Problem Analysis in Concrete Repair and Maintenance of Civil Engineering Structures

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This study deals with experimental investigation for finding the causes of distressed concrete and their effects which reduces the load bearing capacity of the structures. The rehabilitation of existing reinforced cement concrete (RCC) bridges and building becomes necessary due to ageing, corrosion of steel reinforcement, defects in construction/design, demand in the increased service loads, and damage in case of seismic events and improvement in the design guidelines. Today, concrete repair is a major industry, supporting the need of virtually every concrete structure. Each structure requires routine repair and maintenance, ranging from simple protective coatings to repair of spalling concrete to strengthening of under-designed components. Developing effective repair strategies requires an understanding of what caused the undesirable behavior. Understanding the cause allows the repair strategy to address both the cause and the effect. The result is successful long lasting repair. The purpose of this study is to present concrete behavior under embedded metal corrosion, disintegration mechanisms, alkali-aggregate reaction (AAR), moisture effects, thermal effects, load effects and faulty workmanship.

Index Terms – FRR, GFRP, AAR, RCC, C/D, ASTM,MMA.

I. INTRODUCTION

Sometimes in late 1970's, it finally was recognized that there was a major problem with the infrastructure in United States. In 1970's an alarm signal went off to let us know that more than 60% of our bridges were failing and need some form of repair. There was big uproar and considerable funds were pumped in to promote research and development in fixing them. The first Symposium (1981) on repair, rehabilitation and investigations [1], [2] was held in Mumbai as an attempt to bring talents from the west and east together to discuss the problem of universal nature. The deterioration of civil engineering infrastructures such as buildings, bridge decks, girders, offshore structures, parking structures are mainly due to ageing, poor maintenance, corrosion, exposure to harmful environments. These deteriorated structures cannot take the load for which they are designed. A large number of structures constructed in the past using the older design codes in different parts of the globe are structurally unsafe according to the new design codes and hence need up gradation. Using internally placed moving hinge, external post-tensioned straps, dowel shear devices, drilled hole shear transfer devices, grouted subgrade, cantilever shear arm, installing new expansion joint, section enlargement, shear collars, externally post tensioned reinforcement, bonded steel plates and concrete overlays we can strengthen and stabilized the different types of cracking in the reinforced cement concrete structures. The concrete jacketing also improves the load carrying capacity of the pile foundation of bridges. Portland cement mortar, Portland cement concrete, micro silica modified Portland cement concrete, latex modified Portland cement concrete, polymer modified Portland cement mortar with non-sag fillers, magnesium phosphate cement concrete, epoxy mortar, methylmethacrylate (MMA) [6] concrete and shot-crete may be used as repair and overlay materials.

II. OBJECTIVE OF THE PRESENT WORK

In the light of the literature survey presented above, the following objectives of are identified for the present work:

1) To study the embedded metal corrosion in concrete structures.

2) To study the disintegration mechanism of concrete structures.

3) To investigate the effect of moisture in concrete.

4) To study thermal effects in concrete structures.

5) To study load effects in concrete structures.

6) To study effect of faulty workmanship on concrete structures.

III. TESTING METHODS FOR CONCRETE EVALUATION

A thorough and logical evaluation of the current condition of the structure is the first step of any repair project. Concrete in a structure has a number of functions. Concrete is designed to carry loads. Disfunction [4], [5]of concrete structures usually occurs in some form of visible cracking, leaching, spalling, scaling, stains, disintegration, wear, settlement, or deflection. The evaluation of concrete structures can be either a reactive or proactive process. Concrete evaluation is not limited to studies of its physical conditions, mechanical properties, chemical make-up and external manifestation. Understanding its interaction with the environment is equally important. Any thorough investigation starts with a visual review of condition.

1) Acoustic emission and thermography methods are used for locating delaminated concrete.
2) Corrosion activity can be detected by placing a copper-copper sulfate half-cell and using a voltmeter.
3) Chloride content in concrete can be calculated using chloride analyzer.
4) To determine the depth of carbonation, a solution of phenolphthalein is sprayed over the surface of concrete.
5) Petrographic [7] analysis is used to determine the formation and composition of concrete and to classify its type, condition and serviceability.
6) Impact echo method is a reliable method of locating voids, cracks, honeycomb, and other flaws.
7) Ultrasonic pulse velocity methods may be used to locate voids, cracks, and honeycomb.
8) Fiber optics (borescope), video cameras, and periscopes are the tools that allow for remote viewing inside a structure. Remote viewing technique [10] requires larger drilled holes.
9) The monitoring of cracks can be conducted with various tools including optical comparitors, glued glass strips, glued-in-place crack gauge, electrical transducers, and extensometers.
10) One useful in situ test is pull-off test [11], which measures the bond between two layers.
11) Rebound hammer method is used to measure the surface hardness of concrete.

TABLE 1
Standard Test Methods for Evaluating Concrete

S. No.	Designation	Title
1	ASTM C 42	Obtaining and testing drilled [3], [12] cores and sawed beam of concrete
2	ASTM C 805	Rebound number of hardened concrete
3	ASTM C 803	Penetration resistance of hardened concrete [15]
4	ASTM C 597	Pulse velocity through concrete
5	ASTM C 496	Splitting tensile strength of cylindrical concrete [19]
6	ASTM C 78	Flexural strength of concrete (with third-point loading)
7	ASTM C 293	Flexural strength of concrete (with center-point loading)
8	ASTM C 418	Abrasion resistance of concrete by sandblasting
9	ASTM C 876	Half cell potentials of uncoated reinforcing steel in concrete
10	ASTM D 3633	Electrical resistivity of Membrane-Pavement System
11	ASTM C 856	Standard practice for petrographic examination of hardened concrete
12	AASHTO T 259	Resistance of concrete to chloride ion penetration
13	AASHTO T 260	Sampling and testing for total chloride ions in concrete
14	AASHTO T 277	Rapid determination of the chloride permeability of concrete
15	ASTM C 457	Microscopial determination of parameters of the air void system in hardened concrete
16	ASTM C 666	Resistance of concrete to rapid freezing and thawing
17	ASTM C 671	Critical dilation of concrete specimens subjected to freezing
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IV. REPAIR MATERIALS AND PLACEMENT METHODS

Different kinds of defect, repair methods and materials [13], [15], [18] are explained in the table below:

TABLE 2
Repair Materials and Placement Method

Defects	Repair Methods	Materials
• Live Cracks	- Caulking - Pressure injection with 'flexible' filler - Jacketing: * Strapping * Overlaying - Strengthening	Elastromeric sealer 'Flexible' epoxy filler Steel wire or rod Membrane or special mortar Steel plate, post tensioning, stitching, etc
• Dormant Cracks	- Caulking - Pressure injection with 'rigid' filler - Coating - Overlying - Grinding and Overlay - Dry-pack - Shotcrete/Gunite - Patching - Jacketing - Strengthening - Reconstruction	Cement grout or mortar, Fast-setting mortar. 'Rigid' epoxy filler Bituminous coating, tar Asphalt overlay with membrane Latex modified concrete, highly dense concrete Dry-pack Mortar, Fast-setting mortar Cement mortar, Epoxy or Polymer concrete Steel rod Post tensioning, etc.
• Voids [10] • Hollows and • Honeycombs	- Dry pack - Patching - Resurfacing - Shotcrete/Gunite - Preplaced aggregate - Replacement	Dry-pack Portland cement grout, mortar, cement Epoxy or Polymer concrete Fast-setting mortar Coarse aggregate and grout as needed
• Scaling Damage [14]	- Overlaying - Grinding - Shotcrete/Gunite - Coating - Replacement	Portland cement concrete, Latex modified concrete, Asphalt cement, Epoxy or polymer concrete Fast-setting mortar, Cement mortar Bituminous, Linseed oil coat, Silane treatment as needed

• Spalling Damage [6], [7]	- Patching - Shotcrete/Gunite - Overlay - Coating - Replacement	Concrete, Epoxy, Polymer, Latex, Asphalt Cement mortar, Fast-setting mortar Latex modified concrete, Asphalt concrete, Concrete Bituminous, linseed oil, Silane, etc. as needed

V. CONCLUSION

In this experimental investigation the causes and effects of undesirable behavior of concrete members are studied. The test results illustrated in the present study showed that the external strengthening with GFRP composites can be used to increase the shear capacity of RCC structures, but the efficiency varies depending on the test variables such as fiber orientations, wrapping schemes, number of layers and anchorage scheme.

Based on the experimental and theoretical results, the following conclusions are drawn:

1) The pH of newly produced concrete is usually between 12 and 13.

2) In good quality concrete the corrosion rate will be very slow.

3) Accelerated corrosion will take place if the pH is lowered [8], [9].

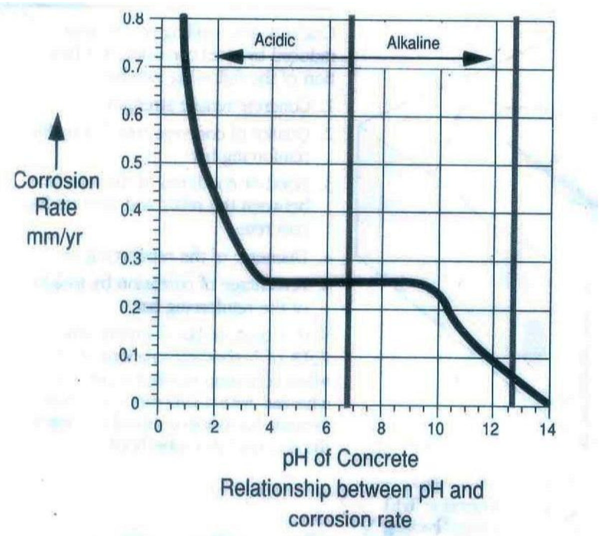

Fig. 1 Embedded Metal Corrosion Process

4) With a cover-to-bar diameter ratio (C/D) of 7, concrete cracking starts when corrosion reaches 4 percent.

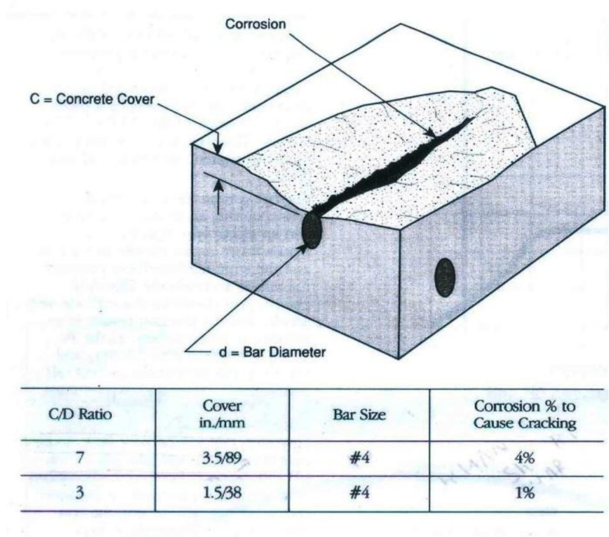

Fig. 2 Corrosion Induced Cracking and Spalling

5) With a cover-to-bar diameter ratio (C/D) of 3, concrete cracking starts when corrosion reaches 1 percent.

6) The research conducted on flexural beams found that in steel more than 1.5 percent corrosion, the ultimate load capacity began to fall, and at 4.5 percent corrosion, the ultimate load was reduced by 12 percent .

7) It was demonstrated that a threshold level of 8000 ppm of chloride ions was required to initiate corrosion when the pH was 13.2 and when pH was lowered to11.6, corrosion was initiated with only 71 ppm of chloride ions.

8) Carbonation will not occur when concrete is constantly under water .

9) Normal weight concrete shrinks from 400 to 800 microstrains.

10) A change of 38° C in a 30.5m length will change the overall length by 22mm.

11) A precast double T-shaped structured member with a 18m span can move 19mm upward at midspan from normal diurnal solar heating, causing the ends to rotate and stress the ledger beam bearing pads and concrete.

12) Hinges open and close with daily temperature changes.

13) The cement mortar converts to quicklime at temperature of 400° C , thereby causing disintegration of the concrete.

14) High slump mixes, incorrect methods of handling concrete, and over-vibration are the causes of segregation.

VI. FUTURE SCOPE

Perhaps in the years to come, we may be able to reduce the large expenses involved in repairs and rehabilitation of our structures and change the public image of our profession. Based on the finding and conclusions of the current study the following recommendations are made for future research in FRP shear strengthening:

1) Strengthening of RCC bridges under IRC loading.

2) Strengthening of existing residential building without interrupting residents.

3) Strengthening of columns using jacketing same as in pile foundation.

4) Strengthening of flexure member using external bonded steel plates at lower cost.

5) To lower the final cost of repair of existing buildings.

6) To improve the asthetic conditions of the bridges, T-beams and existing buildings.

7) FRP strengthening of RC T-beams with different types of fibers such as carbon, aramid & basalt.

8) Study of bond mechanism between CFRP, AFRP and BFRP and concrete substrate.

9) Strengthening of RC L-beams with FRP composite.

10) Strengthening of RC L-section beams with web opening.

11) Effects of web openings of different shape and size on the shear behavior of T & L-beams.

12) Effects of shear span to depth ratio on shear strengthening of beams.

13) Numerical modelling of RC T & L-beams strengthened with FRP sheets anchored at the end.

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