EFFECT OF DEFECTIVE JOINT SEALS ON PAVEMENT PERFORMANCE

by

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ABSTRACT

The reasons for installing and maintaining effective sealants in joints and cracks in pavement are discussed since there is some controversy on the need for such seals. Results are presented of studies made in Europe on the performance of pavement with unsealed joints and the conclusion that in most cases effective joint seals will minimize pavement distress. Various types of distress that develop from joint-seal failures are described and illustrated. A review is included of this six-paper session on methods, equipment, and materials for resealing joints and sealing cracks in concrete pavement.

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Joints in concrete pavements are necessary, but they can be the source of many problems and subsequent pavement distress if they are improperly designed, constructed, or maintained. Joints are designed to control cracking, minimize stresses in the pavement due to volume change, and prevent damage to immovable structures. Joints are expected to provide some load transfer between adjacent slabs and thereby prevent a free edge condition, reduce pavement deflections and stresses, and prevent faulting at joints. Joints are sometimes designed with a reservoir for a joint sealant that will prevent surface water and incompressible foreign materials from entering the opening. It is this last function that is of concern here.

Joint sealants are designed to bond to the concrete in the joint. They are made to withstand many cycles of tension and compression as the joint opens and closes. Sealants are intended to create a waterproof barrier that will prevent surface water from entering the joint and reaching the subbase and subgrade. To be effective, sealants must also resist intrusion of incompressible surface material--sand, gravel, stone, and other foreign objects--into the joint reservoir and the crack or joint below the seal.

Since most sealants have a limited service life, joints must be resealed periodically to ensure that they will perform the functions for which they are designed.

What effect do defective joint sealants have on pavement performance? Do sealant defects prevent joints from performing their proper function in the pavement?

Performance of Pavement with Unsealed Joints

Unfortunately there is not complete agreement among paving engineers on the need for sealing all pavement joints. California uses a plain pavement design with short joint spacing (an average of 15.5 ft or 4.7 m) and an erosion-resistant subbase. The joints are sealed only in mountains areas with more than average precipitation.

In 1979 at the XVI World Congress of the Permanent International Association of Road Congresses (PIARC) the Technical Committee on Concrete Roads presented a report on "Experience with Unsealed Joints."(1)* The report stated that Spain and Austria build many kilometers of pavement with unsealed joints and that France and Germany have both built substantial test sections with unsealed joints. It pointed out that there are also hundreds of kilometers of concrete pavement built with sealed joints that did not require any maintenance for many years.

*Superscripts in parentheses designate references at end of this paper.

The PIARC report concludes that with joint spacings of 4 to 6 m (13 to 20 ft) there is no disadvantage in leaving narrow transverse joints unsealed when

- traffic is light
- traffic is heavy but climate is dry
- traffic is heavy and climate is wet, but pavement is dowelled

Most research in the United States--test pavements with sealed and unsealed joints--has demonstrated some improvements in performance when joints are kept reasonably well sealed.

Pavement Distress due to Joint Seal Failures

Today many engineers are concerned about water in pavements. Workshops, technical papers, research studies, and even text-books have focused attention on this problem. H. R. Cedargren(2) has called attention to the large volume of water that can reach the subbase or subgrade through the joints in a concrete pavement. Water in pavements or, more importantly, water that reaches the subbase or subgrade under a concrete pavement can result in activity that leads to pavement distress.

(Fig. 1) Pumping--the ejection of a mixture of soil and water from under slabs at joints, cracks, and edges--is one of the first symptoms of pavement distress. Mud-pumping can occur when concrete pavements are placed directly on fine-grained, plastic soils. Fines can be pumped from poorly graded granular materials under some conditions and even from cement-modified soilsunder some conditions. (Fig. 2) Continued, uncontrolled mud-pumping can lead to displacement of enough subsoil to create voids under the slab, destroy the uniformity of support, and leave slab ends unsupported. (Fig. 3) Cooperative pumping studies(3) have shown three conditions are necessary for mud-pumping to occur: (1) a subgrade soil that will go into suspension, (2) frequent passage of heavy wheel loads, and (3) the presence of free water between pavement and subgrade.

(Fig. 4) Pumping of granular subbase occurred on the structurally underdesigned sections of the AASHTO Road Test and led to excessive deflections, numerous cracks, and eventual pavement failure. Water in the subbase was an important factor in the process since pumping of subbase material was observed only during and after rains.(4)

(Fig. 5) Pumping or water action at joints, cracks, and pavement edges can also result in faulting of pavement joints and cracks. Faulting can be caused by voids under the leave slab* that permit settlement and may eventually lead to transverse or diagonal slab cracks 1.8 to 3 m (6 to 10 ft) beyond the faulted joint or crack.

* The "leave slab" is the pavement panel on which a vehicle leaves the joint (as opposed to the approach slab).

(Fig. 6) Faulting of joints and cracks on stabilized subbases has been attributed to water action under traffic that results in a migration of fine material from the shoulder or the subbase under the leave slab to the subbase under the approach slab. (Fig. 7) The deposits that build up under the approach slab lift it above the leave slab, creating a fault.

Studies in California(5) and Georgia(6) have identified this phenomenon. As with pumping this research has shown that free water must be present to create conditions leading to faulting. Faulting in California and Georgia was shown to lead to pavement cracking ahead of the joint if the deposit of material under the approach slab raised the pavement enough to destroy the uniformity of subbase support.

(Fig. 8 - blank) One other form of distress in concrete pavement can be attributed to water action in joints. Corrosion of embedded steel in concrete slabs is accelerated by the brine solution from deicing salts entering joints that are not effectively sealed. Investigations have shown that such accelerated corrosion, particularly in northern states where large amounts of deicing salts are used, can cause serious problems. Tiebars installed in longitudinal joints to hold two slabs together are sometimes found to be ruptured as a result of corrosion. Dowels or other load transfer devices can become badly corroded after several years of service. This corrosion can result in a reduction in cross section and subsequent rupture, or it can cause the free end of the dowel to become immobilized due to expansion.

It is obvious from these problems that free water under a pavement can lead to distress. If properly installed and maintained joint seals will prevent surface water from reaching the subbase and subgrade and from entering the shoulder joint, several major forms of pavement distress would be avoided. Waterproof sealing of transverse joints, longitudinal joints, pavement-edge shoulder joints, and open cracks should be an objective during both construction and subsequent maintenance.(7)

Of equal or greater concern than damage from water in the pavement is distress due to infiltration of incompressibles. Narrow joints in plain concrete pavements with short slabs are subject to some infiltration, but far greater damage can occur with the long panels used by some states with mesh dowel designs that result in excessive joint openings.

(Fig. 9) If joints are unsealed or if joint seals are ineffective, foreign materials from the shoulder, surface, or subgrade can enter the joints while they are open in cold weather. When the pavement expands during hot weather, the incompressible materials cause nonuniform pressures on the joint faces. (Fig. 10) Continued expansion of the pavement can cause stresses high enough to cause joint spalling at the surface, (Fig. 11) the edge, or (Fig. 13) even the bottom of the slab. (Fig. 13) Infiltration at the edges of joints can cause longitudinal restraint cracks that can actually split the slabs.

(Fig. 14) If joints become filled with foreign material and are then subjected to slab expansion during hot and humid weather, serious compression failures can result. (Fig. 15) In extreme cases actual pavement buckling or (Fig. 16) blowups can develop. (Fig. 17) If transverse joints are allowed to remain unsealed and to fill with foreign material, the joint openings will increase in size and pavements will tend to grow in length, closing expansion joints at structures and eventually causing damage to bridges and bridge abutments.

(Fig. 18) Most joint sealants today are designed to resist the entrance of foreign materials from the surface of the pavement. Many older-type sealants, however, actually held such materials until eventually the joint was filled. Simply adding additional joint seal to a joint or crack already filled with incompressibles will not help the situation. All foreign material must be removed prior to resealing.

Unsealed cracks may also contribute to pavement distress if the joint spacing permits the crack to open or if the reinforcing across the crack fails. (Fig. 19) At first the crack may be narrow and fairly tight with no spalling. (Fig. 20) As the crack opens, however, infiltration begins and the resultant spalling. (Fig. 21) Water action caused by slab deflection at cracks can also cause faulting here as well as at joints.

Finally, there is another effect of defective joint seals that does not receive as much attention: (Fig. 22) Overfilling joints can have a very detrimental effect on the riding qualities of the pavement. The practice, quite common a few years ago, of pouring large quantities of joint sealer on the pavement surface over joints and cracks was ineffective as a joint sealer and actually detrimental to pavement appearance and rideability.

Excessively wide black joints give the impression of bumps and lack of evenness or continuity in the pavement surface. The resulting wide band of sealant is smooth and even-textured, quite different from the adjacent pavement texture. The tire noise developed when vehicles cross these oversealed joints or cracks is frequently a slapping or sucking noise at each joint or crack. In many cases the overfilled sealant with embedded foreign material actually creates a measurable bump on the pavement surface. Such high spots, usually at regular intervals, create a rough ride and a very objectionable thump-thump-thump. Thus, while overfilling joints may not cause serious distress in the pavement, it certainly has a negative effect on appearance and ride. In some cases excess sealant sticks to tires and is pulled from the joint, destroying its effectiveness. (Fig. 23 - blank)

Closure

Some of the more obvious detrimental effects of unsealed or poorly sealed joints and cracks have been discussed here; more could be mentioned. The attached reference list contains several sources that provide more details on the subject. Other papers to be presented during this meeting describe the effects of joint design and slab design on sealant performance. Methods of evaluating the effectiveness of in-place sealants, repairing pavements prior to resealing, routing out, cleaning, and resealing will be discussed. The final paper will explore, from a contractor's viewpoint, various specifications and contract provisions and their effect on the cost of resealing joints.

As a result of this meeting engineers and contractors should be equipped to do a better job of resealing joints in pavements, and thereby improve pavement performance.

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