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Technical Note

EXPERIMENTAL STUDY ON REHABILITATION OF RC BEAMS USING EPOXY RESINS

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ABSTRACT

This study investigates the use of three different types of Epoxy Resin materialsviz., EXPACRETE SNE1, LAPOX B-47 and HARDENER K-46, and CONBEXTRA EP10, 65 & 120 for repairing the reinforced concrete beams. In this research, 6 standard size beams (150×230×1500mm) for M50 grade of concrete were distress in flexure by applying two points load by taking 90% of the ultimate load. Then, these distressed beams were repaired and retested up to ultimate failure load.

The aim of this study is to determine the suitability of Epoxy Resin material type to be used in RCC beams for repairing and restoring good strength and for considering economical aspects. Hardened concrete specimens were tested for compression, and flexural test. The results of these experiments show that the beams repaired using Epoxy Resin material (EXPACRETE SNE1) gave higher increase in the ultimate load than other Epoxy Resin materials.

The flexural strength increased significantly up to about 15 percent for concrete beams repaired with epoxy resin material (EXPACRETE SNE1) compared to other epoxy resin materials. Deflections were smaller in reinforced concrete beams with epoxy resin compared to conventional concrete beams. Compare to all the three types of epoxy resin materials used i.e. EXPACRETE SNE1 is cheaper than other two materials. Though reinforced concrete beams repaired with epoxy resins is costlier comparatively, it is cheaper than to reconstruct the structure.

Keywords: Epoxy resin; distress; flexural strength; repairs and rehabilitation

1. INTRODUCTION

Reinforced concrete is the most frequently applied structural material because of its good durability, which has been used for many years to build a wide variety of structures from

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houses to bridges. Consequently little maintenance or repair work is usually required on concrete structures that have been designed and built well, with materials of quality, unless they are exposed to particularly aggressive conditions. A period of dynamic growth in its use came during the 1960s as a result of chronic shortage of housing. The commonly held view, that concrete is a durable, maintenance-free construction material has been changed in recent years. Several examples can be shown where concrete did not perform as well as it was expected. Although hundreds of thousands of successful reinforced concrete structures are annually constructed worldwide, there are large numbers of concrete structures that deteriorate, or become unsafe due to inadequacy of design detailing, construction and quality of maintenance, overloading, chemical attacks, corrosion of rebar, foundation settlement, abrasion, fatigue effect, atmospheric effects, abnormal floods, changes in use, changes in configuration and natural disaster (recent earthquake of Gujarat), etc. All of these factors affecting the durability of concrete structures. In recent years, the growing need to maintain and repair structures has brought about a definite variation in the expenditure for restoration compared to the investment for new structures.

It has been estimated that, at present, in Europe (and particularly in Italy) the investments in maintenance and repair work on old structures, represent about 50% of the total expenditure in construction. The expenditure for restoration, therefore, has nearly doubled compared to the last decade, when it was seen to be between 25 to 30%. Some estimates have indicated that in 2010 the expenditure for maintenance and repair work will represent about 85% of the total expenditure in the construction field. It has been forecast that, in the same year in the USA, 50 billion dollars will be spent for the restoration of deteriorated bridges and viaducts. Repair and rehabilitation of deteriorated concrete structures are essential not only to use them for their intended service life but also to assure the safety and serviceability of the associated components so that they meet the same requirements of the structures built today and in future. A good repair improves the function and performance of structures, restore and increase its strength and stiffness, enhances the appearance of the concrete surface, provide water tightness, preventing ingress of the aggressive species to the steel surface durability. Of course the repairing methods rather than replacement structures should become both environmentally and economically preferable. One of the current interests in the field of repairing is reinforced concrete beams for repeated loading condition. This is required for structures such as bridges and offshore structures. The advantages of the rehabilitation techniques are restore and increase strength, restore and increase stiffness, improve functional performance, provide water tightness and improve appearance of the concrete surface etc.

1.1 Aims and objectives of the present study

1. To determine flexural behavior of concrete beams after repair.
2. To study the effective of use of different types of epoxy resins, as rehabilitation material for the structurally distressed RC beams.

1.2 Scope of the study

1. Use of three different types of epoxy resin materials (Expacrete SNE1, LAPOX B-47 and HARDENER K-46, CONBEXTRA EP10, 65 and 120) for 6 No of beams of M50

grade of concrete.

1.3 Literature review

Uses of Epoxy Resins in Repairing: Chung [1] in 1975 carried out a research on epoxy repaired of reinforced concrete beams. Three reinforced concrete beams were used for the test and two point loads were applied to the middle third of the beams Loading was increased by increments until failure then major cracks were repaired by epoxy resin injection. Also in 1977 he and Lui [2] carried out another research on the use of epoxy to repair concrete joints. In this research shear tests were carried out on concrete push-off specimens were first tested until failure and then repaired by epoxy injection.The results of this research proved that the use of epoxy resins to repair concrete joints was very effective.In 1985 Mansur and Ong [3] carried out a research on repairing reinforce concrete beams each with a large transverse rectangular opening using epoxy injection. The opening caused the beams to fail by crushing of the concrete at the four corners of the opening. Ten reinforced concrete beams were tested until failure under a static point load. In1978 Chung and Lui [4] investigated the effect of repairing concrete joints under dynamic loads. Some shear tests using push-off specimens (two series of eight in each) were carried out in order to achieve that purpose using epoxy injection..In1982 a research carried out by Hewlett and Morgan [5] on the static and cyclic response of reinforced concrete beams repaired by resin injection. Ten beams were used in this study. The beams were designed to fail both in tension and in shear. These beams were tested to failure then repaired and retested. A concentrated downward load at mid-span was applied. Amon and Snell [6] suggested the use of pulse velocity techniques to monitor and evaluate epoxy grout repair to concrete. This technique involves the use of a son scope and two transducers one transducer will send the wave through the concrete and the other one will receive it. The U.S. Army Corps of Engineers published the first Federal specification for an epoxy resin system in 1959 and ASTM specification C 881 was first published in 1978. The use of the epoxy systems has since expanded in many directions, because of requirements for solution of coating, patching and present status of epoxies.Epoxies are presently used with concrete in the form of coatings, repair materials, grouts, bonding agents, paints, adhesives, epoxy mortars and polymer concrete, seal coats, penetrating sealers, wearing surfaces, and as admixtures to Portland cement concrete to make epoxy polymer modified concrete. Thus, the appeal for epoxies has been enhanced, both from an economy and performance standpoint.

2. EXPERIMENTAL PROGRAMME

2.1 Materials

Cement: Ordinary Portland cement (Ultra tech cement) of 53 grade confirming to Bureau of Indian Standard is used in the present study. The cement is procured in one lot for use in casting all the specimens. The cement used is tested for its various properties as per IS 4031-1968.

Fine aggregates: The fine aggregate conforming to IS 383-1970 obtained from river bed and has been tested as per IS 2386-1963 for specific gravity, fineness modulus, bulk density, water absorption, bulking of sand.

Coarse aggregates: Coarse aggregate conforming to IS 383-1970 has been obtained from the quarry and tested for its properties specific gravity, fineness modulus, bulk density, water absorption, crushing value and impact value.

W/C Ratio: The w/c ratio adopted is 0.32 for M50 grade of concrete respectively. Clean bore well water available at University Laboratory is used for casting and curing of specimens.

Super plasticizer: The super plasticizer used in the present work is CONPLAST-SP430 (Sulphonated Naphthalene polymer) commercially marketed by Fosroc Chemicals Limited (INDIA). Super plasticizer complies with IS 9103-1979 and BS5075 partIII. Conplast-SP430 conforms to ASTM-494 types 'A' and type 'F' depending upon the dosage used.

Epoxy Resins used: The three types of the epoxy resins are used viz.,Expacrete SNE1,LAPOX B-47, HARDENER K-46,and CONBEXTRA EP10, 65 & 120.

Specifications: The epoxy resin systems comply with ASTM-C-881-78 type III Grade I B or C. All instructions and guidelines given by the manufacturer have to be strictly adhered to, while using ESSEN'S EXPACRETE range of products.

Chemical Resistance: All Conbextra EP products are resistant to oil, grease, fats, most chemicals, mild acids and alkalis, fresh and sea water. Consult Fosroc when exposure to solvents or concentrated chemicals is anticipated.

2.2 Testing program

Table 1: Details of the test beams

Grade of concrete	Designation of beam	Type of epoxy resin used for repairing	Reinforcement details
M50	set 'A' beams	Expacrete SNE1	2-16mm dia at top
	set 'B' beams	LapoxB-47 hardener K-46	3-16mm dia at bottom
	set 'C' beams	Conbextra EP10,65 & 120	2-legged 8mm dia stirrups @ 120mm

The beams were designated as set 'A' beams, set 'B' beams, and set 'C' beams respectively. So that each two beams have been repaired with different type of epoxy resin and compared their strength. Moulds were removed after 24 hours and the specimens were placed for curing. The beams were kept for set without disturbance for 24 hours.

A steel frame with inner dimensions of 600mm (L) X 180mm (B) X 340mm (H) arranged with a set of brackets at top and bottom to fix dial gauges was used for measuring strains. Three dial gauges were gauges were fixed at bottom in order to record the strains. Three gauges were fixed below the beam at middle third and mid span to observe the deflections.

The beams were tested in a Universal Testing Machine under two point loading at middle third points of the span. The whole set up was placed with Universal Testing Machine of 200 ton capacity and subjected to two points loading. Readings on dial gauges were recorded for every incremental load of 2 kN initially up to 10 kN and 5 kN subsequently distributed equally over two points. Dial gauges at top measures compressive strains and those at bottom measure tensile strains. Strains and deflections were recorded with help of the dial gauges for each increment of 2 kN initially up to 10 kN and 5 kN subsequently distributed over two points. Both compressive and tensile strains were measured at top and bottom fibers, respectively and the mean values were calculated. Beams were tested firstly up to 90% of load i.e. up to distress and then after repair they tested completely till ultimate crushing failure takes place.

2.3 Repairing of distressed beams

The distressed beams removed from the testing machine are first chased the cracks to form a 'V' shaped groove as shown in the plate. Then water is sprinkled on prepared groove to remove the loose particles. Then the process of putting is done. The mixture of ESSEN SNE base and the ESSEN SNE hardener are mixed thoroughly and filled in the groove and then PVC nozzle pipes of 8mm diameter are fixed in the cracks and placed at a distance of 50mm to 100mm as shown in the plate and injected into the pipes with the hand blown pressure as shown in the plate. Then the pipes are tied with the wire as shown in the plate. The pipes are cutted down smoothly up to the level of the beam surface as shown in the plate after 24 hours.

Deflections, strains and moment curvature relations: Readings on dial gauges were recorded for deflections at one third span mid span for each set of beams respectively. Readings were recorded to a minimum of 0.01mm with dial gauges with a least count of 0.01mm.Dial gauges were fixed at one third, two third and mid span section points along the span and readings were recorded for every increment load of 2 kN initially up to 10 kN and 5 kN subsequently.

3. TEST RESULTS AND DISCUSSIONS

3.1 Load-deflection characteristics and strain characteristics

Figures show the Load-Deflection curves at mid span section for R.C.C. beams specimens before and after repair. The elastic deflections at initial stage of loading for beams after repair are found to be small when compared to beams before repair. The same trend follows even at final stage of loading in the plastic state, though the deflections are greater at the middle-state of loading. In the load-deflection curve for beams, a linear behavior continues initially, till the first crack produces a district change in slope. The change in slope of curve is accentuated by the incidence of further cracks till the yielding of reinforcement starts. The curve is, however, horizontal at high loads for beams after repair. The final deflections for members after repair were found small compared to the members before repair. Figure show the variation of compressive and tensile strains with load along the depth of section at one-third span and mid span for beam specimens before and after repair respectively. Both compressive and tensile strains follow a linear relation even at high loads for beams after repair. Tensile strains were small in beam members after repair. The compressive and tensile strains were linearly progressive along the depth of section.

3.2 Moment – curvature relations, cracking pattern and crack widths

Figure ure show the moment-curvature relations at one third span and mid span for beams before and after repair, respectively. Both the curves for the beams before and after repair will follow a bi-linear relation with change in slope at the moment of first crack. The curvature varies linearly with moment in all stages of loading, also in the plastic state except change of slope that occurs at the moment of first crack and the moment at first yield of reinforcement. The curvatures are low for beams after repair compared to before repair. The ultimate crushing load at failure is high for beams after repair compared to beams before repair. The crack patterns in R.C.C beams before and after repair are shown in Figure. The maximum crack widths for beams before and after repair are appeared at mid span. The maximum crack widths for beams before repair were observed as 1.2mm. The flexural shear cracks began at mid span at a minimum load of 6 kN and propagated vertically up to the neutral axis. A maximum crack width of 1.2mm appeared at 90% ultimate load in beams before repair and a maximum crack width of 1.3mm appeared at ultimate crushing load of 180 kN at mid span. Web shear cracks began from middle-third span and propagated diagonally towards the centre of span up to the neutral axis. The average crack width is 0.20mm and the maximum deflection was occurred at mid span at ultimate crushing load of 180 kN for beams after repair. All the graphical representations are presented in Figures 1-4.

Table 2: Cost of epoxy resin materials

Type of epoxy resin	Cost of the material per liter
Expacrete SNE1	Rs : 800
LapoxB-47 hardener K-46	Rs : 1000
Conbextra EP10,65 & 120	Rs : 1600

Table 3: Compressive strength of M50 grade concrete

Grade of concrete	Compressive strength (MPa)		
	3 days	7 days	28 days
M50	33.18	43.11	51.5

Table 4: Ultimate load carrying capacity and moment carrying capacity of beam

Grade of concrete	Ultimate load (kN)	Ultimate moment (kNm)
M50	135	37.44

Table 5: Comparison of three types of epoxy resin materials

Type of material used for repair	**Expacrete SNE1 for set 'A' beams**		**LapoxB-47 hardener K-46 for set 'B' beams**		**Conbextra EP10,65 & 120 for set 'C' beams**	
Cost of the Material per liter	Rs : 800		Rs : 1000		Rs : 1600	
Application	before repair	after repair	before repair	after repair	before repair	after repair
Load (kN) applied	165	195	165	180	165	190
Max. deflection, mm at 165 kN	5.42	5.08	5.45	5.51	6.43	5.56

The results of these experiments show that the beams repaired using the Epoxy Resins (Expacrete SNE1) for set 'A' beams are stronger when compared to the other Epoxy Resins (LapoxB-47 Hardener K-46 and Conbextra EP10,65 & 120) used for set 'B' & 'C' beams. Deflections were smaller in reinforced concrete set 'A' beams with Epoxy Resins (Expacrete SNE1) compared to other set 'B' & 'C' beams which have been repaired by Epoxy Resins (LapoxB-47 Hardener K-46, Conbextra EP10,65 & 120). The plates are presented in the form of Figures 1-7.

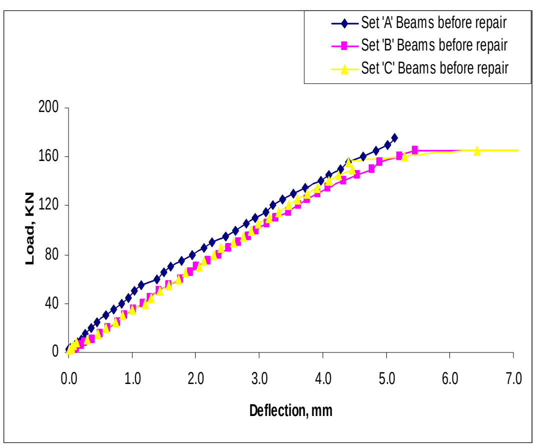

Figure 1. Load-deflection relationships for set 'A', 'B' & 'C' beams before repair

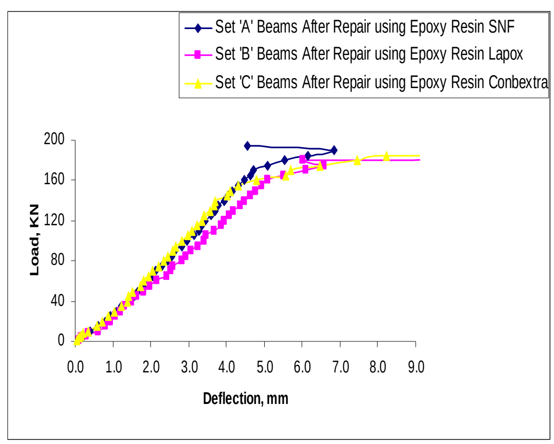

Figure 2. Load-deflection relationships for set 'A', 'B' & 'C' beams after repair

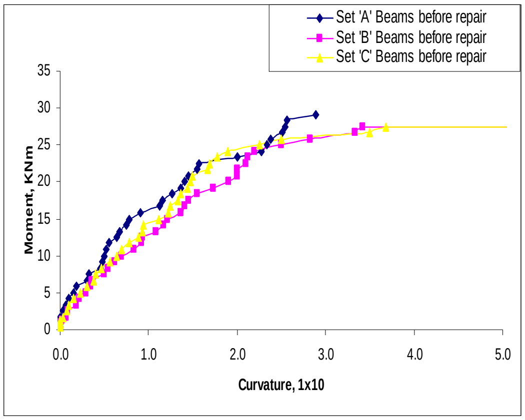

Figure 3. Moment-curvature relationships for set ‘A’, ‘B’ & ‘C’before repair

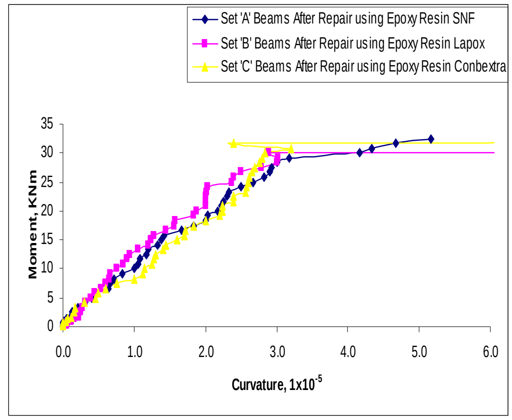

Figure 4. Moment-curvature relationships for set ‘A’, ‘B’ & ‘C’after repair

Plate 1. Mixing ESSEN base and hardener to fill groove and fix the PVC pipes

Plate 2. Fixing the PVC pipes into the grooves

Plate 3. Fixed the PVC pipes into the grooves

Plate 4. Injecting the epoxy resins into pipes

Plate 5. Injecting the epoxy resins into pipes

Plate 6. Beams after test

Plate 7. Beams after test

4. CONCLUSIONS

1. Moment of resistance in flexural deficient beams distressed upto 90% of ultimate stage was restored by the Epoxy Grouting.
2. The increase in ultimate load after repair is observed to be 15%.In flexural deficient beams distressed due to 90% of ultimate loading, the moment of resistance was not only fully restored but there was an improvement in strength by 10% compared to normal beams before repair.
3. Compare to all the three Epoxy Resin materials used for repairing, Expacrete SNE1 is cheaper and also strength increased up to 15%.

4.1 Recommendations for further studies

1. The present work may be extended to estimation of distress levels in flexural deficient and shear deficient beams.

2. The study needs to be extended to other structural elements like columns, slabs and also to beam column joints.
3. The study may further be extended to dynamic loading.

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