STRUCTURAL STRENGTHENING OF DAMAGED R.C.C. STRUCTURES WITH POLYMER MODIFIED CONCRETE

Suresh Chandra Pattanaik
PhD student, KIIT University, Bhubaneswar and Team Head (Advanced Diagnostic Laboratory),
Dr Fixit Institute of Structural Protection and Rehabilitation, C/O-Pidilite Industries Limited, Mumbai

(Paper published in proceedings of WSRR[09] (Workshop 2009 on Rehabilitation and Retrofitting of Structures) held at Indian Institute of Technology, Mumbai from 28th to 30th August,2009)

Abstract: In an aggressive environment like Mumbai polymer modified concrete is very much suitable for repair and rehabilitation of damaged RCC structures because of its excellent moisture resistance properties & high early strength .Not only it strengthens the RCC structural members but also makes a highly durable repair. Though FRP has become more effective for retrofitting but polymer modified concrete is being widely used for cost effective. This paper focuses on some of the important properties and step by step approach for structural strengthening of damaged concrete structures with polymer modified concrete.

1.0 Introduction

The repair and rehabilitation of damaged concrete structures is quite often in a highly aggressive environment like Mumbai associated with high level of pollution, high humidity through out the year, high rain fall along with higher level of chloride contents in the atmosphere. Ageing of the structure and persistent use after the design life of the structure also leads to deterioration of the structures. There are various products available for repair and rehabilitation but polymer modified concrete is most cost effective for improving the high early compressive strength, tensile and flexural strength and reducing the brittle nature. Polymer-modified concrete particularly latex modified concrete such as styren-butadine, acrylic latex, polyvinyl acetate, and ethylene vinyl acetate have been widely used for structural repair and strengthening. Repair to damaged reinforced concrete elements like beams, columns, wall etc., where access is restricted and compaction is not possible and for structural strengthening by Jacketing of RCC columns to increase load carrying capacity are areas of application of micro concrete.

2.0 Factors affecting selection of repair materials

Compatibility of the repair materials with the existing substrate and durability under various conditions in service are of much greater importance. Apart from bond and compressive strength there are some other properties such as dimensional stability (Shrinkage), coefficient of thermal expansion, modulus of elasticity and permeability which should be taken care during selection of a repair material.
The other factors like permeability, chemical and electrochemical compatibility should also be considered. Final selection of the material or combination of materials must then take into account the ease of application, cost, and available labour skills and equipment.

2.1 Properties of Repair material

The use of polymeric materials for repair of concrete structures has been widely accepted

and most effective. A repair material should satisfy the requirements such as good workability, mix stability, ageing resistance, strength, compatibility with substrate, adequate adhesion and low volatile content.

The major properties requirements of the materials are given in Table: 1.

Table: 1

Properties of mortar/concrete	Polymer-resin	Polymer-modified cementitious	Plain cementitious
Compressive strength (Mpa)	50-100	30-60	20-50
Tensile strength (Mpa)	10-15	5-10	2-5
Modulus of elasticity (Gpa)	10-20	15-25	20-30
Coefficient of thermal expansion (per ^{o}C)	25-30 x 10^{-6}	10-20 x 10^{-6}	10 x 10^{-6}
Max. Service temp. (^{o}C)	40-80	100-300	>300

2.2 Properties of Polymer Modified concrete

Polymer modified concrete is a ready to use dry powder which requires only addition of clean water at site to produce a free flowing non shrink repair. It is a cementitious material with additives, which impart controlled expansion characteristics in the plastic state while minimising water demand. It is self compacting with high early and final compressive strength used where hand applied polymer modified concrete is not possible due to inaccessible and congested reinforcements. High early strength facilitates early reinstatement of the structure.There are certain advantages of using micro concrete over normal concrete. It offers excellent resistance to moisture ingress and makes repaired sections highly durable. It can be applied up to 100 mm thickness at one stroke and addition of pre-calculated aggregates of 12 mm down may be required if thickness is more than 100 mm.

Two types of Polymer modified concrete referred as Micro concrete(M.C-1) and (M.C-2) were taken and tested for compressive strength, flow and other properties whose test results are given in Table: 2.

Table: 2

Days	*M.C-1*	*M.C-2*	*Specified*
Water/Powder ratio	0.15	0.15	0.15-0.16
Flow in mm	290	280	>250
Pot life in minutes	45	45	>30
Compressive strength(N/mm^2)			

1 Day	20.5	21.0	10.0
3 Days	36.0	32.0	30.0
7 Days	50.0	46.0	40.0
28 Days	64.0	54.5	50.0

From the above table it shows that the 60% of compressive strength as high as 30-36 N/mm^2 is achieved within the first 3 days making it a versatile material for early reinstatement of the structure. Further the strength increases by another 5-10% by 90 days. There was no bleeding and settling of micro concrete observed during the test.

The other desired properties are as follows:

Flexural strength :5 N/mm^2 at 28 days
% water absorption after 24 hrs :0.45
Chloride content :Nil
Depth of carbonation, mm :Passes the Accelerated carbonation test
Coverage: 1.3 sqm per 25 kg pack at 10 mm thickness

3.0 Repair Methodology

The step by step approach for repair is given as follows:

3.1 Supports: The R C members should be properly supported before chipping the spalled / loose concrete. The props provided shall be adequate to provide sufficient structural support to the load carrying members.

Micro concrete for repair of a congested beam

Micro concrete for strengthening of a beam

3.2 Surface Preparation of concrete: All the spalled cracked concrete or any other pre-applied mortar shall be removed by chipping to expose the reinforcing bars. The concrete shall be chipped to a minimum depth of 10mm behind the reinforcing bars. The areas to be repaired shall be profiled to get rectangular or square shape with an inward tapering edge

3.3 Surface preparation of reinforcement : The exposed reinforcing bars should be cleaned thoroughly to remove all traces of rust, scales, etc., by using wire brush, emery paper etc. The lateral ties/stirrups shall also be cleaned in the same way. After removal of corroded portion, the diameter of the reinforcement shall be checked and compared with the drawings.

3.4 Provision of additional reinforcement: As the diameter of reinforcing bars is reduced substantially (say >20%) additional bars shall be provided as per the design. This additional reinforcement shall be properly anchored to the existing concrete by providing adequate shear connectors. Weld mesh may also be provided if found necessary.

3.5 Provision of shear connectors: Shear connectors of 8mm diameter shall be provided in holes of 14mm diameter and 75 mm deep. These shall be provided at every 500 mm c/c on all the faces of the beams in staggered form. The holes shall be cleaned with compressed air or water jet to remove all the dust etc. and then the shear connectors shall be fixed in the holes using polyester resin anchor grout

Additional reinforcements and shear connectors provided

3.6 Priming of reinforcement bars: The exposed and cleaned reinforcing bar shall be provided with a coat of Epoxy Zinc Primer such that the coated film will have a dry film thickness of 40 microns. The film shall be continuous especially in the regions where pitting, imperfections etc., are present on the surface of the bars. It is important that the rear portion of the bars should not be left without coating. A second coat if needed may be provided to achieve a uniform and continuous film. The additional reinforcement provided and also the shear connectors shall be coated with Epoxy Zinc Primer. The weld mesh if provided shall also be coated with Epoxy Zinc Primer.

3.7 Provision of Epoxy based bonding agent: The base and hardener component of epoxy resin based bonding agent must be mixed well to get a uniform grey coloured mix. Apply the material to properly cleaned and dry concrete substrate using stiff nylon brush by scrubbing it well into the substrate. The coat should be uniform and well spread on the

entire surface area of the repair patch. The mixed material must be applied before the elapse of its pot life and the new repair mortar must be applied before the elapse of overlay time. As a fully dried epoxy resin coat acts as debonding layer, the repair material should be applied whilst the bonding coat is tacky. In case the applied epoxy bond coat gets dry, an extra coat should be applied before application of repair mortar.

3.8 Formwork and shuttering: Slurry tight and strong form work shall be provided. The shuttering for encasement shall be kept ready such that the formwork shall be placed in position and fixed such that the micro concrete can be poured into the formwork within the overlay time of the bonding agent (5 hours). Adequate supports shall be provided for the formwork. Care should be taken to ensure leak proof shuttering. Under no circumstance the slurry should flow out of the shuttering during pouring of micro concrete.

3.9 Mixing of micro concrete: It should be mixed using the appropriate water powder ratio as mentioned in the product data sheet. The mixing shall be done mechanically and under no circumstance hand mixing shall be done. Mixing shall be carried out for 3 to 5minutes to ensure that homogeneous mix is obtained without any bleeding or segregation. In hot climate ice cooled water shall be used to maintain the temperature of mixed material. If the encasing thickness is more than 100 mm, add stone aggregates up to 50 % by weight of micro concrete to the mixed micro concrete directly into the mixer hopper. The stone aggregates must be 12 mm and down and shall be clean, washed and dried. The mixing should be done for 3 minutes in mixer and then pre weighed stone aggregates into the mixer. Mix further for 2 minutes till lump free mix is obtained

Additional reinforcements provided for jacketing

Strengthening of column with micro concrete

3.10 Deshuttering: The shuttering from the sides of the R C members shall be removed after a period of 24 hours. However, the formwork of the soffit shall be retained and removed after 3 days.

3.11 Pouring of micro concrete: The mixer should be poured into the formwork using a suitable funnel or through a hose pipe. It must be poured from one end only. A suitable

hopper / funnel arrangement shall be made at site to facilitate the pouring operations. The pouring operation shall be continuous and it shall not be stopped unless the job is completed. To achieve this sufficient mixers / drilling machines and wok force shall be arranged at site.

Preparation for micro concrete of a column

Repair of a column with micro concrete

3.12 Curing: All the repaired and encased area shall be fully cured as per standard concrete practices. Curing compound shall be used for effective curing of sides and soffits of beams. If a curing compound is applied, care shall be taken to ensure that proper surface preparation is carried out so as to remove any traces of curing compound on the surface. If this is not done, it may lead to debonding of any protective coating applied on top.

Preparation for micro concrete of a beam

Repair of a beam with micro concrete

4.0 Tests for effectiveness of repair

Performance of a concrete repair needs to be measured in physical terms and other parameters such as environmental effects, safety and whole-life costs. The polymeric repair materials fail due to improper surface preparation, wrong application methods, incompatibility of the repair material with the original concrete etc.

The most of the failure takes place at the interface of the bonding for which bond strength is very important. All corrosion related cracks should be tested by corrosion analyzer etc. Structural crack repairs should be tested for an in-situ non destructive load testing to demonstrate satisfactory performance under an overload above the design working value after 28 days.

5.0 Conclusion

Based on above test results and application, polymer modified concrete is a free flowing, self leveling, self compacting and high early strength material which is being effectively used for structural strengthening of deteriorated RCC members of column and beam in an aggressive environment. It can also be used for additional load carrying of those structural members by method of jacketing.

Product used: Dr. Fixit Microconcrete

Repaired building photos: Ramesh Mahal, Mumbai