Rehabilitation of structurally damaged and corrosion-affected structures using polymer systems

M. K. Kamat, B.V. Bhedasgaonkar

The authors report three case studies of structurally-damaged concrete structures where the extent of corrosion of reinforcement was also high. In all the three cases, polymer-based materials were used for rehabilitation.

Corrosion-damaged structures such as bridges in coastal areas, jetties, key walls, hydraulic structures, reservoirs, etc. form a major proportion of structures that need to be rehabilitated. Other structures such as heavy machine foundations develop functional defects and cracking due to excessive vibrations, although the extent of damage in such structures is comparatively less severe than that in marine structures. Considerable advancements have occurred in the field of construction materials, in particular, polymeric materials such as epoxy and other resins, polymer latexes, protective coatings, etc. All these materials have made it possible to repair the structures and bring them back to original state within a very short time.

Following are a few case studies of the works actually executed by authors and they highlight the advantages of polymer-based materials.

Case I: Coastal pump house in Bombay

A pump house, constructed about 12 years back, is intended to pump water from a storage pond into the sea. The storage pond holds water from the storm water drains and other water outlets from low-lying areas during high tide. During repair and maintenance of gates, seawater also comes into the storage pond and the level of water in the pond varies with tide levels.

A major damage to the structure occurred in the main columns forming the portals of the pump house structure. Beams and columns at the water intake side of the pump sump were also badly corroded. Reinforcement in columns and beams showed signs of heavy corrosion. It showed heavy scaling too. The portion of column between high and low tide was most damaged. The size of the column was reduced from 3OOmm x 6OOmm to 230mm x 450mm, indicating an alarming situation from structural point of view also. Bottom reinforcement of the beams gave away completely when loose concrete from bottom was chipped off.

The alternate wetting and drying in sea water, attack of chlorides, attack of effluents which were accumulating in the pond along with general marine environment were the main contributing factors responsible for corrosion. There was no concrete protective system adopted at the time of construction.
Decision was taken to rehabilitate the damaged portion of the structure with polymer modified mortar in preference to conventional jacketing of the elements with concrete. This was on account of considerably better bond, increased flexural and tensile strengths and resistance to chemical attack exhibited by polymer mortars.

B. V. Bhedasgaonkar,Consulting Engineer, 210, BharatBhavan, 1360, Shukrawar Peth, Tarun Bharat Compound, Off. Bajirao Road, Pune411 002.

M.K Kamat, Krishna Conchem Products Pvt. Ltd., 5-B, Mohsin Building, RK. Vaidya Road, Dadar (West), Bombay 400028.

Fig 1 shows the condition of the columns.

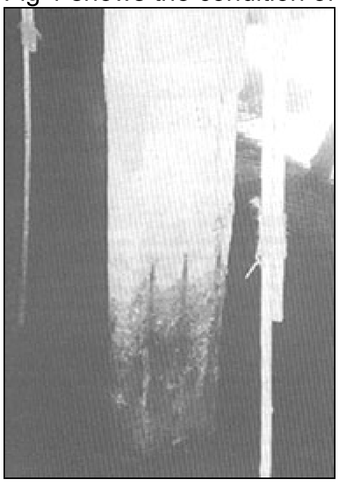

Fig1 : Existing corroded condition of the RC column

Experimental studies carried out on polymer modified systems have proved the effectiveness of polymer addition. Added to their higher mechanical strength values, their cost-effectiveness renders the repair process economical. Most redeeming feature of these systems is the significant increase in toughness values over cement-based systems, Fig 1. This property alone renders the system most useful for repairs since the repaired areas would not deteriorate under dynamic loadings and energy absorption would be far more uniform throughout the section. Thus, microcracking is eliminated
leading to higher durability.

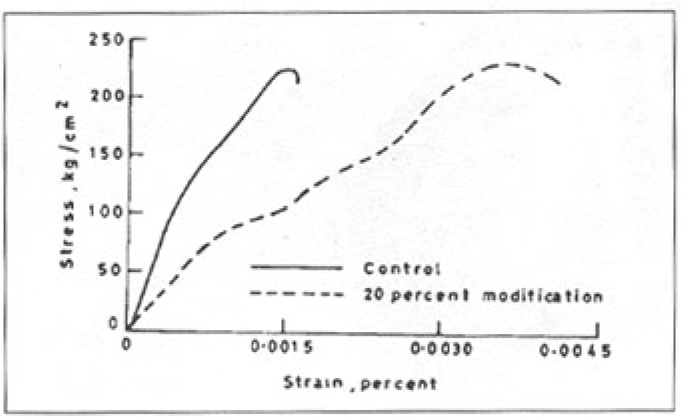

Fig 2 Stress strain behaviour of Monobond latex modified mortar

Prior to repairs, the client got critical portion of the structure tested from Messrs Composites Combines, Bombay. Ultrasonic pulse velocity testing was carried out which indicated a velocity of 3,200 m/s. It was decided to improve the core of columns in these locations by injecting low viscosity monomer Monopol. Core was also impregnated with Monopol by repeated brush application, Fig 3.
This monomer forms a polymer matrix within the concrete matrix and improves the core strength. Moreover, the corroded reinforcement was derusted and protected with IPN anticorrosive coating. Additional reinforcement in the form of main bars was provided. Expanded wire mesh troughs were used to encase bottom reinforcement of beams where shear as well as main reinforcement had given away. Repairs with Monobond polymer latex were carried out on surfaces having

epoxy bond coat. Finally, the entire surface of the structure was given anticorrosive protective coating with Corroseal, Fig 4.

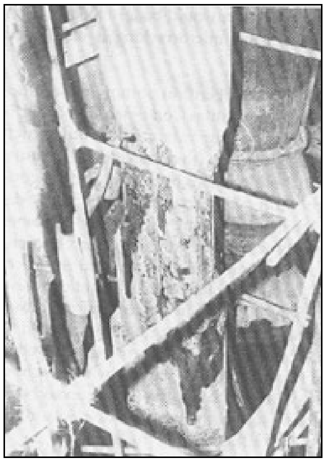

Fig3 : Low viscosity monomer impregnation in the core of the RC column

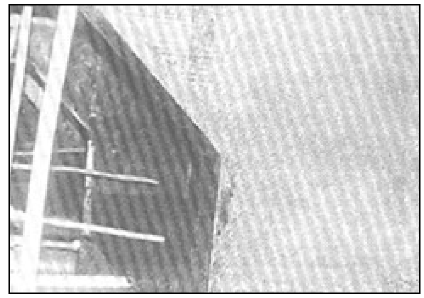

Fig 4 : View of restored RC column after protective coating treatment

UPV tests were conducted on repaired portion at the same location where the earlier tests were conducted. The velocity improved to 3,700 m/s justifying the method of repairs adopted.

Case II: Lime stone crusher foundation for a cement plant.

A leading cement manufacturing plant in Karnataka had problems of severe vibrations in its lime stone crusher foundation. The foundation has four main columns supporting the deck on which the crusher is located. One column developed crack at the column top / deck junction. This also happened to be the location of the construction joint. The crack width increased gradually when the machine continued to be operated even after crack development. This resulted in severe vibrations of the crusher. The cross section of the column top is about 2m x 1.35m. Since the crusher was operated even after the development of the crack, it was felt that there could be a likelihood of the disbonding of the vertical reinforcement from adjacent concrete as well as propagation of the crack, lateral to the direction of the bar due to vibrations. Very low viscosity monomer was selected for impregnation of the core of the column by injecting it into the crack under pressure until no more low viscosity monomer could go in. The amount of low viscosity monomer injected was considerably higher than the crack volume, indicating that the core was impregnated and the possible cracks around the vertical bars were sealed. Finally after 24 hours of low viscosity monomer injection, injectable epoxy resin was injected into the crack to ensure its complete sealing, Fig 5.

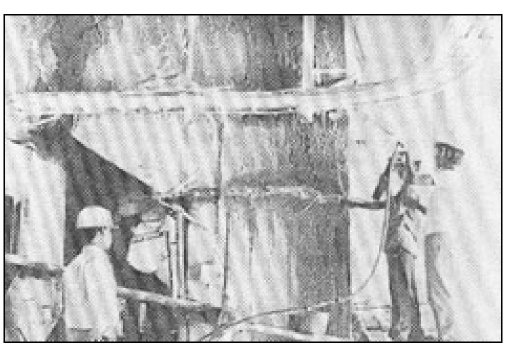

Fig5 : Grouting with low viscosity monomer for foundation of lime stone crusher

The vibration of the foundation was reduced from over 300 microns to within the acceptable limit. The entire work was done in three days and crusher was brought back into operation immediately, resulting in minimum shutdown.

Case III: Overhead water tank at Powai, Bombay

An overhead water tank supplying drinking water to a big campus in Bombay had deteriorated due to ageing and environmental factors. The major problem was corrosion on account of leakage. Critical structural elements had developed severe corrosion. The two ring beams of this Intz-type tank showed spalling of concrete and exposed corroded reinforcement. The bottom dome also showed spalling of concrete and exposed reinforcement in many places. Vertical reinforcement in the columns of staging was also corroded. Construction joints m the vertical walls of the tank were a major leaking spot. It was necessary to strengthen all the structural elements to improve the strength of left-over portion of concrete and make up for the lost structural capacity by additional jacketing with polymer mortars. Hence extensive injection grouting using low viscosity monomer, making up of the lost cross-section of beams and columns and finally redoing the entire inside of tank with polymer modified mortar were adopted. The final waterproofing membrane from inside had to be done using a non-toxic coating. The authorities evaluated the available protective coatings and utilised epoxy stearate system which was non-toxic and watertight coating for the entire internal surface of the tank.

Conclusions

The repair of reinforced concrete structures deteriorated either due to corrosion or dynamic loading or environmental factors, are discussed in the text. Typical methods adopted for rehabilitation have proved their efficacy as shown by NDT tests carried out after the repairs.

The authors hope that vigorous studies on such repair technologies should be undertaken by research institutes as per the demands in the field.

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