New Developments in Correcting Rigid Pavement Pumping

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State and county highways have recently emerged from a five-year period of wartime traffic. Many of the roads are showing evidences of severe damage and premature aging as a result of the important part they played in the national war effort. High-type pavements on primary routes have been especially affected by these abnormal traffic conditions.

The pumping of pavements has been one of the predominant types of failures. In brief, pumping is the process of ejecting the water-suspended subgrade soil at joints, cracks, or the edge of the pavement, because of the deflection of the pavement slab under the action of traffic. The prevention and correction of pumping joints in rigid pavements remains one of the most difficult of the problems that confront highway engineers. In the Indiana State Highway System approximately two hundred fifty miles of roads are, to some extent, in distress from pumping, although this mileage represents only about six per cent of all the rigid pavement in the system.

Pumping has progressed on some of the roads to a stage where the usefulness of the pavement is seriously impaired and its complete destruction is imminent. In other locations, however, the removal of small amounts of material from beneath the pavement is just beginning to become evident. Past experience has shown that most pavements pass from the mild stage to the serious stage of development within a very short time—usually within one or two years.

It has been generally agreed that three factors must be present before pumping action can take place. These factors are heavy traffic in concentrated loads, susceptible subgrade soil, and water in and on the subgrade. The maintenance engineer can control only the third element, that of subgrade water, in attempting to prevent or to arrest pumping at joints.

Established maintenance procedures may be used to good advantage in helping to control the amount of water that will reach the subgrade. Adequate drainage should be provided by keeping side ditches

open and the shoulders maintained with proper slopes away from the pavement. Shoulder maintenance at the edges of the pavement is important, and porous surface material adjacent to the pavement should be avoided. Joints and cracks should be filled with bituminous material at regular intervals to prevent surface water from entering. All these standard practices aid in controlling the accumulation of water beneath the pavement, and in this way tend to prevent pumping.

Treatment of Pumping Joints

In addition to these regular maintenance procedures, new methods have been devised which prevent surface water from reaching the subgrade and at the same time help to control the movement of the pavement slab. These operations consist of the forcing of a waterproof, or a water-resistant, material through holes in the pavement near the joints, to act as a filler for the voids in the subgrade and also as an undersealing material. Two different operations have been developed, one of which is known as mud-jacking and the other as bituminous undersealing.

Mud-jacking was first used a number of years ago to correct settlements in rigid pavements on bridge approaches and embankments. A slurry, consisting of soil, cement, and water, was pumped through holes drilled into the pavement, and the slab was lifted by hydrostatic pressure. In order to give it a sufficient amount of lifting ability, the slurry was mixed to a rather stiff consistency and a satisfactory distribution of the material was obtained by the use of a large number of holes spaced at close intervals. When this method was adapted for use in the treatment of pavement joints, bituminous material was also added to the slurry to make it more resistant to the action of water. The mix was also changed to a thinner consistency, to facilitate the flow to all parts of the subgrade adjacent to the joint which was being treated. In most cases, only one hole was drilled at each joint.

The Maintenance Department of the State Highway Commission of Indiana recently tried out a small mud-jacking machine constructed especially for use in the treatment of pavement joints. The machine consists of a small hopper and pump, which can be moved by one man and placed directly over a hole in the pavement. A thin-mud slurry, containing soil, cement, emulsified asphalt, and water, was mixed in a small bituminous mixer and placed in the hopper. The material was forced through the hole without difficulty, and apparently was well distributed over the subgrade in the vicinity of the joint. The pumping action appeared to be arrested, although it is not yet known how durable the material will prove to be.

Bituminous undersealing was developed in Ohio three years ago. Bituminous material was heated in a regular truck-mounted bituminous distributer and then pumped through a hose, the nozzle of which was placed in a hole in the pavement near the joint. It was found that the material flowed readily and spread in a uniform manner over the subgrade. Also, the material was forced up into the lower part of the joint, forming a water-tight seal. A soft grade of asphalt cement was used in the earlier experiments, because it could be applied at a relatively low temperature, but the material sometimes softened enough in hot weather to come up through the joints. A harder asphalt, corresponding to the joint-filling material generally specified in Indiana, is now being used.

This type of joint treatment was begun in Indiana on an experimental basis during the past season by the personnel of the Indiana State Highway Maintenance Department assisted by some of the members of the Joint Highway Research Project staff. In order to avoid the necessity of accepting delivery of large quantities of the bituminous material, and to scale the operation down so that it could be carried on by a small crew, specially equipped tar-kettles were used instead of large distributors. Several joints were sealed on U. S. 30 in the LaPorte District and on U. S. 52 in the Crawfordsville District, under the supervision of the Maintenance Superintendents in the Valparaiso, Frankfort, and Fowler subdistricts. The treatments appeared to seal the joints successfully and to fill the voids in the subgrade.

In order to inspect the distribution of the underseal, the concrete pavement was removed at one of the joints that had been treated. It was found that the bituminous material had formed an unbroken membrane between the subgrade and the pavement, extending for a distance of approximately four feet on each side of the joint. In addition, the material had been forced into the underneath side of the joint, apparently sealing it.

Some difficulty was encountered in handling the hot asphalt with the small tar kettles. It is probable that heavier equipment with larger pumps would prove to be more practicable.

Correction of Faulted Joints

One of the characteristics of a pumping pavement is the faulting, or misalignment, of the pavement slabs adjacent to the joints. Load-transfer devices have, in general, failed to prevent faulting joints, although they probably retard this action to some extent. Round dowel bars have been about as effective as any other type of installation, but they eventually bend and permit the joint to become faulted.

When pumping first starts, the slab completely recovers its position between load applications, but as material is gradually removed from the subgrade and the magnitude of the deflection is increased, the slab finally fails to recover completely its position and the joint becomes faulted permanently. This action usually causes the concrete to break on a transverse line six to eight feet from the joint. After the break occurs, the pumping action may decrease or stop altogether, and the pavement slab may remain in this condition for some time before further disintegration or faulting occurs. The existence of this faulting is serious, for it produces impact which contributes to the further destruction of the pavement. In addition, the riding quality of the pavement is seriously impaired.

Interesting information about faulted joints was recently obtained in a field inspection on U. S. 30 (divided-lane) in Lake County, Indiana. The data were collected by members of the Testing Department and of the Research Project. In 1937 the State Highway Commission constructed a series of test sections as a part of a regular construction contract on U. S. 30. On the two eastbound lanes the Testing Department developed seven different types of subgrade treatments, each of which was approximately twenty-five hundred feet long. The treatments included sand backfill, limestone dust, water-saturated soil, soil-bituminous mixtures, and stone stabilization. For comparative purposes, the adjacent ten thousand feet to the east of the test sections, located on similar plastic soil, was included in the field investigation.

The amount of faulting was measured at many representative joints on each section and also on the untreated portion, and the total amount of offset was computed. It was found that for the sand, stone dust, and limestone treatments, the total amount of faulting averaged less than two inches per thousand feet, and for the bituminous treatments it was less than four inches, while on the untreated portion, as well as on the water-saturated test section, the total amount of offset at the joints averaged more than eleven inches for each thousand feet. The sixteen miles of eastbound two-lane pavement adjacent to these test sections were considered fairly representative of the untreated portion which was included in the investigation, and it was estimated that the accumulation of all the faulting at the joints would total approximately eighty feet of vertical offset.

The results of this investigation indicate that subgrade treatments eliminate or greatly reduce the pumping of joints and that the amount of faulting is thereby reduced. Also, it was noted that more cracks existed between the joints on the untreated than on the treated sections, although the cracks were not pumping, nor were they faulted to any

appreciable degree, even on the portion of road where the joints were in serious distress.

The correction of the differential vertical displacement between the two slabs adjacent to a joint has proved to be a difficult operation. In the treatments previously discussed, it was observed that vertical movement obtained by the hydrostatic pressure produced by forcing the mud slurry or bituminous material beneath the pavement tended to raise both sides of the joint. The internal friction within the joint structure was sometimes sufficient to lift the higher slab enough to allow the material to flow beneath it, and the hydrostatic pressure was more or less equalized on both sides of the joint. This was found to be especially true with joints with dowels or with other load-transfer devices.

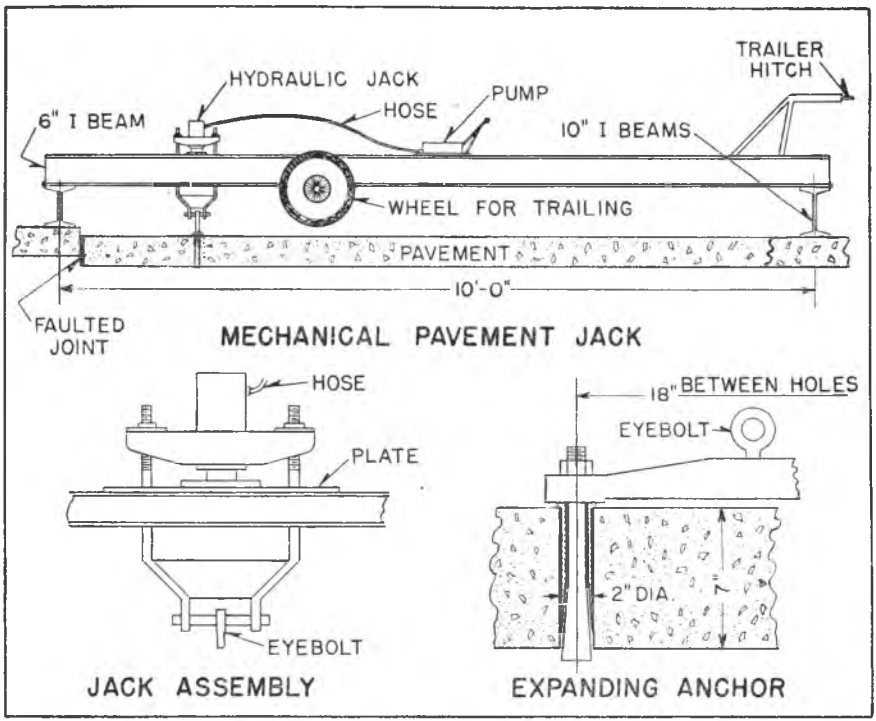
In order to insure a uniform distribution the material used in both the mud-jacking and the bituminous undersealing operation was of a thin consistency. Although this was desirable from the standpoint of filling existing voids and sealing the underneath part of the joint, control of vertical correction of the slab was made more difficult. The material tended to flow from the joint and cracks and from the edge of the pavement. During the experimental undersealing work, several observations were made on the treatment of some of the joints faulted approximately one-half of an inch. It was found that during the treatment the lower slab was raised approximately one-fourth of an inch and the higher slab approximately one-eighth of an inch before the bituminous material was forced out at the side along the edge of the pavement. With the mud jack, more vertical movement can be obtained, especially if the slurry is mixed to a slightly thicker consistency.

It is the opinion of the author that no fluid or semi-fluid material can correct faulted joints consistently and accurately by hydrostatic pressure. The resistance of the joint, and especially of the load-transfer device, usually prevents the lower side from being lifted independently of the other, and the amount of vertical correction which can be obtained before the material flows up through the joints or through the shoulder is uncertain, is generally uncontrollable, and may be negligible.

Since both mud-jacking and the bituminous undersealing operations appeared to be successful in sealing joints, and in filling the voids in the subgrade adjacent to the joints, it seemed desirable to devise some mechanical method of realigning the slabs at faulted joints so that the corrective treatment could be completed. The approach to the problem was direct, and the method developed was simple in its application. A mechanical jack was designed and constructed which will lift a slab in

a positive manner, at the same time restraining an adjacent slab from vertical movement.

This equipment consists primarily of a hydraulic jack mounted upon steel beams, one of which is placed adjacent to the joint, on the higher side, and the other on the lower side eight or ten feet distant. Special expanding shields and tapered shafts are inserted in two holes drilled through the lower slab near the joint, and the shafts are attached to the jack.



In testing this equipment, a typical joint was selected. It was faulted seven-eighths of an inch and the forward slab was broken on a line eight feet from the joint. The joint contained dowel bars. The mechanical pavement jack was attached near the outside edge of the pavement, and the lower slab was raised until it was in alignment with the opposite side of the joint. During the jacking operation, lifting stresses were recorded on a gauge mounted upon the hydraulic jack. It was found that it required a force of approximately five tons to "break" the pavement loose, after which only three tons were needed to continue the lifting. However, as the slab approached the elevation of the adjacent slab, the force required suddenly increased to ten or twelve tons, as the load transfer device tightened up in reversed stresses.

After the slab was lifted into place, bituminous material was forced beneath the pavement in the same manner as in bituminous undersealing. The jack was left in place for about fifteen minutes, to permit the bituminous material to cool and harden. It is the opinion of those who have worked with the machine that this new method of realigning pavement slabs is practicable when used in conjunction with mud-jacking or bituminous undersealing.

Treatment Material

There is still a great need for the development of an entirely new and different material for use in treating joints. The various mixtures that have been used in mud-jacking have not proved to be entirely satisfactory. Mixtures containing soil do not appear to have the inherent strength and durability needed to withstand, for long periods of time, the destructive forces to which they are subjected when placed beneath a pumping pavement. The bituminous cements that have been used for undersealing also have many disadvantages. The high temperatures needed to make this material flow readily, combined with the high fluid pressures used, make the placing of the bituminous material rather hazardous. The use of a full-sized bituminous distributor requires a large crew and does not lend itself to ordinary maintenance operations.

In this work of joint treatment, the cost of the material is relatively unimportant, since a greater part of the cost of the operation is for labor and equipment. For this reason, a new material could be higher in cost, if it proved to be durable, was easily placed, and could be made to harden reasonably soon after placing. The Joint Highway Research Project has initiated a program of laboratory and field research, to investigate the possibilities for a new material of this kind. During the next few months it is expected that several new mixtures will be tested which will be used in experimental joint treatments, both for undersealing and for use in conjunction with the mechanical pavement jack.

The annual destruction of many miles of otherwise good concrete pavements by pumping joints offers a challenge to the ingenuity and resourcefulness of the men who are charged with the responsibility of highway maintenance. A good start has been made in the use of mud-jacking and undersealing treatments, and the mechanical pavement-jacking equipment shows promise of aiding in the problem. It is hoped that with the further developments of these techniques, along with an improvement in the material used, proper preventive and corrective treatments will become standard maintenance practice, and that years of service will be added to some pavements which might otherwise be discarded.