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A Review paper on Repairs and Protection of Concrete based Structures

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ABSTRACT

This paper presents a review on repairs and protection of concrete based structures by using FRP composites. The resulting structure was then tested for the effect after using FRP composites for Rehabilitation and strengthening. In this paper, Structural Health Monitoring basics are covered and need for SHM in future in or India scenario. Use of FRP composites in Rehabilitation and Strengthening of structures is becoming increasingly popular and is opening new possibilities in construction and rehabilitation of structures.

Keywords: Rehabilitation, Structural Health Monitoring, Bridge Strengthening, Repairs.

I. INTRODUCTION

Due to its economy, constructability, and durability, reinforced concrete is a popular choice for bridge construction. One of the mechanisms that can affect the durability of reinforced concrete structures is corrosion of the reinforcing steel.

The major cause of corrosion in concrete bridges is from ingress of chloride ions from saltwater exposure or deicing chemicals through the concrete cover to the level of the reinforcing steel. When present in sufficient quantity, chloride ions break down the naturally formed passive oxide layer on the reinforcing steel.

Corrosion by-products occupy a greater volume than the original reinforcing steel. As a result, the corrosion process expansive forces that can exceed the tensile strength of concrete.

When compared to replacing structures, rehabilitation to extend the service life of existing structures offers many potential benefits including;

- Rapid Construction compared to Replacement;
- Less Traffic Disruption and Delays;
- Less Environmental Impact;

  - Reduced Use of Raw Materials;
  - Reduction in Greenhouse Gas and Thermal Emissions;
  - Reduced Landfill of Existing Materials;

Environmentally Responsible Approach when all Costs are Considered;

Therefore, there is a great need for bridge engineers and Departments of Transportation to provide long term and cost effective solutions to rehabilitate existing bridges which are experiencing corrosion related deterioration.

Advancements in concrete repair methods and corrosion mitigation systems have given bridge engineers many options to repair and extend the service life of actively corroding structures. Today, most structures suffering from corrosion can benefit from some level of electrochemical corrosion protection.

Electrochemical corrosion mitigation systems for reinforced concrete structures provide direct current to embedded reinforcing steel to mitigate corrosion and fall into three general categories: Electrochemical Treatments, Impressed Current Cathodic Protection, and Galvanic Protection.

Electrochemical Treatments are processes that are intended to modify the environment around the reinforcing steel such as to provide long term corrosion mitigation. Examples of electrochemical treatments include electrochemical chloride extraction and electrochemical re-alkalization. Electrochemical chloride extraction passivates corrosion by utilizing a high level of direct current for a relatively short duration to transport chloride ions away from the reinforcing while generating substantial increase in alkalinity around the reinforcing steel. Electrochemical re-alkalization utilizes direct current to transport an alkaline solution into the concrete cover to mitigate corrosion caused by carbonation.

Impressed current cathodic protection systems are designed to provide direct current to the structure via permanently installed anodes and an external power supply. These systems typically use inert anodes to distribute the electrical current to the reinforcing steel. Through the external power supply, impressed current systems provide the user with a high level of control over the level of protection but the electrical systems must be monitored and maintained and may need to be periodically replaced.

Figure 1: Bridge Columns Damaged by Corrosion of Reinforcing Steel

LITERATURE REVIEW

Literature shows that 99% of quality-related defects were due to poor design, detailing, specifications, workmanship, and management. Other factors, including materials, account for the remaining 1%. At the global level, one can conclude that even with substantial advances in the field of repair materials, the industry will still have an unacceptable high level of defects and failures.

Shyam et al. (2013) observed “In this era when there is a great push in our industry for improved construction materials and practices, it will do us no good to have technology that provides ‘high-performance concrete’ if we don’t have ‘high performance people’ to implement this technology.” A lack of attention to detail in design, poor in-place workmanship, and inadequate quality control cause the majority of faults and problems in the concrete repair field (as well as in new construction). Adequate attention needs to be given during the condition evaluation phase of the project, but it is often ignored. Repairing concrete is somewhat analogous to the treatment of disease.

Before remedies can be correctly prescribed, the illness has to be diagnosed, and before the accurate diagnosis is possible, the doctor has to have a thorough knowledge of the disease and its various symptoms treatments and history. The concrete “doctor” needs similar knowledge to prescribe successful treatments for troubled structures. It may be shocking to observe a professional structural engineer who has a limited knowledge of cement-based materials. It must be clear to an engineer that overstress is always the cause of cracking produced in materials, regardless of what factors induced the stress in excess of the material’s strength. It also must be recognised and understood that a repair is not a ‘Band-Aid ®’ that simply covers a concrete structure problem. This incorrect view lends credence to the prevailing viewpoint that concrete repair is so simple that anyone can do it. Most India and most U.S. construction can be characterized as “low-bid, harddollar contracting,” and, as an Engineering News-Record editorial of December 1, 1988, stated, “Clients that want cheap will get cheap.”

Rakesh Singh (2012) studied about cost to design and construct repairs for durability is minimal when compared with the cost of repairing a prematurely deteriorated, already-repaired structure. When addressing problems with repair technology one must also mention the habitual use of outmoded specifications for concrete repair. How good should the repair material be to serve the intended purpose? Supposedly, the most cogent answers should be found in the specifications for a particular project.

CORROSION PROTECTION SYSTEMS

Advancements in concrete repair methods and corrosion mitigation systems have given bridge engineers many options to repair and extend the service life of actively corroding structures. Today, most structures suffering from corrosion can benefit from some level of electrochemical corrosion protection. Electrochemical corrosion mitigation systems for reinforced concrete structures provide direct current to embedded reinforcing steel to mitigate corrosion and fall into three general categories:

- Electrochemical Treatments,
- Impressed Current Cathodic Protection,
- Galvanic Protection.

Electrochemical Treatments are processes that are intended to modify the environment around the reinforcing steel such as to provide long term corrosion mitigation. Examples of electrochemical treatments include electrochemical chloride extraction and electrochemical re-alkalization. Electrochemical chloride extraction passivates corrosion by utilizing a high level of direct current for a relatively short duration to transport chloride ions away from the reinforcing while generating substantial increase in alkalinity around the reinforcing steel. Electrochemical re-alkalization utilizes direct current to transport an alkaline solution into the concrete cover to mitigate corrosion caused by carbonation. Impressed current cathodic protection systems are designed to provide direct current to the structure via permanently installed anodes and an external power supply. These systems typically use inert anodes to distribute the electrical current to the reinforcing steel. Through the external power supply, impressed current systems provide the user with a high level of control over the level of protection but the electrical systems must be monitored and maintained and may need to be periodically replaced.

Galvanic Protection Systems

Galvanic systems provide direct current through the use of dissimilar metals. Like a battery, the more anodic metal naturally corrodes relative to the more noble metal. In reinforced concrete, galvanic anodes provide sacrificial protection to the rebar and do not require external power. Galvanic systems are used to provide low-maintenance protection that can be economically tailored to protect large and small sections of the structure.

Anodes used in galvanic protection systems can be surface applied or embedded into the concrete structure or a new overlay. For embedded systems, zinc is the most common sacrificial anode used today. When compared to metals such as aluminum and magnesium, zinc exhibits a relatively small corrosion expansion which can be managed through mortar shell formulation or by providing sufficient porosity and reinforcing within the anode unit. Embedded zinc anodes are suitable for use with conventionally reinforced, prestressed and post-tensioned concrete.

When galvanic anodes are embedded into concrete, it is important to prevent a buildup of oxides on the anode surface that will significantly restrict the performance of the anode. To combat this, an embedded anode unit will contain chemical activator that generates a soluble corrosion byproduct. Embedded anodes will either be alkali-activated in the pH 14 to pH 14.5+ range or halide- or sulphate-activated whereby salts such as chloride, bromide or sulphate are used. Because halides and sulphates are corrosive to steel and concrete, they may not be acceptable as they may not meet local codes and standards.

If they are used, they should be installed such that the halide or sulphate activator is a minimum of 50 mm (2 in.) away from any reinforcing to minimize the risk of future corrosion. If sulphate activator is used, care should be taken that the sulphate does not come into contact with concrete materials which could be susceptible to damage from sulphate attack.

Figure 2: Alkali-Activated Discrete Galvanic Anode Installed For Localized Protection

Discrete Galvanic Anodes for Cathodic Prevention

The targeted corrosion mitigation approach begins with repairs completed via industry standards, such as the International Concrete Repair Institute (USA) Technical Guideline No. 310.1R–2008 Guideline for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion. In areas where concrete damage exists due to corrosion, this guideline calls for concrete removal to extend beyond the area of active corrosion and for concrete to be removed from the full circumference of all rebar in the repair area. This repair procedure will deal with the areas of most active corrosion.

Unless all chloride contaminated concrete is removed from the structure, chlorides will be present in the concrete adjacent to the repairs. This will create abrupt differences in corrosion potential in localized areas and creates a risk that corrosion activity will be initiated or aggravated in the existing concrete adjacent to the repair, commonly referred to as the “halo effect”. This condition can also be created when modifications are made to existing structures such as expansion joint repairs, slab replacements, and additions to structures such as bridge widening which will create an interface between new and existing concrete.

For almost a decade, embedded galvanic anodes in a discrete or “point” form have been used to provide localized corrosion prevention around concrete repairs. Embedded discrete anodes are installed around the perimeter of the concrete repair as close as practical to the patch edge. The anode spacing is dependent on the amount of steel protected but is generally in the range of 12 to 24 inches which is sufficient to provide cathodic prevention (e.g. prevent the initiation of new corrosion activity adjacent to the repairs). More recently, this type of anode has been produced in various sizes to provide more options for the engineer.

Figure 3: Discrete Anodes Used for Bridge Widening at the Interface between Old and New Concrete

CONCLUSION

Galvanic protection systems for reinforced concrete structures provide engineers and owners with a low maintenance option for corrosion mitigation. This approach can be attractive to owners with structures with corrosion issues that desire more than traditional "patch repair" but do not have the personnel, budget or desire for long term system monitoring and maintenance. Discrete or "point" anodes have been used to provide localized protection around concrete repairs. For structures where global protection is desired for specific structural elements, embedded distributed galvanic protection systems can be an economical and effective approach. Case studies on galvanic protection using embedded distributed anodes for the repair and protection of reinforced bridge elements subject to both marine and non-marine exposure conditions were presented.

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