National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

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These Digests are issued in the interest of providing an early awareness of the research results emanating from projects in the NCHRP. By making these results known as they are developed and prior to publication of the project report in the regular NCHRP series, it is hoped that the potential users of the research findings will be encouraged toward their early implementation in operating practices. Persons wanting to pursue the project subject matter in greater depth may obtain, on a loan basis, an uncorrected draft copy of the agency's report by request to the NCHRP Program Director, Highway Research Board, 2101 Constitution Ave., N.W., Washington, D.C. 20418

Effect of Stress on Freeze-Thaw Durability of Concrete Bridge Decks

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 6-9, "Effect of Stress on Freeze-Thaw Durability of Concrete Bridge Decks," by J. P. Callahan, C. P. Siess, and C. E. Kesler, The Engineering Experiment Station, University of Illinois.

Superseded by NCHRP REPT. 101

THE PROBLEM AND ITS SOLUTION

Some present bridge designs allow a degree of flexibility which, under traffic and other environmental forces, may cause cracking and opening of existing cracks. This, in itself, may be structurally unimportant, but in the presence of deicing chemicals it may contribute to corrosion of the reinforcing and spalling of the concrete by providing access channels for the corrosive agents.

In addition, the stresses resulting from traffic movement may augment those of frost action sufficiently to cause scaling in cases where satisfactory performance would otherwise be expected.

This research was intended to determine whether the durability of air-entrained concrete bridge decks under a simulated harsh environment is significantly affected by externally applied forces. Stated otherwise, this investigation sought a relationship between reinforced concrete performance--as indicated by surface deterioration and cracking--and externally applied loadings of cyclic nature.

The University of Illinois research findings reported do not solve the problem of concrete bridge deck scaling and spalling. They do, however, shed light on the effects of stress in accelerating bridge deck distress and offer additional evidence concerning air entrainment, thermal characteristics, and the failure mode of concrete under the action of corroded reinforcing steel, as well as clues as to what might be tried in design and construction to produce more durable concrete bridge decks. An important contribution toward the alleviation of concrete bridge deck deterioration has resulted, not because of one overwhelmingly important finding, but because of the many findings over the broad scope of investigation. The findings cannot and are not intended to stand alone. They must be considered as, perhaps, other pieces in the large puzzle to be completed before the problem of bridge deck deterioration can be solved. It is unlikely that any of the material contained in the report is suitable for direct application into practice.

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FINDINGS

Bridge deck deterioration not otherwise attributable to obvious causes or violations of material or construction specifications can be divided into two classes: (1) the scaling of surface mortar, and (2) the spalling of concrete due to corrosion in transverse reinforcement.

Stress will have a certain influence on both types of deterioration. In tests conducted as part of this research, static tensile stresses somewhat accelerated the rate of scaling, whereas static compressive and biaxial stresses slightly retarded the development of scaling. In contrast to cyclic tensile stresses, which showed little influence, cyclic compressive stresses has an accelerating effect on the rate of scaling. Scaling can definitely result from freezing and thawing. On the other hand, stress affects spalling by providing the mechanical action for initiating and feathering cracks and for feeding saline solution down to the level of the reinforcement. Once the salt solution gains access to the reinforcement, the optimum conditions for the corrosion reaction consist of cyclic wetting and drying at higher temperatures without the need for additional salt solution. The attempts to develop accelerated corrosion proved unsatisfactory; therefore, the laboratory studies could not be extended for the necessary time period required to observe spalling. The cracking of more highly stressed slabs was extensive and mechanical action resulted in considerable feathering.

The most important finding resulting from this study is that although stress appears to influence somewhat the rate of development of surface scaling, it is not a primary factor. The physical characteristics of the surface mortar, compared with those of the coarse aggregate layer of the concrete, appeared to be the most important factor. Concrete having a tendency to scale cannot be altered by superimposing a particular stress condition so that scaling can be entirely prevented. Conversely, concrete with no tendency to scale cannot be stressed to the point that scaling will occur.

Corrosion of reinforcement at transverse cracks and subsequent spalling of concrete appears to be the most serious problem with respect to durability of bridge decks. From all observations, transverse cracking of bridge decks is a common occurrence. These transverse cracks seem to result primarily from effects not related to vehicle loading--such as shrinkage and consolidation of plastic concrete. The time needed to develop spalling for bridge decks already having transverse cracking will depend on the frequency of deicer application, traffic density, and the depth of concrete cover. There is little doubt that spalling eventually will occur in regions where deicers are used frequently. It is also doubtful that this type of deterioration could be prevented by increasing the cover above the reinforcement, but this might delay its eventual development. An excessively high cement factor in bridge deck concrete would have little apparent remedial effect and could conceivably produce greater amounts of cracking due to increased shrinkage. Alleviation of deterioration associated with transverse cracking can possibly be achieved through revibration or by using corrosion-resistant reinforcement.

APPLICATIONS

These findings are not suitable for direct application to practice but should be of interest to bridge design engineers, construction engineers, concrete researchers, and others concerned with concrete bridge deck durability. To some degree, they answer the question, "What are the effects of stress on concrete durability?" Although the question is not answered conclusively, the findings should be of value in ultimately finding a solution. Concrete researchers will be especially interested in two theories for mechanisms of deterioration.