MICHIGAN'S EXPERIMENT IN USING "UNITUBES" TO FORM TRANSVERSE JOINTS

(Construction Project EBI 33084, C7)

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It has long been common practice to provide transverse joints in rigid pavements at predetermined intervals compatible with the steel percentage, if any, in order to prevent random tension cracks. However, a transverse joint is a point of structural weakness in the pavement, the degree of such weakness being related to slab length, joint construction method, and joint seal quality. In Michigan, a 99-ft slab length with load transfer has been standard since 1946. Construction has generally involved a 1/2-in. wide by 2-in. deep joint groove, formed by inserting a premolded styrofoam filler in a manually formed channel in the plastic concrete, with subsequent hand finishing over the filler. In addition to serving as a groove former, the filler also establishes a plane of weakness for controlled cracking. Joint seal quality has steadily improved during the last decade, yet observations of performance of various sealers under service conditions have shown that an adequate sealer, capable of performing satisfactorily for several years for joint width movements as experienced with 99-ft slab lengths, is yet to be developed.

Recent theoretical computations and laboratory experiments have shown that the strain in a sealer subjected to extension and compression is greatly influenced by the shape factor of the joint--that is, the depth-to-width ratio of the sealer reservoir. The lower the value of this ratio, the less the strain in the sealer. However, a shape factor of less than one does not appear feasible in pavement construction, considering the problems involved in forming the joint groove and the environmental conditions to which the sealer is subjected.

As part of the continuing effort to solve joint problems, in 1960 Michigan authorized construction of an experimental pavement incorporating various slab lengths, different joint forming methods, and joint seal reservoirs with shape factors compatible with theoretical values. Two of this pavement's 18 experimental sections are devoted to study of transverse contraction joints formed using the "Unitube," a proprietary product of the Middlestadt Corp., of Baltimore, Md. The primary purpose of the project is performance comparison of joints built using current standard design and construction and joints formed by other methods, having other groove sizes, and spaced at other lineal intervals.

The test variables were selected and the supplemental specifications for construction were prepared by the Research Laboratory Division. The detailed design of the project was made by the Road Design Division and construction was under supervision of the Road Construction Division. Instrumentation of the pavement during construction, and the necessary research and evaluation studies after completion, became the responsibility of the Research Laboratory Division. This report is confined to the Unitube experimental sections of the project.

Construction of the Experimental Joints

The Bureau of Public Roads approved the incorporation of more than 1000 experimental contraction joints formed with Unitubes, distributed along 11.7 mi of two-lane pavement, in sections from Sta 775+70 to 1085+00 on the eastbound roadway and from Sta 776+23 to 1085+00 westbound, in Construction Project EBI 33084, C7, on Interstate Route I 96.

Each roadway contains two 12-ft lanes with provision for future addition of a third lane on the median side. Therefore, the crown point of the pavement is 6 ft from the median edge of the slab, so that addition of an extra lane will provide a symmetrically crowned pavement. Joint groove dimensions in the Unitube sections are 3/8 by 1/2 in., and transverse joint spacing is 57 ft 3 in. A slab length of 57 ft 3 in. was used because the manufacturer's widest Unitube section available was 13/32-in., which is subsequently crimped to form a 3/8-in. wide groove, and it was felt that the joint seal could not be maintained for a longer slab. The joint is formed by embedding the metal strip near the surface during construction, and subsequently mechanically crimping the strip to provide the joint groove reservoir for sealant material.

At each transverse joint location, standard load transfer assemblies were installed consisting of 1-1/4-in. diam bars, 18-in. long and spaced at 12-in. centers. At structures, 1-in. wide expansion joints were placed in accordance with standard Michigan practice, the number and spacing depending on the length of pavement between structures (in pavement poured after September 19, expansion joints were spaced at approximately 400 ft). A non-metallic base plate 7-1/2-in. wide, approximately 1/4-in. thick, with a 1-in. high trapezoidal parting strip in the center, and of such length as to extend the full width of the pavement and to within 1 in. of the top of the paving forms, was used at all contraction joints. The base plate used with expansion joints was identical, except that the center parting strip was omitted.

Steel reinforcement in the Unitube sections consisted of welded wire mesh sheets, 11 ft 6 in. wide and 15 ft long, with 24 No. 2 gage wires in the longitudinal direction and 15 No. 4 gage wires transversely providing a longitudinal steel percentage of 0.10.

All transverse joints were sealed with a hot-poured, rubber-asphalt type joint sealing compound meeting Michigan's requirement for conformity with the Federal Specifications for Sealers, SS-S-164.

Placement of the eastbound section took place July 24 through August 6, 1962 and on September 25 and 26, 1962, and the westbound section was placed August 7, 1962 through August 21, 1962. Full-width construction was employed, whereby the entire 24-ft width of pavement was placed at one time. The steel reinforcement was placed 3 in. below the surface, and a lap splice length of 13 in. was used for the reinforcement. Transverse tie bars, consisting of No. 4 deformed bars, 30-in. long, were spaced at 40 in. across the longitudinal joint between the two 12-ft lanes. The longitudinal centerline joint was sawed and sealed before traffic was permitted on the slab.

In constructing the pavement slab, the contractor used two 34E dual-drum mixers (one equipped with a side strike-off), a steel carrier, two Jaeger-Lakewood finishing machines, and a Heltzel Flexplane combination finisher-float machine. A self-propelled machine called a "planter," riding the forms directly behind the last mechanical finishing machine, was used to install the Unitubes (Fig. 1).

The sequence of construction operations was as follows:

1. Placing concrete on subbase from first mixer and striking off concrete 3 in. below surface.

2. Placing transverse tie bars.

3. Placing steel reinforcement from carrier.

4. Placing final layer of concrete from second mixer.

5. Spreading and screeding concrete with Jaeger-Lakewood finishing machine.

6. Initial finishing of concrete surface with second Jaeger-Lakewood machine.

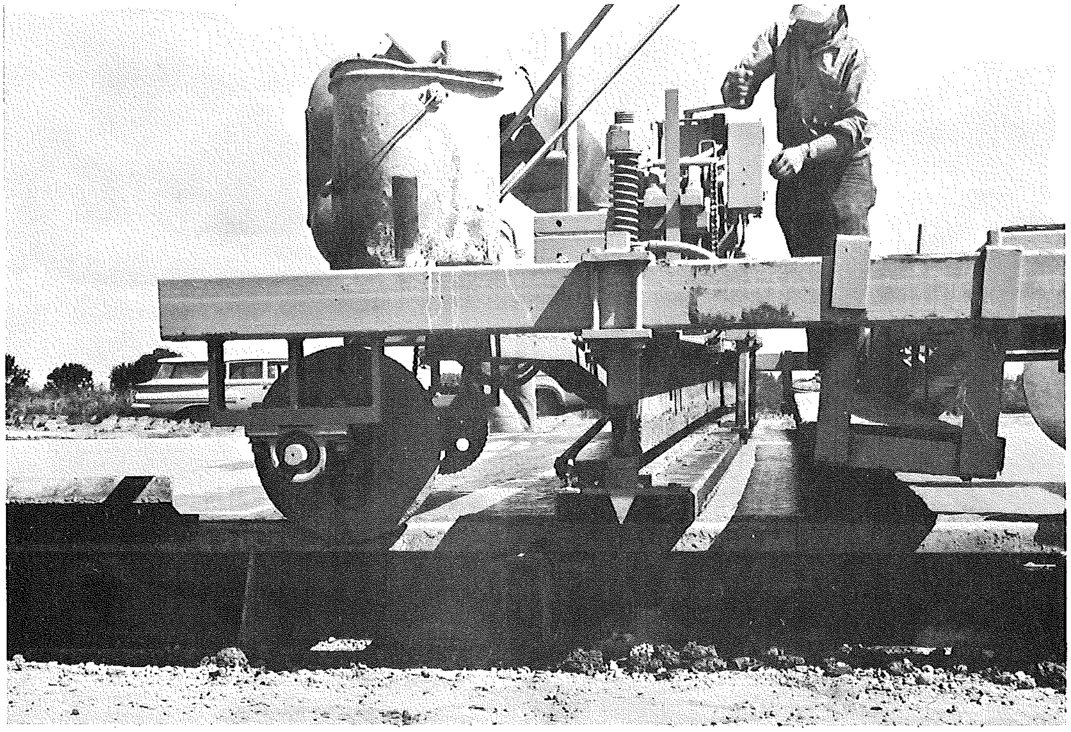

Figure 1. Planter used to install Unitubes.

7. Final machine finishing of concrete surface with Heltzel Flexplane.

8. Forming transverse joints by installation of Unitubes.

9. Final hand finishing of concrete surface.

10. Applying burlap drag finish to concrete surface.

11. Applying white membrane curing compound.

Unitubes were installed in the fresh concrete at the transverse centerline of the load transfer assembly. The tube (Fig. 2) is 2-in. deep and 13/32-in. wide at the top, with each length formed from a single strip of electro-galvanized, No. 30 gage sheet steel. A built-in crown assures that the tube fits the shape of the top surface of the pavement. The installed tube forms a weakened plane for controlled cracking. The procedure for placing the tube was as follows:

1. The planter was guided into proper location and alignment, as designated by marks on the forms, and securely locked in position.

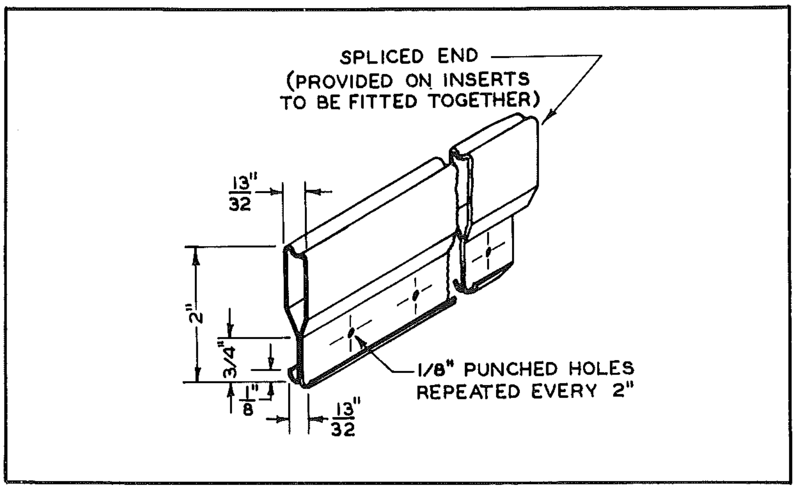

Figure 2. Unitube device.

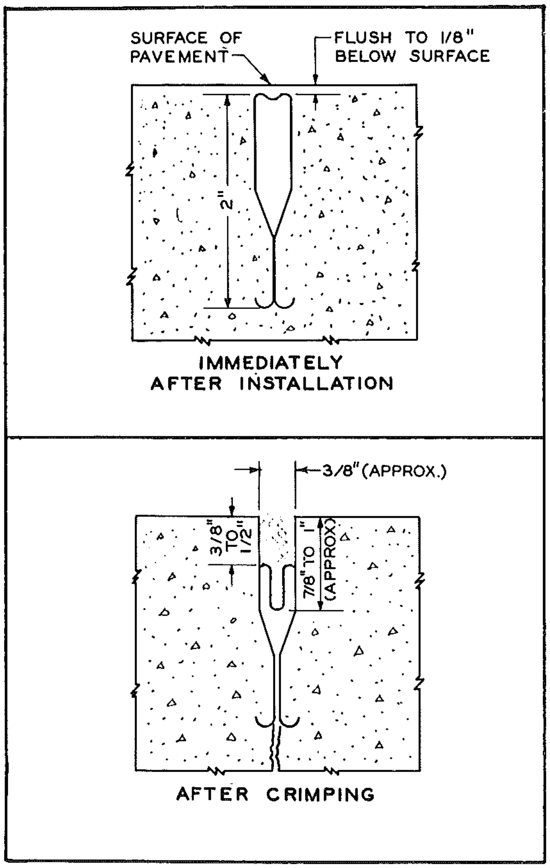

Figure 3. Cross-sections of Unitube joint.

Figure 4. Crimping the Unitube.

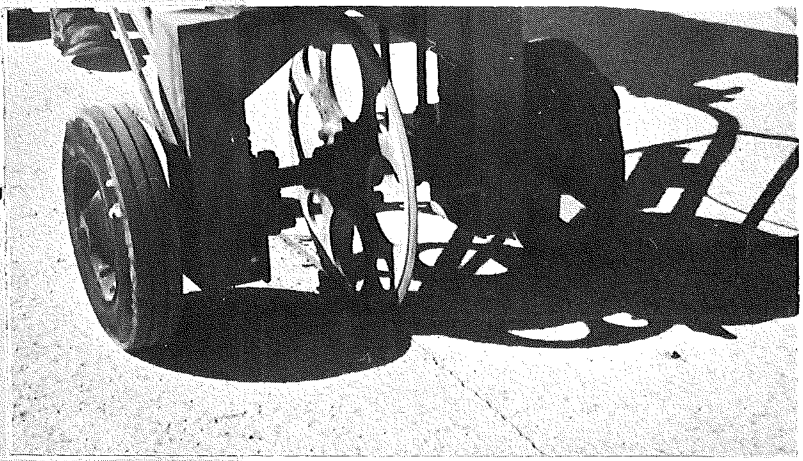

Figure 5. Vibrating crimping disk.

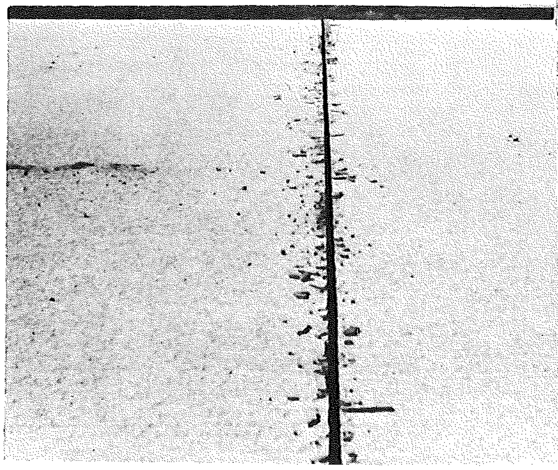

Figure 6. Condition of newly crimped joint.

2. Two 2- by 4-in. tubular guide members, with just enough space between them for the Unitube to pass through, were lowered to the pavement surface.

3. A 5/16-in. mechanically vibrated steel T-bar was lowered between the guide members into the concrete to a depth of 2-1/2 in. to form a groove into which the tube would be inserted.

4. Upon retraction of the T-bar, two lengths of tube with open ends at the forms plugged with styrofoam to prevent mortar from entering, and spliced at the center, were placed between the guide members and slightly depressed by hand to assure proper placement.

5. The tube was then pressed into the formed groove in the concrete by lowering the T-bar to a predetermined depth so that the tube was flush to 1/8 in. below the pavement surface. The T-bar was then vibrated sufficiently to consolidate the concrete against the sides of the tube.

6. The installation was completed by final hand finishing over the tube.

After the pavement had cured for seven days, the Unitube was crimped or folded down into itself, exposing from 3/8 to 1/2 in. of joint side wall above the crimped tubing. Fig. 3 shows cross-sectional views of the tube before and after crimping. The crimping machine consists of a circular vibrating disk mounted in a movable frame. Tube crimping involves lowering the vibrating disk into the tube to the pre-set depth, and then as the machine is pushed forward the tube is crimped. This process is shown in Figs. 4 and 5. The disk penetrates the thin layer of hardened mortar deposited over the tube during final hand finishing operations, depositing the mortar along the joint groove as shown in Fig. 6.

At first, some difficulty was experienced in installing the Unitube to the correct depth, primarily because the machine was designed for pavements with symmetrical crown, whereas this project was constructed with the crown point offset to coincide with the center of the median lane. Thus, the tube generally was set too deep in the center portion of the median lane, creating some difficulty in crimping. However, after the operator became experienced with the installation process, and the tube was manually adjusted as to depth, when required, no further serious difficulties were encountered. It is understood that the manufacturer is now designing an installing machine that can be adjusted to fit various crown designs so that difficulties of the type encountered here may be eliminated in the future.

Joint Sealing

Fig. 7 illustrates the condition of a typical Unitube joint prior to sandblasting. Joint sealing was preceded by sandblasting of the joint groove and the immediately adjacent pavement surface. Just prior to sealing with a hot-poured rubber-asphalt type compound, the joint groove was cleaned by a jet of compressed air. The sealer was heated in a double-boiler, thermostatically controlled kettle and applied to the joint through a conical hand-poured pot (some joints were sealed using a mechanical pouring pot of the double-boiler type). Under provisions in the supplemental specifications, no traffic was allowed on the pavement until transverse joints were sealed.

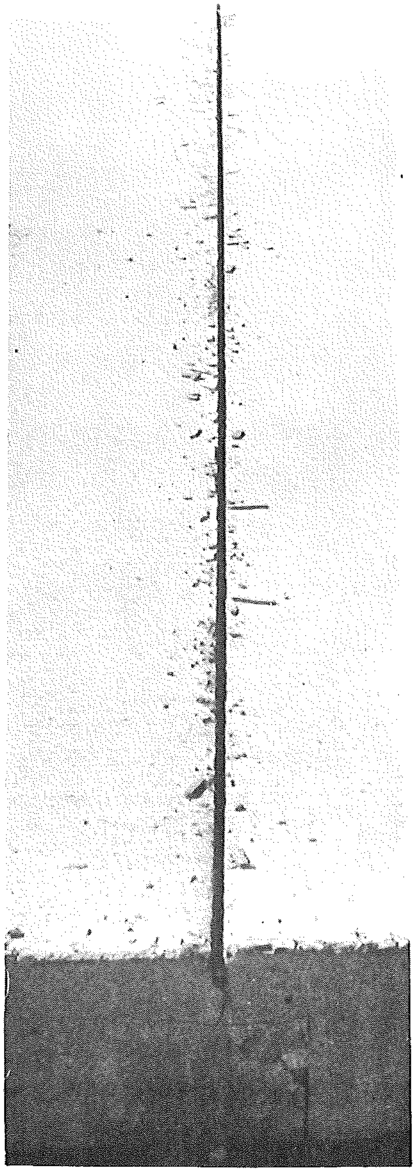

Figure 7. Typical Unitube joint before sandblasting.

Instrumentation and Measurements

Five principal performance factors are under study on the experimental project, including the two Unitube sections:

1. Longitudinal and transverse cracking of individual slabs.

2. Spalling and corner cracking at transverse joints.

3. Adhesion and cohesion failures of the sealer.

4. Magnitude and variation in width of joint opening.

5. Initial surface roughness and roughness changes with time and traffic.

In addition to observations during construction involving climate and materials, regular observations have been scheduled over a period of years, until sufficient data have been obtained to warrant conclusions.

Air Temperature. A record of daily air temperatures throughout the construction period was obtained by means of a Taylor seven-day temperature recorder. The temperatures during construction pours for the eastbound roadway ranged in daily temperature lows from 44 to 62 F and in daily temperature highs from 55 to 86 F. Corresponding daily temperatures during construction of the westbound lanes were 43 to 61 F for daily lows and 64 to 86 F for daily highs. Average monthly air temperature in the vicinity of the experimental project is being obtained throughout the test period from a local station of the United States Weather Bureau.

Concrete Properties. In the Unitube sections, beams were taken for modulus of rupture testing at the usual intervals as required during construction, for testing at 7 days and 14 days. Modulus of rupture values of control beams from concrete pours in the eastbound Unitube section had 7-day flexural strengths ranging from 608 to 696 psi and 14-day strengths from 800 to 1083 psi. For the westbound Unitube section, the 7-day strengths ranged from 721 to 812 psi and the 14-day strengths from 1029 to 1154 psi.

Joint Width Changes. In each test section, ten consecutive joints were instrumented with gage plugs for joint width readings. The gage plugs are 2-in. long by 1/4-in. diam stainless steel countersunk-head rivets, with appropriately machined conical holes in the rivet head. Three sets of gage plugs were placed in the concrete at each joint just after burlap drag finishing, 12 in. from the pavement edge in the traffic and passing lanes, and 12 in. from the longitudinal joint centerline in the traffic lane. Each set was placed symmetrically about the transverse joint centerline 8 in. apart. Initial readings were taken just after the initial set of the concrete with a Starrett 0.001-in. vernier caliper and a second set of readings was taken again just before installing the joint seal. The widths of these 20 instrumented joints are being measured in January and July of each year throughout the test period.

Concrete Temperature. A temperature well for the mid-depth slab temperature was placed in the center of the traffic lane and 3 ft ahead of the first instrumented joint in each section. This well was formed by inserting a template consisting essentially of a 5-1/4-in. long by 1-in. diam bar reduced to 3/8-in. diam at a point 2 in. from the top, into and flush with the concrete surface, just after the burlap drag finishing operation. After initial set of the concrete, the template was removed and a hollow, 1-1/2-in. long, brass plug, with appropriate cap screw, was placed in the formed hole and cemented with hot sulphur. Liquid mercury was poured into the well to a depth of 1 in. Slab temperature readings were recorded at the time of joint width measurements and will be measured at these locations in January and July in conjunction with the joint width readings. In addition, the concrete temperature was measured at each of the joints at the time of plug installation.

Joint and Sealer Condition. An initial condition survey of instrumented joints was made November 27, 1962. In conjunction with this survey, joint width movement and slab temperature were measured, and joint spalling and corner breaks were recorded. First photographs were taken for a continuous pictorial record of performance. Similar condition surveys of joint and sealer performance are being made in January and July of each year throughout the test period.

Pavement Condition. A general pavement condition survey is being made once each year throughout the test period.

Surface Roughness. The initial surface roughness index was obtained November 30, 1962, 12 days before opening of the project to traffic. Roughness is being measured once each year throughout the life of the project.

Traffic Surveys. As supplementary information, traffic surveys are being made each year to determine axle weights and frequencies and average daily traffic.

Schedule of Performance Studies. In summary, the continuing performance observations include the following:

1. Monthly reports of average air temperature.

2. Semi-annual readings of width changes at the 20 instrumented joints, and slab temperature at the two temperature wells, with a semi-annual survey of joint and sealer condition.

3. Annual surveys of general pavement condition, surface roughness, and prevailing traffic conditions.

Project Performance During First Year

On the basis of data secured during the construction period, in the 1963 field surveys, and in regular surveys during January and February 1964, certain preliminary observations may be made regarding performance of the Unitube sections.

Very little cracking was noted during the first winter survey (1963) and while there was some increase in cracking during the following year, 80 percent of the pavement slabs in the traffic lane and 88 percent in the passing lane had not developed a transverse crack by the second winter of service. Fig. 8 shows the frequency distribution of slabs with 0 to 4 cracks per slab. It should be noted that less than 5 percent of the slabs have two cracks or more in the traffic or passing lanes. The average number of transverse cracks per slab is 0.12.

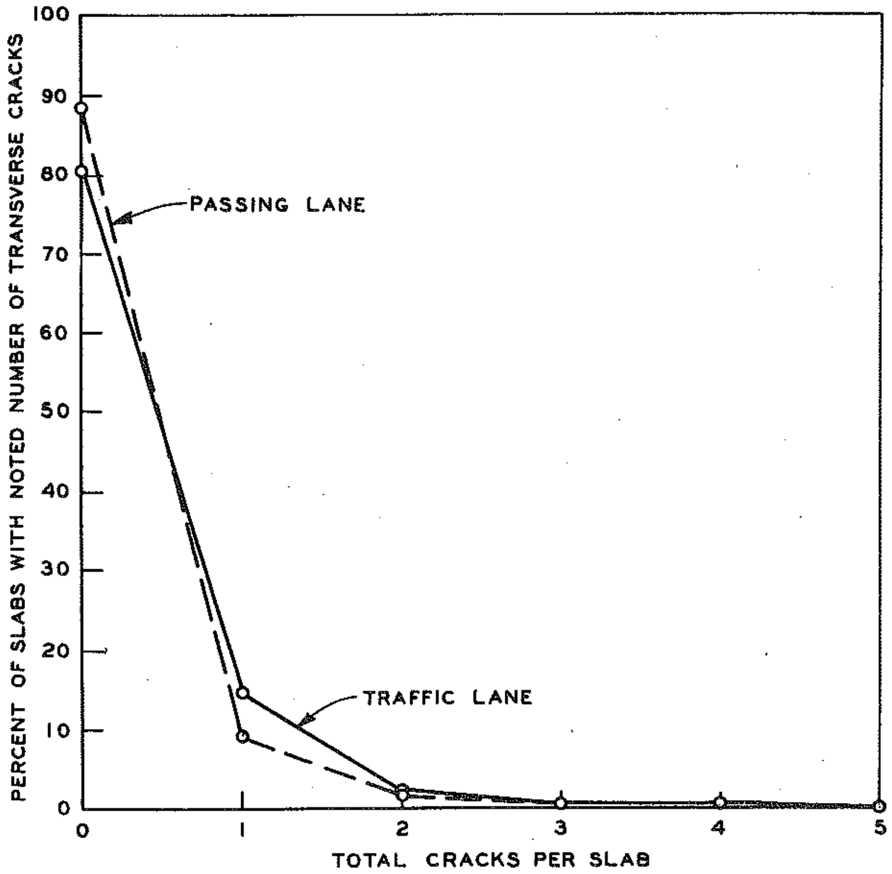

Figure 8. Frequency distribution of cracks per slab for passing and traffic lanes (57 ft 3 in. slabs).

Detailed surveys of the ten instrumented joints in each experimental section were made to determine the amount of spalling along the joint groove and the condition of the joint sealer. The total length of joint groove spalling was determined as 70 in. along the length of the 20 joints, or 0.61 percent of their total length. A joint seal survey conducted on February 10, 1964, disclosed that out of 480 ft of sealed groove for the 20 joints, a total of 40 ft (8.33 percent) had adhesion failure, with bond lost between the vertical joint groove face and the seal. In most cases, this occurred as a small crack along the face and was 1/8- to 1/4-in. deep. It was apparent that the Unitube below the joint seal prevented the seal from sinking into the joint crack during cold weather, when the joint is widest. As a result the joint seal had receded only slightly beneath the pavement surface, a condition less likely to permit entrapment of small stones and dirt above the seal that may eventually mix into the seal.

Roughness measurements have been taken twice on this pavement. The first measurements taken on December 1, 1962, resulted in an average roughness of 136 in. per mile; the second, taken on July 8, 1963, gave an average value of 132 in. per mile.

Performance of this pavement constructed with Unitube joints will be followed as outlined previously and will be reported as significant developments occur.