CORRECTING PAVEMENT PUMPING BY MUD JACKING—INDIANA

By Robert E. Frost
Research Engineer, Purdue University

Early in 1942 a performance survey was made on a portion of U. S. No. 30, located between U. S. No. 41 and a point just south of Valparaiso, Indiana. A report of this survey stressed the seriousness of the pumping action taking place on the outside lanes of parts of this road—not yet five years old (at that time). The report further contained suggestions for methods of treating pumping joints and presented an outline for a research program for the continuation of pumping studies. The results of this performance survey and others in Indiana and other states were presented at the November, 1943 Highway Research Board meeting in Chicago.

Among the new studies were suggestions for treatment of the slabs by mud-jacking and by the installation of French drains. As a result of this report, arrangements were made to conduct mud-jacking research on a section of this road near the Lake-Porter County line. A 2-mile section of road was selected for observation in which various mixes of soil, cement, and bituminous materials were to be forced under some of the slabs that had settled due to pumping action.

In October and November, 1942, 50 pumping joints were treated by mud-jacking. The remainder of the joints in the 2-mile section were left for purposes of comparison. In addition, several joints were treated by draining with various types of drains. This report is a detailed study of that 2-mile section of U. S. No. 30 under observation showing how both the treated and untreated slabs have performed during the 2-yr. period following treatment.

This section is a part of a four-lane-divided concrete pavement in Lake and Porter Counties extending from U. S. No. 41 to Valparaiso, a distance of about 24 miles. This portion of roadway is of modern design in which the 200-ft. right-of-way contains two 22-ft. slabs separated by a 44-ft. dividing strip and a 56-ft. strip on either side of the pavement. The pavement slabs are 9-7-9 in. in section and are reinforced with steel mesh and were constructed with joints. The first portion of this road was constructed in 1937 and the last was completed in 1940. Several experimental-subgrade-treatment sections were installed on the western end of the road. Seven types of treatment were used including saturating the subgrade with water, treating with bituminous materials (AES-1, T-C, MC-1), and replacing the subgrade with granular materials (sand), limestone dust, and crushed limestone.

The soil used in conducting the mud-jacking research consisted of 46 per cent sand, 34 per cent silt, and 20 per cent clay. This soil had a liquid limit of 29.3 and a plastic limit of 22.2. In choosing soil for this purpose an attempt was made to select material free from organic acids and solids.

Four mixes including the use of three bituminous materials (RC-3, cut back asphalt) road oil, and tar), were used on the project. The percentages were calculated on a dry-weight basis and were as follows for three mixes: soil—77 per cent; bituminous materials—7 per cent; and portland cement—16 per cent. The fourth mix contained 3½ per cent of tar.

In October 1944, 2½ yr. after the first survey and 2 yr. after mud-jacking, another survey was made of U. S. No. 30. A detailed survey of the entire 24 miles was not made, but several pictures were taken to show the condition of many of the joints. It was observed that pumping had progressed at a rapid rate and had become a serious problem. Pumping has occurred on both the north and south (particularly the outside) lanes but is more severe on the south lane. At present, the pavement is 7 yr. old and during this time the 24-mile length has served as an excellent "test track" and because of its variation in construction, it has been possible to study the pumping problem, its causes, effects, and, to a limited extent, its cures. Since the entire 24 miles carries the same amount of traffic (with the exception that the south lane carries the heaviest truck traffic) and receives the same amount of rainfall, it has been possible to evaluate the various types of subgrade soils. Visual in-

spection of the 24-mile section showed no pumping on the natural sand section, the 6-in. sand section, or the 3-in. stabilization section. Pumping was very slight at a few of the joints on the limestone treatment, and on a few of the joints on the MC-1, AES, and TC sections. Pumping was exceptionally bad on the water-saturated section and several of the slabs had settled enough to warrant patching. Pumping was found to be severe in the silty-clay drift areas.

In October 1942, previous to mud-jacking, on the special mud-jack section, all cracks were stationed, counted, and all joints were rated as to degree of pumping. Six months after treatment, in May, 1943, another performance survey was conducted on the same 2-mile section. In this survey new cracks were stationed and counted and again the joints were rated according to degree of pumping.

The next survey was conducted in October, 1944 (just 2 yr. after treatment) during which time pumping was found to be slight. The results of this survey were somewhat difficult to evaluate since a series of drains had been installed beneath the outside edge of the slabs for the major portion of the road from Valparaiso to U. S. No. 41. These drains, together with a deficiency of rainfall during the months of May to September, 1944, may account for the fact that pumping was not observed at the time of the October survey. During that period 14.26 in. of rain fell, which was 72 per cent of the normal rainfall for that period (a deficiency of 4.53 in.). On November 6, 11, and 27, similar surveys were conducted (pumping only) since that area was receiving rainfall.

In view of these two conditions, a pumping rating during that survey cannot be taken as a measure of the success or failure of treatment. However, a crack survey was also made in which the development of all new cracks was observed in both the treated and untreated section. (For purposes of comparison, a detailed crack survey was made on the 6-in. sand experimental section.) In addition, the settlement at each joint, inner edge and outer edge of the slab, was noted for both treated and untreated joints.

From a study of the data presented in this report concerning the performance of U. S. No. 30 from Valparaiso to U. S. No. 41 and the two-mile section under observation, the following statements have been summarized:

(1) This work confirms previous studies in that three conditions must be satisfied in order to have pumping. These are: (a) A subgrade consisting of a relatively plastic and impervious clay or silty-clay soil; (b) Heavily loaded vehicles; and (c) A high soil moisture content.

(2) Once pumping starts the rate of progression increases, with severe pavement cracking and settlement resulting.

(3) Each performance survey conducted on U. S. No. 30 has shown that all of the experimental subgrade treatments constructed on the south lane (with the exception of the water-saturated section) have been successful in minimizing or preventing pumping.

(4) Pumping does not occur in natural sand areas or in the sections constructed on 6 in. of sand or 3-in. stone stabilization.

(5) Cracking less than 13 ft. either side of a joint, in the 40-ft. slabs of this section, is due to slab movement initiated by pumping action and cracks past 13 ft. (middle third of slab) are not caused by movement at the joint but by other causes (applies to untreated slabs only). Between the fifth and seventh year of this pavement's life cracking less than 13 ft. from the joint increased 154 per cent while cracking past 13 ft. (or in the middle third) increased only 10 per cent (applies to untreated slabs only).

(6) During the 2-yr. period (fifth and seventh year) cracking less than 13 ft. on rear slabs of untreated joints increased 226 per cent, and cracking on the forward slabs increased 117 per cent. During the same period, cracking less than 13 ft. on rear slabs of treated joints increased only 70.5 per cent and on forward slabs only 51 per cent.

(7) Treatment by mud-jacking reduced the expected increase in 2-yr. cracks (fifth to seventh year) less than 13 ft. from joints from an increase of 154 per cent to an increase of 58 per cent.

(8) Each mud-jack mix was effective in reducing cracking. Only one new crack occurred in seven slabs treated with mix "A"; none occurred on four mix "D" slabs; and 10 new cracks occurred on sixteen mix "C" slabs.

(9) During the two years following treatment, mud-jacking has been successful in reducing the average settlement of slabs at pumping joints. In this period 48 per cent of the treated slabs had not settled as compared to 26 per cent not settling for untreated slabs. Sixty-eight per cent of the treated joints had settled less than one-eighth inch as compared to 53 per cent of the untreated slabs.

(10) The limited data contained in this report regarding mud-jacking procedures prevent recommendation for operational procedures; however, by way of observation the following are pertinent:

(a) The work should be under the direction of an experienced operator or one competent to judge when a slab has been properly treated, since mistakes will perhaps prove detrimental rather than beneficial.

(b) Each slab should be handled as an individual case rather than by following a standard procedure of operation.

(c) Traffic should be kept off of treated slabs for at least 24 hr. following treatment.

(d) In areas where surface drainage is exceptionally poor, the slab should be given some form of supplemental drainage that should receive periodic maintenance.

PUMPING OF CONCRETE PAVEMENTS IN NEW JERSEY, CORRECTIVE MEASURES AND FUTURE DESIGNS

By William Van Breemen

Pumping and faulting at joints in heavy-duty concrete pavements were first observed in New Jersey in 1930. Load transfer at these joints consisted of six ¾-in. round dowels, 20 in. long. An increase to 12 dowels of the same size in later work retarded the rate of deterioration but soon proved ineffective. The use of crushed stone drains along the pavement edge in conjunction with these 12-dowel joints appears to have been at best temporarily effective in postponing faulting. They may be effective to some extent in minimizing pumping.

Until recently, no effort was made to classify pumping and non-pumping types of soil on the basis of detailed physical and chemical analysis. Subgrade soils, with respect to their tendency to pump, have been judged primarily in terms of permeability and susceptibility to erosion. Generally, where pumping has occurred in New Jersey the subgrade soil and the adjacent shoulders were more or less impervious, and the subgrade soil has been eroded.

In 1932 a test road was constructed on silty-clay soil. One joint with no load transfer device, two with six ¾-in. round dowels, two with twelve ¾-in. round dowels, and several with various combinations and sizes of heavy rectangular dowels were installed in the 10-ft. width of pavement. Repeated applications of heavy loads under extremely wet conditions indicated that the use of large rectangular dowels prevented faulting entirely and materially retarded pumping. Following the test, a joint comprising twelve 2-in. depth channel-dowels, 20-in. long, was designed and adopted in standard construction.

A survey in September, 1944 of 60,000 channel-dowel joints in heavy-duty highways disclosed only three joint failures due to pumping. No faulting was found at these joints; failure occurred by simultaneous sagging of both slab ends. Stone drains along the pavement edge were found partially clogged with subgrade soil pumped out laterally at these joints.

A survey of pavements laid on granular