INVESTIGATIONAL CONCRETE PAVEMENTS

REPORTED BY

COMMITTEE ON RIGID PAVEMENT DESIGN

R. D. BRADBURY, *Chairman*

SYNOPSIS

In cooperation with the States of Kentucky, Michigan, Minnessota, Missouri, Oregon and California, the Public Roads Administration is conducting studies on "Joint Spacing in Concrete Pavements" In this report the history and scope of the cooperative studies are reviewed by E F Kelley and the design and construction of the experimental Federal-Aid projects in Kentucky, Michigan, and Minnesota are described by F P Anderson, 2nd, J W Kushing and F C Lang Most of the States have included in their studies additional features of design and construction which were of special interest to them California, Oregon and Missouri will build their experimental projects during the early part of the 1941 construction season The Committee plans to maintain a cumulative record of the service behavior of all these projects and to publish the results in subsequent reports as the data become available

HISTORY AND SCOPE OF COOPERATIVE STUDIES OF JOINT SPACING IN CONCRETE PAVEMENTS

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The experience of the past has demonstrated that transverse joints must be used in concrete pavements if transverse cracks are to be avoided Both experience and research have also shown that if transverse cracks are to be eliminated, the transverse joints must be so spaced as to divide the pavement into relatively short slabs.

Transverse joints in pavements are of two types The first is the so-called contraction joint whose primary function is to reduce temperature-warping stresses These stresses are much higher in long slabs than in short ones. The second is the expansion joint whose function is to provide space for the unrestrained longitudinal movement of the pavement with changes in temperature

There can be no argument concerning the need for closely spaced contraction joints if the formation of transverse cracks is to be prevented but there is no agreement among highway engineers regarding the need for expansion joints or their proper spacing when they are used

Theoretical analysis and the experience in certain localities have led some engineers to conclude.

1. That little or no provision for expansion is required in concrete pavements having normal expansion characteristics, provided that contraction joints are so spaced as to control cracking and are so maintained as to prevent the infiltration of solid materials.

2. That when expansion joints are used it is not necessary to provide enough expansion space to effect complete relief of restraint but, on the contrary, it is desirable from a structural standpoint to provide only enough space to keep compressive stresses within safe limits.

In contrast to this is the rather general conviction, also based on experience and theoretical considerations, that some provision for expansion is necessary and desirable. Thus, questions are raised that can be answered only by extensive full-scale experiments.

A transverse joint in a thickened-edge pavement introduces a source of potential weakness unless the ends of adjoining slabs are connected in some manner that will provide for the transfer of load from one slab to the other. This potential weakness is due to the fact that in a thickened-edge pavement the edge of the slab along a transverse joint is thinner in the central portion than at the ends. Therefore, a given wheel load at an unsupported joint edge will produce much higher stresses in this relatively thin central portion than will the same wheel load when applied to the relatively thick pavement edge between joints

A common type of contraction joint is the weakened-plane or dummy joint which, in the absence of dowel bars, derives all its ability to transfer load from the interlocking of the fractured faces of the slab ends below the surface groove. The experimental work of the Public Roads Administration has shown that the dummy joint is quite efficient in transferring load when it is tightly closed as it is likely to be during the summer, but in cool weather, when contraction of the slab has resulted in an opening of the joint, its efficiency may be reduced to zero However, there are those who maintain that in dummy contraction joints, when these are closely spaced so as to control cracking, it is unnecessary to use dowels or other load transfer devices, particularly when expansion joints are omitted or used only at long intervals. In support of this opinion is offered the evidence of thickened-edge pavements that have suffered no apparent ill effects from the omission of dowel bars from dummy joints. Whether this evidence supports the conclusion or whether the absence of distress in these pavements is merely an indication that they are overdesigned for the loads they are required to carry, is a question on which there is disagreement.

For some years the Public Roads Administration has placed a limitation on the maximum spacing of expansion joints, the present limit being 120 ft., and, with some exceptions, has required the use of load-transfer devices in contraction joints in thickened-edge pavements. This means that dowel bars are required in transverse dummy joints.

These requirements have been questioned by some of the State highway departments and by the Portland Cement Association, with the result that early in 1940 the Public Roads Administration decided to sponsor rather comprehensive cooperative studies of the questions at issue. Accordingly, it proposed an investigational program involving the construction of experimental concrete pavements and offered to participate in their construction on a limited number of selected Federal-aid projects.

The experimental program, as originally outlined, included seven different sections of pavement, six of which were to be included at least twice in any one experimental project.

Four of these sections were for the purpose of making direct studies of the spacing of expansion joints in pavements with closely spaced transverse dummy contraction joints. The slabs were to be of the thickened-edge type, without reinforcement, and the dummy contraction joints were to be without dowel bars and were to be spaced 15, 20 or 25 ft. apart, depending largely on the type of aggregate used. The expansion joints in these four sections were to be at spacings of approximately 120 ft., 400 ft., 800 ft and one mile.

A fifth section, with expansion joints spaced 120 ft. apart, was to be identical with the similar section described above except for the use of dowel bars in the dummy contraction joints. This section was included to provide some comparison of the performance in service of dummy joints with and without dowels.

The sixth section was also of the thickened-edge type with expansion joints at a spacing of 120 ft. It differed from the preceding sections in that it was to be reinforced and was to have one dowelled dummy joint midway between each pair of expansion joints, thus dividing the pavement into 60-ft slabs This section was included in order to give some idea of the relative merits of crack control with closely spaced dummy contraction joints and crack control with steel reinforcement and a smaller number of contraction joints

The seventh, and last, section was to be of nonreinforced concrete, with expansion joints 120 ft apart and with closely spaced contraction joints without dowels. It differed from the similar section in the first group of four only in that the cross section of the slab was to be of uniform thickness so designed as to be approximately comparable, with respect to the maximum combined stresses due to load and temperature, with the thickened-edge slab used in the other six sections.

Six State highway departments are taking part in this investigation. In each State the details of the original experimental program have been modified in varying degree, without detracting from the essential purpose, either to meet local limitations or to include other features of particular interest to the State in which the work is being done. This is particularly true of the Michigan project which is of much broader scope than the others. The experimental pavements in Kentucky, Michigan and Minnesota were completed during the construction season of 1940. In Oregon, California and Missouri construction has been postponed until 1941.

The experimental pavements that have been described are primarily for the purpose of studying the spacing of expansion joints in pavements with closely spaced contraction joints, but this is only one of the primary questions that the investigation is designed to answer The second objective concerns the use of dowel bars in contraction joints of the dummy type. While dummy joints with and without dowels have been included in the experimental pavements it is doubtful if much will be learned from their performance in service that will indicate their relative ability to overcome the potential weakness of transverse joints in thickened-edge pavements

It has been shown by previous investigations of the Public Roads Administration that the efficiency of transverse joints, from the standpoint of stress reduction, cannot be determined by measurements of maximum deflections under load. For example, when a load is applied on one side of a joint the maximum deflections of the two joint edges may be identical but the maximum stress in the loaded edge may be more than twice as great as in the unloaded edge (see figure 32, *Public Roads*, October 1936). The efficiency of joints in pavements can be determined only by accurate and time-consuming measurements of stress deformations in the concrete and it is not practicable to make such observations on pavements under traffic. Therefore, the action of transverse dummy joints is being studied in full-size pavement slabs that are not subjected to traffic

This study is being carried on at the laboratories of the Public Roads Administration where similar studies have been made in the past The previous investigations, while somewhat limited in scope, have indicated quite definitely that, in pavements free to expand and contract, load transfer devices are needed in dummy contraction joints in thickened-edge slabs if these joints are not to be a source of potential weakness The present investigation is more comprehensive than those of the past and will permit the study of several variables that are of interest.

For this special study of dummy joints six test slabs have been constructed, each being 20 ft. wide, 30 ft. long, and with a uniform thickness of 8 in. Each slab is provided with a longitudinal center joint of deformed metal with tie bars, and a dummy contraction joint on its transverse center line.

In four of the test slabs the transverse contraction joint is of the dummy or weakened-plane type, without dowels In two of these slabs the coarse aggregate is gravel; in the other two it is crushed stone. In one slab of each pair the maximum size of coarse aggregate is 1 in.; in the other it is 2½ in.

The fifth slab is identical with the one in the above group in which the coarse aggregate is gravel of the smaller size, except that the weakened-plane joint is provided with ¾ in. round dowel bars spaced 12 in. center to center.

The sixth slab contains gravel aggregate of the larger size and a special type of weakened-plane joint designed so that in adjoining short sections along its length the crack will slope in opposite directions. The purpose of this design is to provide more interlocking of the fractured slab ends than is obtained with the conventional dummy joint.

These test slabs have been constructed so that the width of the joint opening can be controlled at will and so that, with the joints closed, the slabs can be subjected to direct compressive stress, thus simulating the condition of a pavement subjected to compressive stress due to restrained expansion.

This experimental installation provides a means for making a detailed study of the efficiency of weakened-plane joints as affected by

(a) the width of joint opening,
(b) restraint due to direct compressive stress in the slab,
(c) type and size of coarse aggregate, and
(d) presence or absence of dowel bars.

It will be generally agreed by highway engineers that, insofar as it can be done without detriment to the pavement, it will be advantageous to use expansion joints as sparingly as possible and to make the necessary contraction joints as simple and economical as possible. The experimental program that has been described is for the purpose of throwing more light on these troublesome features of concrete pavement design.