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REPAIR AND REHABILITATION FOR SOME OLD CANAL BRIDGES IN AND AROUND VIJAYAWADA

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Abstract: ***The present work emphasize on Rehabilitation of canal bridges in Vijayawada city, Andhra Pradesh, India. The purpose of the paper is to highlight the methods of repair and rehabilitation to be undertaken for structures with defects and deficiencies that necessitate rehabilitation. This project presents an analysis of causes, reasons for occurring different types of damages in the bridges. We have conducted a survey in and around Vijayawada regarding the identification of canal bridges and we found 24 bridges out of which 15 bridges are under damaged conditions. The damages of bridges are again sub-divided into five categories viz., problems such as corrosion; Spalling of concrete surfaces, leakages in the bridges, cracking that exists in bridges and about the surface failure both due to wheel loads and static loads. The rehabilitation process of corrosion involves the removing of concrete and cleaning of steel roads, protecting the steel roads, placing of concrete after protecting the steel roads by the method of form and pump. The rehabilitation process of Spalling involves the roughening the surface profile, adding of bonding agents to the old strata ,laying the surface on old strata by using suitable placement methods. The rehabilitation process of cracking involves initially cleaning of cracks by spraying, addition of epoxy to the cracks, and injecting the sealer material into the cracks, and sealing the surface. The rehabilitation process of leakage involves method of placing of material on the concrete surface to form a uniform thick layer on that surface. This paper also attempts to provide measures available in all aspects and to different methodologies which are required for repairing of the damages that exists in the canal bridges located in Vijayawada.***

Keywords: Repair and Rehabilitation, Spalling, Cracking, Leakage, cracks, patching, sealing of concrete.

I. INTRODUCTION

Now-a-days, the construction manager has to deal not only with the new types of structures to be constructed, but also deals with facilities already constructed. Bridge infrastructure comprises of concrete and steel structures. Over the service life of a bridge, its constituent materials are continuously subjected to 'Fatigue and wear-tear due dynamic vehicular loads'. Poor quality of construction and lack of regular Maintenance could potentially lead to major retrofit in bridge structure. So, construction work in connection to already constructed structures is called as "REHABILITATION OF STRUCTURES". The term Rehabilitation in broad sense implied restoring structure to its original condition. Technique developed to meet new functional or other requirements. In general, the structures may need rehabilitation for one of the following reasons:

- Normal deterioration due to environmental effect.
- New functional or loading requirements entailing modifications to a structure.
- Damage due to accidents.

At any given point of time, there are far more structures which have already been built than those under construction. However, lot of engineering and management effort is put in for the structures under construction against negligible effort to maintain the long-term serviceability of the structures which are already built. Maintenance of constructed facilities involves preventive care and also repairs and rehabilitation. Due to various reasons, no unified discipline or system has been developed to deal with these aspects. It is important that one should derive the desired benefits from any constructed facility. Hence, rehabilitation work becomes an essential part of construction management. Rehabilitation of structures is a multi-disciplinary activity. Many a time, it involves the use of specialized techniques and systems. The engineer has to know the design aspects, construction practices, hydrology, chemistry, the combined action of construction material and the environmental factors, the safety aspects, both before and during the construction. Thus, rehabilitation of structures is a much more demanding assignment than constructing a new facility. Repair and rehabilitation engineering is a specialized field, which calls for skills and abilities beyond design and construction engineering. The systematic approach to deteriorate structure is necessary and there should be balance between technology management and economics, the first task when a structure shows sign of cracking, palling or any other sign is to determine whether the is damage is structural or non-structural. The engineer in charge of rehabilitation should have qualities of an investigator, structural designer, material technologist and awareness of application techniques. The objective of the present work is to identify the various structural defects in different canal bridges which lead to deterioration in and around Vijayawada and to explore the different solutions to overcome those problems in such a way that the life span of the structure may be prolonged. We have conducted a survey in and around Vijayawada regarding the identification of canal bridges. The project highlights the problems such as corrosion; Spalling of concrete surfaces, leakages in the bridges, cracking that exists in bridges and about the surface failure both due to

wheel loads and static loads.

II. THEORETICAL BACKGROUND

The repair and rehabilitation of structures include the following:

- Inspection methods, assessments, monitoring, maintaining of structures.
- Concrete durability, fatigue issues in bridges, laboratory studies, dynamic testing
- Seismic strengthening.
- General repairs.

The repair and rehabilitation methods involve the attachment of new materials to existing structures or applying protective coatings to the structures. Research in rehabilitation includes the prevention of corrosion of steel which is the most important structural member used in the construction. Research in design, behaviour and analysis of bridge construction and buildings includes studies in materials, components and complete structural systems. Materials studies have included normal-and high-strength systems, efforts of materials aging and materials deterioration on component properties; bond between concrete and steel reinforcement and use of headed reinforcement.

A. FACTORS AFFECTING THE DETERIORATION OF THE STRUCTURES

The damage or deterioration of structures can be attributed to the following basic causes:

Environmental factors:

These factors are atmospheric pollution, earth-quakes, floods, normal ageing the structures, etc. in the case of historic TajMahal in Agra, the very high sulphur content in the atmosphere on account of a refinery, and the development of industries in the surroundings area have led to the deterioration of the surface characteristics of the marble in the structure.

Design deficiencies:

The damage to the structure can occur either on account of errors in design parameters or on account of factors which have not been taken into the consideration while designing the structure. For example, in the case of Koyna dam in Maharashtra, the area in which the dam was constructed was considered outside the seismic zone. However, a severe earthquake occurred causing distress to the structure and rectification work had to be carried out.

Unanticipated stress conditions:

There are a number of structures which have been subjected to forces and the stress not anticipated and hence not taken into account in the design. A few examples of such conditions are high floods allowing overflow of water above the bridge, even if the bridge was designed with a free board above HFL, localized deep scouring, etc.

Construction materials:

Deterioration occurs due to the poor quality of the materials used in the construction. Sometimes, the wrong type of material not suited to the particular locality may also lead to deterioration.

Defective construction:

In many projects, proper supervision and adequate inspection have not been carried out during the construction stage. Such structures may not show deterioration immediately when put into use but are bound to show distress on account of the defective construction combined with other natural elements such ageing, atmospheric effects, etc. Construction deficiency is one of the major reasons for distress in structures. As the saying goes “Prevention is Better than Cure”, hence, supervision and quality control are the most important aspects in the construction of any project to avoid difficulties at a later stage.

\B. MAJOR VISUAL INDICATORS OF DISTRESS CONDITIONS IN STRUCTURES AND THEIR REASONS

These indications can be listed as follows

- Formation of cracks in the structure in different patterns and sizes.
- Formation of strains due to the problem of rusting.
- Peeling of plastering.
- Spalling of concrete.
- The nature of the exposed reinforcement.
- The yielding or snapping of steel.

We will now briefly discuss the distress conditions that may be exhibited and the possible reasons in the following type of works.

Brick Masonry:

Due to the presence of the sulphates in the mortar, cracking and spalling at edges may occur in brick masonry. There may be even the bursting of individual bricks. The exhibition of surface erosion of the brick-work is very common. If the brick and the mortar that were used did not have sound quality, then there may be discoloration cracking and then it indicates overloading or differential movement of the foundation. If there is shrinkage on drying, then steeped cracking pattern may be indicated.

R.C.C. Work:

The formation of cracks, scaling and spalling will occur due to development of excessive stresses. Swelling will also take place due to alkali-aggregate reaction. Excessive deflection and yielding of steel occurs due to the problem of overloading. De-colouration and erosion also occur due to chemical attacks. If the concrete had been poorly prepared, then this will allow seepage of water leading to corrosion of steel and also erosion of the concrete surface. The diagnostic chart developed by WARNER for R.C.C. structures is reproduced. This will be an excellent guide for diagnosing the problem in R.C.C. structures.

Steel Structures:

Rusting and de-colouration of the steel occur due to chemical agents and electro-chemical action. The distortion of the structure may occur due to improper rivets or bolts or by sudden shock and impact loads. Yielding of steel and excessive deflection may occur due to the problem of over loading.

III. FIELD INVESTIGATION

In this section the details of field survey done are discussed. The fact is that the city wakes up to such impending dangers every day as most of the bridges constructed across Rave's,

Eluru and other canals are either in bad condition or are on the verge of collapse… hence REHABILITATION is required.

We have conducted a survey in and around Vijayawada regarding the identification of canal bridges and we found 24 bridges out of which 15 bridges are under damaged conditions. The project highlights the problems such as corrosion; Spalling of concrete surfaces, leakages in the bridges, cracking that exists in bridges and about the surface failure both due to wheel loads and static loads.

Table 3.1 Locations and Failures of Canal bridges in Vijayawada City

S.NO	LOCATION	FAILURES
1.	DEVINAGAR	CORROSION
2.	AMERICAN HOSPITAL	LEAKAGE
3.	ELURU LOCKS	SURFACE FAILURE
4.	FIRE STATION	LEAKAGE
5.	GUNADALA	SCALING
6.	LENIN CENTRE	CRACKING
7.	MUTHYALAMPADU	CORROSION
8.	BRIDGE NEAR POLICE QUARTERS	SCALING
9.	PRABHAS COLLEGE	SCALING
10.	FOOT BRIDGE NEAR FLOWER MARKET	SCALING
11.	SINGHNAGAR	CORROSION, CRACKING
12.	TUMMALAPALLI KALA SHEKTRAM	CRACKING
13.	YENAMALAKUDURU	CORROSION
14.	ZINKHANA GROUNDS	SURFACE REPAIR
15.	POLICE CONTROL ROOM	SURFACE REPAIR

The damages that we have analyzed from the observations made are categorized under “FIVE” divisions which are as follows:

- Corrosion
- Scaling and spalling of concrete
- Cracking
- Leakage
- Surface failure of the bridges

The five types of problems observed are shown in the following Figures 1 to 5.

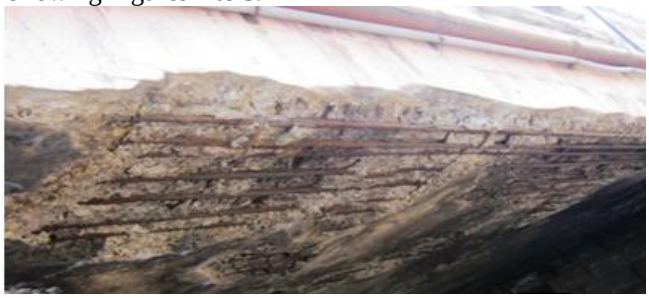

Figure.1(a) Corrosion Effect of Alluri Sitaramaraju Bridge

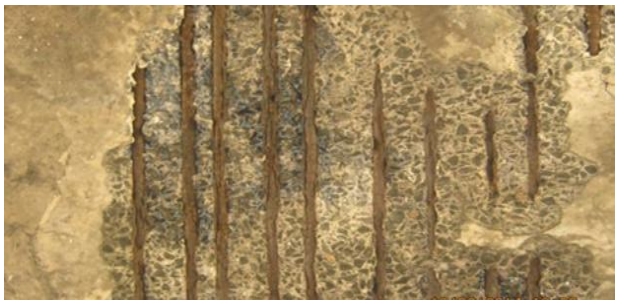

Figure 1(b). Corrosion Effect of Alluri Sitaramaraju Bridge

Figure 2. Picture showing signs of the Spalling of the bridge at Gunadala

Figure 3. Cracking Effects of Eluru Locks

Figure 4. Leakage Between Structural Slab And Insulation Board

Figure 5. Surface repairs of the canal bridge near Eluru locks

IV. SUGGESTED MATERIALS FOR THE REPAIR & REHABILITATION

The process of rehabilitation of the damage of the bridges may not only involve the use of one single material. There are different of materials that are available in the market that

are used for the repairing if the bridges. The materials used for one particular repair depends upon the type, extent, place and factors affecting the damage. The present chapter deals with other materials that are used for rehabilitation of damages apart from suggested materials in the above methods. The other materials that can also be used for rehabilitation of studied damages are explained below.

A. MATERIALS USED FOR CORROSION:

The following are materials and its uses that are used in as additives in the dry mix concrete method, the method which is used to place concrete after cleaning of steel rods which undergone corrosion.(Table.1)

TABLE 1: ADDITIVES IN DRY MIX SHOTCRETE

Additives	Benefit
Silica fume	Increased thickness Increased density Increased freeze-thaw resistance Increased chemical resistance Reduced rebound Increased adhesion Increased flexural and compressive strength
Accelerators	Increased/build-up of layers Reduced initial set time Increased early strength gain
Steel fibre	Elimination of shadows and voids which are created with conventional reinforcement Improved impact resistance
Polypropylene fibres	Reduced plastic shrinkage cracking
Latex	Improved flexural, tensile bond strengths Increased resistance to freeze-thaw and chemical attack

B. MATERIALS SUGGESTED FOR SCALING

In order to have a good bonding between the repair material and the existing concrete, special materials called "Bonding Agents" are used. Three types of bonding agents commonly used are:

- Cement based slurries
- Epoxies
- Latex emulsions

For Portland cement based repairs and overlays cement or sand cement slurry is used. After the substrate has been prepared immediately before placing the repair material a thin coating of creamy grout must be thoroughly boomed or brushed into prepared surface.

In case of latex-modified or micro silica-modified repair materials or overlays, the bonding grout can be boomed in the form of mix itself.

Latex bonding agents are also used in the industry.

Example:

- Styrene butadiene
- Acrylic
- Polyvinyl acetate

Bonding agents are not designed to compensate for poor surface preparation. Bonding agents must be easily absorbed into pore structure and must be compatible with repair and substrate material. Re-emulsifiable polyvinyl acetate bonding agents should not be used in structural applications. This agent can re-emulsify after being subject to wet-dry cycles, resulting in eventual loss of bond. A variety of epoxy products are available for use as bonding compound. The materials must meet the requirements of ASTM C 881- "Epoxy-resin based bonding systems for concrete', related to physical properties such as bond strength, viscosity, thermal compatibility and shrinkage. Use of an epoxy bonding agent may produce a vapour barrier, resulting in the failure of the bond. Epoxies have poor creep properties and should be avoided when the repair is subjected to constant loading. The additional step in the repair process, application of a bonding agent, may create an additional quality assurance problem. Bonding agents are not designed to compensate for poor surface preparation. Successful use of bonding agents must include the bonding process as described above.

Measuring Bond strength:

Evaluation of the bond between the repair materials and substrate is important in assessing the quality of the repair. In recent years, various test methods are used extensively, while others have had little use in the field. Understanding the limitations in the reliability or applicability of each test method is critically important in achieving the performance goals. A brief review of some of the test methods currently in use is presented below.

Slant shear test:

It is used by most manufactures of repair materials to evaluate product performance. The test is economical and is easily reproduced. Bond values are determined by taking the load at failure divided die elliptical bond area. The results are highly variable depending upon the compressive strength and degree of sandblasting used. Slant shear bond values are difficult to correlate with field performance.

The method used for assessing repair materials, the slant shear test is far from being representative of the actual in situ conditions. When the results of other test methods are compared with those obtained from the slant shear test, it is evident that the latter can give rise to inaccurate conclusions. Bond strengths values are generally higher when evaluated by slant shear method or by the direct shear method, as compared to the direct tension method.

Direct shear method:

This method measures shear bond between the repair material and the substrate. Field and laboratory core specimens are tested in especial guillotine apparatus. Shear bond values are determined by taking the load at failure divided by bond area. Correlations can be developed between laboratory and field tests.

Hence, above are the different types of bonding agents that can be used in the repairing of scaling of the concrete surfaces.

B. MATERIALS USED IN THE CONTROL OF LEAKAGE:

Various materials are used to accomplish different objectives in process of repairing leakage problem. Common applications and materials include:

Resurfacing industrial floors:

- Epoxy resin/silica sand
- Methacrylate/silica sand
- Steel fiber reinforced Portland cement concrete
- Latex modified Portland cement concrete

Resurfacing vertical surfaces as a free treatment to chemical resistant coatings:

- Epoxy resin/silica sand
- Latex modified Portland cement concrete

Placing overlays to protect concrete parking and bridge decks from chloride intrusion:

- Latex modified Portland cement concrete
- Latex modified Portland cement mortar
- Layer epoxy resin/broad cast sand
- Micro silica modified Portland cement concrete
- Low water/cement(dense) Portland cement concrete

Redirecting run off to prevent surface pounding:

- Low water cement ratio Portland cement concrete
- Latex modified Portland cement mortar or concrete
- Milling, sawing and grinding

Hence above said are the different materials that are used for different applications in damage of leakage.

C. MATERIALS RECOMMENDED FOR THE DAMAGE OF CRACKING:

The material used for crack repair must be such as to penetrate easily into the crack and provide a durable adhesion to the crack surfaces. The larger the modulus of elasticity of the material, the greater will be the obtainable adhesion strength. The interface of the material and the crack surfaces should be such as not to allow infiltration of water and to resist all physical and chemical attacks. Currently, the following fluid resins are used for crack injection:

- Epoxy resin (ER)
- Polyurethane resin (PUR)
- Acryl resin (PMMA) and
- Unsaturated polyster resin

Polymer based latexes:

The types of materials that can be used in repairing of cracks can be either polymers or epoxies. The use of particular material for cracking depends upon its crack width.

The commonly used polymer latexes are:

- Polyvinyl acetate(PVA)
- Styrene butadiene rubber(SBR)
- Poly vinyl diene dichloride(PVDC)

Epoxy based materials:

Epoxy, polyester and acrylic resins are as a class designated as the thermo setting materials because when cured the molecular chains are locked permanently together. Unlike thermo plastics they do not melt when heated but lose strength with an increase in temperature. They are generally supplied as two or three component systems: resin, hardener end fillers.

The resins are broadly classified as:

- Epoxy resin
- Unsaturated reactive polyester resins
- Unsaturated acrylic resins

Acrylic resin systems form high strength materials and are based on monomers of very low viscosity or blends of monomers with methyl-methacrylate monomer. Polyester and acrylic resins contain volatile constituents which are inflammable. Most acrylic resins are highly inflammable with a flash point below 100C, and vapours also cause toxic reaction. The properties of commonly used resins are:

Epoxy resins: These have high strength, good bonding characteristics, and high impact resistance, high chemical resistance can may be made to provide a non-slip finish.

Polymer resins: These differ from epoxy resin in that these can be laid over wider temperature range and have a better resistance to heat. They are mixed with cement and fine hard aggregate, and laid in thickness up to 15mm.

Poly vinyl acetate: It is used as a bonding aid when thin mortar overlays are applied to existing concrete. The liquid can be applied straightaway on to a clean, sound surface and allowed to dry. The slight re-emulsification of the film on being re-wetted by application of fresh mortar topping provides a good bond.

Natural rubber latex: It is an admixture with excellent adhesive properties and it is difficult to mix with ordinary Portland cement. It is often used with less alkaline high alumina cement for patching or for underlayment's on floors which are to receive vinyl tiles.

Styrene butadiene rubber: It is an effective alternative to PVA with high water resistance. Unlike Pac, the dried film does not develop grab on rewetting\. So it will act as bonding layer, if allowed to dry out. Therefore mortar mix should be applied while the tack coat of SBR is still wet.

Acrylic reins: These admixtures have excellent water resistance and improve bond strength when mixed with mortars. Seamless, non-dusting thin floor overlays can readily produce with acrylic resins.

Styrene acrylic resins: A mixture of tough styrene with acrylic resin using 1:3 cement sand mortar can be used to produce hard wearing floor overlays at a reasonable cost.

D. MATERIALS USED FOR SURFACE REPAIR:

The following are the different materials that are used in process of surface repair.(Table.2)

Table 2. REPAIR MATERIAL INGREDIENTS

INGRE DI-ENT	DESCRIPTION	BENEFIT
Binder	The binder is glue that binds all fillers and aggregates together to form a composite material.	Portland cement is used for most general repair work. Polymer materials such as epoxy and acrylic are used for the special applications.

Fine aggregate	Aggregates are used to reduce binder volume and enhance mechanical properties. Fine aggregates may be used without the addition of large aggregates.	Fine aggregates properly graded reduce binder content and shrinkage. Special aggregates are used to improve the aggregate abrasion resistance.
Coarse aggregate	These are more efficiently reducing overall binder volume than fine aggregates and enhance general mechanical properties.	Coarse aggregates reduce drying shrinkage. Special aggregates are used to enhance abrasion resistance.
Special fillers	These fill in spaces left by the final coarse aggregates. Some filler (fly ash, micro silica) replace some of the cement required. These will improve the internal cohesion.	Micro silica increases the strength and reduces permeability.
Polymer modifiers	These are used to enhance the properties of the repair material. Latex is the most common. Other modifiers improve acrylic, PVA and epoxy emulsions.	Some polymers enhance the properties of the repair material. Latex is used to reduce permeability and increase bond strength with the substrate, and reduce modulus of elasticity.
Fiber reinforcement	Plastic or steel fiber reinforcement is used to add tensile strength and toughness to the material.	Fiber reinforcement provides control of shrinkage cracking. Steel and in some cases plastic fiber enhances toughness to impact and abrasion.
Misc. chemical modifiers	These are used to enhance and modify behaviour of the repair material. These include accelerators, retarders, shrinkage compensating additives, expanding agents, air entraining admixtures.	Use of modifiers allows control of some properties of the uncured and cured materials.
Repair material	The repair material is a blend of binders, aggregates, fillers, and enhances optimizing effectiveness, constructability, durability and predictability.	Material design should be kept simple. Do not use more ingredients than necessary. More complex materials generally cause more problems.

V. CONCLUSION

Vijayawada is one of the developed cities situated on the bank of Krishna River in Andhra Pradesh, India. Many canal bridges are constructed across the canals for passage of the transportation. But, the fact is that the city wakes up to impending dangers every day as most of the bridges constructed across Ryve's, Eluru and other canals are either in bad condition or are on the verge of collapse. The footpaths of many bridges are in bad shape reflective of the gloomy side of the administration. The best example is the bridge across Ryve's canal near Lenin centre. This bridge is caving in, posing a danger to pedestrians. The footpaths of the bridge have almost collapsed and there are no proper railings as well. There are four bridges in Gunadala that lead to flyover which is under construction. None of them is motor able. In fact, three of them are in a dilapidated condition. The footpath bridge near Ramavarapadu is still in use though it is in a dilapidated condition. The skew bridge near Ramalingeswara Nagar is another classic example. The railing of bridge on Eluru canal near Singhnagar, Nidamanuru bridge on Ryves' canal, Sitaramapuram bridge are some of the bridges that need immediate attention. So, proper attention is needed in rehabilitating the damages of canal bridges across the canals in Vijayawada. It is impossible that the bridge which is in damaged condition cannot be taken back to the position is like when constructed. The other alternative method is rehabilitation and repairing of the damaged bridges. Through this paper, the various repair and rehabilitation necessary for the observed damages in various canal bridges are highlighted. By using these simple techniques and methods, we can analyze and diagnose the damage in the bridges, and rehabilitation can be performed. By doing so, we can prevent the collapsing of the bridges, to some extent, by increasing the life span of the bridge.

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