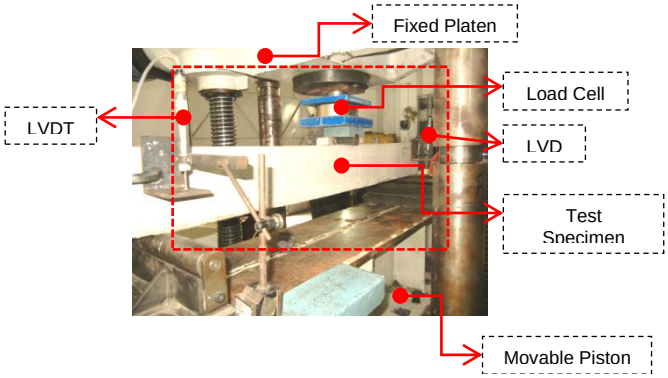

Figure-3 Test setup for flexural testing of beams

2.3 Testing Method and Test Observations

In order to crack all beams in flexure, three point bending tests were performed. The testing setup is shown in Figure 3. Two LVDTs and one load cell as shown in this figure were used to measure deflection and load, respectively. All tests were performed at a loading rate of imposed deflection as 2mm/min using universal testing machine. The values of load and deflection were automatically recorded using data acquisition system named as strain smart. During each test, cracking pattern of each beam was also observed.

3. PRE-CRACKING OF RC BEAMS

All beams were initially cracked in flexure. The load-deflection curves of one of the beams selected for each retrofitting method are shown in Figure 4. The un-loading point in each case was decided during each test when macro-cracks were appeared. In Figure 4, it can be noticed that the un-loading point in all cases is beyond the yield point of steel reinforcing bars after which macro-cracks start appearing. Cracking pattern of each RC beam is shown in Figure 5, where it is obvious that the cracks are flexure cracks and visible with naked eyes (macro-cracks).

Beam-1 was retrofitting using epoxy mortar chemdur-31, beam-2 was retrofitted by epoxy resin chemdur-52 and beam-3 was retrofitted using SBR-Latex mortar.

Sci.Int.(Lahore),28(3), 3001-3005,2016 ISSN 1013-5316;CODEN: SINTE 8

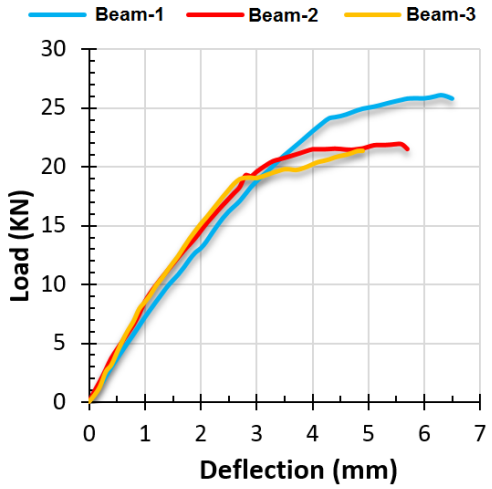

Figure-4 Load-deflection curves of initially cracked beams

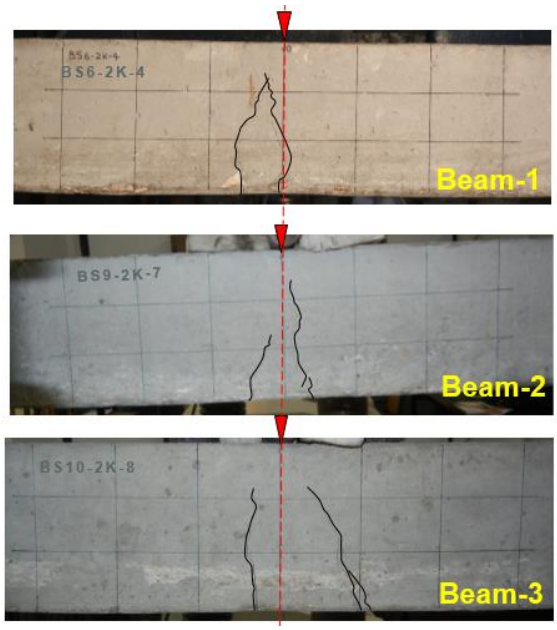

Figure-5 Initially cracked beam's cracking pattern

4. RETROFITTING METHODS

After initial cracking of all the beam specimens, retrofitting process was initiated. Three methods of retrofitting using different materials adopted in this study are discussed below.

4.1 Using Epoxy Mortar (Chemdur-31)

Technical data related to epoxy mortar "**Chemdur-31**" is provided in Table 2. Two out of six initially cracked beams were retrofitted by this method. In order to use this kind of epoxy mortar for crack sealing, specimens are cleaned and cracks are widened up to 5mm with the help of cutter for application of chemical. Chemdur-31 epoxy mortar has two components: A & B, which are mixed at ratio recommended by vendor. After preparation, chemdur-31 epoxy mortar is filled in the cracks, with the help of trowel and later on applied over the surface to seal properly all filled cracks.

4.2 Injection of Epoxy (Chemdur-52)

Technical data related to low viscosity injectable epoxy "**Chemdur-52**" is provided in Table 2. Two out of remaining four initially cracked beams were retrofitted by this method which is comprised of two stages.

First stage: after widening of cracks by cutter, the plastic nozzles are installed and then cracks are sealed by using epoxy mortar chemdur-31 in such a way that void is left between crack and epoxy.

Second stage: when the epoxy mortar is hardened, chemdur-52 epoxy is prepared by mixing of its components (A & B) and injected with pressure in the cracks through nozzles already installed in first stage. Finally the nozzles are also sealed with the help of epoxy mortar.

4.3 Using SBR Latex

Last two beams were retrofitted using SBR-Latex mortar. Application of this kind of material to seal the cracks requires widening and cleaning of cracks. Cement sand mortar is prepared using SBR-Latex in liquid form with the dosage recommended by manufacturer. In this study 4 litter SBR-Latex per 50 kg of cement dosage is used. The cracks are properly filled and sealed with the prepared SBR-Latex mortar. The specimens are then cured using water for 15day before retesting.

5. RESULTS AND DISCUSSION

5.1 Retrofitting by Chemdur-31

Load deflection curve of initially cracked RC beam before and after retrofitting with epoxy mortar chemdur-31 is shown in Figure-6, where it can be noticed that with sealing of cracks with chemdur-31 not only flexure capacity of RC beam is restored but also improved. An improvement of 13.5% in load carrying capacity in bending upto yielding of steel bars was exhibited by retrofitted beams.

Crack pattern before and after retrofitting is shown in Figure-9, where it can be observed that cracks did not appear on the same location as they were before retrofitting. This shows the positive effect of chemdur-31 epoxy to retrofit the damaged beams. Cracks in retrofitted beams were spread out over 300mm length on each side of centreline of beam.

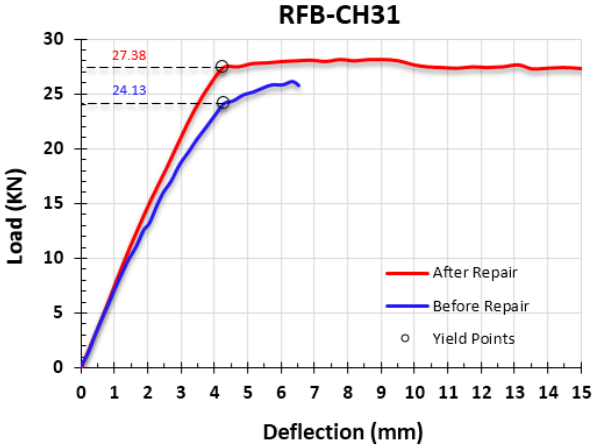

Figure-6 RFB Specimen load deflection curve

5.2 Retrofitting by Chemdur-52

Load deflection curve of initially cracked RC beam before and after retrofitting with injectable epoxy chemdur-52 is

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shown in Figure-7, where it can be noticed that with sealing of cracks with chemdur-52 not only flexure capacity of RC beam is restored but also improved. An improvement of 6.7% in load carrying capacity in bending upto yielding of steel bars was exhibited by retrofitted beams.

Crack pattern before and after retrofitting is shown in Figure-9, where it can be observed that cracks did not appear on the same location as they were before retrofitting. This shows the positive effect of chemdur-52 epoxy to retrofit the damaged beams. Cracks in retrofitted beams were spread out over 300mm length on each side of centreline of beam.

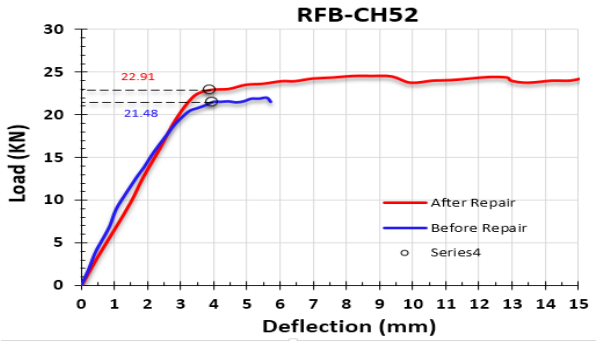

Figure-7 RFB Specimen load deflection curve

5.3 Retrofitting by SBR-Latex Mortar

Load deflection curve of initially cracked RC beam before and after retrofitting with bonding agent SBR-Latex is shown in Figure-8, where it can be noticed that with sealing of cracks with SBR-Latex not only flexure capacity of RC beam is restored but also improved. An improvement of 13% in load carrying capacity in bending upto yielding of steel bars was exhibited by retrofitted beams.

Crack pattern before and after retrofitting is shown in Figure-9, where it can be observed that cracks did not appear on the same location as they were before retrofitting. This shows the positive effect of SBR-Latex mortar to retrofit the damaged beams. Cracks in retrofitted beams were spread out over 150mm length on each side of centreline of beam.

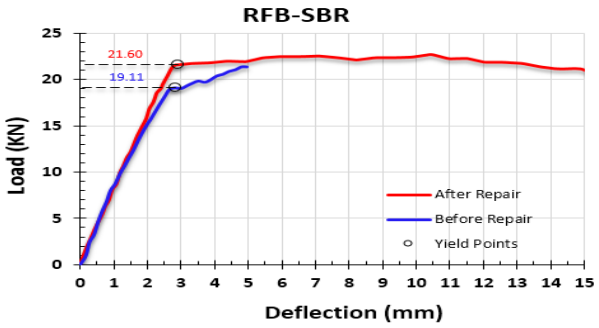

Figure-8 RFB Specimen load deflection curve

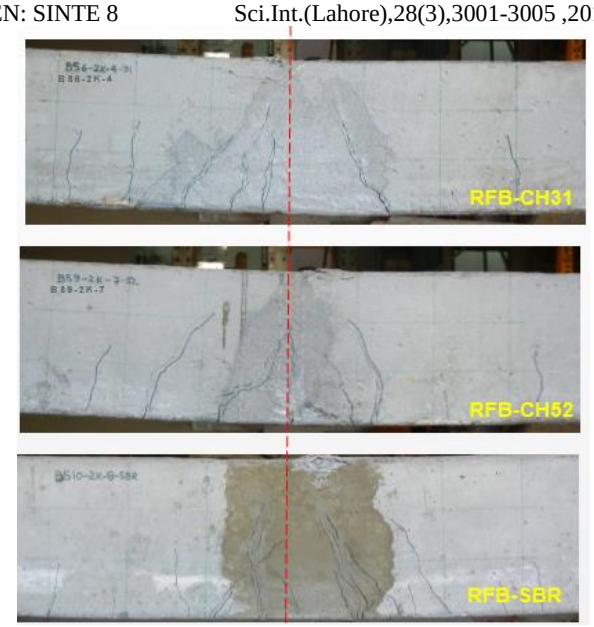

Figure-9 RFB Specimen's cracking pattern

6. CONCLUSION

Flexural behavior of retrofitted beams with three different materials/ techniques was investigated. Based on the findings of this study following conclusions were drawn:

- All materials/ techniques investigated in this study not only contributed to restore flexural strength of initially cracked beams but also improved it.
- Among three different materials epoxy mortar chemdur-31 exhibited batter results in-terms of flexural strength improvement which was 13.5%.
- Cracks location in retrofitted beams is shifted away from the region or location where sealing material is applied. The region over which cracking occurs is increased: Cracks are spread out over large area this observation was true for all the materials / techniques employed in this study.

5. ACKNOWLEDGEMENT

The technical support from Dr. Wajahat ali (Imporient Chemical) and Imporient chemicals for provision of chemicals for this experimental study is highly acknowledged.

REFERENCES

[1] Waleed A. Thanoon, M.S. Jaafar *, M. Razali A. Kadir, J. Noorzaei "Repair and structural performance of initially cracked reinforced concrete slabs" Construction and Building Materials 19 (2005) 595–603

[2] Alessandra Aprile, Enrico Spacone and Suchart Limkatanyu "Role of Bond in RC Beams Strengthened With Steel and FRP Plates" J. Struct. Eng. 2001.127:1445-1452.

Sci.Int.(Lahore),28(3), 3001-3005,2016 ISSN 1013-5316;CODEN: SINTE 8

[4] Dehwa, H. A. F., et. al., "Durability Performance of Repaired Reinforced Concrete Beams", ACI Materials Journal, Vol. 91, No. 2, Mar.-Apr. 1994, pp.167-172.

[5] ACI Committee 224, "Causes, Evaluation and Repair of Cracks in Concrete Structures", American Concrete Institute, 1993, 22 pp.

[6] ACI Committee 503, 2007, "Specification for Crack Repair by Epoxy Injection (ACI 5037-07)".

[7] Razali, M., Kadir, A. & Noorzaci J. 2005. "Repair and structural performance of initially cracked reinforced concrete slabs." Construction and Building Material J. 19(8): 595-603.