Jimma University

School of Graduate Studies

Jimma Institute of Technology

Civil Engineering Department

Construction Engineering and Management Stream

IDENTIFICATION OF PROBLEMS AND CHALLENGES IN APPLICATION OF CONCRETE AND MASONRY STRUCTURES REPAIR FOR THE CASE OF BEKO BRIDGE B/N SHISHINDA AND BITA WORDEA

Independent Case Study submitted to the School of Graduate Studies of Jimma University in Partial fulfillment of the requirements for the Degree of Masters of Engineering in Civil Engineering

BY: ADDISU FENTA

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JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

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CONSTRICTION ENGINEERING AND MANAGEMENTS STREAM

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DECLARATION

This Independent project entitled: "Identification of Problems and Challenges in Application of Concrete and Masonry Structures Repair'' is my original work and has not been presented for a degree in any other university.

M______________________ ____________________________

Signature Date

Acknowledgement

First thanks to God for each and every success in my life and satisfactory accomplishment of this case study.

Second I would like to thank Ethiopian Road authority (ERA) and Jimma University giving me chance of MSC programme in construction management and engineering.

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Abstract

This case study work is undertaken to identify defects on beko bridge b/n Shishinda and Bita woredea in southern nations and nationality region, to evaluate seriousness of defects, challenges and problems in application of repairing. The bridge was selected by assessing bridge inventory data from Ethiopian Road Authority which is the most defected bridge in Kafa zone.

The study is conducted to restore maximum strength of the structure to extend serviceability and durability of a bridge at minimum maintenance cost and with in short period of time without interruption of traffic flow, following identify defects prevailing on the structure, Identify proper material to repair each defects Conduct proper preparation work methods to restore the defect part material application procedure.

The main purpose of the study is prevention of further progress of bridge defects, removal of damaged parts and restoration of section which needs regular inspection of bridge conditions not to incur high replacement cost and interruption of traffic flow.

A descriptive case study was used in the design. It was attempted to collect data from Beko bridge defects by using simple tools local labor around the area to identify defect types and seriousness of the defect. Case study research design has been selected to collect each defect cause and analysis each defects causes.

As shown form bridge repair identification problem and challenges on Beko bridge. Since bridges are vital structure to access the road, it is difficult to replace defected bridges not obstacle the access and needs expensive construction,. Ensure the appropriate and timely action is taken on bridges requiring repair and rehabilitation work, strength its risk assessment and priority setting process, with particular consideration given to bridge identification as poor condition more closely monitor inspections' compliance with the bridge inspection manual so that critical bridge information is accurately updated. Ethiopian road authority should prepare brief manual for bridge maintenance and continuous supervision by upgrading bridge maintenance contractors.

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Chapter one

Introduction

1.1Background

Bridges are vital components of the road network that contributes greatly to the national development and public daily life. Any damage or collapse of bridge can risk the lives of road users as well as create serious influence to the entire country. Bridge rehabilitation can be much more involving than designing and constructing a new bridge. (ERA conducted Inventory and Inspection of Bridges along the Federal roads (FBII), 2006).

The bridge where the study carried on Beko Bridge at Kaffa zone b/n Shishinda and Bita worda. It has 21m span length and 7m width Slab Bridge. Road across the bridge between Shishinda and Tepi is eroded gravel road. It requires a great deal of effort to tie-in all concerned disciplines together in-order to build-back a distressed bridge to its original condition, cost effectively. While in the initial designing it is mandatory to design within the prescribed limits of Bridge Repair Manual, it may not be possible to follow such regimentation in mending the distresses in old bridges. Due to the fact that lack of experience in bridge maintenance works, many professionals tend to recommend bridge replacement.

This option usually calls for tremendous amount of budget and interruption of traffic flow. In order to properly utilize this big amount of money, skilled manpower is mandatory. In this regard, this manual, believed to greatly assist bridge engineers in introducing type of defects and causes as well as application of the required level performance in Concrete Bridges defect mitigation.

The basic policies of the Bridge maintenance should have at least the following concepts. The maintenance procedure consists of initial inspection, deterioration prediction, Inspection evaluation, judgment, remedial measures, and recording. To clarify the role of maintenance in the structure's life from planning/design to the end of service life, maintenance shall be taken into consideration at the planning stage of the newly constructed structure, because the design concept and the construction method can be changed depending on the level of maintenance. Performance based concept is introduced in accordance with the international trend of codes. Basically, all of required performance on the target structure is checked in each inspection stage, and based on the inspection results; the structure's conditions not only at the time of inspection but also at the end of the intended service life should be evaluated and judged.

(4)The Maintenance manual can have two sub-parts like, "Sub-part 1: Maintenance Fundamental" describing the basic concept and the flow of maintenance, and "Sub-part 2:

Standard Specification for Maintenance" describing the specific procedures adopted for each deterioration mechanisms. Categories of maintenance are defined, with considering engineers' activities.

Repair works generally add no extra strength to the bridge structure, but are only remedial measures taken to restore/bring back/ the serviceability of the bridge. Repair basically means the rehabilitation of the target bridge to restore necessary function and performance maintaining the present load carrying capacity of the bridge. (FHWA Bridge Preservation Expert Task Group.[3])

1.2 Statement of the problem

Heavy traffic loads and increment of the load acting frequencies that may occur through time after the construction of the bridge structures is one of the basic causes for structural cracks on reinforced concrete members. Insufficient structural design and errors in interpreting the drawings during construction, large impact forces caused by defect of road surfaces and aging of the concrete are also main causes of the structural cracks. The structural cracks can further be classified as flexural, shear, torsion, and compression cracks based on the internal stress which brings about the cracks. [Alberta Infrastructure and Transportation, (2005)]

The prevailing problem during observation for identification of defects on BKO Bridge are Flexural cracks under beam girder, Scoring of abutment, Peel off top surface of slab concrete, Separation of aggregate and cement paste around girder beam and soffit slab, Leakage under soffit slab, and Breakage of concrete railing.

1.3Objective

1.3.1General objective

Aim of general objective of the study is restoring maximum strength of the structure to extend serviceability and durability of a bridge at minimum maintenance cost and with in short period of time without interruption of traffic flow.

1.3.2pecific objective

Aim of specific objective of the study,

- Identify defects prevailing on the structure,
- Analyze cause of each defect
- Identify proper material to repair each defects
- Conduct proper preparation work methods to restore the defect part material application procedure

1.4 Significance of the study

Bridge maintenance is work performed during the service life of a structure to maintain its designed load capacity, other functional capability and serviceability. Ensure that the structure completes its designed service life which includes the following functional requirements: Load capacity, Height clearance, Width, Suitability of safety barriers;

Maintenance works which would allow minimizing the costs and at the same time ensuring the necessary safety and traffic possibilities. Bridge Maintenance increase the bearing capacity of the bridge or its elements disregarding the presence or absence of any defects up to a level which is higher than the initial bearing capacity.

The main purpose of the study is prevention of further progress of bridge defects, removal of damaged parts and restoration of section which needs regular inspection of bridge conditions not to incur high replacement cost and interruption of traffic flow.

Chapter Two

Literature review

2.1. Definitions

Repair of reinforced concrete involves treatment, after defects have occurred, to restore the structure to an acceptable condition. Defects cause some compromise in condition or function relative to the original, and this generally means that a process or processes have resulted in movement, loss of material, and/or loss in materials properties. Repairs are therefore mostly reactive, and initiated when evidence of deterioration becomes apparent. Etebar, defines the objective of repair as being to restore or enhance one property such as durability, structural strength, function or appearance. Walker indicates that rehabilitation refers to bringing degradation under control to enable a structure to continue to serve its intended purpose. This can be either repairing to bring concrete back to a state similar to the original, or using methods to arrest deterioration processes to enable ongoing service. The literature appears to make little or no differentiation between 'repair' and 'rehabilitation. (Bridge Inspector's Reference manual.FHWA; 2006)

2.2. Engineering significance concrete repair

Reinforced concrete has become a universal dominant construction material in the past 50 years. There is a vast stock of major structures and infrastructure constructed with reinforced concrete in the UK. These structures are subject to a range of degradation mechanisms, which results in the generation of defects. The nature of the deterioration mechanisms and the form of the structures is often such that repair is necessary at a stage considerably before serious structural implications arise. This has, and will continue to, generate a legacy of demand for repair of structures that are still serviceable but suffer defects in durability, cosmetic or safety function. It should be noted that the majority of reinforced concrete structures meet or exceed their intended service life (Walker5). However, many will have undergone some maintenance and repair.

2.3. Bridge Maintenance Policies

Bridge rehabilitation can be much more involving than designing and constructing a new bridge. It requires a great deal of effort to tie-in all concerned disciplines together in-order to build-back a distressed bridge to its original condition, cost effectively. While in the initial designing it is mandatory to design within the prescribed limits of Bridge Repair Manual, it may not be possible to follow such regimentation in mending the distresses in old bridges. Due to the fact that lack of experience in bridge maintenance works, many professionals tend to recommend bridge replacement.

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In order to properly utilize this big amount of money, skilled manpower is mandatory. In this regard, this manual, believed to greatly assist bridge engineers in introducing type of defects and causes as well as application of the required level performance in Concrete Bridges defect mitigation.

The basic policies of the Bridge maintenance should have at least the following concepts. The maintenance procedure consists of initial inspection, deterioration prediction, Inspection. Evaluation, judgment, remedial measures, and recording.

To clarify the role of maintenance in the structure's life from planning/design to the end of service life, maintenance shall be taken into consideration at the planning stage of the newly constructed structure, because the design concept and the construction method can be changed depending on the level of maintenance.

Performance based concept is introduced in accordance with the international trend of codes. Basically, all of required performance on the target structure is checked in each inspection stage, and based on the inspection results; the structure's conditions not only at the time of inspection but also at the end of the intended service life should be evaluated and judged.

(4) The Maintenance manual can have two sub-parts like, "Sub-part 1: Maintenance Fundamental" describing the basic concept and the flow of maintenance, and "Sub-part 2: Standard Specification for Maintenance" describing the specific procedures adopted for each deterioration mechanisms. Categories of maintenance are defined, with considering engineers' activities. (ICRI - ACI, 1999. *Concrete Repair Manual)*

2.4. Methodology for Selecting Maintenance Actions

Basis of maintenance of concrete structure is that the structure is adequately maintained such that its performance is always above the required level during its service life. However, since concrete is used in different structures such as buildings, dams, bridges, etc., which perform under different environmental conditions, it is not possible to lay down identical performance criterion for all structures.

2.4.1 Maintenance Category

Due to the fact that there must be different actions for different situation, the maintenance action can be classified into four different categories specified as follows;

A. Preventive maintenance -- the maintenance to prevent the appearance of visible deterioration on the structure during the service life.
B. Corrective maintenance -- the maintenance in which, appropriate counter measures should be taken after degradation appearance of the structures has appeared.
C. Observational maintenance -- the maintenance carried out primarily on the basis of visual inspection without any direct measure and permits certain deterioration of the structure.
D. Non-inspection maintenance -- the maintenance applied to the structure in which the direct inspection is difficult or practically impossible to be carried out, such as underground structures.(FHWA-HIF-11042)

2.4.2 Maintenance Strategy

For fulfilling the rational and reliable maintenance activities in order to keep the performance of structure always above its required level, it is necessary to evaluate the time-dependent degradation process of the performance of structure during the life, with adequate reliability. However, since the performance degradation cannot be always strictly analyzed based on the current engineering level. It should be verified indirectly considering a future deterioration condition expected by using the deterioration evaluate model. Here, it is needless to say that the periodic inspection results are indispensable for evaluating the performance of structure.

The overall processes mentioned above are surely carried out on the basis of the "maintenance strategy". Namely, the maintenance strategy comprehensively encompasses "inspections", "estimation of deterioration levels and rates", "evaluation of performance of structure", "remedial actions", and "recording". Off course, the combination of these steps differs to the different maintenance category, considering the importance of the structure, hazards to the third parties, and environmental conditions.

The complexity and magnitude of the repair procedure will depend on whether: Only the cause of the defect has to be removed; the structure must be restored to original condition; the structure needs to be upgraded for its load carrying capacity and / or for its geometry.

There are several options in the evaluation of restoration of the true function of a defected structure and these could be: Total replacement of the structure; a combination of partial replacement and repair; based on the severity of defect in localized areas of the structure; Undertaking extensive rehabilitation/ strengthening measures.

There are several repair methods applicable to defect and the most suitable method can be selected by comparing alternative methods from technical and economical points of views.

However, this approach is complex and difficult unless by experienced engineers. For the convenience to select repair methods, relation charts of defect types and repair methods are recommended for major defects.

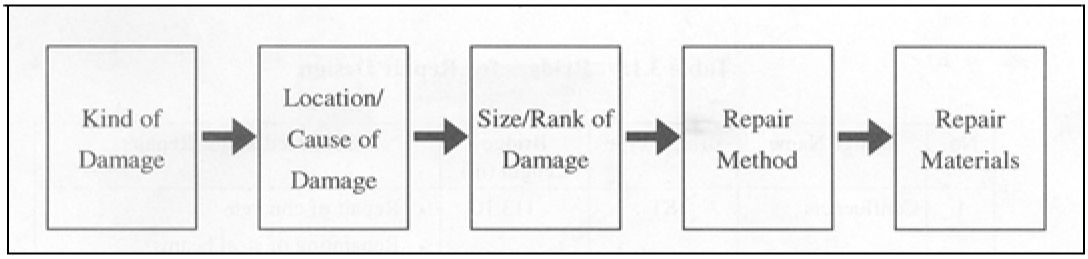

Figure 1: Maintenance Strategy

If an inspection indicates that remedial measures need to be taken, there are several basic steps bridge owners can take to rehabilitate a bridge structure. The causes and mechanism of defect in a particular case must be identified, then the optimal strategy devised as follows: assess the bridge condition, detailed investigation, diagnosis, special tests and re-calculations for appropriate selection of rehabilitation strategies; determine the type, rate and extent of defect and cause, and assess the structural performance due to deterioration and defect; identify all relevant rehabilitation strategies for future management of the structure; predict the development of defect for each strategy in order to estimate future cost; calculate the cost and benefit for each strategy; Determine the strategy or set of strategies that requires the minimum investment for the expected life of the structure (an appropriate life-cycle cost analysis). Upgrading or downgrading of the structure may also be considered;

Define future inspection and maintenance requirements. Maintenance of today's bridge infrastructure presents many challenges. Transportation engineering and maintenance personnel must maintain around the clock service to millions of people each year while maintaining millions of cubic meters of concrete distributed throughout their facilities. This infrastructure includes bridges. Presently only a limited number of accurate and economical techniques exist to test these structures for integrity and safety as well as insure that they meet original design specifications. No single technology can locate all physical anomalies or irregularity in and below the concrete, these techniques along with data fusion can assist in the following investigations, to name a few: Locating voids and delaminating in bridge pavements and scour around bridge support columns. Determining location and types of reinforcing steel in concrete. Ensuring quality control on new concrete installations.(Dorsch, D. F.1995, pp. 320–325.)

2.5. Major Defects of Concrete Structures

2.5.1 Cracking

Concrete is by nature a brittle material, so reinforced concrete structures are destined to suffer cracking. Cracking cannot be prevented completely with present techniques. Not all types of concrete cracking, however, pose problems; some are detrimental to structures but others are not. Damaging cracking includes those types that cause water leakage due to cracking throughout the member, excessive deflection, aesthetic concerns and defect to the durability of the structure.

Cracks in concrete may described in a variety of ways. Some of the more common ways are in terms of surface appearance, depth of cracking, width of cracking, current state of activity, and structural nature of the crack. Cracking can be an important indicator of deterioration taking place in concrete and possible corrosion of reinforcement steel depending on the size, extent and location of the cracks. Cracks of concrete are classified as structural or non-structural cracks.

Phenomenon: - Generally, cracking represents the deterioration of concrete. Surface appearance which is pattern or map cracks and individual cracks can give the first indication. Individual cracks indicate tension in the direction perpendicular to the cracking. Depth cracking is a self explanatory as may be surface, shallow, deep and through type. Active or dormant state of cracks, width of cracks, and structural nature of crack (structural or non structural) can be listed as different types of it. Cracking after reinforcement corrosion owing to the increase of corrosion of reinforcement; cracking before reinforcement corrosion that induces the corrosion of reinforcement.

Figure 2: Cracking

2.5.1.1Structural Cracks

Structural cracks are those cracks which result from insufficiency of the section to withstand the flexural, shear, settlement and other stresses developed in that section due to dead and live loads applied upon it. Structural cracks are caused by load stress and are divided into flexure and a shear cracks. Flexure cracks are vertical and start in the maximum tension zone and proceed toward the compression zone. Shear cracks are found near the bearing area and begin at the bottom of the member and extend diagonally upward. Structural cracks will usually be substantial in width, and the opening may tend to increase as a result of continuous loading and creep of the concrete.

2.5.1.2 Non-structural cracks

Non-structural cracks are divided into temperature, shrinkage and mass concrete cracks. These cracks are relatively minor and generally do not affect the load carrying capacity of the member. They can, however, provide openings for water and contaminants, which can lead to serious problem. Non-structural cracks are those cracks which result from workmanship problems, shrinkage of concrete and other minor causes. Peel off, Delaminating, Void Disintegration of concrete differs from sapling in that larger pieces of intact concrete are lost when sapling occurs. Two of the most commonly used terms to describe disintegration are Scaling and dusting. Calling is the gradual and continuing loss of surface mortar and aggregate over an area.

Dusting is the development of a powdered material at the surface of hardened concrete. Dusting will usually be noted on horizontal concrete surfaces that receive a great deal of traffic. Expansion beneath the surface of concrete, for example as a result of reinforcement corrosion, produces tensile stress, which exceed the concrete strength and areas of the concrete surface break away.

De lamination occurs when layers of concrete separate at the level of outermost layer of reinforcing bars. Delaminated areas give a hollow sound when tapped with a hammer. The resulting depression by delaminating is called a spall. A spall is a roughly circular or oval depression in the concrete resulted from separation and removal of portion of surface concrete. Sapling means the breaking away of concrete flakes. Separation of concrete flakes defects the structure. Sapling is defined as the development of fragments, usually in the shape of flakes, detached from a layer mass. A spall is a roughly circular or oval depression in the concrete.

Figure 3: Non Structural crack

2.5.2 Honey Comb

Honeycomb refers to voids left in concrete due to failure of the mortar to effectively fill the spaces among coarse-aggregate particles. Course aggregate with air space appear on the surface of concrete. Honeycombing occurs where the spaces between coarse aggregate particles are inadequately filled, with the result that the hardened concrete has an open structure. Honeycomb preferably shall be repaired at the construction time, before handing over the original work, with supervision. Concrete surface is not smooth as desired. Spots and small voids are visible. Accumulation of bigger size aggregates is observed. Due to pour-out of cement paste, bondage of aggregates seems very poor.

Honeycombing refers to voids in concrete caused by the mortar not filling the spaces between the coarse aggregate particles. It usually becomes apparent when the formwork is stripped, revealing a rough and 'stony' concrete surface with air voids between the coarse aggregate. Sometimes, however, a surface skin of mortar masks the extent of the defect. Honeycombing may extend some depth into the member. Honeycombing is always an aesthetic problem, and depending on the depth and extent may reduce both the durability performance and the structural strength of the member.

Figure 4: **Honey Comb**

To minimize the incidence of honeycombed concrete: Ensure the mix has sufficient fines to fill the voids between the coarse aggregate. Use a mix with appropriate workability for the situation in which it is to be placed. Ensure the concrete is fully compacted and the placing methods minimize the risk of segregation. Ensure the reinforcement layout and the section shape will permit the concrete to flow around the reinforcement and completely fill the forms. Check that the formwork is rigid and well braced, the joints are watertight and any penetrations through the formwork e.g. form ties, is properly sealed. When handling and using cement or fresh concrete, avoid skin contact. Wear suitable protective clothing. Spoiling, Scaling, Wearing Spoiling is loose of quality appearance due to many external reasons. Wear and abrasion of the concrete surface are caused by being exposed to traffic and water flow. Wearing and abrasion is the result of external forces acting on the surface of concrete member like erosive action of sands in running water over the concrete surface. If additional water is added at the time of delivery of concrete in order to increase the workability of concrete it causes an increase in the water cement ratio of the concrete leading to a reduction in strength and durability of concrete. Which can be manifested in surface defects like scaling, crazing and dusting improper finishing and curing operations cause surface scaling? The arterials and finishing and curing operations that cause dusting of concrete surfaces also cause thin surface scaling. The procedures used to prevent dusting will prevent this type of surface scaling.

2.6. Causes of Concrete Defects

2.6.1 Causes for Concrete Cracking

2.6.1.1 Cause of Structural Crack

Heavy traffic loads and increment of the load acting frequencies that may occur through time after the construction of the bridge structures is one of the basic causes for structural cracks on reinforced concrete members. Insufficient structural design and errors in interpreting the drawings during construction, large impact forces caused by defect of road surfaces and aging of the concrete are also main causes of the structural cracks. The structural cracks can further be classified as flexural, shear, torsion, and compression cracks based on the internal stress which brings about the cracks. The user of this Bridge Repair Manual shall identify the real cause of cracks, analyze loads and quantify the magnitude of stresses and strains developed in the sections and finally arrive at amount of reinforcement that shall be applied to repair these types of cracks.

2.6.1.2 Cause of non structural crack

There are several causes of non structural cracks which develop on reinforced concrete bridge components. Among those causes, the most common ones are shrinkage of concrete due to lack of proper curing mechanism, defect on concrete surface during formwork removal, absence of proper expansion joints, and other similar workmanship problems. Cause for Concrete Peel off, Delaminating, Void Spall can be caused, by corroding reinforcement and friction from thermal movement dye to which reinforcing steel is often exposed. Due to the increase of pop-out or scaling resulted from separation and removal of portion of surface concrete. The major cause of de lamination is expansion of corroding reinforcing bars. This is commonly caused by intrusion of chlorides or salt. An inadequate drainage system can severely limit the life span of a concrete deck due to deterioration by leakage of corrosive deicing mainly.

Expansion beneath the surface of concrete, for example as a result of reinforcement corrosion, produces tensile stress, which exceed the concrete strength and areas of the concrete surface break away. It leads to an unacceptable low level of safety for the third parties. Voids form when concrete fails to fill areas in a form, typically those under large blackouts, in very deep placements, or that are heavily reinforced. Voids are almost always structural defects requiring re p a i r. Causes of honeycomb and voids include stiff or unworkable concrete, segregation, congested rebar, insufficient consolidation, and improper placing practices.

2.6.2 Causes for Concrete Honey Comb

Honeycomb surfaces are caused by the use of a dry mix that was not properly consolidated. The concrete mix should be designed to provide a workable mix for the type of consolidation that will be used on the job. When honeycombing occurs, don't just add water to the mix to correct the trouble. That will decrease the strength and durability of the concrete. The mix should be redesigned to provide improved workability or the procedure for consolidating the concrete should be improved.

Honeycombing is caused either by the compaction not having been adequate to cause the mortar to fill the voids between the coarse aggregate, or by holes and gaps in the formwork allowing some of the mortar to drain out of the concrete. In some cases, the member shape and detailing/placement of the reinforcement compounds the effect of inadequate compaction. It is caused by the loss of cement grout where form work is inadequately sealed or by segregation of the wet concrete. It can be caused by segregation of material during concrete casting, insufficient compaction of concrete and it can also be caused by the loss of cement grout, leaking of cement paste, where form work is inadequately sealed. Honeycomb forms when mortar fails to fill voids between coarse-aggregate particles. The defect may be purely cosmetic or, depending on the location and extent of honeycombing, may be structural and require repair. For instance, honeycombing behind post-tensioning anchors may require repair so the post-tensioning forces don't cause compressive failure of concrete in the bearing area.

Preventing honeycomb and voids starts with attention to concrete mix pro portions Proper techniques for forming, rebar placement, and concrete placement also are important .Provide enough paste. Concrete not containing enough cementations material and fine sand will be prone to segregation and won't flow well. Consider adding a blend sand or additional Portland cement or fly ash to increase the amount of fines. Increasing the ratio of fine-to-coarse aggregate will increase workability only if 5% to 10% of the sand passes the No.100 sieve. Increase slump. Even with the correct amount of paste, a mix can lack workability and won't flow into place. To improve flow, increase slump to 6 to 8 inches by adding a water reducer or super plasticizer.

Reduce aggregate size. If closely spaced reinforcement or other obstacles hinder concrete flow, consider reducing coarse aggregate size below the maximum allowed by ACI 318-99, “Building Code Requirements for Structural Concrete.” Such a change requires an overall re v i.e. w of mix pro portions. Control setting rate. Slow placement rates and high ambient and concrete temperatures can cause concrete to stiffen, reducing its flow ability. Adding a retarder may help, but retarders don’t necessarily prevent slump loss.

Forming and rebar placement: Review reinforcement details. Closely spaced rebar, insufficient clearance between the rebar and forms, and closely spaced lap splices all interfere with concrete flow and vibration. Work with the steel detailer to minimize these problems. Provide access to f o rms. Narrow or tall forms prevent observation and access during concrete placement. Consider reducing lift heights or using flexible tremie hose. You may have to cut placing ports into forms containing heavily reinforced sections. Build tight form joints. Mortar loss through form joints may cause honeycomb, particularly with wetter mixes. Tighten or tape form joints as necessary.

Vibrate properly .Workers must be trained to vibrate concrete correctly to ensure that it flows around reinforcing steel, embedment, and blackouts. Ensure flow under blackouts. Build up a head of concrete on one side of small blackouts, and vibration the concrete until it appears on the other side. Large block outs require concrete to flow many feet laterally, so you may need to use p o u r pockets beneath these block outs. Drill holes in the bottom of a block out to allow displaced air to escape. Avoid delays. If the placement is not going as fast as planned, ready – mix trucks may have to wait before discharging material and the concrete will start to stiffen. You can reduce stiffening by using retarding admixtures, but a better approach is to alert the concrete producer when unavoidable placing delays occur.

2.6.3 Causes for Concrete Spoiling, Scaling, Wear

Some aggregates used in concrete react chemically with high alkali cements, causing disruption of the concrete. This form of deterioration or spoil is called alkali-aggregate reaction, and results in extensive cracking. Scaling, i.e., local flaking or peeling away of the near-surface portion of a concrete slab is the most common type of surface distress, especially in areas exposed to cyclic freezing and thawing, and deicing chemicals. A comprehensive evaluation of factors responsible for concrete surface scaling disclosed that, the following may causes. Concrete materials, proportions, and properties (air content, air void system, aggregate, cement paste, aggregate-paste interface, compressive strength, water-cementations materials ratio, degree of saturation of concrete, and chemical admixtures); Construction practices (consolidation, finishing, curing, hot and cold weather protections, drainage, and surface treatments); concrete maturity; and Dicing salts (salt type, concentration, timing of exposure) on scaling.

Therefore, Concrete should be air-entrained for the protection of the paste during freezing. Concrete should have a good air-void system consisting of numerous fine, discrete spherical and near-spherical air voids of sizes up to 1 mm, the majority of which should be very fine.

A. Concrete should be made using well-graded, well distributed, and frost-resistant aggregates.
B. Concrete should be properly placed, finished, and cured.
C. Concrete should be matured, i.e., it should undergo a period of air-drying and should attain a compressive strength of at least 28 MPa (4000 psi) prior to the first exposure to freezing and deicing salts.

2.7 Repair Methods for Concrete and Masonry Defects

For proper repair works there are at least four basic procedures to be followed; such as Removal of Concrete, Surface cleaning, Surface cleaning, and Repair Material Application.

A. Removal of Concrete

When removal of part of concrete structure is required, use power driven chipping tools or hydro demolishing equipment to remove all loose or defective concrete. Avoid defect to sound concrete to remain in place. Avoid hitting reinforcement steel with the chipping tools. Once the initial concrete is removed, use small power-driven chipping or hydro demolishing equipment to undercut all exposed reinforcement steel. Expose the entire perimeter of the steel bars for the full area of the repair. Provide a minimum clearance of 1cm between the exposed steel and the surrounding concrete or two times the maximum aggregate size, whichever is greater. Remove additional concreter as necessary to keep the repair area to a reasonably uniform depth. Defect to sound concrete or to the bond of reinforcement steel outside the repair area shall be repaired at the Contractor’s expense. The Contractor shall obtain approval of the completed concrete removal before proceeding to surface preparation.

B. Surface cleaning

The area to be repaired shall be cleaned by abrasive blasting, high pressure water blasting, or other methods approved by the Engineer. All loose particles, dirt, deteriorated concrete, or other substances that would impair the bond of the repair material shall be removed. Exposed reinforcement steel of concrete, rust and other contaminants shall be cleaned and this should be followed with a high pressure air blast for final cleaning.

C. Substrate Preparation

Unless directed otherwise, use a bonding agent if cement mortar or concrete is used for the repair material. Use either a cement scrub or epoxy as the bonding agent. Follow the manufacturer’s recommendations for bonding agents if pre-packed repair material is used. Avoid using an epoxy bonding agent with rapid setting repair materials. Apply a cement scrub coat bonding agent to the saturated surface-dry substrate by scrubbing, brushing, or other methods approved by the Engineer immediately before placing the repair material. Apply an epoxy bonding agent in accordance with the manufacturer’s recommendations. Ensure that any bonding agent used does not set or cure prematurely, creating a bond breaker.

Where saturated surface-dry (SSD) conditions are needed, pre wet the substrate by pounding water on the surface for 24 hr. before placing the repair materials. If pounding is not possible, achieve SSD conditions by high-pressure water blasting 15 to 30 min. before placing the repair material. A saturated surface-dry condition is achieved when the surface remains damp when exposed to sunlight for 15min.

D. Repair Material Application

Place the repair material in an approved manner ensuring that the repair material is in intimate contact with the substrate and free of voids. Follow the manufacturer’s recommendations for pre packed repair materials. Place the repair materials so that the original lines and surfaces of the structure can be restored.

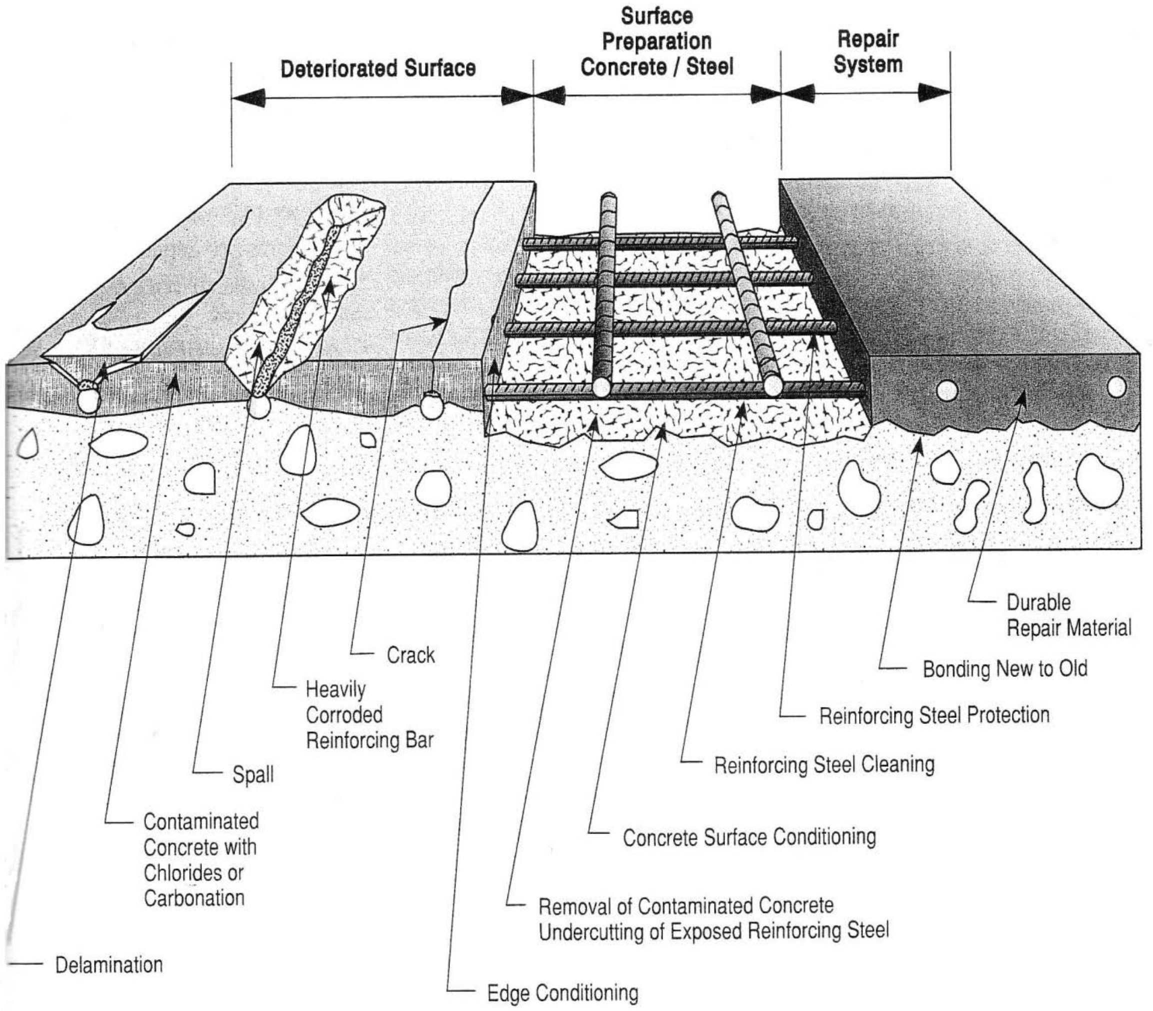

Figure 5: Anatomy of Surface Repair (Emmons and Vaysburd, 1995

Repair methods for Concrete and masonry Structure Cracks, It is common practice by contractors to hack/chisel out such areas and to have them repaired by application of ordinary mortar constituted of cement and sand. These kinds of repairs eventually fail due to shrinkage and lack of proper bonding between the old and the new mortar or concrete.

Typical repair systems for cracks are epoxy or cementations based. Epoxies are applicable to small, deep cracks. Application can be by gun injection or pouring after appropriate preparation. Cementations systems are used for large, shallow cracks. Application can be by hand, troweling or gun spraying. If the crack is reasonably deep repairs are undertaken through buildup.

Before sealing or injecting any materials, it is important to ascertain why and how the cracks originated; this will significantly affect the selection process of repair materials. All cracks should be thoroughly cleaned to ensure a strong bond develops between interfaces. In reinforced concrete, cracks wider than about 0.3 to 0.4 mm should be sealed and filled by injection. Before deciding the most appropriate method/material for repairing/sealing a crack, a determination should be attempted on its cause and whether it is active or dormant. Whether the crack is active, may be determined by periodic observation. A crack resulting from a rare load-application, and which has ceased to propagate, can be repaired (if it is wider than about 0.3 to 0.4 mm) by pressure-injection with suitable epoxy- formulation so that the integrity is restored and any adverse influence on the service life the structure is eliminated or minimized.

Dormant cracks, in excess of about 0.3 to 0.4 mm width, must be cleaned and then filled and sealed, by epoxy-injection for widths up to about 1 mm, and fine cement grout for wider cracks. Where live crack width exceeds about 0.3 to 0.4 mm, "V-groove" should be made along the crack, the groove and the cracks cleaned by a dry air-jet, and then filled to parts of its depth by a flexible filler to prevent ingress of moisture and other deleterious materials. After the crack has become dormant, the filler can be removed and the crack cleaned and filled with a rigid (epoxy) filler.

Caulking method is used for cracks wider than about 0.5 mm. cutting the concrete along the cracks, and then fill the materials which are Elastomeric sealer for seal it, and cement grout or mortar, fast-setting mortar for dormant cracks. In case of non-corroded reinforcing bar, after cut the concrete with figure " V" or " U " type, and then filled the materials. " U "type, after cut the concrete at both side of the cracks, then should have chipping off among area. " V "type is easily to cut the concrete although, but also easy to take off the filled materials. So recommend to use "U "type. In case of corroded reinforcing bar, should take off the rust in the first place. There are many cases to be rusted expand around, so must be repaired including such area. Stitching "across "the cracks in reinforced concrete members are done either along the cracks or as a series of bands around the members. Reinforcement is placed across the cracks in suitable grooves which are suitable grunted or gahnite / shot Crete d. Steel pins are used to stitch across the cracks.

Jacketing method involves fastening of external material over the concrete members to provide the required performance characteristics and restoring the structural value. The jacketing materials are secured to concrete by means of bolts and adhesives or by bonding with existing concrete. Fiber-glass reinforced plastics, and polypropylene can also be used for jacketing.It is possible to repair non structural cracks by filling the gap using high polymer special adhesive materials like epoxy resin; however structural cracks can be effectively maintained if and only if the load carrying capacity of the section is improved by provision of sufficient reinforcement system. Therefore this Bridge Maintenance Manual separately deals with the above two types of cracks. The user of this Bridge Repair Manual shall conduct a detail structural investigation of the bridge to categories the observed cracks as structural or non structural before applying any of the maintenance schemes specified below.

Cracks of reinforced and plain concrete components like deck slabs, girders, curb and railings, concrete abutments and piers, and other components of bridge shall be repaired as per this section of the Bridge Repair Manual of repair. The main purpose of structural crack repair is to restore structural integrity across the crack, to increase load carrying capacity of the section and to block access of water and other harmful chemicals to the reinforcing steels. Stitching with reinforcement steel pins bonded with epoxy resin.

This task involves repair of single live cracks width more than 5 mm or multiple cracks width of more than 3 mm, together with water leakage, free lime or salt. In bearing area, single crack width of more than 3 mm and multiple crack width of 1 mm which cause reduction in loading capacity.

This is Bridge Repair Manual applied when tensile strength must be reestablished across major cracks. Stitching a crack tends to stiffen the structure, and the stiffening may accentuate the overall structural restraint, causing the concrete to crack elsewhere. Therefore, it may be necessary to strengthen the adjacent section using external reinforcement embedded in a suitable overlay.

The work covered by this division of the Bridge Repair Manuals consists of furnishing all labor, materials and equipment to perform all operations in connection with the complete installation of the work, which involves drilling holes on both sides of a crack and grouting in stitching dogs (U–shaped metal units with short legs) that span the crack according to defect analyses and/or as specified herein.

Material, Epoxy adhesives used to rebound the crack should conform to ASTM C 881, Type I, low-viscosity grade.

High yield strength Reinforcement bar reinforcing steel AASHTO M31Procedure

Drilling holes on both sides of the crack, cleaning the holes, and anchoring the legs of the dogs in the holes, with either a non shrink grout or an epoxy-resin-based bonding system. The stitching dogs should be variable in length and orientation or both, and they should be located so that the tension transmitted across the crack is not applied to a single plane within the section but is spread over an area.

Spacing of the stitching dogs should be reduced at the end of cracks. In addition, consideration should be given to drilling a hole at each end of the crack to blunt it and relieve the concentration of stress.

Where possible, both sides of the concrete section should be stitched so that further movement of the structure will not pry or bend the dogs. In bending members, it is possible to stitch one side of the crack only. Stitching should be done on the tension face, where movement is occurring. If the member is in a state of axial tension, then the dogs must be placed symmetrically, even if excavation or demolition is required to gain access to opposite sides of the section.

The dogs are relatively thin and long and cannot take much compressive force. Accordingly, if there is a tendency for the crack to close as well as to open, the dogs must be stiffened and strengthened, for example, by encasement in an overlay.

Note: Stitching will not close a crack but can prevent it from propagating further. Where there is a water problem, the crack should be made watertight as well as stitched to protect the dogs from corrosion. This repair should be completed before stitching begins. In the case of active cracks, the flexible sealing method (Act No. 104) may be used in conjunction with the stitching techniques.

No remedies (repairs) to the newly repaired concrete shall be performed without the prior inspection and approval the Employer's Representative. On completion of the works, the site shall be cleaned of all surplus materials and waste, and left in clean, tidy condition

2.7.1 Injection with flexible filler

Description: The task involves repair of single live cracks width of more than 1 mm or multiple crack width of more than 1 mm. In bearing area single crack of less than 1mm with no water leakage in concrete bridge structures.

This Bridge Repair Manual covers the repair of cracks for flexible seals of an active crack against the migration of water into the crack. This method involves routing out active cracks; cleaning them by sandblasting, air-water jetting, or both; and filling them with flexible Bonder or other suitable field-molded flexible sealant. Flexible Bonder is used for active cracks when a bond breaker is placed over the crack.

The work covered by this division of the Bridge Repair Manuals consists of furnishing all labor, materials and equipment according to defect analyses as shown on the Drawings and/or as specified herein.

Figure 6: Injection with flexible filler

Material

Flexible sealant or mastic, polyethylene strip / pressure-sensitive tape bond breaker. Non Structural cracks observed on RC or Plain Concrete components of bridges are effectively repaired with high polymer materials such as Epoxy resin, polyurethane resin, Acrylic and others; either by high pressure injection (up to 30N/mm2) or low pressure injection (up to 2 N/mm2) techniques. The main purpose is to restore structural integrity across the crack and to block access of water and other harmful chemicals to the reinforcing steels.

Procedure

Traffic warning signs shall be established at both ends of the work sectionFor a recessed flexible seal, the crack should be routed to provide a sealant reservoir (slot) that complies with the requirements for width and shape factor of a joint having equivalent movement. Selection of a suitable sealant and installation method should follow the procedure for equivalent joints as given in ACI 504R (Ref c).

The crack should then be cleaned by sandblasting, air-water jetting, or both. A bond breaker should be provided at the bottom of the slot to allow the sealant to change shape without a concentration of stress on the bottom. The bond breaker may be a polyethylene strip, pressure-sensitive tape, or other material which will not bond to the sealant before or during cure. Narrow cracks subject to movement, where esthetics are not important, may be sealed with a flexible surface seal. By using a bond breaker over the crack, a flexible joint sealant may be troweled over the bond breaker providing an adequate bonding area.

To maintain hydraulic efficiency in some structures, it may be necessary to cut the concrete surface adjacent to the crack and to place the retaining cap flush with the original flow lines. The crack should then be cleaned by sandblasting, air-water jetting, or both. The mastic is placed into the routed crack slot and a retaining cap placed over the mastic to confine it. A simple retainer can be made by positioning a metal strip across the crack and fastening it to expandable anchors or grouted bolts installed in the concrete along one side of the crack. No remedies (repairs) to the newly repaired concrete shall be performed without the prior inspection and approval the Employer's Representative.

On completion of the works, the site shall be cleaned of all surplus materials and waste, and left in clean, tidy condition.

2.7.2 Injection with rigid epoxy filler

Description

The task involves repair of single dormant crack width of more than 1 mm or multiple crack width of more than 1 mm. In bearing area single crack width of less than 1mm with no water leakage in concrete bridge structures such as deck slab and girder.

Epoxy injection of cracks in concrete is a highly skilled process and its success depends largely on the efficiency of the operator. Considerable skill and experience are needed for the successful application of epoxy resin materials. They have to be applied within a very limited time before they harden and have to be handled cleanly to avoid contamination of both the resin mixture and the people working with them. Therefore, the Supervisor should make sure that the Contractor's personnel appointed for this particular job are a specialist on the matter.

This Bridge Repair Manual covers the repair of cracks for rigid sealing, dry, moist or wet cracks in reinforced concrete members by means of an epoxy injection system. However, unless the crack is dormant (or the cause of cracking is removed, thereby making the crack dormant), cracking will probably recur, and structural repair by injection should not be used.

This system shall consist of a paste epoxy used to seal the surface cracks and an injection epoxy used under low pressure [1400kPa max.] to penetrate and fill the cracks and bond the crack surfaces together. Material for each epoxy shall consist of a two-component modified resin bonding system. The unmodified resin shall be known as Component A and the hardener as Component B. The work covered by this division of the Bridge Repair Manuals consists of furnishing all labor, materials and equipment according to defect analyses as shown on the Drawings and/or as specified herein

Accurate batching and proper mixing of the components is crucial for attaining maximum strength and other properties of the epoxy materials. Chemical reactions start as soon as the resin components are combined and the working time shall depend on the system, the temperature and the handling process.

Materials

Epoxy Injection fluid shall confirm the following Bridge Repair Manual requirements: The resins for crack injection system shall have a two part solvent free low viscosity, polymer. The flexible, low viscosity, polymer, crack injection resin system when mixed in the proportions specified by a supplier, supplied & injected in to cracks in concrete, the resin shall form a slightly flexible & impermeable barrier in both dry & damp condition, and thus, shall form permanent seal in cracked concrete.

Procedures

Traffic warning signs shall be established at both ends of the work section. The contractor shall prepare access and platform on which workers shall stand and perform the crack maintenance operation. No separate payment shall be made for preparation of false works to access the defected part of the bridge. Any expense related to preparation of access is assumed to be incorporated in unit rate of crack maintenance operation.

A-The cracks shall be as clean as possible before injection. It shall be free from dusts using a proper brushing material like disc sander or wire brush. By drilling holes at close intervals along the cracks, the epoxy resin will be injected under pressure.

B-Cracks at the surface shall be sealed to keep the epoxy from leaking out before it has gelled. The surface can be sealed by brushing an epoxy on the surface of the crack and allowing it to harden. Entry ports for epoxy shall be provided, spaced far enough apart to assure that when the adhesive material shows at the adjacent port, it has completely filled the crack to its full depth. Entry ports shall be spaced along cracks and spacing usually determined by the tightness of the crack and the depth of the concrete substrate. Spacing is generally between 15 and 35 mm. A small reservoir shall be provided below the bottom of the port to aid in resin flow.

Injection ports shall be inserted into the drilled holes to about 13 mm allowing for the small reservoir below the port. Care will be taken not to seal the ports from resin flow. If surface port system is used, care will be taken to insure that the crack is open at the point below the port, and that there is a proper reservoir beneath the port.

A surface seal or epoxy patch meeting the requirements of this Bridge Repair Manual shall first be applied to the exterior crack to prevent the escape of the injection resin. The cracks shall be covered with a bead of Epoxy Bonding Paste and smoothed with a putty knife to insure sealing.

Injection of the epoxy resin into a crack shall, unless permitted by the Engineer, begin first at the entry port of lowest elevation and continue until uncontaminated epoxy flows out of the adjacent port. The connection between the entry port and the mix head of the injection nozzle must be sufficiently tight to prevent epoxy from running out on the concrete surfaces. After injection at a given port is complete, this port shall be plugged and injection started at the next adjacent port. This procedure shall be repeated until the crack is completely filled. Epoxy injection requires personnel with a high degree of skill for satisfactory execution.

The process used for epoxy injection shall fill the entire crack with liquid epoxy resin system and shall contain the resin system in the crack until it has hardened. The Contractor shall be responsible for drilling and removing three, a minimum of 5-cm-diameter cores from the injected concrete at locations determined by the Contracting Officer to determine the completeness of the injection repair.

Injection shall be considered complete if more than 90 percent of the void is filled with hardened epoxy. If injection is not complete, rein injection and additional cores may be required at the direction of the Contracting Officer at no additional cost to the Employer.

No remedies (repairs) to the newly repaired concrete shall be performed without the prior inspection and approval the Employer’s Representative. Upon completion of resin injection, all excess material shall be removed from the exterior surfaces of the concrete. The final finished surfaces shall match the texture of the surfaces adjoining the repair areas.

2.7.3 Caulking using Cement grout (Hydraulic) or Cement rigid epoxy filler

Description

The task involves repair of single dormant cracks width of more than 5 mm or multiple cracks width of more than 3 mm, together with water leakage, free lime or salt. In bearing area, single crack width of more than 3 mm and multiple crack width of 1 mm which cause reduction in loading.

The job consists of cleaning the concrete along the crack, Cutting the concrete following along the crack with a concrete saw or with hand or pneumatic tools and opening the crack sufficiently in to “v” or “u” shape to receive the cement grout or mortar installing injection ports (grout nipples) at intervals astride the crack (to provide a pressure-tight contact with the injection apparatus), sealing the crack between the injection ports, flushing the crack to clean it and test the seal, and then grouting the crack.

Materials

Mixture of neat Portland cement and water, Portland cement. Other additives and admixtures (siliceous residue, diatomite) may be added on the approval of the Engineer. The proportions of ordinary Portland cement to sand will depend upon the size of the spaces to be filled and will vary from a neat grout to about 1:2 mix. Mix containing two parts sand to one part cement can be successfully pumped if all the sand passes the No. 16 sieve and 15 percent or more passes the No. 100 sieve. The amount of water to be added depends upon the consistency required. Grouts with as little as 16 liters of water per bag of cement could be handled and it should seldom be necessary to use more than 35 to 40 liters of water per bag of cement. Where necessary and approved by the Engineer, admixtures to Portland cement grout mixtures may be added for delaying the setting time, increasing flow ability minimizing segregation and shrinkage. Apply Bond-Aid at a rate of 32.5-m²/3.8 liter for brush application. For spray application, dilute with a small amount of water to a suitable spraying viscosity and apply at a rate of 23.2-m²/3.8 liter.

Materials shall conform to the following requirements: Fine aggregate (natural sand) the grading shall comply with AASHTO M6-81Portland cement AASHTO M 85-01, Air-entraining admixture AASHTO M 154 Water: Water shall be fresh, clean, and free from injurious amounts of sewage, oil, acid, alkali, salts, or organic matter.

2.7.4 Repair methods for Concrete Peel off, Delaminating and Void

Concrete voids are created due to poor vibration of fresh concrete during pouring (unable to vibrate it sufficiently) or failure to vibrate it before the initial setting time. Concrete voids on the permanent structures have to be maintained to restore the integral concrete strength of the structure designed to act as a unit, and to protect reinforcements and the concrete from effect of water leakage or dampness which potentially generates rusting and deterioration. Removal of the defective concrete and replacement with a suitable material and workmanship are the major techniques discussed under this Bridge Repair Manual.

2.7.4.1 Concrete Void repair by using Dry-Pack mortar

The task involves repair of partial range of honeycomb or de lamination, which affect the durability of concrete bridge structures. This item shall consist of furnishing the necessary labor, material and equipment to repair honeycomb and delaminating in concrete bridges with dry-pack methodology, the item includes preparation, mixing, placing, finishing and curing of the dry-pack mortar.

Dry packing is a process of ramming or tamping into a confined area a low water-content mortar. Because of the low w/c material, there is little shrinkage, and the patch remains tight and is of good quality with respect to durability, strength, and water tightness. This technique has an advantage in that no special equipment is required. However, the method does require that the craftsman making the repair be skilled in this particular type of work.

Materials

The material needed for maintenance by dry-packing method is a slurry bond and a low water-content mortar. The cement slurry bond coat consists of equal parts of cement and fine sand and the mortar consists of one part cement, two and one-half (2½) to three (3) parts sand passing a No. 16 sieve, and only enough water so that the mortar will stick together when molded into a ball by slight pressure of the hands and will not exude water but will leave the hands dry.

If the patch must match the color of the surrounding concrete, a blend of Portland cement and white cement can be used. About one-third white cement is adequate for blending, but the precise proportions should be determined by trial. Dry pack mortar shall consist of type I or II Portland cement, clean sand that will pass a 1.18mm (No. 16) sieve, and clean water.

Procedures

The Employer's Representative will indicate what part of the existing structure is to be removed and the required dimension of the new work. The area to be repaired should be undercut slightly so that the base width is slightly greater than the surface width.After the area or slot is thoroughly cleaned and dried, a bond coat should be applied. Placing of the dry-pack mortar should begin immediately.

Dry-pack mortar should be placed in layers having a compacted thickness of about 10 mm (3/8 in.). Each layer should be compacted by use of a hardwood stick. It is usually necessary to scratch the surface of the compacted layers to provide bond for the next layer. One layer may be placed immediately after another unless an appreciable rubbery quality develops; if this occurs, work on the repair should be delayed 30 to 40 minutes. Under no circumstances should alternate layers of wet and dry materials be used.

Successive layers of dry pack are placed without interval, unless the material becomes spongy, in which case there should be a short wait until the surface stiffens. Areas should be filled flush and finished by striking a flat-sided board or the flat of the hardwood stick against the surface.

After being finished, the repaired area should be cured. Procedures for curing and protection of dry pack are essentially the same as those for concrete. Additionally, the dry pack repair area should be protected and not exposed to freezing temperatures for at least 3 days after application of the curing compound.

No remedies (repairs) to the newly repaired concrete shall be performed without the prior inspection and approval the Employer's Representative. On completion of the works, the site shall be cleaned of all surplus materials and waste, and left in clean, tidy condition. Concrete Void repair by using Portland Cement/Sand mix mortar blended with Epoxy Resin

The task involves repair of wide range of voids, which affect the durability of concrete bridge structures. Volume of less than 600 cm^3.The concrete Void will be repaired by a Portland Cement/sand mix mortar blended with Epoxy Resin. The plastering will be applied either using a pressure grout or conventional hand tools. In areas where formwork erection and concrete casting is possible, the maintenance operation is done using a Portland Cement Concrete. The suitable concrete mix shall have a minimum cement content of 340kg/m3 with a maximum nominal aggregate size of 10mm and a slump in the range of 25mm to75mm. The same techniques of mixing and paving of the cement based polymer modified concrete shall be adopted as concrete peel of maintenance.

Materials

Like the maintenance concrete peel off and/sapling, all ingredients of mortar and concrete materials shall fulfill the Standard Technical Bridge Repair Manual – 2002, Division 8400 of ERA. The Epoxy Resin and cement based polymer modified concrete shall also fulfill the Bridge Repair Manuals set above.

Procedures

Employer's Representative will indicate what part of the existing structure is to be removed and the required dimension of the new work. Determine the extent of defective area by sounding with a hammer or other approved method and mark the area to be removed. Remove all defective concrete portions marked up to 10 mm below the reinforcement, if any, using the following techniques

- Small pneumatic hammer
- Small electric jackhammer
- Sludge hammer and chisel

The concrete may be removed using high - pressure water blasting. In all the aforementioned techniques, care must be taken to avoid defect to the surrounding concrete.After properly cleaning the removed part, the old concrete surface shall be primed with Epoxy Resin (avoid applying too thickly). The concrete Void will be repaired by a Portland Cement/sand mix mortar blended with Epoxy Resin. The plastering will then be applied either using a pressure grout or conventional hand tools. In areas where formwork erection and concrete casting is possible, the maintenance operation is done using a Portland Cement Concrete. The suitable concrete mix shall have a minimum cement content of 340kg/m3 with a maximum nominal aggregate size of 10mm and a slump in the range of 25mm to75mm. The same techniques of mixing and paving of the cement based polymer modified concrete shall be adopted as concrete peel of maintenance.

Forms and scaffolds shall be erected both for the actual construction purpose and for curing of the fresh mortar or the Portland cement concrete. No remedies (repairs) to the newly repaired concrete shall be performed without the prior inspection and approval the Employer's Representative. On completion of the works, the site shall be cleaned of all surplus materials and waste, and left in clean, tidy condition.

2.7.4.1Preparatory works

It is always better to avoid imperfections such as honeycombing in concrete rather than have to repair them. However, if honeycombing does occur then it can be repaired using the following techniques. The extent and depth of the honeycombed area first needs to be defined. This can be done by chiseling out the affected area to expose sound concrete or by using non-destructive testing techniques such as impact-echo. If the honeycombed area is small in extent and depth does not significantly jeopardize the quality of the cover concrete protecting the reinforcement then, it can be repaired by patching with mortar of a similar colour to the base concrete. Any lightly attached stones should be removed before the mortar is worked into the spaces between the aggregate ensuring that it completely fills the honeycombed area. The area should be slightly over filled and screeded off to give a similar texture to the surrounding surface. The patch should then be cured. Consideration needs to be given to the appearance of the repaired surface relative to adjacent untreated surfaces. As a general rule, mortar used for patching should be made from the same materials as the original concrete except that a proportion of off-white cement should be mixed with the original cement to lighten the colour and thus better match the existing surface. If the honeycombing is extensive and penetrates down to the reinforcement or even deeper then it is necessary to cut out the defective concrete and replace it with sound concrete. It is essential that the reinforcement be surrounded by sound concrete. The advice of a suitably qualified engineer should be obtained to check that the load-carrying capacity of the member, as repaired, will be satisfactory.

2.7.4.2 Resurfacing

Honey combing may be repaired by using Dry-Pack Patching Resurfacing Gunite / shot crete Gunite Pre-placed aggregator-surfacing method, here-in after, describing about polymer concrete overlay. A polymer concrete overlay protective system has been used as an experimental project in several countries. The overlay consists of an application of monomer resin to the desk surface, followed by an application of the fine aggregate. The process is repeated until four layers have been placed. The overlay is relatively impermeable and skid resistant. Generally, the resin is over the deck and fine aggregate is covered over the resin. After polymerization, the excessive aggregate is removed and the process is repeated for other layers. The four layers produce a thickness of about 12 to 15 mm. The overlay system consists of the following steps for each layer.

1- Surface Preparation,
2- Mixing And Application of monomer Resin,
3- Fine Aggregate Application and compaction,
4- Polymerization of Monomer and Removal of excess aggregate.

2.7.5 Repair methods for Scaling, wearing and spoiling of Concrete

Scaled concrete surfaces can be repaired by applying a thin resurfacing of concrete properly bonded to the underlying old concrete. All defective concrete must be removed from the surface, by scarifying or scrubbing with hydrochloric acid, before applying the new concrete.

A thin layer of neat cement paste should be brushed into the damp surface of old concrete just before the new concrete is placed to secure a good bond. The new concrete is placed, finished, and cured by normal procedures. Any relief joints present in the old concrete should be carried through the new resurfacing.

2.7.6 Other defects, causes and repair methods

2.7.6.1Scouring and Erosion

Bridge scour is one of the three main causes of bridge failure. It has been estimated that 60% of all bridge failures result from scour and other hydraulic related causes. It is the most common cause of highway bridge failure in some countries like the United States, where 46 of 86 major bridge failures resulted from scour near piers from 1961 to 1976. Scour failures tend to occur suddenly without prior warning and are very difficult to monitor during flood events.During flooding, although the foundations of a bridge might not suffer damage, the fill behind abutments may scour. This type of damage typically occurs with single-span bridges with vertical wall abutments.

Foundations must transfer all loads imposed on the bridge into the ground. If the foundation is not strong enough or deep enough to do this, the bridge will be destroyed. If the foundation embedment into the ground is not sufficient to account for erosion and scour that may occur over the life of the bridge, the bridge is vulnerable to collapse under design flood and wind conditions.

Predicting the incidence, location, and magnitude of coastal erosion and scour is difficult, and present-day bridge codes and standards do not prescribe clear-cut solutions for designers. Therefore, designers should be conservative with their foundation designs. This means foundations may need to be stronger, deeper, and higher than what has historically been used. Lessons learned from Hurricane Ike and other recent coastal storm events should be incorporated into foundation designs.

Erosion refers to a general lowering of the ground surface over a wide area. Erosion can occur across a wide range of timeframes – it can be gradual, occurring over a long period of time (many years); more rapid, occurring over a relatively short period of time (weeks or months); or episodic, occurring during a single coastal storm event over a short period of time (hours or days).Scour refers to a localized loss of soil, often around a foundation element.

Scour occurs when floodwater passes around obstructions in the water column. As the water flows around an object, it must change direction and accelerate. Soil can be loosened and suspended by this process or by waves striking the object, and be carried away. Pilings, pile caps, columns, walls, footings, slabs, and other objects found under bridges can lead to localized scour. Scour effects increase with increasing flow velocity and turbulence, and with increasing soil erodibility.

Figure 7: Scouring and Erosion

The effects of scour can change throughout the life of a structure. Accumulations of silt and debris may reduce the channel of a river or cause it to follow a different course.Similarly the uncontrolled extraction of gravel or sand from river beds can affect the flow, causing scour at bridges further along the river. As scour can completely undermine the foundations of a bridge and thereby cause it to collapse, it is essential that its occurrence is detected at an early stage or preferably prevented. Sometimes scour causes large holes in river beds or washes large sections of the bank away. Many bridges have been destroyed by scour. Rivers can easily damaged or destroy bridges. Usually, bridges are damaged when the river is too big to go through the waterway under the bridge, or when the river changes its path.

There are 3 reasons why a river may not be able to go through the waterway of a bridge:

1. A river can grow and become too big for the waterway.
2. The waterway under the bridge can be blocked by parts of old bridges, trees, fences and other debris.
3. The waterway under the bridge was not made big enough.

If there is a flood which is too big for the waterway under the bridge, the river may do 3 things:

1. Wash away the bridge.
2. Wash away the road embankment and the road, and go round the bridge.
3. Wash away the fill in front of the abutments, and scour big holes in the river bed.

If the-waterway is too small, another bridge or some culverts may be needed to carry the extra; floodwater. River can change their path slowly or very quickly. Change of path can, after a time, cause damage to a bridge.

2.7.6.2. Water leakage and deteriorations

Causes of water leakage

An extended water leakage leads to the deterioration of the bridge part prone to this specific defect. The repair technique dealt under this Bridge Repair Manual therefore enables to protect the concrete section from being continuously degraded.

Water leakage under concrete may be caused due to cracks, voids, concrete porosity, absence of impermeable wearing course, defect to joint sealants, or blockage of drains.

Stopping serious and wide range of water leakage that passes through cracks or voids which, may progress and cause a reduction in loading capacity together with leaching free lime or salt is an essential activity.

Bridge drainage is also an important inspection-item since any trapped or pounded water can cause a great deal of defect to a bridge and is also a safety hazard. Therefore, an effective system of drainage that carries the water away as quick as possible is essential to the proper maintenance of the bridge.

Accumulation of debris compounded by design oversights is principal cause for surface drainage inlet-clogging. The ponds and puddles of water that form on the bridge deck pose the problem which constitute a safety hazard and can cause extensive bridge deterioration.

Downspouts and horizontal pipe-runs, which are poorly designed with inadequate slopes and sharp directional changes at the elbows, are conducive to plugging drains.

Corrosion: - drainage water often carries corrosive elements that attack drainage pipes and concrete. Clogging and slow drainage accelerate deterioration of girder, side beam and internal part of deck slabs as well as rebar corrosion.

Figure 8: Water leakage and deteriorations

2.7.6.3. Repair by Grouting – using Portland cement

The task is applicable for stopping serious and wide range of water leakage through cracks or voids which may progress and cause a reduction in loading capacity, together with leaching free lime or salt.

Wide cracks may be repaired by filling with Portland cement grout. This method is effective in stopping water leaks, but it will not structurally bond cracked sections.

Materials

Grout mixtures may contain cement and water or cement plus sand and water, depending on the width of the crack. However, the water - cement ratio should be kept as low as practical to maximize the strength and minimum shrinkage.

Procedures

Traffic warning signs shall be established at both ends of the work section

Clean the concrete along the crack

Install built-up seats (grout nipples) at intervals astride the crack to provide a pressure tight connection with the injection apparatus. Seal the crack between the seats with a cement paste. Pump grout into the crack through the nipples. Maintain the pressure for several minutes to ensure good penetration of the grout. The grout should have a water-cement ratio of one part cement to one to five parts water. After the crack is filled, the pressure should be maintained for several minutes to ensure good penetration. No remedies (repairs) to the newly repaired concrete shall be performed without the prior inspection and approval the Employer’s Representative.

On completion of the works, the site shall be cleaned of all surplus materials and waste, and left in clean, tidy condition

2.8. General procedure for Application of materials

The areas to be treated must be free from all unsound material that is dust oil, corrosion, by-products and organic growth. Smooth surfaces should be roughened; all loose material and surfaces removed and steel cleaned to bright metal preferably using wet grit or water blasting techniques or equivalent approved methods.

The prepared substrate concrete should be thoroughly soaked (preferably 24 hours before) with clean water until uniformly saturated without any standing water. Highly porous substances may require sealing with polymer admixture.

Mix of priming material shall be as per the specification of the manufacture. Placing Shall be applied using spray techniques. Make sure air is not entrapped and ensure total protection is achieved to the satisfaction of the Resident Engineer. Manufacturer specification shall be strictly followed. Application of curing membrane should take place as soon as practicable after final finishing after any residual surface water form trawling has evaporated. But generally, manufacturer specification shall be strictly followed It is important that the surface of the coating is protected from strong sun light and drying wind with curing membrane.

For maximum curing efficiency, if the surface is subject to strong sunlight or drying winds, a second coat should be applied. This waiting time is generally 15 minutes, whilst the first coat is still tacky, depending upon temperature and the effects of wind.

Overcoat as per the specification of the manufacturer. To obtain maximum adhesion to coatings and cement based substrates, the surfaces of the reveals should be primed with bonding primes. Sealant must be applied as per the specification of the manufacturer. Biowash shall be spray applied. It Kill active mould, fungal and bacterial spores and chlorophyll containing organisms such as moss, Lichen and algae, within a maximum of two days, Remain active after its initial application, guarding against subsequent infection for up to two years.

Application should take place after cleaning visible areas of growth by wire brush, scraper or mechanical means. Apply biowash undiluted by brush, roller or airless spray to areas exhibiting visible contamination, ensuring that all surfaces are thoroughly wetted. Wash off bleach solution and remove dead growth by hosing or brushing. Allow to dry before subsequent treatment.

Chapter Three

Bridge repair Methods

3.1. Research design

The strategy followed in this research was, first, to formulate the research design. Then Data and information sources were determined based on the formulated research design. On the basis of the data and information sources the research instruments were decided. Then the required data were collected and analyzed. Finally, available documentary sources were reviewed for cross-checking the validity and conformity of the information obtained through the overall research work.

A descriptive and exploratory case study was used in the design. It was attempted to collect data from Beko bridge defects by using simple tools local labor around the area to identify defect types and seriousness of the defect.

Case study research design has been selected to collect each defect cause and analysis each defects causes.

Improvement of functions by replacing damaged parts .Control the progress of deterioration & damage to restore necessary function and performance maintaining the present load carrying capacity of the bridge. Repair works generally add no extra strength to the bridge structure, but are only remedial measures taken to restore/bring back/ the serviceability of the bridge. The standard repair methods include crack injection, section restoration, Surface coating. For proper repair works there are at least three basic procedures to be followed; such as Removal of Concrete, and masonry surface cleaning, repair Material Application.

3.2. Source of data and data collection

Data were obtained from actual instigation of each cause of defects in the selected study area during maintenance of the bridge by Ethiopian road authority. Data collected through actual investigation where each defects are visible including the following resources,

Materials

- Small tools dagger, barrel for clearing the area around to be free from dangerous animals and insects like snake,
- Small tools like hammer, shovel, for chiseling of defect parts

- Water, brush for cleaning of chiseled part
- Materials eucalyptus, nail are used for temporary structure to creat access for investigation of defected part.
- Safety material such as safety shoe, helmets to protect from accidents and hazards.

Labor

Skilled Labor

- ✓ Carpenters to construct the scaffold
- ✓ Mason and technician for maintaining the defected part

Non skilled Labor

- ✓ Chiselers, to chisel the defected part.
- ✓ Daily labor, for clearing the area around, cleaning the defected part and assistance for skilled labor

3.3. Data analysis

The analysis of the study work is based on the concept of measurement of data. The information gathered through actual investigation was supplemented and verified by explanations based on literature review. The data was analyzed using both quantitative and qualitative approaches.

Generally, the study comprised of the following stages Preliminary activities were at identifying repairing method. and study area; Identification of the principal sources data, outlining the main headings Of the problem, and formulation of the problems; Development of the research methodology, both research strategy and data Collection Design of appropriate research instruments (labor, tools and equipments);Summarizing data gathered through actual investigation analysis of current status of bridge based on all defects gathered. Applicability of the project was reviewed.

Means of improvement of different defects visible on the bridge were identified and studied. Critical review of the research and its findings, as well as related. Recommendations; Report on the completed research work, consisting of data gathering, analysis, associated recommendations. ,

3.4 Limitations of the Research Methodology

As asses on the analysis data is collected on actual investigation. However, the study work is limited by several factors. Due to shortage of budget to full fill all resources like labor, material and equipment to identify each defects. Difficulty to assess seriousness of each defect, since detail chiseling is needed to identify depth of defects. Defects like scouring is difficult due to coverage with water major defects around girder beam need construction of scaffolding to create easy access.

Chapter Four

Present defects, problems and applications

Visible On the Bridge

4.1. The following defects shown on the bridge

4.1.1 Cracking

Concrete is by nature a brittle material, so reinforced concrete structures are destined to suffer cracking. Cracks in concrete may described in a variety of ways. Some of the more common ways are in terms of surface appearance, depth of cracking, width of cracking, current state of activity, and structural nature of the crack. Cracking can be an important indicator of deterioration taking place in concrete and possible corrosion of reinforcement steel depending on the size, extent and location of the cracks. Cracks of concrete are classified as structural or non-structural cracks.

Structural cracks are those cracks which result from insufficiency of the section to withstand the flexural, shear, settlement and other stresses developed in that section due to dead and live loads applied upon it and are divided into flexure and a shear cracks. Flexure cracks are vertical and start in the maximum tension zone and proceed toward the compression zone. Shear cracks are found near the bearing area and begin at the bottom of the member and extend diagonally upward.

Structural cracks will usually be substantial in width, and the opening may tend to increase as a result of continuous loading and creep of the concrete. Non-structural cracks: - are divided into temperature, shrinkage and mass concrete cracks. These cracks are relatively minor and generally do not affect the load carrying capacity of the member. They can, however, provide openings for water and contaminants, which can lead to serious problem. Non-structural cracks are those cracks which result from workmanship problems, shrinkage of concrete and other minor causes.

Cracking after reinforcement corrosion owing to the increase of corrosion of reinforcement; cracking before reinforcement corrosion that induces the corrosion of reinforcement;

4.1.2 Honeycomb

Honeycomb is a defect on the surface of concrete. Course aggregate with air space appears on the surface of concrete. Honeycombing occurs where the spaces between coarse aggregate particles are inadequately filled, with the result that the hardened concrete has an open structure

4.1.3 Water Leakage

This can take place at expansion joints and through concrete decks where waterproofing is absent or has failed. It will penetrate most readily at construction. Joints and areas of porosity particularly where the sections are thin.

4.1.4 De lamination

De lamination occurs when layers of concrete separate at the level of outermost layer of reinforcing bars.

4.1.5 Breakage

Breakage is a damage of destruction of concrete member, caused by collision of vehicles, Boats or other external force on bridge components.

4.1.6 Corrosion of reinforcement

The presence of excessive amounts of chloride ions, originating from the use of the admixture calcium chloride, will also destroy the passive layer, which prevents corrosion. When reinforcement corrodes it expands causing tensile stress in the Surrounding concrete which result in cracking and sapling.

Reinforcement bars rust and covering concrete is peeled off due to insufficient cover Peel off Peel off due to insufficient cover Thickness of concrete cover is generally indicated in the drawings, however the cover would become insufficient due to inadequate setting of spacer, error of reinforcement bar arrangement and movement of bars during casting of concrete. Insufficient cover is hardly detected at the time of casting concrete, however the reinforcement bar will gradually rust and swell and the concrete cover start to be peeled off.

Bridge scour is the removal of sediment such as sand and rocks from around bridge abutments or piers. Scour, caused by quickly moving water, can scoop out scour holes, compromising the integrity of the bridge. Bridge scour is one of the main causes of bridge failure. The effects of scour can change throughout the life of a structure. Accumulations of silt and debris may reduce the channel of a river or cause it to follow a different course.

4.2. Cause of defects

In concrete structures Defect in concrete structures result from many factors such as Poor design detailing construction deficiencies Structural failure due to overstress Due to excessive loading Chemical attack, Settlement of the foundation, Changes to the support or loading conditions caused by scour or silting, Failure of bearings or expansion joints, traffic collision defect

4.2.1Cause of cracks

Lack of curing and quick removal of form, etc. Variation of temperature and moisture External forces of bending moment, shearing force and fatigue differential settlement of foundation corrosion of rebar for lack of covering, chloride damage and carbonation, etc.

Fatigue/overloading on Girder / Deck Slab cracks will occur on girder/beam and deck slab by the repeated and overload wheel load. Cracks in one direction develop into a mesh of cracks Intervals of cracks are reduced by the wheel load and water through the slab and finally some parts of the concrete will peel off. Cracks will occur on girder/beam and deck slab by the repeated and overload wheel load.

Cracks in one direction develop into a mesh of cracks Intervals of cracks are reduced by the wheel load and water through the slab and finally some parts of the concrete will peel off.

4.2.2 Cause of Honeycomb causes

Cause of Honeycomb causes - are segregation of material during concrete casting, insufficient compaction of concrete and leaking of cement paste through forms. It is caused by the loss of cement grout where form work is inadequately sealed or by segregation of the wet concrete. Honeycomb shall be repaired at the construction time, before handing over the original work, with supervision. Appearance of honey comb on concrete structures resulting

1. Decrease concrete strength

2. Exposing rebar exposure for external environment

4.2.3 Cause De lamination

The major cause of de lamination is expansion of corroding reinforcing bars. This is commonly caused by intrusion of chlorides or salt. Delaminated areas give a hollow sound when tapped with a hammer.

4.2.4 Water Leakage

Water leakage occurs due to the following causes. Cracks Porous construction joints Honeycomb and cold joints Cast-in-fittings such as drain pipe, etc. Deterioration of concrete Corrosion of reinforcement the corrosion of reinforcement is caused by carbonation and chloride attack. Carbonation involves the protective alkaline environment provided by good quality concrete.

4.3. Measuring and Quantifying Defect

Figure 9: Scaffolding during measuring and quantifying of defects

4.3.1. Measuring Defects

Different defects estimated using traditional instruments like measuring tape, and observational estimation because there is limitation of standard measuring instrument.

4.3.2. Quantity Estimation on concrete structure

4.3.2.1 Average Method /virtual cube for Honeycomb & Peel off

Depth of honeycomb and/or peel off are not uniform In order to estimate quantities used for repair complicated defect is virtually replaced by a cube with simple rectangular repair and average repair depth. Average repair depth is calculated: Partition of overall chipping area into some small areas with their representative depths;

Each partition has the area of A i and representative depth of d i

Overall chipping area $A = \sum A_i$

Average repair depth $d_{ave} = \sum A_i d_i / \sum A_i$

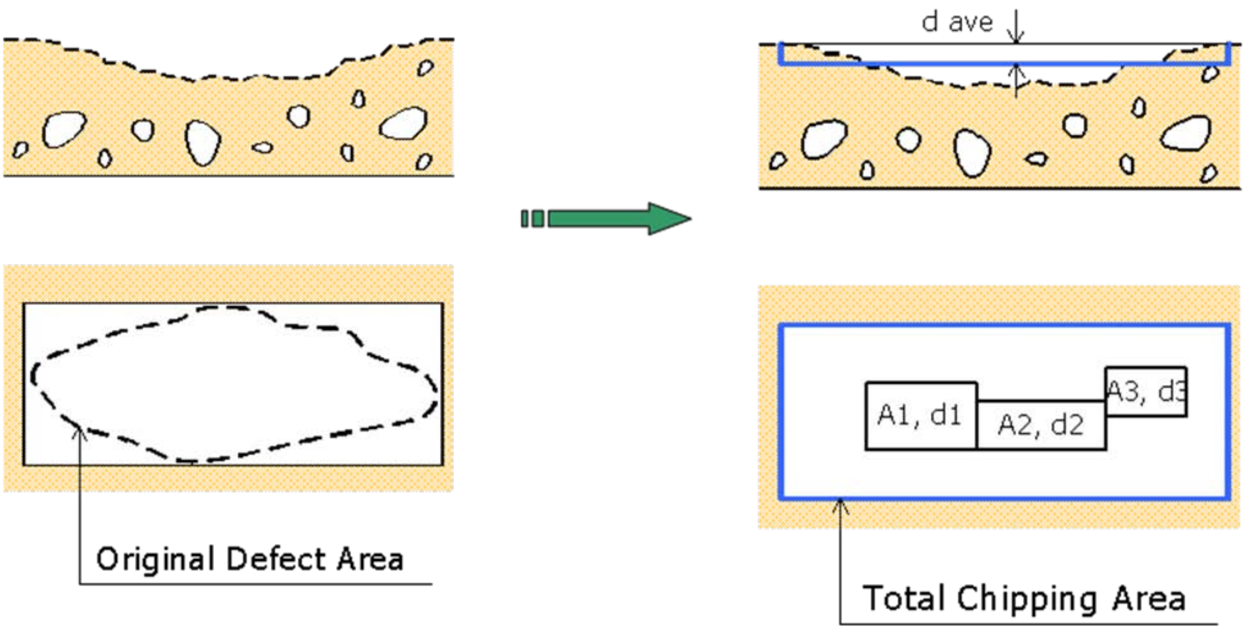

Figure 10: Average Method /virtual cube

4.3.2.2 Crack Measuring

Find depth of crack types of crack measurements Drilling core Use of ink and Chipping Ultrasonic Test Coring is drilled at center of crack Ink is poured into a crack followed by chipping work to a depth until such ink is disappeared. This is to transmit ultrasonic wave from a transmitter (T) to a receiver (R) and measure the transmission Width of crack measured by calipers.

4.3.3. Measuring Instruments/tools used Concrete members

Crack, separation, honeycomb → Ultrasonic flaw detector

Concrete strength → Schmidt hammer

Position, cover, diameter of steel bar → Profometer

Corrosion of steel bas → Corrosion hunter for steel bar

4.4. Materials, Their Property and Application

Materials used for bridge repair work are:-

- EMACO R S88CT
- Fosroc Rendroc Tgxtra
- Fosroc Nitbond
- Bond EP+Fosroc solvent
- Fosroc Nito mortar Fc
- Fosroc Nitro fill Eplv

Rheofibr used as additive, for crack controlling agent in EMACOR S88ct, Fosroc Rendroc TGxtra

Materials Used for Bridge Repair Work

We use unusual materials rather than normal cement mortar

Nitobond EP

- Epoxy Resin concrete Bonding Agent
- Base and Hardener
- Base is White and Hardener is Green
- Bonding fresh wet cementitious materials to Existing surface

Mix Proportion

1. Can of base,1can of hardener
2. On site Mixing
3. Each component shall be thoroughly to Disperse any Sedimentation

EMACO S88 CT

- Polymer and Acrylic Fiber reinforced
- Cementitious pre- bagged ready to use repair mortar
- Polymer used for compensate shrinkage
- Fiber used improve tensile Strength

Mix proportion

- 3.5Liter of water
- 25kg bag EMACO S88CT Powder

EMACO S88 CT

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- Polymer and Acrylic Fiber reinforced
- Cementations pre- bagged ready to use repair mortar
- Polymer used for compensate shrinkage
- Fiber used improve tensile Strength

Mix proportion

- 3.5Liter of water
- 25kg bag EMACO S88CT Powder

Renderoc TGXtra

- Polymer – Modified Cementitious Repair mortar

Mix proportion

- 4.5 Liter of water
- 25kg bag renderoc TGXtra powder
- 8g of polypropylene Fiber

Nitomortar FC

- Epoxy resin fairing crack repair mortar
- Base and Hardener: Base: white
- Hardener: Black

Mix proportion

- 1 can of Base (4.965kg)
- 1can of hardener (0.9kg)

Nitofill EPLV

- Low Viscosity Epoxy Injection Resin System
- Base and Hardener

Mix Proportion (1 Liter)

- 1can of base (0.87kg)
- 1can of Hardener (0.17kg)
- Each component shall be thoroughly stirred until the liquid becomes clear

Materials Used

1) Cement Type

Portland cement Mortar/Concrete

Non-shrinkage Mortar/Concrete

2) Polymer-Modified Cement Type

Polymer Cement Mortar/Concrete

3) Resin Type

(Epoxy) Resin M

Chapter Five

Conclusion and recommendation

5.1. Conclusion

Based on the results obtained from the study work bridge defects can be identified and treated easily using the following procedure

1. Clearing around the defected bridge to create access for mobilization of resources and create good working condition.
2. Erect scaffolding around defect part where there is no easy access for identification defects and application of materials on the bridge structure.
3. Identify defect types using appropriate measuring instrument to quantify amount of defects and to identify chemical application type.
4. Removing of defected part and cleaning using appropriate instrument.
5. Finally apply right chemicals with exact instruments for each defect type.

5.2. Recommendation

As shown form bridge repair identification problem and challenges on Beko bridge. Since bridges are vital structure to access the road, it is difficult to replace defected bridges not obstacle the access and needs expensive construction,. Ensure the appropriate and timely action is taken on bridges requiring repair and rehabilitation work, strength its risk assessment and priority setting process, with particular consideration given to bridge identification as poor condition more closely monitor inspections' compliance with the bridge inspection manual so that critical bridge information is accurately updated.

Finally I recommend Ethiopian road authority should prepare brief manual for bridge maintenance and continuous supervision by upgrading bridge maintenance contractors for the following facts.

- Repairing of bridges needs minimum contract cost, short contract period, can be maintain without interruption of traffic flow compared with replacement of bridge.

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