FAULTING OF SHORT SLAB CONCRETE PAVEMENTS

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Research Laboratory Section
Testing and Research Division
Research Project 70 F-113
Research Report No. R-895

Michigan State Highway and Transportation Commission
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Lansing, December 1973

Summary

This report discusses the reasons for faulting of short slab rigid pavements constructed without load transfer. Specifically, Monroe County Rd 151, a plain concrete pavement, with 15-ft slab length, that was built upon an 8 to 10-in. layer of crushed limestone over an old concrete pavement.

A section of the faulted pavement was removed for observation, and evidence was found indicating water-induced migration of particles greater than 0.1-in. diameter. Also, there was a small void under the slab.

It is concluded that greater emphasis on drainage is a prime requirement of base design and construction.

Background Information

During recent years, there have been numerous suggestions for use of short slab, plain concrete pavements, to reduce initial cost. The suggestions usually have included proposed increases in the thickness or strength of the base to "prevent faulting." However, many such ideas proved ineffective because the mechanism that causes the typical step-down or ramp type faulting was not known. Figure 1 is a portion of an actual road profile, showing the typical faults at joints.

The State of California probably has used the short slab pavement more extensively than elsewhere. Both cement treated and bituminous stabilized bases were used, along with skewed joints and variable joint spacing. The continuing occurrence of faulting led to closer observation, and some interesting facts were noted. In one case, a roadway was faulted in the typical fashion, but a change in the direction of traffic caused a reversal in the faulting. In a relatively short period of time, the magnitude of faulting was as bad as before, but the direction of faulting had reversed. In another case, a roadway had performed satisfactorily for several years, then faulted in just a few months.

There have been many different ideas concerning the cause of such progressive faulting, but no facts to substantiate them. It has been obvious for some time that this type of problem is caused by the rate of loading rather than the loading itself, since the same wheel loads traverse both sides of the joints. However, it appears that many workers have been so convinced that granular base materials are "free-draining," that the occurrences of significant quantities of water between the slab and base was overlooked for a long time.

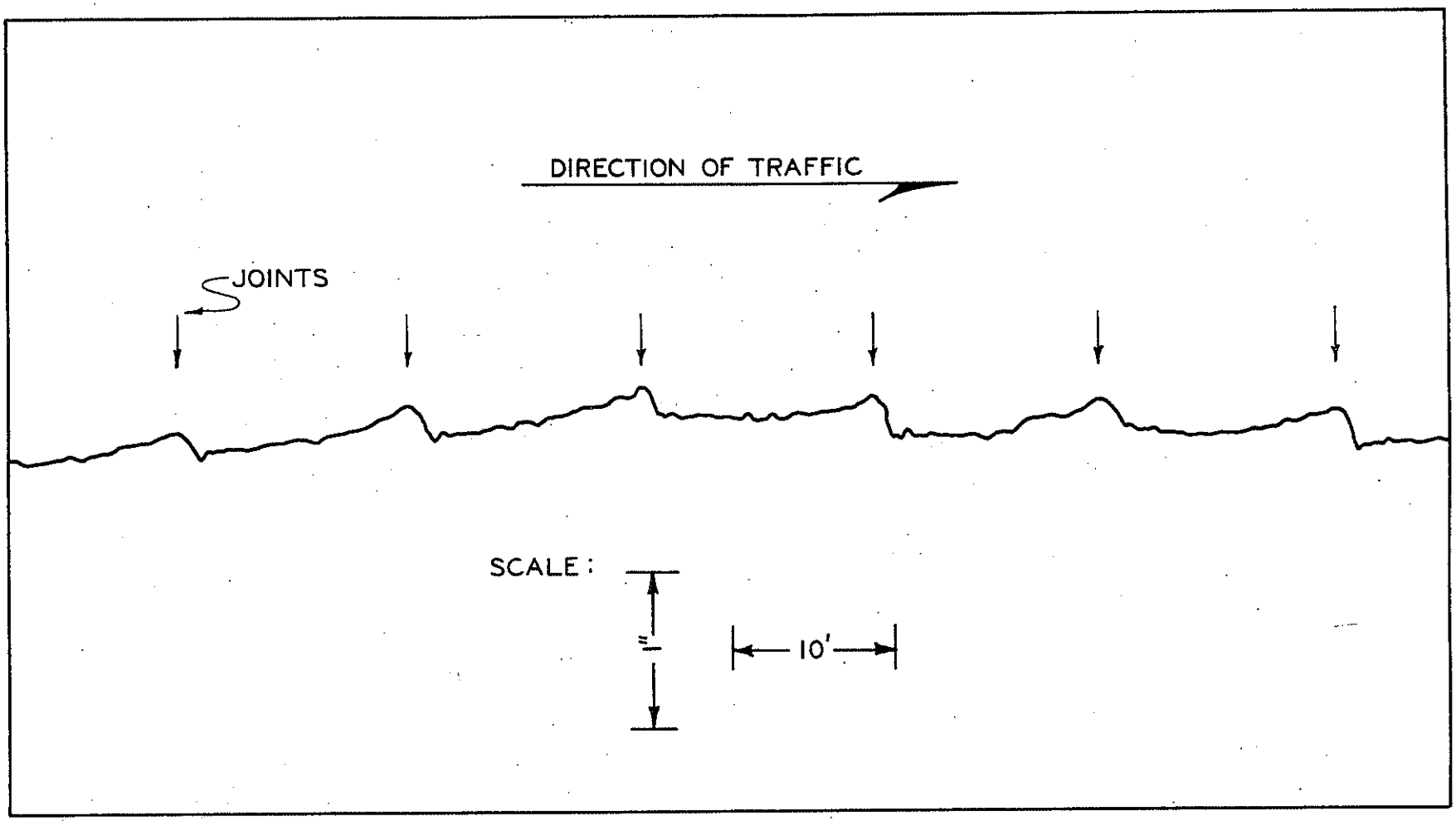

Figure 1. A portion of the profile of County Rd 151, showing the downward steps in the direction of traffic.

In June 1970, Michigan Research Report R-743 discussed faulting of short slab pavements noting that, "Initiation of faulting may result from the marked difference in the rate of load application to the leading and trailing edges of the slabs. The rate of load application is roughly 15 times greater for the leading edges than for trailing edges on the CR 151 pavement."

In the meantime, the State of California, in cooperation with the Federal Highway Administration and the Portland Cement Association, had completed comprehensive research on the cause of faulting. The study indicated that faulting was caused by free water under the slab, being pumped repeatedly forward at slower speeds as the approach slab was loaded; then quickly backward as the load traversed the joint and caused sharp downward motion of the leading edge of the next slab while the approach slab rebounded. Since doubling the velocity of water increases by about a factor of four the size of a particle that can be moved, such fluid motion effectively acts as a pump to move materials under the slab. Some colored sand inserted beneath a California slab, was moved about five feet in only a few weeks. Both shoulder material, and fine material eroded from the surface of cement treated base, were found under the raised slab ends. Shoulder material was also found intruded within a bituminous treated base.

The California study provides the information required to design a base for greater resistance to faulting. The main factors are to provide erosion resistance in the base, far better drainage under the slab and shoulder, stabilization of the shoulder, and eliminate as much as possible the intrusion of water through cracks and joints.

Observations: County Road 151

Monroe County Route 151 is a plain concrete pavement with 15-ft slab length and no load transfer, built upon 8 to 10 in. of crushed limestone over an old concrete pavement. It was built by the state and turned back to the County when the eastern portion of State Trunkline 151 was abandoned, with the completion of I 75. After five-years of relatively light use, a survey showed isolated faults of 3/16 in., 1/8-in. faults at about 3 percent of the joints and 1/16 in. or greater faults at about 20 percent of the joints. By seven years of age, the isolated faults approached 5/16 in., 1/8-in. faults were quite common, and nearly every joint had faulted at least 1/16 in. Rideability had deteriorated considerably, especially for stiffly suspended vehicles.

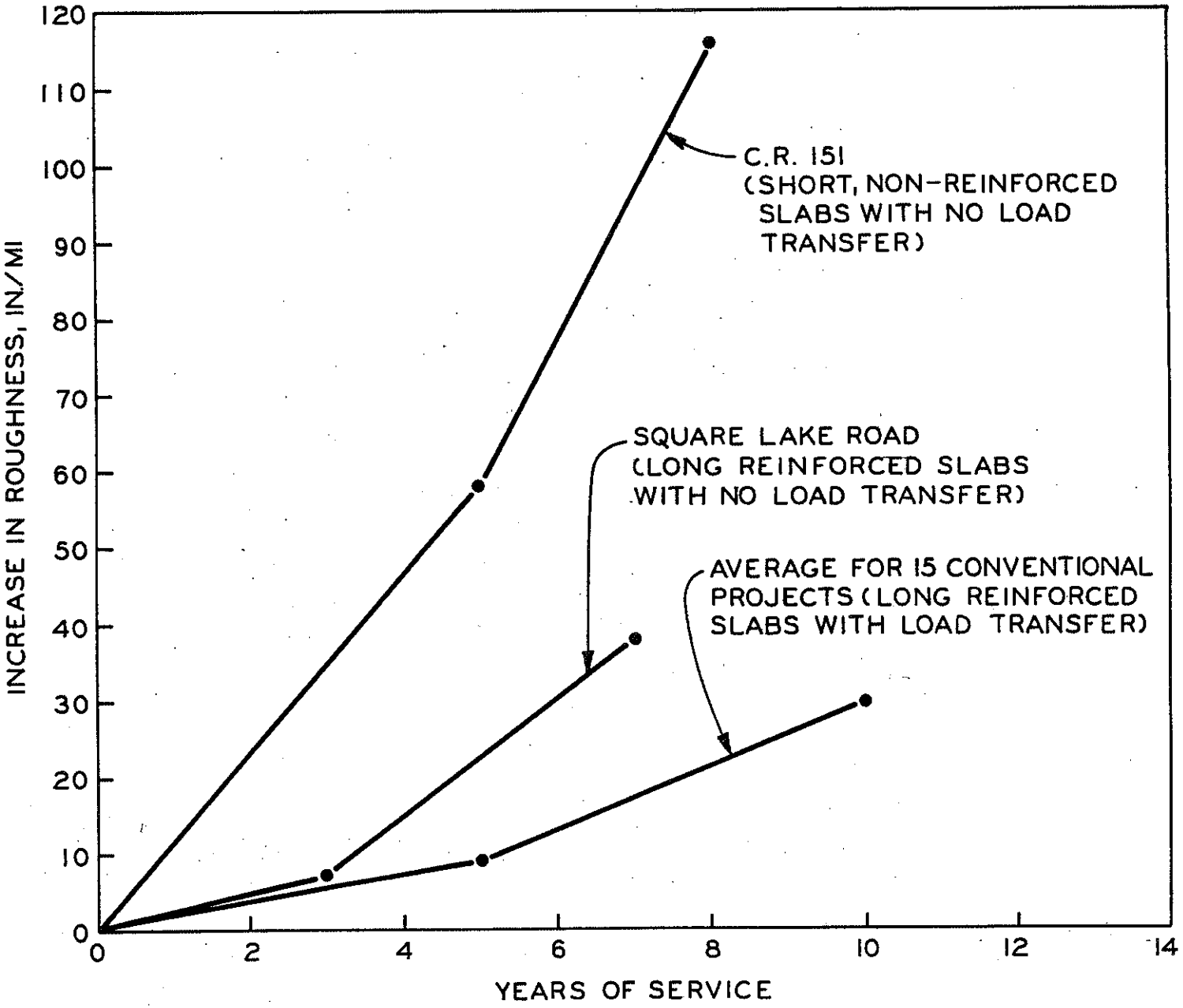

Figure 2. Increase in roughness vs. years of service.

Research Report No. R-743 also contained a plot of the amount of roughness increase, versus years of service, for CR 151 as compared with some other roads. Figure 2 shows that same information, updated to include the three additional years since the report was published. It is obvious that the rate of increase in roughness is considerably greater for the short slab pavement, even though the amount of traffic on that route is much smaller than for the other routes.

Successive price increases for conventionally and continuously reinforced concrete pavements have caused the proposal, on several occasions, of reverting to the plain concrete design. The current steel shortage has brought further problems, especially for continuously reinforced pavement. Due to these problems, it was decided that further investigation of the Monroe County project should be done to determine whether there was evidence of the water induced migration of fines under the slabs, and just what size particles had been moved.

We felt that the joints with maximum faulting might contain some movement due to differential settlements, and not be entirely typical of the problem in general. Therefore, a joint was chosen that had a 1/4-in. fault near the shoulder, and perhaps 1/8 in. near the centerline joint. The full lane width was removed, 3 ft on each side of the joint.

Inspection of the limestone base showed evidence of a void beneath the pavement, and of water erosion under the low side of the joint near the shoulder. Only the coarsest crushed limestone was left in the surface over this localized area. An approximate 1/4-in. depth of finer particles had been transferred to the opposite side of the joint. This 1/4-in. layer could be removed with a trowel, before striking the coarse crushed material underneath. The granular material under the high side of the joint was not as fine grained as one might expect. An apparent collection of very fine material was found nearer the pavement centerline but, suprisingly, under the low side of the joint. Evidently, as the slab slanted toward the shoulder, some of the very fine material migrated inward.

Small samples were taken from the very surface of the base at three locations. Although the samples were smaller than soil samples normally would be, sieve analysis was made by the Laboratory's Soils Unit for general information. Table 1 shows sample location and results of the tests. These results are not presented as highly accurate representations of the grain size distribution beneath the slab, because of the small sample size and very limited number of samples collected.

TABLE 1
SIEVE ANALYSIS OF SMALL SAMPLES
GRANULAR BASE MATERIALS FROM COUNTY ROAD 151

Locations

Sample No. 1 - Approach slab, (high side of joint) 1-ft from shoulder, 6-in. from joint.

Sample No. 2 - Leave slab, (low side of joint) 1-ft from shoulder, 6-in. from joint.

Sample No. 3 - Leave slab, 3-ft from shoulder, 2-1/2-ft from joint.

RETAINED FRACTIONAL
(Percent)

Sieve Size	Sample No. 1	Sample No. 2	Sample No. 3
1-in.	0	0	0
3/4-in.	0	8	5
3/8-in.	1	34	38
No. 8 - (0.094-in.)	21	24	21
No. 200 - (0.002-in.)	62	24	31
PASSING NO. 200			
Sieve Analysis	1	1	1
By Washing	15	9	4

These results are intended only to give a rough idea of the size of particles that evidently have been moved by water under the slab. It seems evident from the results that the elimination of ultrafine materials from the base will not prevent faulting. If drainage of the base is such that free water can collect under the slab, particles of considerable size can be moved.

Discussion

Experimental evidence from many sources points to the fact that the existence of free water under rigid pavement slabs is far more prevalent than has previously been supposed. The numerous problems that result from such a factor seem to indicate that a new approach is required in the selection of base materials, with far greater emphasis on drainage.

While cement and bituminous stabilized bases have been recommended as possible solutions to pavement problems as a whole, a careful combination of design features obviously is required if the solution to one problem is not to result in the beginning of a different problem. For instance, a neighboring state had trouble with "tenting" or localized heaving of joints, in a relatively new concrete pavement, on cement treated base. This was due to freezing of water that infiltrated through the joints.

Illinois has had some success with bituminous stabilized base, but the pavements placed on that base usually are continuously reinforced, and therefore have no joints. The application of jointed concrete pavement on the same base might lead to varying results.

Trenched cross-sections, where granular materials are placed in depressed troughs cut in clay, are obvious candidates for collection of water, and can be expected to fault if no load transfer is provided. This type of section resulted in extreme faults on the old Detroit Industrial Expressway. Therefore, it appears that the replacement of so-called frost susceptible materials with granular materials can solve one problem and lead to another if the total environmental system is not considered.

Another solution to faulting, presently being tried for plain pavements in some places, is the use of thicker slabs. However, given the presently recognized cause of faulting, this solution seems doomed to failure if the base conditions are such that free water can collect under the slabs.

Recent work in bituminous stabilization of aggregates has resulted in the development of porous mixes that allow through passage of very large quantities of water. The State of California is experimenting with such mixes, placed over a granular filter blanket, as base for short slab pavements. Such installations require design of the bituminous mix and filter blanket to prevent infiltrated soil from clogging the water passages. This in turn requires great care in the selection and production of aggregates. The concept does seem to provide a reasonable approach, based on the facts now known. However, long term performance of this type of system in an area of severe frost and heavy salting evidently has not been proven as yet.

Conclusions

Removal of a portion of faulted pavement on Monroe County Route 151 has shown evidence of water erosion of the base and a small void beneath the slab. Crushed limestone particles greater than 0.1-in. diameter appear to have been moved by the water.

This, along with reported occurrences of water beneath slabs in other investigations, leads to the conclusion that greater emphasis on drainage is a prime requirement for pavement base design and construction.

Please note that photos have been eliminated from this report in order to speed printing. However, some pictures of the base of County Road 151, as well as profiles of that road surface, are available for review at the Research Laboratory for anyone interested in further detail.