



Early Concrete Cracking on Bridge Decks and Overlays

Prepared for
WHRP Structures
Technical Oversight Committee

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Topic/Problem Statement: Document literature from 2000 to the present relevant to transverse cracking of new concrete bridge decks and map cracking of concrete deck overlays. New Wisconsin research will seek to identify factors contributing to such early-age cracking.

Keywords: Deck, crack, early, transverse, map, concrete.

Summary

We found a considerable number of articles, research reports and ongoing research devoted to early-age bridge deck cracking, its causes, and prevention. The research suggests drying shrinkage, curing problems and thermal forces as likely contributors. Approaches include the use of fibers in concrete, better curing methods, polypropylene reinforcement and more.

We found three publications each in 2007 and 2006, two each in 2005, 2004, 2003 and 2002, and one each in 2001 and 2000. Of these 16 citations, four are state research reports from Indiana (2002), New Jersey (2002), Ohio (2006) and Oregon (2000). Four citations were from *Transportation Research Record* (in 2007, 2006, 2003 and 2001), and the remaining eight publications are journal articles and conference proceedings.

Three studies in progress include work in Indiana, New Jersey and New York.

Citations

Results are listed chronologically, with the most recent citations shown first. Links to online copies of cited literature are provided when available. Contact the WisDOT Library to obtain hard copies of citations.

Title: Use of alternative materials to reduce shrinkage cracking in bridge decks

Author(s): Michael D. Brown, Cuyler A. Smith, J. Greg Sellers, Kevin J. Folliard, John E. Breen

Date: November/December 2007

Source/URL: *ACI Materials Journal*, Vol. 104 (6), November/December 2007: 629-637.

Description: 9 pp.

Contents: Early age transverse cracking, a crack pattern drying shrinkage generally causes, affects more than 100,000 U.S. bridge decks, according to several state departments of transportation in a 1996 survey. Resistance restrained drying shrinkage cracking improvement is treated as achievable through concrete material properties. The authors discuss various test methods as they relate to material shrinkage cracking resistance determination, and present materials-based methods for drying shrinkage control. Extensible concrete, shrinkage-reducing admixtures, shrinkage-compensating concrete, and fibers are among the materials discussed. That there was adequate restrained drying-shrinkage cracking reduction through several of the alternative mixtures was confirmed in large-scale bridge deck specimens and determined in small laboratory specimens.

Title: Unrestrained early age shrinkage of concrete with polypropylene, PVA, and carbon fibers

Author(s): Thanasak Wongtanakitcharoen, Antoine E. Naaman

Date: April 2007

Source/URL: *Materials and Structures*, Vol. 40 (3), April 2007: 289-300.

Description: 12 pp.

Contents: Plastic shrinkage cracking due to restrained shrinkage is a primary problem that often occurs in concrete structures with a relatively large surface area, such as concrete walls, bridge decks, slabs, and overlays. These applications are susceptible to rapid changes in temperature and humidity resulting in high water evaporation and high potential for shrinkage cracking. Free shrinkage at early age is one of the most influential factors leading to tensile stresses in concrete structures. When the tensile stress is higher than the tensile strength, cracking occurs. The addition of micro-fibers in amounts as small as 0.1% by volume is an effective method to control plastic shrinkage cracking. However, the effect of fibers on the free shrinkage and water evaporation of concrete is not clearly understood. The main objective of the study described in this paper is to evaluate the influence of fibers on the free shrinkage and water evaporation of fiber reinforced cement composites during the first 24h after mixing, with particular attention to fiber content, fiber bond, and fiber stiffness. Prismatic concrete specimens of 1000,mm in length and 100 × 60,mm in cross section were tested to measure their unrestrained shrinkage strain. Simultaneously, flat concrete specimens of dimensions 327 × 230 × 50,mm were tested to determine loss of water by evaporation. The tests were carried out under adverse environmental conditions known to encourage high shrinkage, namely high temperature, low relative humidity, and exposure to high volume and velocity of air flow. Three types of fibers, polypropylene, PVA, and carbon fibers were investigated at four different fiber volume fractions, namely: 0.1%, 0.2%, 0.3%, and 0.4%. Experimental results are presented and conclusions are drawn.

Title: Causes and prevention of bridge deck overlay cracking with very-early strength latex-modified concrete

Author(s): Kyong-Ku Yun, Ki-Heun Kim, Won-Kyong Jeong, Sung-Kwon Kim

Date: 2007

Source/URL: *Transportation Research Board Annual Meeting 2007*, Paper 07-0318.

Description: 22 pp.

Contents: This study was designed to analyze the causes of map and transverse cracking in very-early strength latex-modified concrete (VES-LMC) and to provide control methods for minimizing the occurrence of cracks in the field in Korea. The project selected for instrumentation included a bridge deck overlay with VES-LMC having more than 7,000m² with 70mm thickness. The field instrumentation included Button for measuring air and concrete temperatures and portable weather station for measuring wind speed and relative humidity. The field applications were performed twice: midnight of November 8 and nine in the morning of November 9, 2005. The proposed prevention of cracking was verified at another field application program. The results are as follow: The map cracking of bridge deck overlay with VES-LMC in Korea was caused by initial plastic shrinkage cracking within a few hours by improper and delayed curing (curing compound and delayed until tining) and was propagated into wider cracks, i.e., visible to the eye, within a week. To prevent map cracking on bridge deck overlays with VES-LMC, the recommendations were as follows: apply curing compound as soon as possible after placement and before tining, and reapplied after tining if necessary; fog immediately after strike-off during dry conditions. Thermal cracking was identified as a major cause of transverse cracks at very-early age in bridge deck overlay with VES-LMC in Korea; drying shrinkage made them wide enough to be visible after one or several weeks. Thus, prevention methods should focus on VES-LMC material properties affecting the susceptibility of a concrete overlay to transverse cracking. Recommendations on VES-LMC material properties to reduce cracking included the following: low early strength concrete as possible; low amount of VES cement; low hydration temperature; minimum cement paste volume and free shrinkage. A verification program in a field application was performed in order to prove the effectiveness of prevention methods of map cracking and transverse cracking. The proposed methods were verified because no cracks were occurred during 90 days after installation of the overlay.

Title: Transverse Cracking of High Performance Concrete Bridge Decks After One Season or 6 to 8 Months

Author(s): Richard Miller, Amir Mirmiran, Prakash Ganesh, Monica Saproo

Date: March 2006

Source/URL: FHWA/OH-2006/6, Final Report.

Description: 108 pp.

Contents: Cracking is a major problem with newly placed concrete decks. These decks tend to develop full depth, transverse cracks and partial depth longitudinal cracks within a few months of the concrete being placed. A literature review showed that several other states had experienced similar problems. A review of data from Ohio bridge decks showed weak correlations between deck cracking and slump, time of year when the deck was placed, shrinkage, chloride permeability and compressive strength, but there was no clear relationship between cracking and any of these properties. Data also suggested that using a coarse aggregate with an absorption > 1% may help mitigate deck cracking but will not always stop it. As part of this study, 3 bridge decks were instrumented. One was a standard class "S" concrete deck and the other two were high performance concrete. The class "S" deck showed only hairline cracking after 1 year, but transverse cracking occurred in the HPC decks. Instruments were placed in the decks to monitor strains. From the data, it appears that cracking is caused by several factors. High heat of hydration caused the plastic concrete to expand. When the concrete sets and cools, tensile stresses develop. Further tensile stresses develop through drying shrinkage. Restraining the deck against normal thermal movement contributes to additional tensile stress. Autogenous shrinkage, where high heats of hydration cause water evaporation during hydration, and plastic shrinkage may cause more tensile stress. Recommendations for mitigating cracking include using lower cement contents, adding pozzolans and retarders, using slightly higher water/cement ratios, using larger aggregates, taking steps to limit shrinkage and eliminating restraints.

Title: The role of specimen geometry and boundary conditions on stress development and cracking in the restrained ring test

Author(s): Akhter B. Hossain, Jason Weiss

Date: January 2006

Source/URL: *Cement and Concrete Research*, Vol. 36 (1), January 2006: 189-199.

Description: 11 pp.

Contents: Early-age cracking can be a significant problem in concrete pavements, floors, and bridge decks. Various test methods have been developed to assess the potential for early-age cracking, however due to the economy and simplicity of the ring test, it has become widely used. Although the ring test procedures employed by various authors are similar, they vary in terms of curing duration, specimen geometry, and boundary conditions. This paper describes an experimental study of restrained ring specimens tested using different geometries and boundary conditions. Specimen geometry was found to have a significant effect on the stress development and age of cracking in the restrained ring specimens. Specimens that shrink uniformly along the radius show the greatest variation in the age of cracking with thicker specimens cracking at a later age. Acoustic emission testing has been used to illustrate that specimen boundary condition substantially influence crack development and propagation in the restrained rings.

Title: Measurement of volume change in cementitious materials at early ages review of testing protocols and interpretation of results

Author(s): Gaurav Sant, Pietro Lura, Jason Weiss

Date: 2006

Source/URL: *Transportation Research Record No. 1979*, 2006: 21-29.

Description: 9 pp.

Contents: Early-age cracking in concrete bridge decks, pavements, and super-structure elements has served as the impetus for substantial research on early-age shrinkage in cementitious materials. Much of this research has indicated how mixture proportions, constituent materials, and construction operations can be altered to reduce the risk of cracking. Unfortunately, many unrestrained shrinkage-testing protocols do not provide a comprehensive picture of the early-age shrinkage exhibited by cementitious materials, especially those used in higher-strength concrete. In this paper, the authors review several early-age shrinkage testing procedures. A testing protocol is presented to show how chemical shrinkage can be measured by using buoyancy measurements. A comparison of the measured autogenous shrinkage is made by using four measurement methods: a sealed membrane, a corrugated tube, a noncontact measurement in a rigid mold, and the ASTM C 157 standard. The results of the autogenous and chemical shrinkage tests are compared with one another to describe fully early-age length change. It is shown that through careful experimentation and interpretation, the results of these tests can be completely correlated with one another. This can provide the end user with reliable test procedures to compare different paste compositions and different admixtures and can provide inputs for models that quantify cracking potential.

Title: Transverse cracking of concrete bridge decks: State-of-the-art

Author(s): Rambod Hadidi, M.A. Saadeghvaziri

Date: September 2005

Source/URL: *Journal of Bridge Engineering*, Vol. 10 (5), September 2005: 503-510.

Description: 8 pp.

Contents: This state-of-the-art paper presents the results of a comprehensive literature review of the cause of transverse deck cracking. It includes compilation of experimental and analytical research results as well as survey studies on the effects of different factors on concrete deck cracking. Consistent with the past work on the subject, causes of transverse deck cracking are classified under three categories, namely: (1) material and mix design, (2) construction practices and ambient condition factors, and (3) structural design factors. The literature review revealed that the first two items have been studied extensively over the past several decades, while literature is limited on the effect of structural design factors on deck cracking. This paper evaluates the existing work in depth and presents recommendations on mix design and construction procedures to reduce the potential for transverse deck cracking. Furthermore, areas for additional research are identified.

Title: Transverse cracking of concrete bridge decks: Effects of design factors

Author(s): M. Ala Saadeghvaziri, Rambod Hadidi

Date: September 2005

Source/URL: *Journal of Bridge Engineering*, Vol. 10 (5), September 2005: 511-519.

Description: 9 pp.

Contents: Early transverse cracking is one of the dominant forms of bridge deck defects experienced by a large number of transportation agencies. These cracks often initiate soon after the bridge deck is constructed, and they are caused by restrained shrinkage of concrete. Transverse cracks increase the maintenance cost of a bridge structure and reduce its life span. Most of the past efforts addressing transverse bridge deck cracking have focused on changes over the years in concrete material properties and construction practices. However, recent studies have shown the importance of design factors on transverse bridge deck cracking. This paper presents results of a comprehensive finite-element (FE) study of deck and girder bridge systems to understand and evaluate crack patterns, stress histories, as well as the relative effect of different design factors such as structural stiffness on transverse deck cracking. The results of this study demonstrate the development of transverse deck cracking and emphasize the importance of these design factors. They also recommend preventive measures that can be adopted during the design stage in order to minimize the probability of transverse deck cracking.

Title: New experimental method for studying early-age cracking of cement-based materials

Author(s): Zhen He, Xiangming Zhou, Zongjin Li

Date: January/February 2004

Source/URL: *ACI Materials Journal*, Vol. 101 (1), January/February 2004: 50-56.

Description: 7 pp.

Contents: In this paper, a novel ellipse ring apparatus and its application for testing early-age cracking in restrained cement-based materials are presented. This method can accelerate crack propagation of cement-based materials and automatically record the starting point of a crack. Using this method, the effects of different kinds and contents of alkali on early-age shrinkage and cracking of cement-based materials have been investigated. The experimental results have shown that the cracking sensitivity of mortar with high alkalinity is more notable than that of plain mortar. The mechanism of such a behavior is further investigated using electrical resistivity measurement and hydration heat measurement.

Title: Reduction of early-age cracking of a concrete bridge deck

Author(s): Steven J. Camisa, David G. Tepke, Andrea J. Schokker, Paul J. Tikalsky

Date: 2004

Source/URL: *Proceedings of the 2004 Concrete Bridge Conference*, 2004, CD-ROM.

Description: 13 pp.

Contents: This paper describes how two lanes of a 27 -span, 2700 -foot long, partially curved continuous steel girder bridge were cast during the summer of 2001 in Pennsylvania. Extensive transverse cracking over the entire length of the bridge was observed immediately following the removal of moist curing. Prior to the placement of the two remaining lanes in an adjacent bridge during the summer of 2002, research was conducted to determine the likely causes for the early -age cracking. Recommendations were made to the Pennsylvania Department of Transportation (PennDOT) to reduce the concrete placement temperature, modify the concrete mixture design, alter some key construction practices, and change the placement sequence. Cracking in the eastbound lanes was reduced by 62 percent over the previously cast lanes. Crack surveys were used to document performance.

Title: Practical tool to accurately estimate tensile stresses in concrete bridge decks to control transverse cracking

Author(s): Rambod Hadidi, M.Ala Saadeghvaziri, C.T. Thomas Hsu

Date: May 2003

Source/URL: *Practice Periodical on Structural Design and Construction*, Vol. 8 (2), May 2003: 74-82.

Description: 9 pp.

Contents: This paper describes a simple method to estimate tensile stresses due to early age time dependent loadings in concrete bridge decks with full composite action between the deck and girder. These stresses can cause transverse deck cracking if they exceed the modulus of rupture for concrete, and need to be checked. A system of equations for a pin-roller supported composite girder is developed to estimate the deck stresses due to the volume change in concrete caused by shrinkage and/or other effects. These equations are further extended to consider different boundary conditions. The results of this method agree very well with the results of finite-element analyses. It is proposed that this practical method be used as a tool during bridge design to examine concrete bridge deck stresses against the possibility of transverse cracking. A Microsoft Windows application that is easy to use is developed and presented. Furthermore, an overview of factors causing the volume change in bridge deck concrete and their typical magnitude is presented herein to further simplify the use of this practical method.

Title: Quantifying early-age stress development and cracking in low water-to-cement concrete: restrained-ring test with acoustic emission

Author(s): Akhter B. Hossain, Brad Pease, Jason Weiss

Date: 2003

Source/URL: *Transportation Research Record No. 1834*, 2003: 24-32.

Description: 9 pp.

Contents: Early-age cracking has been found to occur in some concrete bridge decks, slabs, and pavements when the volumetric changes associated with drying, hydration, and temperature reduction are prevented. While free-shrinkage tests can quantify length change, they may not always be sufficient for detecting materials that are prone to cracking, since the potential for cracking is influenced by complex interactions of strength gain, stiffness development, creep, shrinkage, the degree of restraint, and toughness. The simplicity of the ring test enables it to be used as a comparative test to screen potential mixture designs. From the use of this test, AASHTO developed a provisional standard ring test that establishes specimen geometry; however, the provisional standard does not provide an approach for quantifying stress development or indicating how close a specimen may be to failure. Described is a simple stress solution for quantifying the results of the ring test. Issues related to ring and free-shrinkage specimen geometries are discussed to improve the fundamental understanding of the information provided by the ring test. Also described is how elastic stress and actual stress can be compared to measure the stress relaxation in a material. To better illustrate the microcracking and visible-crack development process, acoustic-emission testing was performed. These experiments indicated that specimens with a higher level of restraint exhibited more microcracking as a part of the stress relaxation process.

Title: Cause and Control of Transverse Cracking in Concrete Bridge Decks

Author(s): M.Ala Saadeghvaziri, Rambod Hadidi

Date: December 2002

Source/URL: FHWA-NJ-2002-019, Final Report.

Description: 203 pp.

Contents: Many concrete bridge decks develop transverse cracking and most of these cracks develop at early ages, some right after construction and some after the bridge has been opened to traffic for a period of time. Transverse cracks usually occur when concrete is set and widen with time. These cracks have been observed in most geographical locations and on many superstructure types. It is estimated that more than 100,000 bridges in the United States develop early transverse cracks. These cracks are typically full depth, located 1-3 m (4-12 ft) apart along the length of the span, and usually observed over transverse reinforcement. It has been reported that transverse cracking is the predominant form of deck cracking. These cracks reduce the service life of the structure and increase maintenance costs, which is of paramount importance in highway maintenance activities. Transverse cracks accelerate reinforcement corrosion, especially in regions where deicing chemicals are applied. Corrosion damage has been observed even on epoxy coated reinforcing bars. Freeze-thaw cycles of water in cracks and leakage of water to supporting structures may also reduce service life of structures. Cracks in concrete occur when a restraint mass of concrete tends to change volume. Volume change in concrete depends on the properties of its constituents and their proportions as well as environmental conditions such as ambient temperature changes and humidity. Restraint, which is basically due to composite action of deck and girder, depends on design characteristics of the bridge (i.e., structural design factors). Construction techniques also contribute to volume change and/or to degree of restraint of concrete mass. Factors associated with mix design/material and construction procedures have been the

subject of a significant number of research studies over the past several decades. Structural design factors, however, have not been the subject of much research in the past and they were the main thrust of this research study. Using 2-D and 3-D linear and nonlinear finite element models many design factors such as girder stiffness, deck thickness, girder spacing, relative stiffness of deck to girder, amount of reinforcements, etc., were studied. The research study also included a comprehensive review of the existing literature as well as survey of 24 bridges in the state of New Jersey. Results of each research task are presented and discussed in detail. Furthermore, based on analytical results and literature review, the effect of various factors are quantified and specific recommendations for possible consideration in design are made. These are classified under the three major categories: 1) material and mix design; 2) construction practice and ambient condition factors; and 3) structural design. A simple Windows application program to more accurately estimate deck stresses during design is also developed under this study. Future research needs are also identified.

Title: Investigation of Bridge Deck Cracking in Various Bridge Superstructure Systems

Author(s): R.J. Frosch, D.T. Blackman, R.D. Radabaugh

Date: February 2002

Source/URL: FHWA/IN/JTRP-2002/25, Final Report.

http://rebar.ecn.purdue.edu/JTRP_Completed_Project_Documents/SPR_2404/FinalReport/spr_2404_Form1700.pdf

Description: 281 pp.

Contents: Many bridges in the state of Indiana have been identified to have cracking in the concrete deck. Cracking has been identified in the negative and positive moment regions of bridges on both the top and bottom surfaces and can appear before or shortly after the opening of the structure to live loads. Significant crack widths and various degrees of cracking exist in different bridge systems including both concrete and steel superstructures. This research project was divided into five phases to determine the factors affecting transverse and longitudinal bridge deck cracking, as well as, to develop design recommendations that minimize or prevent these types of bridge deck cracking. The research focused on the design and construction of new bridge decks. However, an overview of overlay cracking is also presented. The first phase was a field evaluation to investigate the scope of the problem. Using the information gathered from the first phase, the second phase instrumented a typical bridge structure to provide an understanding of the behavior of transverse cracks in a concrete bridge deck. With the findings from the previous two phases, the third phase conducted a laboratory investigation to study the effects of shrinkage and restraint of a concrete deck and to determine the contribution of stay-in-place steel forms to the formation of transverse cracking. The fourth phase evaluated the effect of formwork type on restrained shrinkage. In the final phase, the effect of reinforcing bar spacings and epoxy thickness on crack width and spacings were evaluated. Based on the research investigation, transverse deck cracking is caused by restrained shrinkage of the concrete deck while longitudinal cracking is caused by a combination of factors including restrained shrinkage and a construction detail that turns the leg of an angle used to support stay-in-place formwork into the deck. Design and construction recommendations are provided to minimize transverse, longitudinal, and overlay map cracking.

Title: Field investigation of high-performance concrete bridge decks in South Carolina

Author(s): Michael F. Petrou, Kent A. Harries, Gerald E. Schroeder

Date: 2001

Source/URL: *Transportation Research Record No. 1770*, 2001: 12-19.

Description: 8 pp.

Contents: A high-performance concrete (HPC) mixture has been used on several bridge construction projects in the upstate region of South Carolina. The majority of these bridge decks, although not all, have experienced problems with early-age cracking both before being opened to traffic and immediately thereafter. The cracking exhibited in these bridge decks presents a significant obstacle to the widespread adoption of HPC materials for bridges in South Carolina. In an effort to determine likely causes of the cracking experienced in these concrete bridge decks, sight inspections were made of nine bridges in the Greenville-Spartanburg, South Carolina, area, and a thorough review of construction documentation from three of these sites was carried out. In addition, a review of the South Carolina Department of Transportation concrete specifications was conducted. It was concluded that observed cracking has two likely causes. Early-age shrinkage cracking resulted from a rich concrete mixture combined with poor curing practices. Load-induced cracking, appearing shortly after the spans were open to traffic, may result from the placement of relatively stiff decks on more flexible bridge superstructures. Improved on-site quality control and quality assurance are recommended for all aspects of mixing, placing, and curing when HPC is used. It is also recommended that a more appropriate HPC mix design be developed for use in bridge decks. Such a concrete mix would have enhanced durability characteristics and should not be a high-strength mix. Adoption of the eight FHWA performance criteria for HPC is recommended.

Title: Polypropylene Fiber Reinforced Microsilica Concrete Bridge Deck Overlay at Link River Bridge

Author(s): Eric W. Brooks.

Date: February 2000

Source/URL: OR-EF-00-11, Final Report. http://ntl.bts.gov/lib/10000/10500/10590/link_river.pdf

Description: 25 pp.

Contents: In 1997 ODOT overlaid the Link River Bridge with microsilica concrete, reinforced with polypropylene fibers (FMC). The manufacturer claimed the fibers would reduce plastic shrinkage cracks and settlement cracking during the early life of the concrete, as well as reduce the formation of intrinsic cracking. The northbound lane was constructed with the FMC while the southbound lanes were constructed with plain microsilica concrete. Neither side showed much initial cracking when the curing blankets were removed. The latest inspection two years after construction found only minor cracking in the northbound lane and very little in the southbound lanes.

Research in Progress

Results are listed chronologically, with the most recent citations shown first. Links to research project Web sites or TRB Research in Progress listings are provided when available.

Title: Bridge Deck Material Properties

Principal Investigator(s): n/a. New York State Department of Transportation, (518) 457-6195 or

<http://www.nysdot.gov/>

Start Date: 6/30/2007

RIP URL: <http://rip.trb.org/browse/dproject.asp?n=13731>

Sponsor Organization: New York State Department of Transportation

Contents: This project will produce a final report that will explain the mechanics of bridge deck cracking together with a computer model that can be used as a tool to analyze the potential for bridge deck cracking. The project will determine a comprehensive mechanics-based theory for the analysis of early age cracking of composite bridge decks subjected to hydro-thermal volume changes. Implement theory in a Finite Element Model (FEM) computer program.

Title: Bridge Deck Cracking and Composite Action Analysis

Principal Investigator(s): Hani Nassif, Rutgers University, (732) 445-4414 or nassif@rci.rutgers.edu

Start Date: 6/1/2006

RIP URL: <http://rip.trb.org/browse/dproject.asp?n=14452>

Sponsor Organization: New Jersey Department of Transportation

Contents: According to the American Society of Civil Engineers (ASCE) Report Card, the US infrastructure received a grade point average of D (i.e., poor rating) in 2005. Moreover, the National Bridge Inventory (NBI) (Federal Highway Administration, 2004) stated that of more than 594,470 bridges in the United States, about 150,981 (25.4%) are structurally deficient or obsolete. Major decisions must be made to allocate the limited funds available for repair, rehabilitation, and replacement. An investment of at least \$1.6 trillion is needed in the next five years to alleviate the problems. Accordingly, many State departments of transportation expend significant effort and resources on the construction of durable concrete bridge decks. Existing data and current research indicate that specific modifications to construction procedures, materials, and design details can significantly reduce the degree of cracking in bridge decks and thus reduce exposure of reinforcing steel to the corrosive effects of deicing chemicals as well as decrease freeze-thaw damage. A great deal is known about the factors that affect cracking in bridge decks, and what is needed is to implement this knowledge and monitor deck performance. However, there is need to fully understand the effect of various design parameters that are related to bridge cracking behavior. To study the cracking behavior of bridge decks, a detailed 3D FE model will be developed. A general-purpose finite element program, ABAQUS, will be utilized to derive the model. ABAQUS includes a variety of routines that allow for defining specific material models and provisions, such as concrete cracking and tension stiffening models, reinforcing steel rebar, boundary conditions, bond behavior (e.g., shear studs) and interaction between the reinforcing steel bars and concrete, and its mechanical properties. In addition, early-age cracking is often associated with material properties of concrete, especially concrete mixes that have high early-age strength development or high shrinkage performance. Furthermore, the FEM results will be validated using field results from various sources including those developed at Rutgers University and relate the possible cause of cracking on the bridge decks (e.g., thermo-stresses, heat of hydration, shrinkage, and live load). Once the model is validated and calibrated using field and laboratory measurements, the parametric study on modifying the design procedure can be carried out. The results of this research will add to that knowledge and will lead to reduction in bridge deck cracking, an improvement in durability, and an increase in the useful life of bridges.

Title: Investigation of Bridge Deck Cracking in Various Bridge Superstructure Systems

Principal Investigator(s): Robert J. Frosch, Purdue University, (765) 494-2256 or frosch@purdue.edu

Start Date: 9/1/1999

RIP URL: <http://rip.trb.org/browse/dproject.asp?n=5137>

Sponsor Organization: Indiana Department of Transportation

Contents: The objective of this study is to determine how the dominant factors affect early age transverse bridge deck cracking. Once these parameters are isolated, design and construction recommendations will be made to minimize or prevent transverse deck cracking.