

Normal and Reactive Powder Reinforced Concrete Structures using Epoxy Injection Technique

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Abstract— The paper deals with the repair and strengthening of reinforced concrete beam element in a structure by means of epoxy treatment. Concrete is used in roads, highways and airport pavements because of its load carrying capacity and low maintenance. Better knowledge of speedy repair techniques would be a further advantage in supporting the use of concrete pavements. This examines the repair and restoration of concrete pavements systematically by distress classification and the underlining objectives of each concrete repair and restoration technique. It also covers the composition and characteristics of a broad range of repair materials for cracks, spalling, potholes, rough patches and sunken slab. The review covers techniques used in routine maintenance of concrete pavements but excludes slab replacement. Emphasis will be given to road pavements but they are also applicable to other concrete pavements.

Key words: Concrete, Repair and Epoxy Treatment

I. INTRODUCTION

Concrete Pavements also known as Rigid Pavements have a relatively long service life, provided these are properly designed, constructed and maintained. With mega projects like National Highway Development Project (NHDP) and Pradhan Mantri Gram Sadak Yojana (PMGSY) the pace of concrete pavement construction has increased recently. This is, because concrete pavements are known to perform better with minimum maintenance. The concrete pavements can serve upto its design service life and even beyond, if timely repairs are undertaken. Load transfer mechanism of the concrete pavement is through beam action and accordingly the concrete pavements are expected to perform relatively better than flexible pavements on weak sub-grades, as these can bridge small soft or settled areas of sub-grades. Concrete is used in roads, highways and airport pavements because of its load carrying capacity and low maintenance. Better knowledge of speedy repair techniques would be a further advantage in supporting the use of concrete pavements.

II. LITERATURE REVIEW

The most common adhesive used for strengthening is epoxy. There are some limitations with the use of epoxy adhesives, including poor fire resistance. Therefore, other adhesive was used to strengthen concrete beams in flexure. Cement-based bonding material would be beneficial to produce strengthening system that is fire resistant, also it significantly lower the cost of retrofitting on existing structures.

In contrast to Clear's work, other research indicates good performance of epoxy coated reinforcement. A 1993 study by Erdogdu and Bremner, "Field and Laboratory Testing of Epoxy-Coated Reinforcing Bars in Concrete," documented the performance of epoxy coated reinforcement in concrete that was exposed to simulated marine environments in Maine. Concrete slab samples with damaged epoxy coated reinforcement (1% to 2% of the coating removed prior to casting) and undamaged epoxy coated bars were evaluated in laboratory and field conditions over a two year study period. The laboratory results showed no measurable corrosion on the undamaged bars for the entire test period. The damaged bars exhibited some corrosion. In the field tests, both the damaged epoxy coated bars and the undamaged epoxy coated bars were in good condition with only small pits detected on the damaged bars.

III. REPAIR METHODS OF CONCRETE

There are a range of concrete repair and restoration techniques which are used as corrective, preventive, and corrective-and-preventive measure. They can be used individually but are typically more effective when several are used together. Although concrete repair and restoration does not necessarily increase structural capacity of a pavement, it does extend the pavement's service life. Besides the above, special techniques are available for best results in the repair and strengthening operations. They are described below:

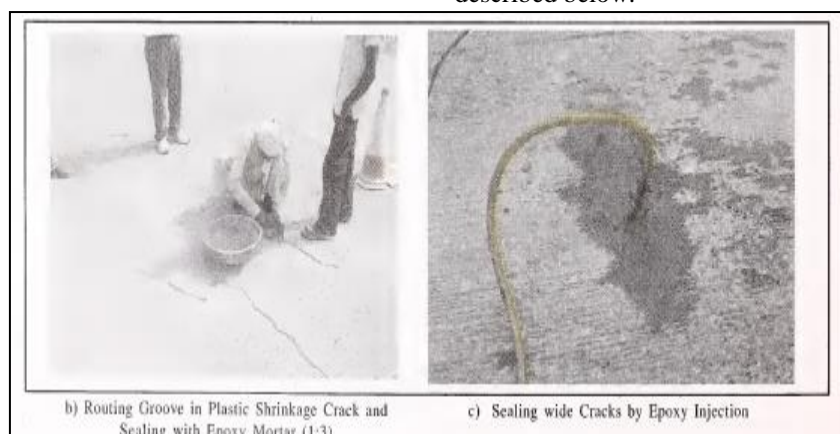


Fig. 1:

A. Corrective Techniques

Corrective techniques are used to repair a given distress and improve the serviceability of the pavement.

1) Full-Depth Repairs

Full-depth repairs fix cracked slabs and joint deterioration by removing at least a portion of the existing slab and replacing it with new concrete. This maintains the structural integrity of the existing slab and pavement.

Full-depth repair is also appropriate for shattered slabs, corner breaks, punchouts in CRCP, and some low-severity durability problems. It involves marking the distressed concrete, saw cutting around the perimeter, removing the old concrete, providing load transfer, and placing new concrete. Each repair must be large enough to resist rocking under traffic, yet small enough to minimize the amount of patching material.

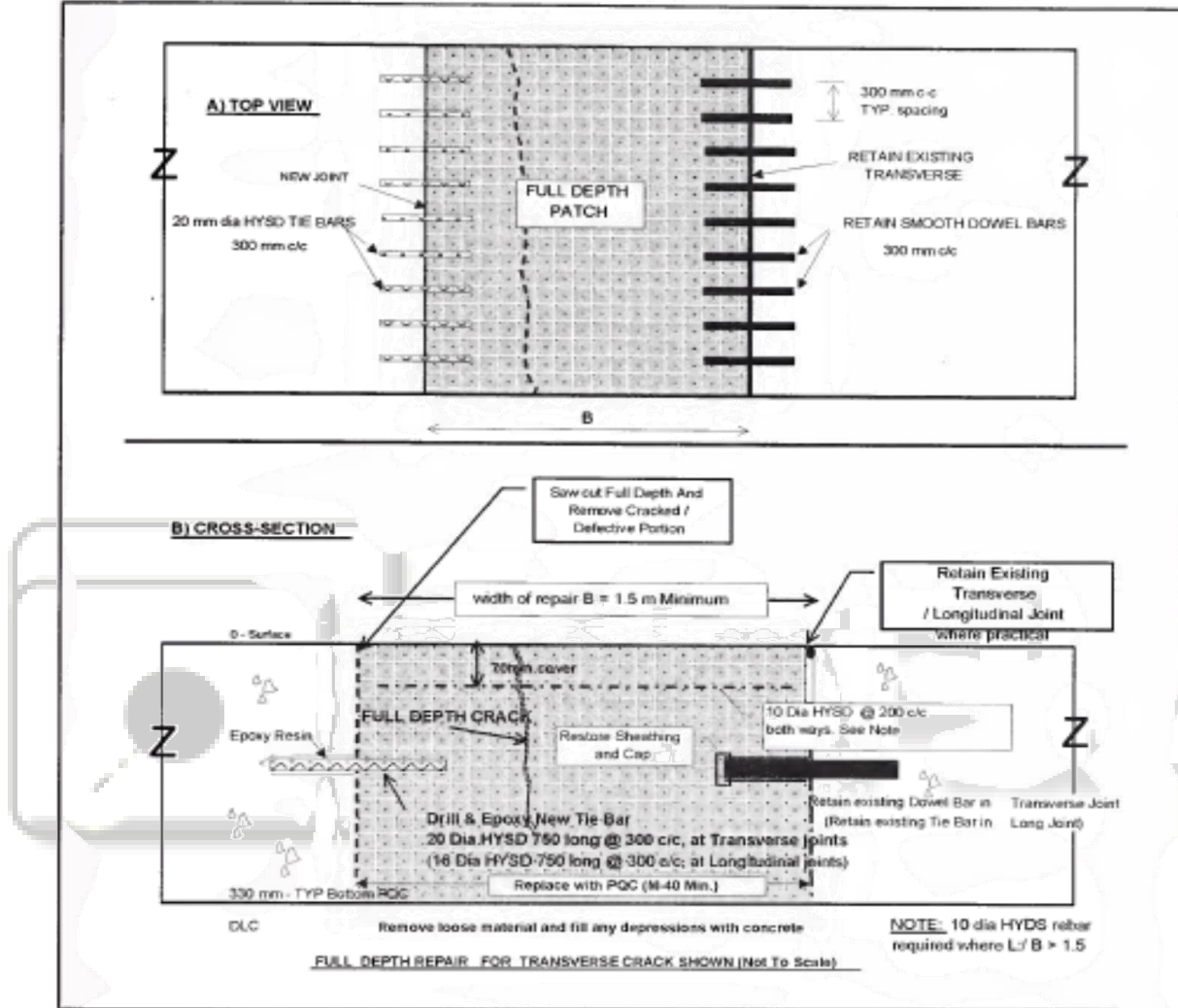


Fig. 2:

2) Partial-Depth Repairs

Partial-depth repairs correct surface distress and joint/crack deterioration in the upper third of a concrete slab. When the deterioration is greater in depth or reaches embedded steel, a full-depth repair must be used instead. It involves removing the deteriorated concrete, cleaning the patch area, placing new concrete, and reforming the joint system.

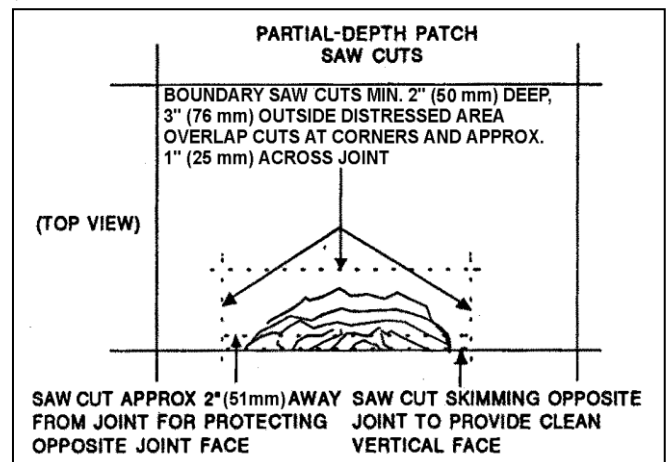


Fig. 3:

3) Cracking and Seating

This technique is used prior to placing an asphalt or concrete overlay to control reflective cracking in the overlay. It is sometimes referred to as pavement breaking or pavement shattering. It is intended to create concrete pieces that are small enough to reduce horizontal slab movement to a point

where thermal stresses which contribute to reflective cracking will be greatly reduced, yet still be large enough and still have some aggregate interlock between pieces so that the majority of the original structural strength of PCC pavement is retained. It is used to re-establish support between the subbase and the slab where there may be voids.

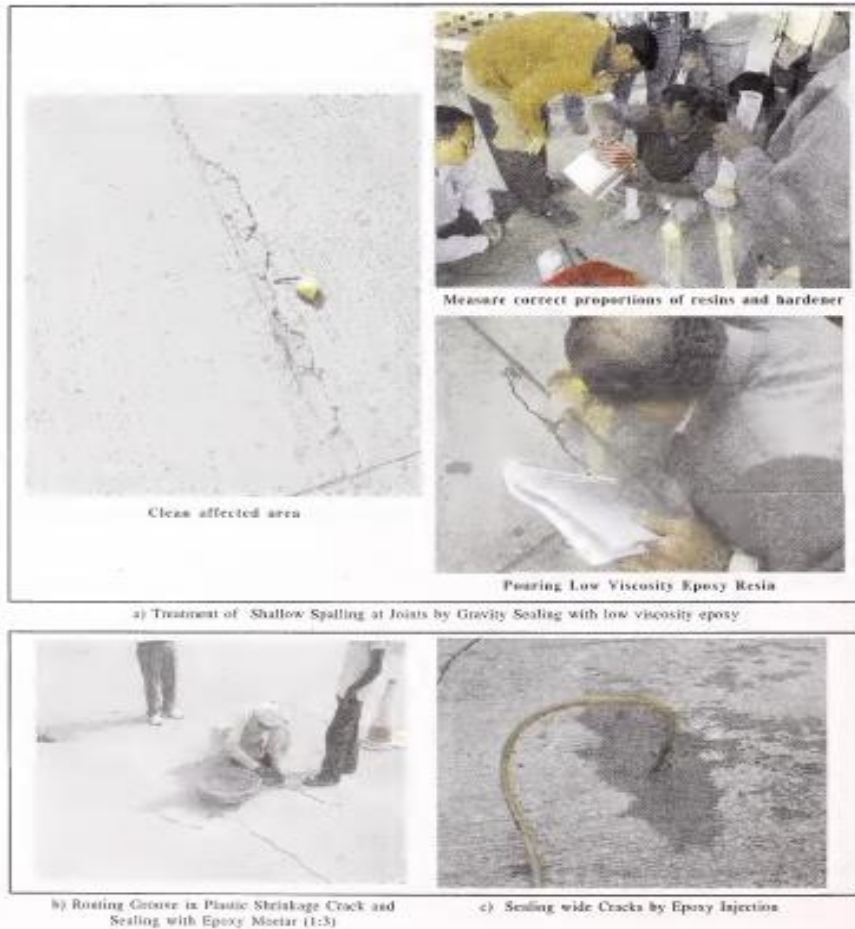


Fig. 4:

B. Preventative Techniques

Preventative techniques are proactive activities that slow or prevent the occurrence of a distress in order to maintain serviceability.



Fig. 5:

1) *Joint and Crack Resealing*

Joint and crack resealing minimizes the infiltration of surface water and incompressible material into the joint system. Minimizing water infiltration reduces subgrade softening; and slows pumping and erosion of subgrade or subbase fines. Minimizing incompressibles reduces the potential for spalling and blow-ups. It applies where the width of cracking (or longitudinal joint opening) is at least 1 mm or the surface arris is spalled. It suggests the use of urethane as a substitute for silicone sealant where distillate fuels are likely to be in concentration.

2) *Retrofitting Concrete Shoulders*

Retrofitting concrete shoulders adds a tied concrete shoulder to an existing pavement. It is similar to dowel-bar retrofit because it decreases the critical edge stresses and corner deflections and reduces the potential for transverse cracking, pumping, and faulting. On CRCP, retrofit concrete shoulders can decrease the outside pavement edge deflection and cantilever action, which reduced the potential for punchouts.

3) *Retrofitting Edge Drains*

Adding a longitudinal drainage system to a pavement aids in the rapid removal of water and may prevent pumping, faulting, and durability distress from developing.

C. *Corrective-and-Preventative Techniques*

Corrective-and-preventative techniques are used to repair and slow down or prevent the occurrence of a given distress and improve the serviceability of the pavement.

1) *Diamond Grinding*

Diamond grinding improves a pavement ride by creating a smooth, uniform profile by removing faulting, slab warping,

studded tyre wear, and patching unevenness. This extends the pavement's service life by reducing impact loadings, which can accelerate cracking and pumping.

2) *Dowel-Bar Retrofit*

Dowel-bar retrofit increases the load transfer efficiency at transverse cracks and joints in PCP and JRCP pavements by linking the slabs together so that the load is distributed evenly across the joint. Improving the load transfer increases the pavement's structural capacity and reduces the potential for faulting.

3) *Slab Undersealing*

Slab undersealing is a means to stabilise existing pavement slabs by filling small voids beneath the slab and base or base and subbase. The undersealing is intended to restore slab support and does not include the lifting of the pavement slab (slab jacking) to a prescribed elevation or to an original profile. Several grouts have been trialled and Portland cement grout was found to produce best results.

4) *Cross-Stitching*

Cross-stitching is used to repair longitudinal cracks that are in a fair condition. It increases load transfer at the crack by adding steel reinforcement to restrict widening of the crack. It is not an alternative for cracks that are severely deteriorated or functioning as a joint.

5) *Grooving*

Grooving restores skid resistance to concrete pavements. It increases the surface friction and surface drainage capabilities of a pavement by creating small longitudinal or transverse channels that drain water from underneath the tyre, reducing the hydroplaning potential.

| S.No. | Type of Defect | Extent of Damage | | Type of Product |
|-------|------------------------------|---|---------------|---|
| | | Maximum Surface Area | Minimum Depth | Recommended for Trial |
| 1. | Full Depth Repair | All | Full Depth | Conventional Cement Concrete with additives |
| 2. | Small Popouts | < 0.12 m ² | 30mm | Epoxy Mortar (1:3) |
| 3. | Spalled Joints, Scaling | < 0.12 m ² , Longest Dimension not Exceeding 600 mm | 65 mm | Epoxy Mortar (1:3) |
| | | | 75 mm | Epoxy Concrete (1:8) |
| 4. | Large Spalled Areas, Scaling | > 0.12 m ² , or Longest Dimension Exceeding 600 mm > 0.5 m ² | 30mm | Elastomeric Concrete |
| | | | 100mm | Polymer Modified Cementitious Concrete |
| 5. | Corner Breaks | < 0.12 m ² | 30mm | Epoxy Mortar |
| | | > 0.12 m ² | 65 mm | Elastomeric Concrete / Epoxy Mortar |

Table 1: Guideline for Selection of Type of Product for Repair of Common Defects in Concrete Pavements

IV. REPAIR MATERIAL OF CONCRETE

The most common materials for damage repair works of various types are cement and steel. In many situations non-shrinking cement or an admixture like aluminum powder in the ordinary Portland cement will be admissible. Steel may

be required in many forms, like bolts, rods, angles, channels, expanded metal and welded wire fabric. Wood and bamboo are the most common material for providing temporary supports and scaffolding etc., and will be required in the form of rounds sleepers, planks, etc. Besides the above, special materials are available for best results in the repair and strengthening operations. They are described below:

A. Shotcrete

Shotcrete is a method of applying a combination of sand and portland cement which mixed pneumatically and conveyed in dry state to the nozzle of a pressure gun, where water is mixed and hydration takes place just prior to expulsion. The material bonds perfectly to properly prepared surface of masonry and steel. In versatility of application to curved or irregular surfaces, its high strength after application and good physical characteristics, make for an ideal means to achieve added structural capability in walls and other elements. There are some minor restrictions of clearance, thickness, direction of application, etc.

B. Epoxy Resins

Epoxy resins are excellent binding agents with high tensile strength. There are chemical preparations the compositions of which can be changed as per requirements. The epoxy components are mixed just prior to application. The product is of low viscosity and can be injected in small cracks too. The higher viscosity epoxy resin can be used for surface coating or filling larger cracks or holes. The epoxy mixture strength is dependent upon the temperature of curing (lower strength for higher temperature) and method of application.

C. Epoxy Mortar

For larger void spaces, it is possible to combine epoxy resins of either low viscosity or higher viscosity, with sand aggregate to form epoxy mortar. Epoxy mortar mixture has higher compressive strength, higher tensile strength and a lower modulus of elasticity than Portland cement concrete. Thus the mortar is not a stiff material for replacing reinforced concrete. It is also reported that epoxy is a combustible material. Therefore, it is not used alone. The sand aggregate mixed to form the epoxy mortar provides a heat sink for heat generated and it provides increased modulus of elasticity too.

D. Gypsum Cement Mortar

It has got rather limited use for structural application. It has lowest strength at failure among these three materials.

E. Quick-Setting Cement Mortar

This material is patented and was originally developed for the use as a repair material for reinforced concrete floors adjacent to steel blast furnaces. It is a non-hydrous magnesium phosphate cement with two components, a liquid and a dry, which can be mixed in a manner similar to Portland cement concrete.

F. Mechanical Anchors

Mechanical type of anchors employs wedging action to provide anchorage. Some of the anchors provide both shear and tension resistance. Such anchors are manufactured to give sufficient strength. Alternatively, chemical anchors bonded in drilled holes polymer adhesives can be used.

V. CONCLUSION

- Comparing the strengthening effect of the cement-based bonding material system to the epoxy strengthening system, it is clear that the cement-based bonding material provides a similar flexural load capacity.

- All types of cement-based bonding materials that were used can contribute to increase load carrying capacity of the concrete members.
- Concrete structures can be strengthened by the use of cement-based bonding material.
- For beams strengthened with epoxy adhesive debonding of the fibres was the failure.
- Full composite action was obtained between the concrete and cement based bonding material.
- The strengthened specimens showed an increase in flexural load carrying capacity up to 8% using cement-based bonding material and 11% with an epoxy adhesive.
- The failure of beams strengthened with cement-based bonding material was caused by rupture of the longitudinal fibres.

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