Investigation of Load Transfer Characteristics of Dowels

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This paper will describe a study being conducted on the load transfer characteristics of dowels used in airfield pavement expansion joints. Field installation and dowel and slab instrumentation will be discussed. A specially-designed cart for applying single wheel loads will be described and data obtained as a result of preliminary tests using a 50,000-pound load will be presented. Plans for application of the data obtained to the design of a test facility for evaluation of load transfer devices in general will be described.

● ABOUT a year and a half ago, the U. S. Naval Civil Engineering Research and Evaluation Laboratory began a study of load transfer characteristics of dowels across an expansion joint in a concrete slab. This paper represents a progress report indicating the general outline of the project, the instrumentation used, and the type of data which has been obtained to date. The Navy has a current need for a realistic method of evaluation of load transfer devices. The method must provide for the interrelation of several of a given device, and it must be applicable to any combination of device spacing and slab thickness. This method, when developed, will eliminate any necessity for in-service evaluation tests.

To provide fundamental field data from which a realistic evaluation procedure may be developed, loading tests are being made on a portland cement concrete slab 10 in. thick, 15 ft wide, and 50 ft long. The slab was designed according to Navy procedure, and the concrete has a compressive strength of 6160 psi and a rupture modulus of 795 psi based on 28-day specimens. The slab is built in 25-foot sections joined by dowels across a ¾-inch expansion joint. A transverse weakened plane joint is provided at the center of each 25-foot section. Fifteen 1⅛-inch diameter steel dowels 20 inches long are placed on 12-inch centers across the joint and are capped in accordance with established construction procedure. The effective embedment of the dowels is 9 inches on each side of the joint. The slab is constructed on a prepared subgrade having a modulus of subgrade reaction of about 200 pounds per cubic inch as indicated by bearing tests with a 30-inch diameter plate made just prior to construction of the slab.

Each dowel is instrumented with 14 SR-4 strain gages to measure shear and moment in the dowels. The moment gages are placed in longitudinal slots 5⁄16 inch wide, 1⁄16 inch deep, and 9 inches long. These slots are placed on both ends of the dowels to cover the effective embedment of the dowel on both sides of the joint. The slots are placed 180° from each other so that when the gages on one end of the dowel are on the upper side, those on the other end are on the lower side. In these slots, strain gages (A-8) are placed at ¾″, 1½″, 2¼″, 3¾″, 5¾″, and 7¾″ from the face of the joint on both ends of the dowels. To measure the shear transmitted across the joint, strain gages are placed on the bar in the joint space. One gage is placed on each side of the dowel on the neutral axis and is inclined at 45°. The moment instrumentation of the dowels is shown in Figure 1. From top to bottom is shown the transition from the original slotted bar to the finished instrumentation.

Before installation in the field slab, the instrumented dowels were loaded at the center while supported at the ends as a simple beam. Moments were calculated for various loads and were used to calibrate each of the gages for the strain readings. Moment-strain factors have been determined for each gage so that after a

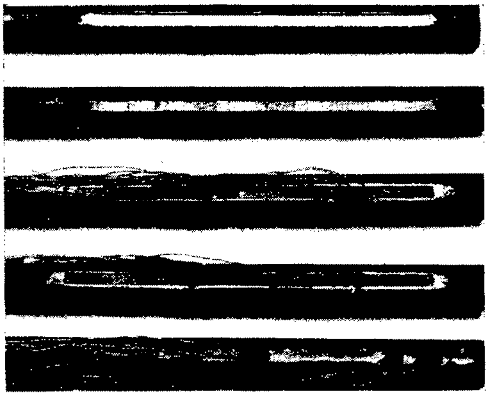

Figure 1. Moment instrumentation of the dowels.

Figure 3. Center dowel and brass rods from transformers.

field test the strain for a given gage can be multiplied by the moment-strain factor to determine the moment on the dowel at that gage position. The shears across the joint are calculated from the strain indicated by the shear gages. Differential transformers with a linear range of ±0.15 inch are used to measure slab deflections under both static and dynamic loads. The transformers are in the subgrade beneath 10 of the dowels on both sides of the joint. Economic limitations prevented the use of transformers under every dowel. The transformers are in specially-made plastic cases about 4 inches below the surface of the subgrade. Each case is mounted on the upper end of a steel rod which has been driven 10 feet into the subgrade. The rods are free-standing inside a pipe casing from an elevation 5 feet below the surface of the subgrade. The core of each transformer is attached to a brass rod by a thin, flexible wire which passes through a hole in the top of the plastic case. The brass rod, in turn, passes through an aluminum plate at the surface of the subgrade and extends about 3 inches into the concrete. The aluminum plate is the top of a bellows which is mounted on the top of the previously-mentioned pipe casing and which is independent of the free-standing steel rod that supports the transformer case. The aluminum plate can

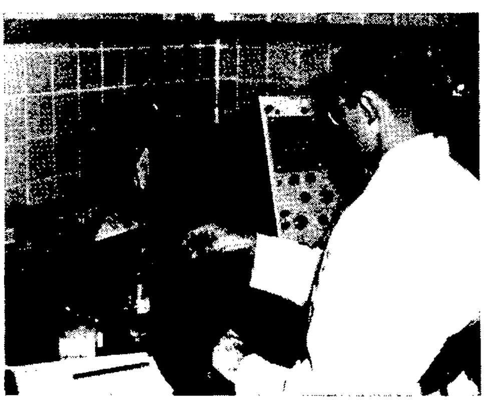

Figure 2. Calibration of transformers.

Figure 4. Slab instrumentation prior to construction of slab.

move downward only. Downward movements of the brass rod relative to the aluminum plate are prevented by a stop attached to the rod on the upper side of the plate. A tee is attached to the upper end of the rod to assure bonding of the rod in the concrete. Thus, when the slab deflects downward, brass rod and aluminum plate move downward as a unit by compressing the bellows, but when the slab deflects upward, only the rod moves upward. Figure 2 illustrates the laboratory calibration procedure for the transformers.

Because the null output of the transformers is extremely sensitive to frequency changes near 60 cps, a Baldwin Type M Strain Indicator operating at 1000 cps is used as the power source. At this frequency, variations in the line frequency will have little effect on the null output of the transformers. An oscilloscope was used to determine the null point of the transformers. To supplement slab deflection readings obtained with the transformers in static tests, slab surface deflection measurements are made with mechanical deflection dials. A close-up view of the center dowel and the brass rods from some of the transformers is seen in Figure 3. Figure 4 is a view of some of the slab instrumentation just prior to construction of the slab.

For application of single wheel loads which simulate actual loading of airfield pavements by large bombers, a B-45C tire and wheel have been mounted on a specially-designed 50-ton capacity cart which is illustrated in Figure 5. This cart has a ground clearance of 36 inches and a minimum wheel base of 23 feet; so it can be used as a reaction load for subgrade bearing tests when not in use for application of wheel loads. The tire has a diameter of 56 inches, a width of 16 inches, and can be loaded up to 100,000 pounds with tire pressures up to 250 psi. The load is applied to the axle of the wheel by two 7-inch diameter hydraulic cylinders which are mounted in the center of the cart. The reaction weight is supplied by the weight of the cart itself and by water contained in steel tanks placed symmetrically around the cylinders. The tanks have a total capacity of about 30 tons of water. The total weight of the cart when the tanks are full of water is about 52 tons. The hydraulic system is designed to operate at pressures up to 1300 psi. With its own engine, generator, and hydraulic power system, the loading cart is self-

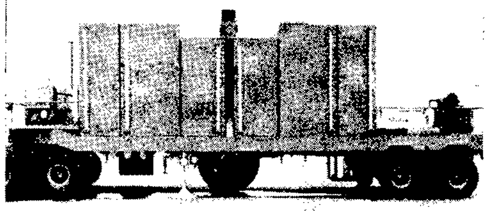

Figure 5. 50-Ton capacity cart for application of wheel loads.

sustaining. Figure 6 presents an actual static loading test with the wheel in the center of the slab.

Initial tests have been made with a static load of 50,000 pounds and a tire pressure of 200 psi applied at the center of the slab with the tire-print tangent to one face of the joint. The results of these initial tests indicate that the moment distribution along the dowel over which the load was applied appears to be as shown in Figure 7. The maximum moment is about 2,700 inch-pounds and appears to be about 0.6 inch from the face of the joint. The moment diagram is stopped at the last gage

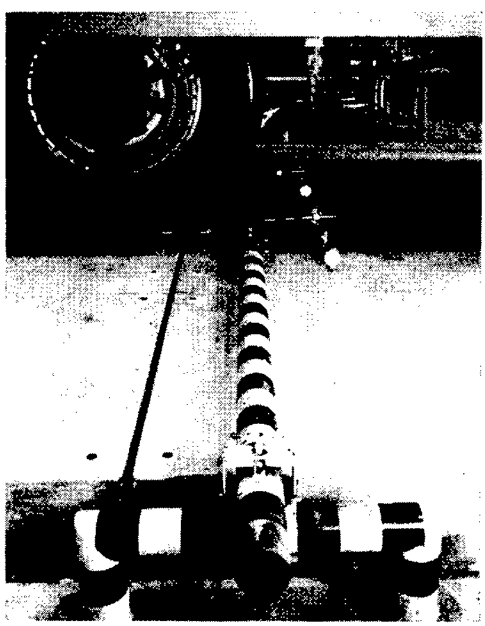

Figure 6. Static loading test.

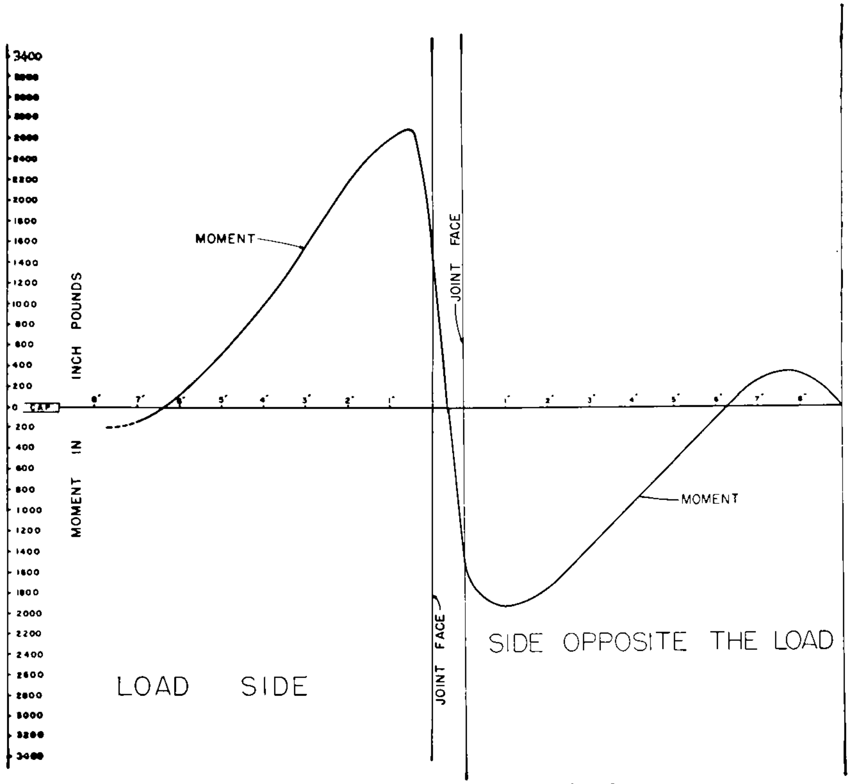

Figure 7. Moment diagram for center dowel.

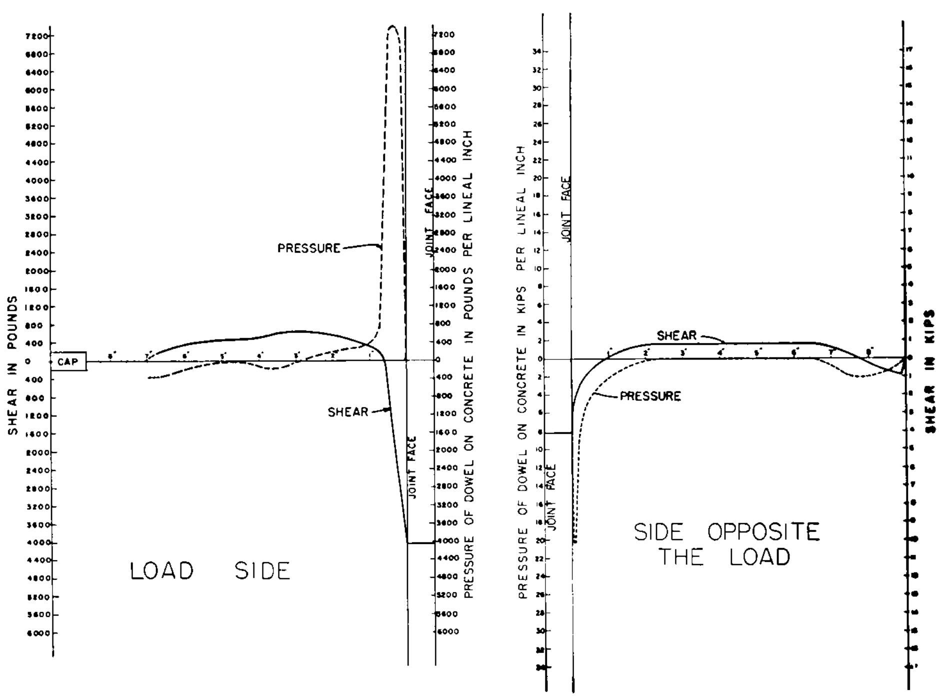

Figure 8. Shear and pressure diagrams for center dowel.

position on the load side because the amount and direction of the moment from there to the cap have not been determined.

Shear and pressure curves calculated from the moment curve are shown in Figure 8. The shear transmitted across the joint is about 4000 pounds. The maximum pressure on the load side is 7,400 pounds per lineal inch and on the side opposite the load is 20,400 pounds per lineal inch.

Additional static tests are planned using a 50,000-pound load at 200 psi tire pressure with the load applied over dowels closer to the corners of the slab. Dynamic tests using the same load will be applied over the same places that the static loads were applied. To determine the effects of higher loads and higher tire pressures, static and dynamic loading tests will be made with various combinations of loads and tire pressures up to a maximum of 100,000 pounds and 250 psi, respectively.

The moment, shear, and deflection data will be used to develop a method of load transfer device evaluation based on field values. A small slab containing three 1⅛-inch diameter dowels spaced 12 inches on centers will be constructed on a subgrade with a modulus of 200 pounds per cubic inch. Loads will be varied until the moment, shear, and deflection values correspond with those from field tests. Other transfer devices also will be cast in small slabs and similar loads applied to observe their performance under the same conditions which prevailed in the dowel tests. Moment, shear, and deflection data from field tests will be used in current theoretical load transfer equations to observe the correlation.

Field testing is continuing and subsequent data will be released for publication in the appropriate technical journals.