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Bridge Repair Method in Ethiopia

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ABSTRACT

I was dispatched with an aim to assist Ethiopian Roads Authority to adopt bridge management cycle funded by JICA, with which bridges are properly maintained and service level of road network is improved. Supervision/ quality control and technology / skills of bridge repair works were introduced through on-the-job training using innovative repair materials in Ethiopia. It was pointed out the issue of existing Bridge Management System in the developing countries and proposed countermeasure through on-the-job training.

Keywords. preventive maintenance, breakdown maintenance, bridge repair, repair material, Bridge Management System

BRIDGE MANAGEMENT SYSTEM (BMS)

Philosophy of Bridge Management System. Bridge Management System (hereinafter referred to as BMS) means to manage bridges lifetime throughout design, construction, operation and maintenance of the bridges. As funds available is tight and limited, road/bridge authorities around the world are facing challenges related to bridge management method and escalating maintenance requirements. Bridge management systems help road/bridge authorities to meet their objectives, such as building interfaces of bridge inventories, inspection databases, planning for maintenance, repair and rehabilitation in a systematic way, optimizing the allocation of financial resources, and increasing the traffic safety of bridge users.

BMS aims 1) collection of inventory data, 2) site inspection, 3) assessment of condition and soundness, 4) repair, strengthening or replacement of components; and 5) prioritizing the allocation of funds. BMS is a means of managing bridge information to formulate maintenance programs within cost limitations. BMS includes four basic components: data storage, cost and deterioration models, optimization and analysis models, and updating functions. BMS is widely used in developed countries since the past two decades.

Incident Management and Emergency Response. Maintenance Manual for Roadways and Bridges, AASHTO 2007 and JSCE bridge maintenance manual, recommend from breakdown maintenance to preventive maintenance. Figure 1 shows Deterioration Curve of preventative maintenance philosophy. Figure 2 shows Deterioration Curve of breakdown maintenance. Any management work done to move to a more

prevention-oriented philosophy of maintenance can be folded easily into an asset management approach to the maintenance, operation, and expansion of transportation infrastructure.

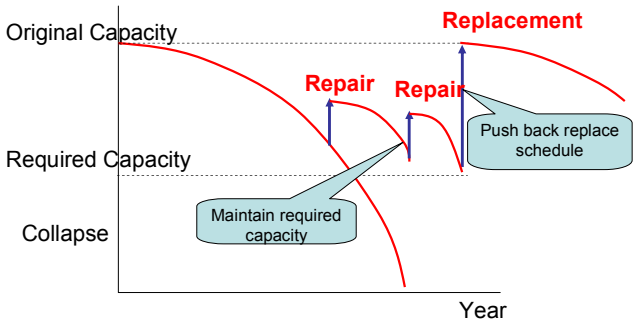

Figure 1. Preventive Maintenance Philosophy

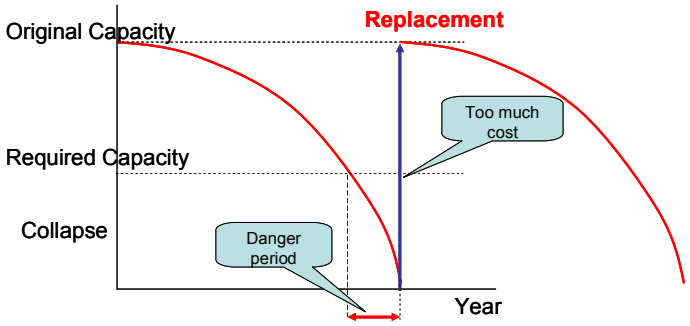

Figure 2. Breakdown Maintenance Philosophy

An incident on the roadway or on the shoulder can either directly impact flow of traffic by blocking lanes, or can create an incident impact by distracting drivers that pass by. Time is an essential element to minimize disruption. Preventive Maintenance can minimize disruption and support Incident Management and Emergency Response.

EXISTING BMS IN ETIOPIA

Ethiopian Roads Authority (ERA) implemented BMS since 2004, moving towards realizing this system by establishing Bridge Management Branch Office, upgrading the existing ERA-BMS software, launching nation wide bridge inventory and inspection projects, conducting capacity building focused trainings to ERA and Regional Road Authority engineers as well as by formulating bridge rehabilitation projects for the selected bridges that need immediate intervention.

Then after, in valuable cooperation with JICA, a series of trainings that focused on bridge inventory, inspection works, bridge design checking and capacity building activities are given to a number of Bridge/road workers and engineers residing in different districts.

In 2005, the so called `Federal Bridge Inventory and Inspection project' was launched in aiming to have well organized bridge database. In completion of this project, after 13 months, ERA, for the first time since establishment in 1943, could own a huge size of bridge database. Nearly, 3000 bridges and 27000 culverts have been registered with their detail information.

In 2008, similarly, the `Regional Roads Bridge Inventory and Inspection project' was also launched in aiming dissemination of BMS to Rural road Authorities and to have full data of bridge and culvert existing in the country.

As a result, as of September 2008, 4407 bridges and 40567 culverts (opening length < 4 m) were registered with all kinds of geographical, physical and condition data.

The ERA-BMS software brought a radical change in making available and operating the bridge database as well as producing multipurpose information / reports with in a few minutes from the computer.

The project is going to be financed by a Road Fund Administration. The consultants will use all the available database and documents (Manual, forms, software) necessary to run the service. This service shall cover all bridges and culverts along the Federal roads under the corresponding district jurisdiction.

DESIRABLE BMS IN DEVELOPED COUNTRY

BMS is moving smoothly on Bridge Management Cycle (BMC), like bridge inventories, inspection databases, assessment, planning for maintenance, repair and rehabilitation in rotation. Figure 3 shows BMC in developed country.

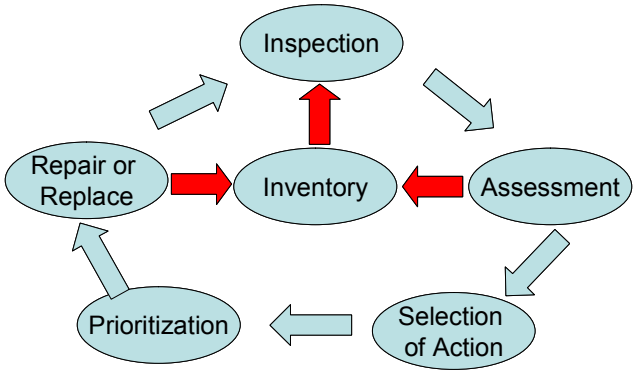

Figure 3. Bridge Management Cycle

As of now, BMC is moving based on preventive maintenance philosophy in developed country.

ISSUE OF BMS IN DEVELOPING COUNTRY

I was dispatched with an aim to assist Ethiopian Roads Authority to adopt bridge management cycle, with which bridges are properly maintained and service level of road network is improved. I regretted to find that real maintenance method was breakdown maintenance.

The reason is improper repair method, being showed in BMS manual in Ethiopia. Regarding Honeycomb or reinforcement corrosion like exposed re-bar, manual repairing operation is to use cement mortar for cover. Ethiopian concrete engineers know that cement mortar occurs crack/delamination easily and it does not work well for repair material.

As a result, Ethiopian concrete engineers are waiting till becoming big damage, applying to replace concrete repair method.

I also found same issue in Pakistan. National Highway Authority prepared BMS in 2006 funded by World Bank. BMS manual shows as follows for honeycomb repair method.

Rank D; The damaged point is repaired by injecting with a cement-based products or as described on the count C. The special inspection has to be requested.

Above comments mean that Pakistan also uses cement mortar for honeycomb repair. The fact of the matter is that developing country is breakdown maintenance.

HISTORY OF REPAIR MATERIALS

Polymer-Modified Concrete. Polymer-modified concrete (PMC) has at times been called polymer-portland cement concrete (PPCC) and latexmodified concrete (LMC). It is defined in ACI 548.3R as portland cement and aggregate combined at the time of mixing with organic polymers that are dispersed or redispersed in water. The types are as follows.

(1) Latexes

(2) Redispersible Powders

(3) Epoxy resins

Latexes. Latex has been defined as a dispersion of organic polymer particles in water (Walters 1987). Polymer Latexes acts in several ways:

(1) It functions as a water-reducing plasticizer, producing a mortar with good workability and lower shrinkage at lower water/cement ratios.

(2) It improves the bound between the repair mortar and the concrete being repaired, providing, of course, that it is applied and used properly.

(3) It reduces the permeability of the repair mortar to water, carbon dioxide and oils and also increases its resistance to some chemicals.

(4) It acts, to some degree, as an integral curing aid, but careful curing is generally still essential.

(5) It increases the tensile and flexural strength of the mortar.

A microscope picture shows effect of polymer, which disperse cement matrix and decrease width of Crack. When an unmodified cementitious mortar sets and the excess water evaporates, shrinkage occurs, causing micro cracking of the cement matrix, some ‘deep’ cracks 4-5 micro-meter wide being formed.

When a polymer latex is incorporated, the water/cement ratio is lower and hence shrinkage is lower so that the micro cracks are less wide (1-2 micro-meter). In addition, the polymer forms ‘elastic bands’ across these micro cracks, increasing tensile and flexural strengths and further reducing permeability of the mortar

Redispersible Powders. In the early 1980s polymer modified repair mortars were blended on site from sand, cement, latex and water. This resulted in some problems of

unsatisfactory mortars due to the lack of adequate quality control (poor sand, inadequate labour, unsatisfactory mixes, etc.).

To overcome this problem, there are 'bag and bottle' mixes of latex, pre-blended sand and cement which eliminate on-site blending.

A further development has been the use of redispersible spray-dried polymer powders which may be factory blended with graded sand, cement and other additives to give mortars and bonding coats simply by the addition of water on site.

These polymer powders were based on copolymers of vinyl acetate and other 'monomers' such as ethylene or vinyl 'Versatate'.

Acrylic Powders. From 1995, some of the acrylic powders have been developed. The 'all in the bag' factory blended, quality controlled repair mortars incorporating redispersible polymer powders are becoming more popular and are more cost effective than the 'bag and bottle' mixes.

Polymer modified cementitious mortars are mainly used for the repair of reinforced concrete where the cover to be replaced is more than 12 mm in thickness. In some instances, they are used in conjunction with a protective coating in lower cover situations (down to approx. 6 mm) Where the cover is less than 12 mm, and no protective coating is to be applied, then resin repair mortars are normally recommended.

Formulations incorporating lightweight fillers are also available for vertical and soffit repairs in developed country. Such lightweight repair mortars can be applied approximately 75 mm deep without any formwork and are used as an alternative to replacement concrete.

Acrylic resin systems are chemically simple in that the liquid resin component contains both the 'blocked hooks' and the 'eyes' in the right proportion intimately mixed together. Figure 4 shows Reactive Hooks and Eyes of Acrylic Resin. This means water quantity is alterable as hardener is water for acrylic resin.

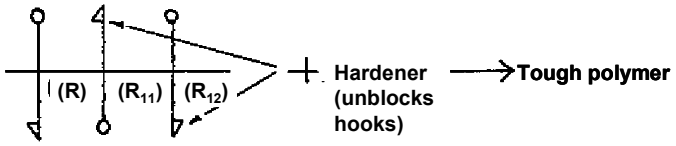

Figure 4. Reactive Hooks and Eyes of Acrylic Resin

Epoxy resins. Type of Resin Repair Mortars is as follows.

1) Epoxy Resins

2) Unsaturated Reactive Polyester Resins

3) Unsaturated Acrylic Resins

Epoxy resins are most commonly used, but polyester and acrylic resins are also used especially where rapid strength development is required. Epoxy resins consist of a reactive resin which can, in much simplified non-chemical terms, be considered as a material with reactive 'hooks', and a hardener (also called curing agent) with reactive 'eyes'. Figure 5

shows Reactive Hooks and Eyes of Epoxy Resin. This means mix proportion of epoxy resin and hardener is important and strict.

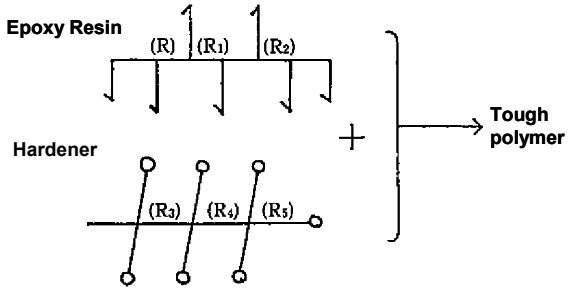

Figure 5. Reactive Hooks and Eyes of Epoxy Resin

Synthetic fibers. Synthetic fibers, polypropylene fibers length is 12 mm, benefit the concrete in both the plastic and hardened state. Some synthetic fibers may be used as secondary reinforcement. Some of the benefits include: (1) Reduced plastic settlement cracks, (2) Reduced plastic shrinkage cracks, (3) Lowered permeability, (4) Increased impact and abrasion resistance, (5) Providing shatter resistance

Polymer bonding aids. When applying conventional concrete, sprayed concrete or sand/cement repair mortars, bond is often a problem. In particular, where the repairs are to be carried out at high ambient temperature, water loss at the interface between the repair material and prepared concrete may prevent proper hydration of the cement matrix at this interface. The use of an epoxy resin or polymer latex bonding aid can assist in achieving a reliable bond.

The Pot life (Working Life) is the period of time within which the epoxy resin formulation must be applied at a given ambient temperature. After this time has elapsed, the cure process is already so far advanced that the mixture can no longer be allowed to be applied and its starts hardening in the mix pot.

The open time (Maximum Overlay Time, Tack Free Time) starts when the adhesive has been applied to the parts being bonded. They have to be joined together within this time. If the open time is exceeded, the adhesive strength is sharply reduced.

History of Open Time. On 1990s, bonding agent, some additional adhesion has no open time. The first layer of patching material should be applied immediately (within 10 minutes) after the bonding coat. Considering workability, a longer 'open time' bonding coat have been developed on 2000s. Maximum open time is that Epoxy resin bonding agent is 3 days and Polymer cementitous bonding agent is 2 weeks in Japan as of now.

MARKET RESEARCH IN ETIOPIA

Restoration method was recommended as follows.

(1) To use Bonding agent between existing concrete and repair mortar (primer) due to perfect bonding

(2) To use Powder Polymer modified cementitious repair mortar due to no crack appearance

(3) To use Fiber reinforced repair mortar due to no crack appearance.

Above method is almost common in Japan. JICA expert team tried to find innovative repair materials for the alternative of cement mortar in Ethiopia on Dec 2010. The result of market research is Table 1.

Table 1. Result of Market Research in Ethiopia

	Company name	Sika	BASF	FOSROK
1	Polymer modified cementitious profitting mortar *(For Material of Restoration of Damaged Members)*	SikaCeram-531Joint 564 birr/1pack(25kg) [22.56birr/kg]	non	Rendroc TGXTRA 276birr/25kgpack
2	Polymer Fiber reinforced repair mortar *(For Material of Restoration of Damaged Members)*	Geotextile (cloth type) 80 birr/m2 [for building water proof]	EMACOS88CT 546.25birr/25kg [21.85birr/kg] pre-packed type Polypropylen fiber 138birr/1bag/1m3mortar short fiber 12mm for site mixture	Fosroc PPF 212.75birr/1bag/1m3mortar short fiber 12mm for site mixture
3	Epoxy resin mortar *(For Sealing Material of Crack Injection Method)*	Sikafloor-156 2150birr/10kg [215birr/kg]	ConCresive2200 189.75birr/1kg 569.25birr/3kg [189.75birr/1kg]	NitoBond EP 391.00birr/1liter
			(Non stock) MASTERTOP1240PLUS cost	NitoMortar FC 1,610.00birr/5liter
4	Resin mortar	SikaLatex (mortar mixture) 845birr/5liter 3,116birr/20liter	(Non stock) REOMIX141 63.25birr/1liter	non
5	Another mortar for concrete repair	non	non	non
6	Anti-corrosion primer (corrosion inhibitor) *(For Treatment Material of corrosion re-bar on Restoration of Dameged Members)*	(Non stock) Sika PRIMAIRE263 Sika Floor263 3,726.6birr/20kg	(Non stock) CONCRESIVE ZR	(Non stock) Nitoprime Zincrich 241.50birr/1liter
7	Bonding agent between existing concrete and repair mortar (primer) *(For Restoration of Damaged Members)*	SikaLatex (Bonding layer) 845birr/5liter 3,116birr/20liter [155.8birr/1liter]	CONCRESIVE1414 322birr/1liter	NitoBond EP 391.00birr/1liter
				(Non stock) Nitobond AR 74.75birr/1liter
8	Crack injection material *(For Material of Crack Injection)*	non	CONCRESIVE1300 695.75birr/1liter	Nitofill EP1V 287.5birr/1liter
9	Crack routing & patching material	Sika cryl-s 48birr/300ml for complete stop of crack groth	non	non
		Sika flex PRO-3WF 235birr/300ml for crack width is being increased		

Product name was collected by brochure through three product companies and put them on Table 1. Their availability was confirmed at business agent in Ethiopia. Colour portions show procurement is available in Ethiopia.

REPAIR MARERIALS

Proposed repair work material. Following repair work materials was proposed considering availability in Ethiopia. Refer to Table 2. Polymer fiber reinforced repair mortar prefers pre-mix of polymer and fiber, like EMACO88CT.

Table 2. Proposed Repair Work Material in Ethiopia

Restoration of Damaged Members	
Bonding Agent	Acrylic Powders
NitoBond EP or Concresive1414	EMACOS88CT (BASF)
NitoBond EP or Concresive1414	RendrocTGXTRA (FOSROC) + Polypropylen Fiber
Crack Injection	
Sealing	NitoMortar FC or Concresive2200
Injection	Nitfill EPLV or Concresive1315

REPAIR EQUIPMENTS

Bridge repair work requires following equipments, refer to Table 3. Market research for bridge repair equipments was conducted in Ethiopia and prepared as much as possible.

Table 3. Bridge Repair Equipments

1	flatbed truck with a winch	7	sandblasting equipment
2	air compressor	8	hand tools for steel, carpentry, concrete work
3	small concrete mixer	9	staging (scaffolding)
4	electric drill	10	paint outfit
5	small concrete mixer	11	miscellaneous survey equipment
6	small, portable high-pressure water pump		

EDUCATION OF BRIDGE REPAIR WORK

Explanation of innovative materials. Innovative materials are products by chemical company. It is necessary to read specification sheet of each materials carefully, and follow application procedures (or instruction for use) and safety precautions strictly. I had done explanation of innovative materials. Especially I focused on resins which might cause sensitization by skin contact. During use of resins, avoid contact with skin and eyes. Ensure adequate ventilation and avoid inhalation of vapours.

On-the-job training of innovative materials. Regarding Acrylic Powders (Polymer modified cementitious mortars), essential point includes: (1) Preparation of substrate, (2) Mix of Bonding Agent, (3) Application of Bonding Agent, (4) Mixing of Acrylic Powders, (5) Application, (6) Curing, (7) Storage

Preparation of substrate. It is essential that the substrate to be repaired is sound, clean and free of all contamination. The damaged areas of concrete to be removed should be clearly identified. The perimeter of the area should be saw cut to a depth of 10mm and the edges cut as neatly as possible keeping the sides square. Feather-edging is not permitted and a minimum thickness of 10mm must be maintained over the whole repair area.

Mix of Bonding Agent. The ‘hardener’ and ‘base’ components should be stirred separately before mixing to disperse any settlement. The entire contents of the ‘hardener’ tin should then be poured into the ‘base’ tin and the two materials thoroughly mixed using a suitable slow-speed drill and mixing paddle for 2 minutes until a fully uniform colour is obtained.

Application of Bonding Agent. It is point to check maximum overlay time and minimum overlay time. I found workability of trowel-applied repairs near minimum overlay time is better than near maximum overlay time.

Mixing of Acrylic Powders. Acrylic Powders must be mixed mechanically. Mix for 3 minutes after all the powder has been added until mortar is homogeneous and lump free. Add water, if necessary, within the limits given, until the required consistency is achieved. Mix for a further 1-2 minutes.

Application. After mixing, Acrylic Powders can be sprayed or trowel applied. Successful use of trowel-applied repairs is highly dependent upon the surface preparation and the skill of the individual mason. Every effort should be made to ensure that masons are experienced, and close field observation of the work should be made. Proper troweling technique should be used to prevent the entrapment of air at the bonding surface which can cause reduced bond strength.

Curing. Of particular importance is proper curing of polymer cement mortars so that the patch material does not dry before hydration is complete. Special curing provisions may be advisable for repairs where accessibility is difficult.

Storage. Store out of direct sunlight, clear of the ground on alleys, protect from rainfall. It is forbidden to use expired products.

EDUCATION OF SAFETY CONTROL

Safety Manager. Safety Manager shall be assigned to implement safety activities such as safety patrol, safety education and instructions at site for the safety of all persons entitled to the Work. I had Education and found Safety Technician from local staff is effective and sustainable way. Figure 6 shows DRMC, contractor agency of ERA, staff had safety work education at site

Figure 6. Education by Safety Technician

Equipment for Safety Control. Some people are sensitive to resins, hardeners and solvents. Use only in well ventilated areas. If working in confined areas or in cases of insufficient ventilation, suitable respiratory protective equipment must be used. The use of barrier creams provides additional skin protection. Should accidental skin contact occur, remove immediately with a resin removing cream followed by soap and water. In case of contact with eyes, rinse immediately with plenty of clean water and seek medical advice. If swallowed seek medical attention immediately.

It is essential to wear suitable protective clothing, gloves and eye/face protection. Proper wearing equipment is Figure 7.

Figure 7. Proper Wearing Equipment

Traffic Control in Ethiopia. Proper traffic control is important for repair work to avoid working area and damaged area, considering working hours and curing period against deterioration of load bearing capacity.

CONCLUSION

On-the-job training for supervision/ quality control and technology / skills of bridge repair works was conducted using innovative repair materials on each ERA district offices in Ethiopia for smooth moving of Bridge Maintenance Cycle and preventive maintenance.

The issue of BMS in developing countries was pointed out, which is to use cement mortar for restoration of damaged concrete member as honeycomb repair. It is common cement mortar does not work well for concrete repair, so that breakdown maintenance is used in developing countries.

The countermeasure for replace of cement mortar was introduced. It is (1) To use Bonding agent between existing concrete and repair mortar due to perfect bonding, (2) To use Acrylic Powders (Powder Polymer modified cementitious) repair mortar due to no crack appearance, (3) To use Fiber reinforced repair mortar due to no crack appearance.

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