R-743

OFFICE MEMORANDUM

MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

June 2, 1970

To: R. L. Greenman
Engineer of Testing and Research

From: L. T. Oehler

Subject: Pavement Joint Spacing in Portland Cement Concrete Pavements. Research Project 39 F-7(14). Research Report No. R-743.

This report discusses Item 3 of the May 7, 1970 meeting of the Pavement Selection Committee where the suggestion was "... to try a 56-ft spacing or even a 42-ft spacing in the belief that this would result in a smoother riding pavement." We do not see how introducing more joints in a pavement by closer joint spacing will result in a smoother riding pavement, either initially or after years of service. In the past when joint grooves were formed, shorter joint spacing generally resulted in high initial roughness. With sawed joint grooves, shorter joint spacing may not result in an increase in initial roughness but there appears to be no reason that it will improve it either. However, all pavement evaluation studies have shown that deterioration, when it does take place with time and service, is most predominant at the joint. Thus, increasing the number of joints by shorter joint spacing will eventually increase the roughness.

Our experience with 99-ft reinforced slabs is that after 10 years of service the average is 1.5 transverse cracks per slab, and after 15 years of service 2.5 cracks per slab. In general, these cracks are prevented from opening by reinforcing steel and are neither apparent to the motorist nor do they contribute to a reduction in riding quality of the pavement. In 1963, when the joint spacing was changed to 71-ft 2-in., the weight of reinforcing steel remained the same in order to slightly increase the safety factor against yielding of the steel. We can expect slightly less transverse cracking with 71-ft 2-in. slabs than with 99-ft slabs and a reduction in opening of the cracks because of a reduced design stress in the steel reinforcement. It is true that reductions in slab length result in reduced transverse cracking but when these cracks are well controlled by reinforcement, as they are in our current design, they are much less deleterious than the increased number of joints which are much more likely to require maintenance.

One frequently advanced reason for shorter joint spacing is the improvement in sealing of the joints. It is true that neither hot-pour rubber-asphalt nor cold-pour polyurethane currently available will properly seal joints at a 71-ft 2-in. spacing unless initial joint width is increased beyond normally acceptable limits. However, continued annual surveys of joint seal condition indicate that neoprene seals are doing a very satisfactory job of sealing these joints.

Older pavements, constructed with poured joint sealant and base plates, generally begin to show serious joint failures after 10 to 15 years of service. However, some prediction can be made of future joint problems on specific projects by observing the amount of joint spalling during the first 5- to 10-year service period, since joint spalling has been shown statistically to correlate well with future, more serious, joint problems such as blowups. In general, our neoprene sealed pavements are not old enough to have developed any serious joint problems but lack of joint spalling and the clean condition of the joint grooves indicates that there will probably be a large reduction in joint problems with neoprene seals and sawed joints. Dowel corrosion should also be reduced by the new joint seals.

With respect to the other suggestion made at the Pavement Selection Committee meeting, concerning a 30-ft joint spacing without reinforcement, our objections are more strenuous. From our own observation and experience, as well as that of other states, we feel that a non-reinforced slab design is a serious mistake. Other states are constructing plain slabs, both with and without load-transfer at joints. We feel that even lightly traveled pavements require load-transfer and this is indicated by the 5-year history of the no-load-transfer project on County Road 151 where, after 5 years of service, the roughness has increased from 116 to 174 inches per mile, a 50-percent increase. Fifteen conventional concrete pavements were selected at random for comparison and after 5 years of service the average increase in roughness was 9 inches per mile compared to 58 for the undoweled pavement.

Figure 1 graphically shows the 5-year increase in roughness of C. R. 151 as compared to the fifteen other conventional pavements. The Figure also shows the 3-year roughness history of Square Lake Rd, another pavement built without transverse joint load transfer. Even the worst conventional pavement has a better history of riding quality than either of the two built without load transfer, and the average of the 15 conventional pavements is far better.

Three states that used unreinforced slabs and undoweled joints in trunkline pavement after World War II were Missouri, Texas, and Mississippi, but these pavements became very rough after a few years of service because of faulted joints.

Two conclusions from "The Michigan Test Road Final Report on the Design Project" as published in 1959 have a direct bearing on this. These are:

"Plain concrete pavement with dowels at contraction joints perform better than plain concrete pavement without dowels at contraction joints."

"Joint spacing of approximately 10 feet would be necessary to completely prevent transverse slab cracking."

The Michigan Test Road showed that for 30-ft plain slabs, approximately every seventh slab had a transverse crack; however, these transverse cracks, when they occur in a non-reinforced slab, are much more serious because opening and closing of the crack takes place with seasonal temperature and moisture changes, surface water can drain into the base; and these cracks will fault under traffic loading, just as the 15-ft slabs have done on C. R. 151.

There has been some discussion of improving the pavement support structure in order to prevent faulting, without the use of load-transfer. The Soil Section's suggestion for no-dowel ramp design was to increase the selected subbase from 4 in. to 6 in. and its density requirement from 95 percent to 100 percent. The density of the sand subbase would remain 95 percent but its thickness would be reduced from 10 to 8 in. and, therefore, the total thickness would remain unchanged. They remarked further, "We question, however, whether the above strengthening, or even thicker gravel, will prevent faulting of short slabs, especially for mainline application under greater traffic volume and speed." We have followed the performance of the projects at Square Lake Rd and C. R. 151 and, in both cases, faulting has occurred at the joints at an early age as shown in Figures 2 and 3, even though on the latter project the traffic is very light.

We would add that since the mechanism that allows faulting to occur is not understood, and the particular properties of the base that permit faults to progress are not defined, it does not seem possible to design a base to eliminate faulting. We also note that the stiffer the base, the more rocking can be expected when slabs warp.

Short-slab pavements without load transfer generally tend to fault at the joints in a manner that leaves the trailing edge of each slab higher than the leading edge. This can clearly be seen in Figure 2, where the vertical faces of the faulted joints are visible in one lane but not the other. This type of deterioration was evident on the old Detroit industrial Expressway, where fault magnitudes reached an inch or more and riding quality was extremely poor. While some slab rocking may be evident, it seems obvious that there is a rearrangement of the soil under the slabs. Since both ends of the slab carry the same traffic loading, the faults must result from factors other than loading alone. It is possible that slab curling may give a ramp effect that would cause trucks to vault onto the leading edge of the next slab. It seems more likely, however, 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 C. R. 151 pavement.

The theory of aggregate interlock seems to be negated by available evidence. One experimenter reported that cracks had to be smaller than 0.020 in. for significant load transfer to result. The C. R. 151 job, along with the Detroit Industrial Expressway, shows the theory to be ineffectual in the prevention of faulting. This can be foreseen because the joints on a 20-ft slab length open nearly 1/8 in. at maximum, leaving only air space between the faces.

County Road 151 was constructed over an existing concrete pavement, overlaid by a layer of crushed limestone of 8 in. average thickness. It is difficult to see how a firmer base than this could be constructed practically; and yet as shown in Figure 4, faulting has occurred at 75 percent of the joints.

Figures 4 and 5 show that 75 percent of the joints on C. R. 151 and 70 percent of the joints on Square Lake rd are faulted to some degree. Although the Figures show that the proportion of larger faults on Square Lake Rd is greater than on C. R. 151, the measured roughness of Square Lake Rd is lower. This can be attributed to the shorter joint spacing on C. R. 151 which provides more faults per mile than pavements with longer slab length.

In summary, we are definitely convinced that changing our pavement design from reinforced slabs and load-transfer joints would be a serious regression. For reinforced slabs and doweled joint design, shortening the slabs would not have any advantages since the current neoprene seals are generally doing a satisfactory job of sealing the joints in the 71-ft 2-in. slabs. Previously, on the experimental transverse joint project, shortened slab spacing down to 57-ft 3-in. was tried in order to see if these shorter slabs would result in better sealing from the hot-pour rubber-asphalt, but it was found that even the shorter slabs did not resolve the sealing problem with this material in the joint configurations used. However, as an experimental feature we would not be averse to trying in a given project, spacings of 71-ft 2-in., 57-ft 3-in., and 43-ft 4-in. to compare the resulting performance of these slab lengths. However, we would not recommend slabs without load-transfer for even an experimental project since we feel that there is sufficient information available with respect to the deficiency of this design.

TESTING AND RESEARCH DIVISION

Engineer of Research
Research Laboratory Section

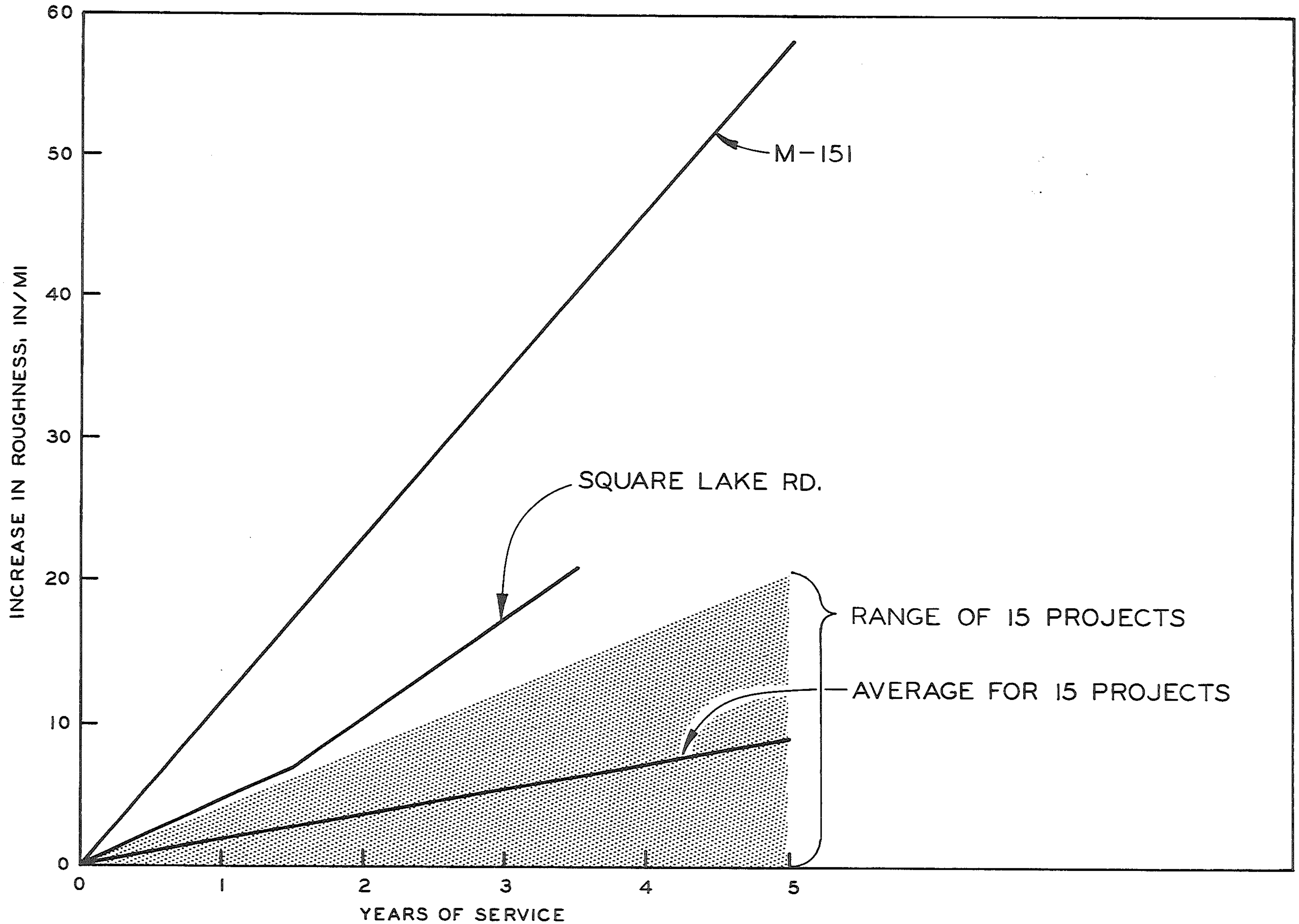
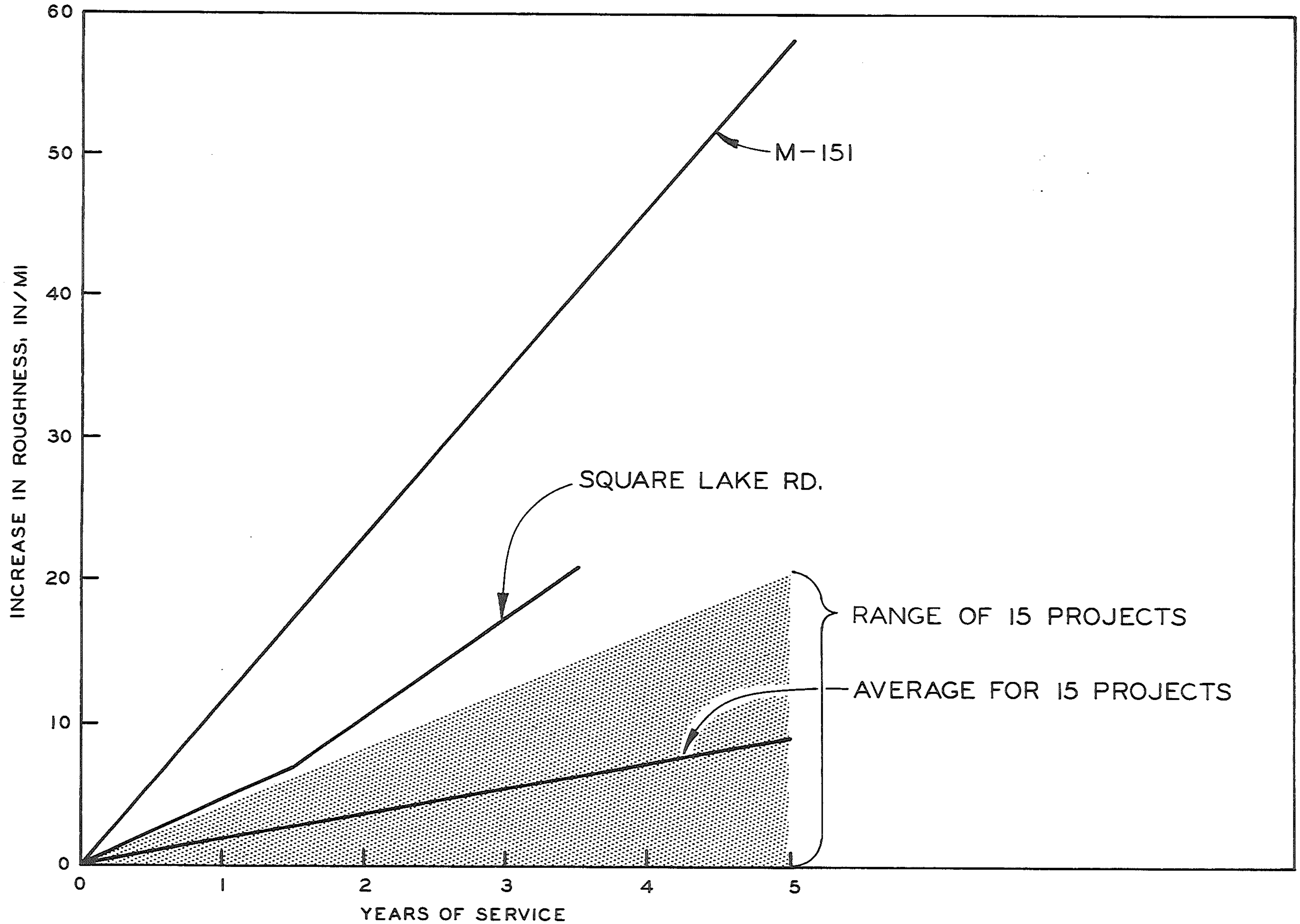


Figure 1. Increase in roughness vs. years of service.



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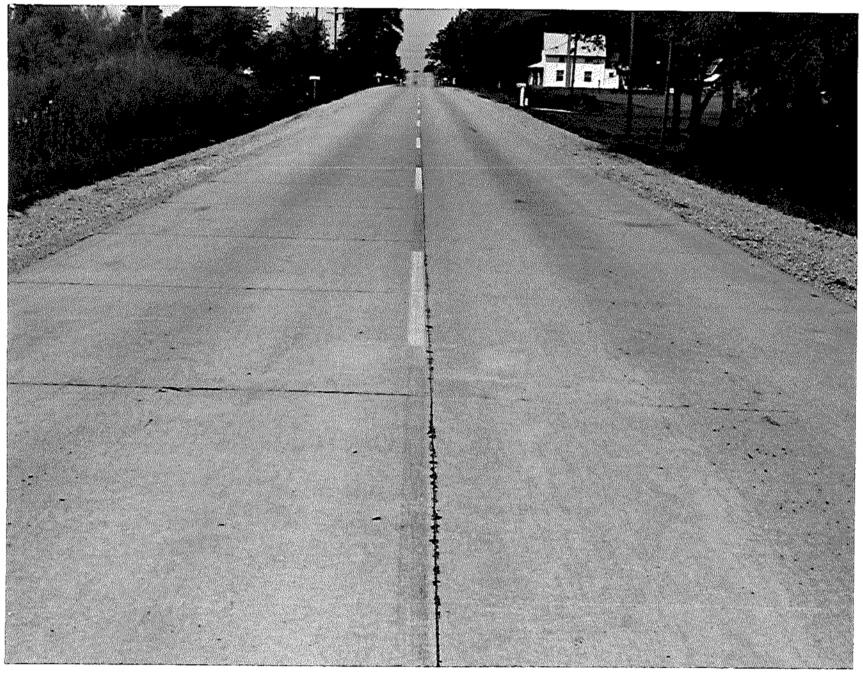

Figure 2. Joint faulting on C. R. 151 which has occurred by depression of the approach slab in relation to the leaving slab; as a result, joints are more visible in the left lane looking into the faulted face than on the right lane, looking away from the faulted face.

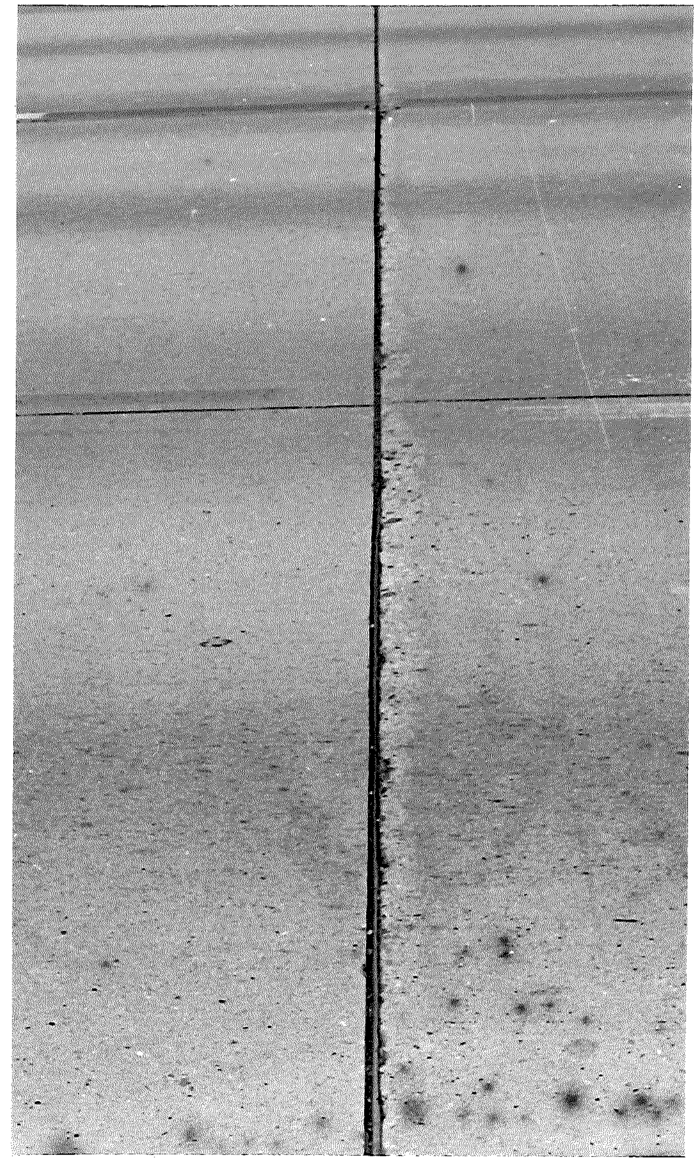

Figure 3. Joint faulting on Square Lake Rd showing damage done by snow plow blade in striking upper edge of faulted joint.

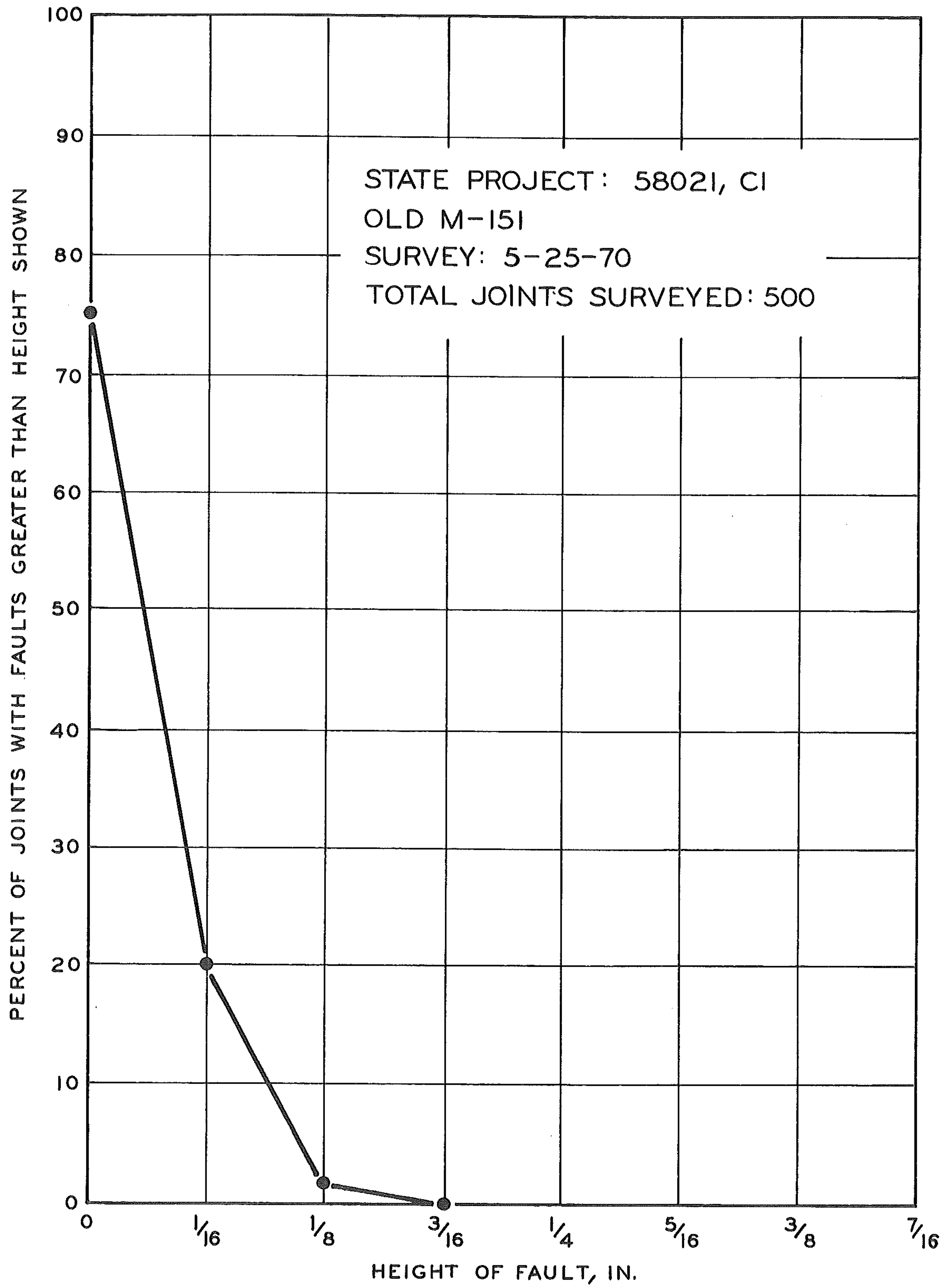

Figure 4. Transverse joint fault distribution.

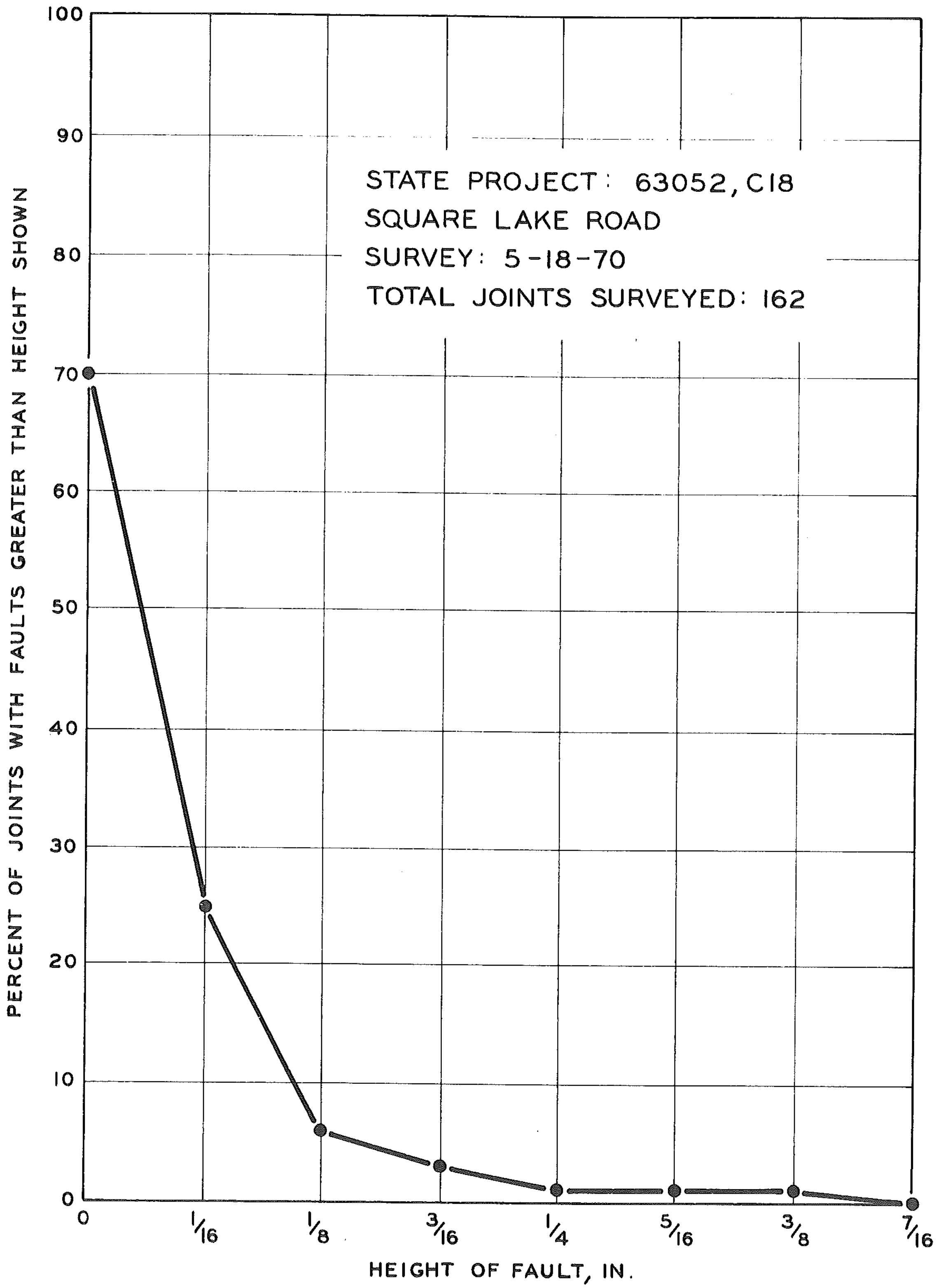

Figure 5. Transverse joint fault distribution.