COMPARATIVE STUDY OF DIFFERENT TYPES OF REPAIR MATERIALS IN FLEXURE

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Abstract

Repair and retrofitting of existing structures have become a major part of the construction activity. Some of the structures are damaged by load induced stresses, environmental effects etc. To avoid high cost of structural replacement and to maintain structural integrity different repair and rehabilitation techniques are required. The most common form of repair for a deteriorated concrete is through patching, thus increasing the design life of the structure. The objective of this experiment is to investigate the performance of different types of repair materials (mortar based and commercial repair products).Seven RCC beams of size 1500mm×150mm×200mm were casted which include one concrete beam as control specimen (no repair)and six beams were casted by providing a wide mouthed trapezoidal notch at the bottom surface of the beam and all beams were cured for 28 days. Beams with notches were then patched with six selected types of repair materials in which one is repaired with normal concrete, three with mortar based repair materials and two with commercially available repair products and membrane cured for 28 days. All these beams were tested for flexural strength using two point loading in loading frame. Results were compared with control beam (no repair) and beam repaired with normal concrete. .

Keywords: *Mix Design, Repair, Curing, Flexure, Failure.*

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1. INTRODUCTION

Repair and rehabilitation of concrete infrastructure is an important aspect of maintenance activities of a building structure, pavement, or a bridge in the world. The annual cost to the owners for repair, protection and strengthening is increasing day by day. Recent investigations of repairs to bridge decks and other structures have indicated an over-whelming incidence of premature failures resulting from a variety of factors. It is generally observed that a repair section in the concrete structure is mostly performed at the joints or in the tension area. Tension is induced in the concrete by bending of the structure due to loading or due to environmental conditions. Therefore, the flexural test method would be an appropriate method to study performance of different repair materials. Here it is aimed to study the flexural performance of different repair materials to strengthen or repair reinforced concrete beams. The performance of each repair material was assessed through flexural behaviour of different specimens.[1]

Seven RCC beams of size 1500mm×150mm×200mm were casted. These specimens include one concrete beam as control specimen (no repair). Six beams were casted by providing a wide mouthed trapezoidal notch at the bottom surface of the beam and all beams were cured for 28 days. Beams with notches were then patched with six selected types of repair materials in which one is repaired with normal concrete, three with mortar based repair materials and two with commercially available repair products from BASF construction chemicals and membrane cured for 28 days. All these beams were tested for flexural strength using two point loading in loading frame. Results were compared with control beam (no repair) and beam repaired with normal concrete (R_{NC}).

2. MATERIALS

The materials used in this investigation were cement, fine aggregate, coarse aggregate, conventional steel, water, super plasticizer (Conplast SP-430), silica fume, fly ash, commercially available repair products called EMACO S48C T, EMACO™ S46 T and Roff concrete bond.[6,7]

3. EXPERIMENTAL PROGRAM

The experimental study consists of casting of seven RCC beams of dimensions 1500mm× 150mm×200mm. Out of seven beams one beam was used as control specimen (no repair), and six beams were casted in such a way that a wide mouthed trapezoidal notch is created at the bottom surface of the beam which represents the damaged or deteriorated area that needs to be repaired using the repair materials. This notch was created at the middle third region of the beam. Beams with notches were patched with four selected types of repair materials using suitable bonding agent.

All beams have same flexural reinforcement of two #10mm diameter deformed steel reinforcing bars as bottom reinforcement and two #8mm diameter deformed steel reinforcing bars as top reinforcement. The flexural reinforcement is chosen to provide an under reinforced section with a flexural dominating behaviour. The shear reinforcement consists of #6mm diameter deformed steel reinforcing bars as closed stirrups spaced at 150mm along the beam longitudinal axis. [9]

3.1 Mix Design

The mix proportion of M20 grade concrete designed as per IS 10262-1982 is 0.52:1:1.596:3.370.[8]

3.2 Casting

Cube moulds of 70mm were used for casting mortar cubes to determine the compressive strength of repair materials at 7days and 28days. Plywood mould of size 1500mm×150mm×200mm were used for casting of beams. The internal surface of the mould is cleaned and a coat of oil is applied. The reinforcement cage prepared earlier is kept in the mould. To obtain the required clear cover mortar blocks of 25mm thickness are kept at each end. The mould is filled with concrete in three layers with height of each layer equal to 1/3rd height of the mould and compacted uniformly with tamping rods. The top surface is smoothened and the mould is kept for drying to about 24 hours. Repair beams were casted with the same procedure as that of control beam expect that a trapezoidal notch is created in the flexure zone.

3.3 Curing

Pond curing method is adopted. All the test specimens are removed after 24 hours of casting from the moulds and placed in the tank for 28 days. After 28 days all the specimens are taken out from the tank and kept for air drying.

3.3 Repair of Beams

After 28 days of curing the beams are kept for air drying. Prior to patching of the repair materials the surface of the substrate concrete has to be prepared. The surface of the substrate concrete is chipped off using a hammer and chisel so that weak concrete is removed. Then all the loose particles, dust and debris are removed. The mixed material of bonding agent (Roff concrete bond) is evenly applied over the prepared and cleaned surface with a brush.[6]

3.4 Testing Procedure

3.4.1 Compression Test

Cube specimens are used for determining characteristic compressive strength. The load at which cube specimen fails is recorded. The compressive strength is calculated by dividing the ultimate load by cross sectional area of the specimen.

Cube compressive strength = ultimate load / c/s Area

Table 1: Compressive strength of repair materials

Repair material	Curing period	
	7 days	28 days
	Strength (N/mm^2)	Strength (N/mm^2)
Normal concrete	18	30
SF mortar	34.218	47.221
FA mortar	28.775	41.565
EMACO S48C T	38.776	55.689
EMACO S46 T	35.034	51.361

3.4.2 Testing of beams

After the completion of air drying (24 hours) the specimen are cleaned to remove grit and dirt with the sand paper. White washing was done on all the sides of the beam and were kept ready for testing. White washing was done to facilitate easy detection of crack propagation. The testing is carried on structural loading frame. The loading reaction frame of 1000KN capacity consists of two movable steel I-sections. These I-sections were adjusted to have an effective span of 1300mm. The beam to be tested is placed over these two supports. Steel rollers with grooved steel plates are placed between the beam and the I-section to provide two point loading system .By using plumb bob the centre line of the beam and the hydraulic jack were made to coincide with each other in order to prevent eccentric loading on beam. Proving ring of capacity 500KN was placed in its position to record the load values. Dial gauge was placed exactly beneath the mid-span of the beam to record deflection. The test set up is shown in the Fig 4.The load was applied at a regular interval of 0.725 KN. The load and corresponding deflection values are recorded and tested till the failure of the beam. The comparison of load versus deflection curve of control beam (C) with all repaired beams is shown in the Fig 1 and. 2

Table 2: Test results of all beams

Repair material Group	Material Designation	Ultimate Load, Pu (KN)	% decrease in load compared to control beam	% increase in load compared of normal concrete
Reference	Control	39.995	-	-
R_{NC}	Normal concrete	34.195	14.5	-
RG_1	R1	34.92	12.69	2.12
	R2	34.195	16.32	2.12
	R3	35.645	10.88	4.24
RG_2	R4	37.095	7.25	8.48
	R5	35.645	10.88	4.24

Table -2: Test results of all beams (continued)

Repair material Group	Maximum deflection (mm)	% of Control beam	Pu/ Pu-control	Approx. Cost (Rs)
Reference	18.543	-	1.000	-
R_{NC}	19.812	106.85	0.855	45
	22.454	121.09	0.873	35
RG_1(Mortar based repair materials)	18.085	97.5	0.855	30
	17.932	96.7	0.891	40
RG_2(Commercially available repair products	22.606	121.91	0.927	500
	16.104	86.85	0.891	400

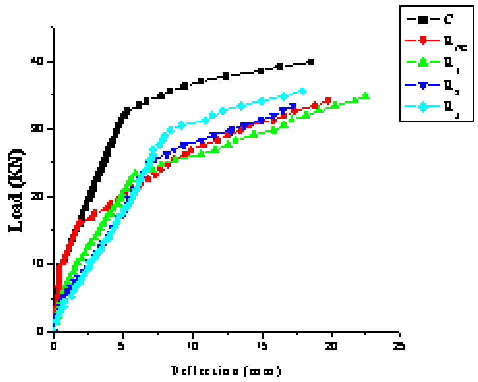

Fig 1. Comparison of load deflection curve of control beam and R_{NC} with R_1,R_2 & R_3

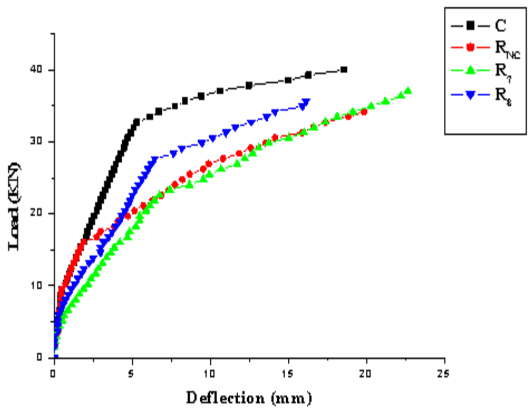

Fig 2. Comparison of load deflection curve of control beam and R_{NC} with R_4 & R_5

3.4.3 Failure modes of beams

The failure mode of all the beams is shown in the Fig 3 to Fig 8

Fig 3. Control beam(C) failed in flexural crack

Fig 4. R_{NC} beam (repaired with normal concrete) failed in flexural crack

Fig 5: R_1 beam (SF mort) failed due to debonding

Fig 6: R_2 beam (FA mort) failed due to debonding and R3 beam ((SF+FA) mort) failed in flexural crack

Fig 7. R_4 (EMACO S48C T) failed in flexural crack

Fig 8. R_5(EMACO S46C T) failed in flexural crack

4. CONCLUSIONS

1. The flexural strength of the beams repaired in tension with selected repair materials i.e. R_1 to R_5 increased in comparison with beam repaired with normal concrete (R_{NC}). The increase in flexural strength is in the range of 2.12% to 4.24%.
2. From the repair materials of same group RG_1 (mortar based materials), it is seen that the beam repaired with R3[SF(10%)+FA(20%)] materials exhibits better performance.
3. From the repair materials of same group RG_2 (commercial based products), it is seen that the beam repaired with R_5 (EMACOS48C T) material exhibits better performance. The percentage of increase in flexural strength in comparison with the beam repaired with normal concrete (R_{NC}) is 8.48% and decrease in strength is 7.25% in comparison with the flexural strength of control beam (C).
4. From the study of modes of failure of the beams it is observed that beams repaired with materials R_1 and R_2 failed due to bonding ,R_3 failed in flexural cracks and R_4 and R_5 also failed in flexural crack.

5. Among commercial repair products, EMACOS48 CT (R_4) shows better performance. The increase in flexural strength is 8.48% in comparison with capacity of control beam and the decrease in strength is 7.25% compared to beam repaired with normal concrete.
6. From this study it can be concluded that damaged parts subjected to tensile flexural stresses can be repaired using commercial repair material R_5 by retaining the capacity of the beam nearer to its original capacity.
7. The costs of commercially available repair products are expensive compared to the cost of locally available repair materials.

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