



Study on Causes of Cracks and its Remedial Measures in Reinforced Concrete Bridge Piers and Abutment of Major Bridge

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ABSTRACT

The Useful life of a buried concrete, containment structure for low level nuclear strength may be controlled by the loss of its load-bearing capacity or an increase in permeability. The Latter factor is controlled by the general degradation of the concrete and by the presence of discrete cracks reducing from extremely applied loads or from restraint to normal volume changes. To be able to predict the effects of cracks on permeability, it is necessary to understand the causes and mechanisms of discrete crack formation in reinforced concrete structures. The Objective of this report is to provide an overview of the design and behavior of reinforced concrete members and to discuss the factors affecting the formation of cracks in hardened concrete. The Underlying philosophy of modern reinforced concrete design is presented, and it is shown that it allows for the formation of cracks of controlled widths under service loads. Models for predicting the width of flexural cracks are reviewed. Factors Affecting drying shrinkage cracks and approximate methods for considering them are discussed. An Example is provided to illustrate how to determine whether drying shrinkage cracks will develop under specific conditions. This is followed by a discussion of techniques to predict the number and widths of drying shrinkage cracks. The abutment and piers of a bridge shows different crack patterns when it's subjected to gravity loads and as well as moving loads, for that cracks in abutments and piers will be treats by using injectioning of Epoxy resins, retrofitting techniques etc.

Keywords: Discrete crack formation, service loads, flexural cracks, Epoxy resins, retrofitting techniques

I.INTRODUCTION

Over the past 20 years, extensive research has been conducted to study the causes and mitigation methods of bridge approach settlement or "the bump at the end of the bridge." The bridge approach settlement is defined as "the difference in elevation of approach pavements and bridge decks caused by unequal settlement of embankments and abutments." Many Departments of Transportation (DOTs) are significantly impacted by bridge approach settlement, as it causes unsafe driving conditions, rider discomfort, poor public perception of the state infrastructure, structural failure of bridges, and long-term maintenance costs. The bump is noticeable with about ½-inch of differential settlement between the bridge and approach (Wahls 1990), becomes problematic at 1 inch (Zaman et al. 1994), and causes serious riding discomfort at about 2 to 2.5 inches (Stark et al. 1995). In lieu of specifying tolerable



movement as total settlement, Wahls (1990) indicated that tolerable movement should be measured as differential settlement over span length. A slope of less than or equal to 1 inch per 250 feet (1/250) for continuous spans and 1/200 for simply supported spans was considered acceptable. Once the bridge approach settlement becomes unacceptable, DOTs need to repair, provide maintenance, or reconstruct the bridge approach.

Briaud et al. (1997) indicated that at least 25 percent of the 600,000 bridges in the US, or about 150,000 bridges, are affected by bridge approach settlement. Similar statistics were shown by other studies. The Stark et al. (1995) study reported that 27 percent of the 1181 bridges in Illinois had significant differential bridge approach movement and that adjacent states such as Iowa, Wisconsin, Michigan, Ohio, Indiana, Missouri, and Kentucky exhibited similar percentages. Ha et al. (2002) reported that 24.5 percent of the Texas DOT bridges indicated a bump. Another study conducted by Luna et al. (2003) for Missouri DOT (MoDOT) reported that 17 percent of the bridges exhibited bridge approach settlement and an additional 15 percent required remediation.

The cost of repairing the bump ranges from \$60 to \$187 million with an average of \$100 million per year (Briaud et al. 1997 and Schafer and Koch 1992). Other statistics were gathered from Kentucky DOT, which spends about \$1000 per bridge per year (Dupont and Allen 2002), and Texas DOT, which reported spending a total of about \$6.3 million per year (Ha et al 2002). If the bridge needs to be replaced, which Briaud et al. (1997) estimated to be another 35 percent of the 600,000 US bridges, \$78 billion would be spent.

Because of the considerable amount of money spent on repairing bridge approach settlement, DOTs and the FHWA have funded numerous studies to determine the causes, mitigation methods, and maintenance techniques of bridge approach settlement. The present research "Evaluation of Bridge Approach Settlement Mitigation," sponsored by the Wisconsin Department of Transportation (WisDOT), is aimed at selecting the most cost-effective methods that can be competently executed during construction and that can reduce overall maintenance costs in Wisconsin. The purpose of this report is to document the performance and effectiveness of two mitigation techniques, geosynthetic reinforced fill and flowable fill, installed behind four Wisconsin bridge abutments. This report includes an extensive literature review, discussion of the field investigation, and performance evaluation of field results of these four bridges.

II. BRIDGE COMPONENTS AND THEIR ELEMENTS

A thorough and complete bridge inspection is dependent upon the bridge inspector's ability to identify and understand the function of the major bridge components and their elements. Most bridges can be divided into three basic parts or components Figure 1.1

- Deck
- Superstructure
- Substructure

The ability to recognize and identify basic member shapes requires an understanding of the timber, concrete, and steel shapes used in the construction of bridges. Every bridge member is designed to carry a unique combination of tension, compression, and shear. These are considered the three basic kinds of member stresses. Bending loads cause a combination of tension and compression in a member. Shear stresses are caused by transverse forces exerted on a member. As such, certain shapes and materials have distinct characteristics in resisting the applied loads.

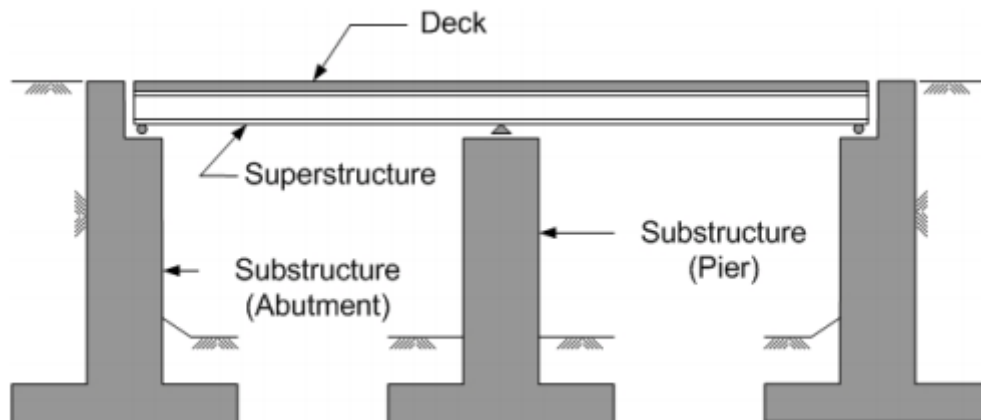


Figure 1 : Shows Basic Member Shapes

III. BRIDGE VISUALIZATION

The structure which is made upon the river or a gap without closing the way beneath is known as a bridge. It is required for the passage of roadways, railways and carriage way. In the beginning men used the fallen trees or wooden logs for making bridges over the river or gap.

COMPONENTS OF BRIDGES

Superstructure:

The part of the bridge on which the loads are directly applied is called the superstructure. Deck slabs, Beam Girders and Trusses are example of the superstructure.

Substructure: The portion of the bridge structure below the level of bearing and above the foundation is called as sub-structure. Piers and Abutments are called sub-structure.

Pier and Abutment Cap: The pier or abutment cap is the block resting over the top of the pier or the abutment. It provides the immediate bearing surface for the support of the superstructure at the pier or abutment location, and disperses the loads from the bearings to the substructure evenly.

Piers: Piers are the structures located at the ends of bridge spans at the intermediate points between the abutments. The function of the pier is two-fold: to transfer the vertical loads to the foundation and to resist all horizontal forces and transverse forces acting on the bridge.

Abutment: An abutment is the substructure which supports one terminus of the superstructure of a bridge and at the same time, laterally supports the embankment which serves as an approach to the bridge.

Bearing: Bearings are provided in bridges to transmit the load from the superstructure to the substructure in such a manner the bearing stresses induced in the substructure are within permissible limits.

Footing/foundation: The part of the bridge which is in direct contact with the earth and transmits all the loads directly to the earth is called the footing/foundation.

Wing wall: Wing walls are provided at both ends of the abutments to retain the earth filling of the approaches. The soil and fill supporting the roadway and approach embankment are retained by wing walls, which can be at right angles to the abutment or splayed at different angles.



Bed block: A reinforced concrete bed block resting over the top of the piers & abutments is generally provided to evenly distribute the dead and live loads on the pier and abutments.

Super elevation: Super elevation is tilting the roadway to help offset centrifugal forces developed as the vehicle goes around a curve. Along with friction it keeps a vehicle from going off the road. Super elevation is required on curved path.

Camber: Camber is the cross slope provided to the road surface in the transverse direction to drain off the rain water from the road surface.

IV. REMIDIAL PLANNING

FEASIBLE OPTIONS

The remedial treatment of a bridge structure must first be analyzed by the investigation of the problems at hand. Through the case study of the bridge, these problems have been identified and potential solutions are generated. Combining the broad base of knowledge, the system for the remedial works of bridge abutment movement has been created.

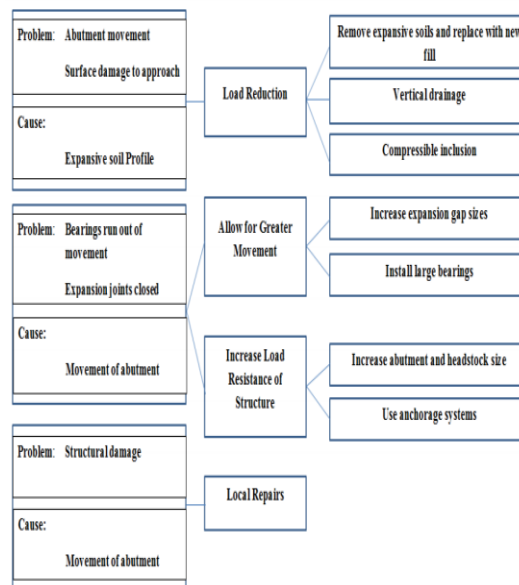


Figure 2.: Shows Problems, causes and remedial options for bridge abutment movement.

DECISION ANALYSIS

Numeric scoring models such as Weighted Constraint Matrix have been developed to allow multiple constraints to be used for concept feasibility studies. These models can combine economic evaluation output with technical and subjective constraint to create a decision making environment that is more holistic (and realistic) in nature.

PIERS

Piers are an integral part of the load path between the superstructure and the foundation. Piers are designed to resist the vertical loads from the superstructure, as well as the horizontal superstructure loads not resisted by the abutments. The magnitude of the superstructure loads applied to each pier shall consider the configuration of the fixed and expansion bearings, the bearing types and the relative stiffness



of all of the piers. The analysis to determine the horizontal loads applied at each pier must consider the entire system of piers and abutments and not just the individual pier. The piers shall also resist loads applied directly to them, such as wind loads, ice loads, water pressures and vehicle impact.

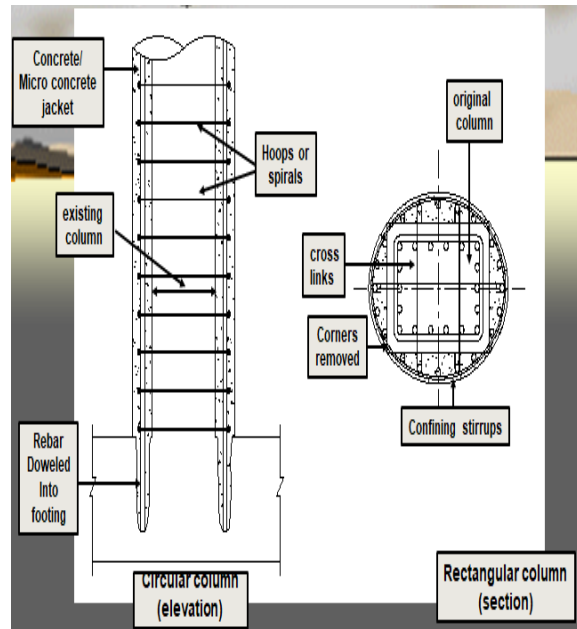


Figure 3 : Shows Confinement of Columns By Concrete Jacketing

PIER TYPE AND CONFIGURATION

Numerous components are viewed as while choosing a dock type and arrangement. The specialist ought to consider the superstructure type, the qualities of the component crossed, range lengths, connect width, bearing sort and width, skew, required vertical and flat leeway, required wharf stature, style and economy. For extensions over conduits, the dock area with respect to the floodplain and scour delicate locales will likewise be considered. The association between the wharf and superstructure is typically a fixed or development bearing which permits revolution the longitudinal way of the superstructure. This has the impact of dispensing with longitudinal minute exchange between the superstructure and the wharf. In uncommon situations when the wharf is basic with the superstructure, this longitudinal pivot is controlled and minute exchange between the superstructure and the dock happens.

Wharf types represented in the Standard Details will be viewed as a stuck association with the superstructure. On evaluations more prominent than 2 percent, the superstructure will in general move downhill towards the projection. The low end projection ought to be planned as fixed and the development joint or joints put on the tough side or top of the line projection. Thought ought to likewise be given to fixing a greater number of wharfs than a run of the mill connect on a level evaluation.

ossings. They are particularly appropriate where a long wharf is required to offer help for a wide extension or for a scaffold with an extreme skew point. Nonstop or disconnected footings might be determined for multi-section wharfs. The architect ought to decide assessed costs for both balance designs and pick the more affordable arrangement. Where the reasonable separation between confined footings would be under 4'- 6", a consistent balance will be determined. A variety of the multi-section wharf in Standard for Multi-Columned Pier is created by discarding the top and setting a segment under every brace. This detail has been utilized for steel supports with brace dividing more noteworthy than 12'. This arrangement is treated as a progression of single section wharfs. The specialist will consider any extra powers that might be prompted in the superstructure cross edges at the dock if the wharf top is wiped out. The wharf top may not be wiped out for docks in the floodplain, or for consistent piece structures which need the top to encourage



substitution of the section amid future restoration. In Standard for Highway Over Railroad Design Requirements for further subtleties on docks supporting scaffolds over rail lines.

BOTTOM OF FOOTING

Elevation The bottom of footing elevation for piers outside of the floodplain is to be a minimum of 4' below finished ground line unless the footings are founded on solid rock. This requirement is intended to place the bottom of the footing below the frost line. A minimum thickness of 2'-0" shall be used for spread footings and 2'-6" for pile-supported footings. Spread footings are permitted in streams only if they are founded on rock. Pile cap footings are allowed above the ultimate scour depth elevation if the piling is designed assuming the full scour depth condition. The bottom of footing elevation for pile cap footings in the floodplain is to be a minimum of 6' below stable streambed elevation. Stable streambed elevation is the normal low streambed elevation at a given pier location when not under scour conditions. When a pile cap footing in the floodplain is placed on a concrete seal, the bottom of footing is to be a minimum of 4' below stable streambed elevation. The bottom of concrete seal elevation is to be a minimum of 8' below stable streambed elevation. These requirements are intended to guard against the effects of scour.

PIER CONSTRUCTION

Except for pile encased piers (see Standard for Pile Encased Pier) and seal concrete for footings, all footing and pier concrete shall be placed in the dry. Successful underwater concreting requires special concrete mixes, additives and placement procedures, and the risk of error is high. A major concern in underwater concreting is that the water in which the concrete is placed will wash away cement and sand, or mix with the concrete, and increase the water-to-cement ratio. It was previously believed that if the lower end of the tremie is kept immersed in concrete during a placement, then the new concrete flows under and is protected by previously placed concrete. However, tests performed at the University of California at Berkeley show that concrete exiting a tremie pipe may exhibit many different flow patterns exposing more concrete to water than expected. A layer of soft, weak and water-laden mortar called laitance may also form within the pour. Slump tests do not measure shear resistance, which is the best predictor of how concrete will flow after exiting a tremie pipe. Footing excavation adjacent to railroad tracks which falls within the critical zone shown on Standard for Highway Over Railroad Design Requirements requires an approved shoring system. Excavation, shoring and cofferdam costs shall be considered when evaluating estimated costs for pier construction, where applicable. Erosion protection is required for all excavations.

PIER TYPES

The pier types most frequently used in Wisconsin are:

- Multi-column piers (Standards for Multi-Columned Pier and for Multi-Columned Pier – Type 2)
 - Pile bents (Standard for Pile Bent)
 - Pile encased piers (Standard for Pile Encased Pier)
 - Solid single shaft / hammerheads (Standards for Hammerhead Pier and for Hammerhead Pier – Type 2)
- Design loads shall be calculated and applied to the pier in accordance

V. RESULTS AND DISCUSSION

The achievement of extension development on delicate ground depends on appropriate arranging, investigation, plan, development control and site supervision. Be that as it may, from the two case accounts exhibited in this paper, clearly they are fundamentally the same as in nature and can be arranged to be brought about by the accompanying elements:- - Inadequacy of geotechnical plan for the methodology dikes or projections. - Lack of comprehension of the subsoil condition and mindfulness on the conceivable issues/disappointment that could occur amid development. - Lack of development control and site supervision by the Consultant To avoid bank and projection disappointment because of flimsiness, both roundabout and non-roundabout (wedge) disappointment surfaces will be checked utilizing limit balance investigations. A fast primer beware of the dependability of the bank is conceivable utilizing adjusted bearing limit condition of



qallow = (su. Nc/FOS)

It is additionally essential for plan advisor, specialist's site agents and contractual worker to have some key geotechnical learning so any anomalies at site can be spotted and prudent activities did before disappointment happens. At long last, legitimate full-time site supervision by the expert's delegates with satisfactory encounters and information are likewise essential to avoid disappointment because of un-built brief works.

This paper investigates the structure and conduct of extension projections and scaffold decks when exposed to sidelong development.

Theoretical examination expresses that the scaffold projection itself ought to be sufficient to withstand the sidelong weights forced, in any case, examination concerning span. Projection development can possibly make generous harm the extension structure, bringing about mind-boggling expenses of fix and support.

The inquire about attempted has prompted the end that projection development is an issue of to a great extent obscure amount and in spite of examination, developments may at present happen unexpected. In any case, these developments can be tended to and redressed using explicit activities. M. Rashidi et al.

The consequences of the contextual investigation featured that the issues distinguished in encompassing soils, street approaches, connect projection, and extension and bearing joints are interconnected.

As the dirt profile extends, abundance loads are set on the extension projection and street approaches.

This thusly causes the development of the projection into the extension deck which makes the auxiliary issues found in the development and bearing joints and furthermore the basic breaking of the solid in the wingwall of the projection.

These issues, while not promptly basic, will keep on intensifying whenever left untreated as the projection keeps on moving, along these lines putting expanding measures of burden on the structure.

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