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

Superseded by NCHRP Rept. 106

Revibration of Retarded Concrete for Continuous Bridge Decks

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 18-1, "Revibration of Retarded Concrete for Continuous Bridge Decks," by H. K. Hilsdorf and J. L. Lott, Structural Research Laboratory, Department of Civil Engineering, Engineering Experiment Station, University of Illinois.

THE PROBLEM AND ITS SOLUTION

There exists a very serious concern about the maintenance problems created by spalling of reinforced concrete bridge decks. Transverse, longitudinal and weakened-plane cracking of continuous concrete bridge decks can be caused by changes in deflection and rotation of the formwork over supports during construction. The formation of cracks while the concrete is still in a plastic state may also be caused by early shrinkage of the cement paste, deflections and rotations of the supporting structure of the bridge due to the dead weight of concrete, or the top reinforcing steel causing restraint to subsidence, particularly in deeper slabs. It is often theorized that such restraint may result in the formation of horizontal plane-of-weakness zones or cracks, as well as voids around the reinforcing steel. Thus, the problem in its most direct terms seems to be that cracks, and possibly internal voids, do occur in plastic concrete placed for bridge decks. How can these deficiencies be corrected?

Revibration of retarded concrete can be useful in eliminating surface and interior cracks in plastic concrete, thereby producing a more homogeneous and crack-free bridge deck in its hardened condition. The University of Illinois undertook an 18-month study of revibration that surveyed the extent to which revibration or delayed vibration has been used in placing bridge deck concrete, determined by laboratory tests that surface and interior cracking can be significantly reduced by revibration, determined the effect of revibration on finishing and the durability of bridge deck surfaces exposed to deicing chemicals and freeze-thaw cycles, and determined an effective means of revibration in the field.

FINDINGS

Independent of the cause of cracking, surface revibration is an effective and economically feasible method to close surface cracks, internal cracks or plane-of-weakness cracks in plastic concrete as long as the penetration resistance is not in excess of 60 psi. This condition is reached between 30 and 60 minutes prior to initial set (defined as time that penetration resistance reaches 500 psi) for most bridge deck concrete. If the energy level is chosen such that surface revibration results in the formation of a moisture film over the entire concrete surface, no additional finishing except belting or brooming is required after revibration.

Surface revibration can be effectively employed to repair cracks and voids up to a depth of at least 4 in. from the concrete surface.

Surface revibration at a high energy level closes early shrinkage cracks and can improve moderately crusted concrete surfaces. However, a revibration energy level that is too low may lead to the formation of additional closely spaced surface cracks. In all cases of moderate or severe crusting, extensive additional finishing after revibration was required.

In the laboratory experiments, form deflection to produce a concrete curvature of approximately 5×10^{-4} inches^{-1} (reciprocal of radius of curvature) was required to develop surface cracking in the specimens. Cracks were concentrated near transverse reinforcing bars.

Under the normal laboratory environment, no significant shrinkage cracking could be observed prior to or after initial set. Shrinkage cracks penetrating beyond the level of the top reinforcement were developed only in the case of severe drying conditions (high wind and temperatures of 95 or 100 F). The formation of planes of weakness at the level of the top reinforcement could not be found under regular laboratory conditions or under the simulated wind and high-temperature conditions. However, plane-of-weakness cracks were artificially produced.

Variations of the layout of the top reinforcement, or of the concrete cover, had no apparent influence on the effectiveness of revibration.

Revibration had no statistically significant effect on the compressive strength of retarded concrete.

Surface revibration had no pronounced effect on the abrasion resistance of concrete.

Laboratory experiments showed no significant difference between the surface scaling resistance of revibrated and non-revibrated concrete. It should be stressed, however, that scaling is the only type of surface deterioration produced in the laboratory.

Surface revibration did have an effect on the air void characteristics of concrete. It resulted in an increase of the spacing factor close to the surface from an average value of 0.0070 in. prior to revibration to 0.0077 in. after revibration. Surface revibration had no measurable effect on the air void system of the concrete at a distance of more than 1 in. from the surface.

No significant effect of external revibration with a vibrating table on the air void characteristics and the paste content distribution of concrete could be found.

Surface cracks had no measurable effect on the scaling resistance of concrete.

Internal vibration is an inefficient and impractical method of revibrating concrete bridge decks.

The feasibility of revibration of bridge deck concrete in the field has been demonstrated by two experiments conducted in Kansas. Surface revibration of the entire width of the deck, in one case, appears to be the most practical approach. It is important that the revibration energy level, the shape of the vibrating pan, and the supporting system for the surface vibrator be carefully controlled. Penetration resistance of a sample subjected to the same exposure conditions as the bridge deck slab can be used to determine the proper time to begin revibration.

No known cases of the use of revibration of retarded concrete bridge decks were reported in a survey of the 50 states of the United States, the District of Columbia, and ten provinces of Canada. Two cases of unintentional revibration of concrete bridge decks were reported; however, no unusual effects were noted in either case. Apparently experience in the use of revibration of bridge deck concrete did not exist prior to this investigation (at least in the United States.)

APPLICATIONS

The findings from this study will probably be of interest to design and construction engineers and specification writers responsible for reinforced concrete bridge decks. Although the information produced in this report is not final and conclusive, evidence has been produced that the technique of revibration produces no harmful effects in the short term, at least in the laboratory and on a limited number of field experiments, and offers promise of producing more durable concrete over the long term. Many questions remain to be investigated, particularly those concerned with the basic mechanisms of spalling, laboratory procedures for producing that phenomenon in an accelerated testing environment, and virtually all the parameters involved in vibration or revibration. Nevertheless, field experiments show the feasibility of revibration of bridge decks. The equipment necessary to do this requires further development, and construction procedures undoubtedly need to be standardized and improved. For those not prohibited by specifications or standards from trying new construction techniques, revibration might be tried as an experimental project.