Crack Control Joints in Bituminous Overlays On Rigid Pavements

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This research study concerns a method of controlling reflection cracks in bituminous concrete overlays over the transverse joints of rigid pavements. The study was undertaken to determine whether sawing and sealing joints would extend the maintenance-free life of the overlay sufficiently to justify the additional cost.

The experimental sections have been under observation for three years. Results to date indicate a substantial extension of the maintenance-free life of the overlay and consequently a reduction in the annual cost per square yard of bituminous concrete overlays.

● CONNECTICUT greatly accelerated its road building program, as did most other states, spurred by the rapid rise in the use of automobiles following World War I. A substantial amount of the pavements constructed on main routes was of portland cement concrete. The advent of World War II brought about a forced reduction of the maintenance effort. Reduced maintenance during the war, the passage of time, and a further rapid increase in motor vehicle registration made the rehabilitation of these pre-war roads mandatory. The use of bituminous concrete in resurfacing and widening held best promise for large-scale salvaging of the old pavements at the least immediate cost.

It was soon learned that transverse and longitudinal joints in the concrete pavement reflected through the overlay, thus presenting a new maintenance problem. Unfortunately, repairs were not undertaken until spalling and raveling of the cracks had become quite severe. The repairing of the spalled areas became a continuing operation, eventually reaching significant proportions.

A great deal of thought was given to finding a solution for this problem. Some experimental reinforcing of the bituminous concrete across the joints was tried, however, the results were not encouraging.

In April 1958, A. L. Donnelly, at that time Director of Research, Connecticut State Highway Department, conferred with Egons Tons, Research Engineer, Massachusetts Institute of Technology, regarding published information of work towards solution of the problem of reflection cracks (1). Test installations on Route 1A in Walpole, Mass., were inspected. As a result of this meeting the Connecticut Highway Department decided to experiment with sawed joints in bituminous concrete overlays.

EXPERIMENTAL PROJECTS

Two overlay projects already scheduled for construction during the summer 1958 were selected for the experimental work.

Project 1

Location.—This project is on US 7 in the City of Norwalk. US 7 is the main north-south highway in the western part of the State. The project starts approximately 1,300 ft north of US 15, the Merritt Parkway, and extends northerly approximately 7,400 ft. The northerly portion of the project is the crack control test section, the southerly portion the control.

TABLE 1

BITUMINOUS CONCRETE MIX USED IN EXPERIMENTAL PROJECTS

Analysis	Design Mix	Job Mix
% Passing Sieve:		
7/8-in.	100	-
3/4-in.	95	100
1/2-in.	90	93.1
3/8-in.	75	82.3
No. 4	53	56.7
No. 10	40	43.3
No. 20	29	30.7
No. 40	19	19.3
No. 80	12	8.9
No. 200	5	4.5
Bitumen (85-100 pen.) (%)	6.0	6.35
Agg. plus bitumen (%)	100.0	99.45
Temp. of mix (°F)	290	290

Original Pavement.—The overlaid pavement consists of 20-ft wide 8-in. thick reinforced concrete pavement built in 1926. The reinforcing consisted of ½-in. deformed marginal bars placed 4 and 10 in. from the edge of the slab near the top and 4 in. from the edge near the bottom of the slab. The outside corners contained two ½-in. diagonal bars, the inside corners one bar of the same dimension. One ft of gravel subbase was placed in earth and 2 ft in rock cuts. The slabs are 40 ft long and 10 ft wide with ½-in. expansion joints. Load transfer devices and longitudinal tie bars were not used at that time.

Traffic.—In 1958 the traffic volume was 14,000 ADT. Commercial vehicles accounted for 4 percent of the traffic. The 1960 traffic count was still 14,000 ADT with approximately the same percentage of trucks.

Overlay.—The overlay, consisting of two 1¼-in. courses of hot-laid bituminous concrete, was placed with a Barber-Greene paver and compacted by a 10-ton tandem roller. The average haul from plant to job site was 43 mi. The design mix as well as the job mix are given in Table 1.

Project 2

Location.—This project is on US 1 in the Town of East Haven. The crack control joint test section consists of the two westbound lanes of a divided highway extending from the Farm River Bridge westerly approximately 0.4 mi. The two eastbound lanes in the same area are the control.

Original Pavement.—This pavement was constructed in 1942 and is of portland cement concrete reinforced with fabric or bar mat at the rate of approximately 61 lb per 100 sq ft. Slab length is 75 ft 9 in. between expansion joints. Intermediate ¼-in. dummy or warping joints are spaced at 25 ft 3 in. Load transfer units at expansion joints and ½-in. longitudinal tie bars, 2 ft 6 in. long and spaced 2 ft 6 in. on centers, were used.

Traffic.—The 1958 traffic count was 10,000 ADT. Commercial vehicles accounted for 18 percent of the traffic. The opening of the Connecticut Turnpike in January 1958 undoubtedly changed the traffic pattern on this section of US 1. Although no current traffic counts are available, the count is believed to be substantially the same as in 1958.

Overlay.—The bituminous concrete overlay on this project was essentially identical with that on Project 1. Two-course construction was used, thickness being the same, and the material was furnished from the same source and placed by the same contractor. The average haul from the plant was 5.9 mi.

PROCEDURES

Project 1

As stated previously, the northerly half of the pavement was selected for the test installation, the southerly half was the control. The joints to be sawed were carefully referenced prior to paving, and references transferred to the overlay with paint on completion of the paving operations. The overlay was placed between July 15 and 19, 1958.

Initially, 92 joints, involving approximately 0.70 mi of pavement, were referenced. In the course of paving operations and as a result of vandalism, approximately one-third of the references were destroyed. Where references were lost, no attempt was made to form crack control joints, thus reducing the total number to 60 joints. Some references have been lost in later test projects, but not to the extent encountered on this project.

Sawing operations were scheduled for mid-September for two reasons: (a) vacation travel would be somewhat reduced and consequently less interference with traffic would be experienced and (b) the bituminous concrete would be cooler and less likely to foul the concrete saw. Unfortunately the sawing operation was delayed until October 20th, resulting in some reflection cracking before sawing. Sawing was completed on October 22.

The joints were sawed $^3/_8$ in. wide and $1^3/_4$ in. deep using diamond saws. Three blades, separated by 4-in. diameter spacers $^3/_{64}$ in. thick, were mounted on the saw shaft, the two outside blades cutting to a depth of $1^3/_4$ in., the center blade, which had essentially a clean-out function, to a depth of one inch. The sawed joint was cleaned by means of compressed air. No further cleaning was undertaken.

Sealing of the joints was scheduled to follow the sawing operation. Unfortunately, inclement weather delayed sealing until October 30. The sealing was completed on November 4. This delay in sealing apparently did not seriously affect the sealing operation or the performance of the sealer.

The sealer material was a hot rubber asphalt compound, conforming to Fed. Spec. SS-S-164, applied with a combination melter and applicator.

Project 2

The bituminous concrete overlay was placed between June 9 and 12, 1958. The experiment consisted of sawing and sealing 27 joints 28 ft long, in the westbound roadway. Due to conditions beyond control, sawing was delayed until October 14. Early October temperatures were below 32 F on several occasions prior to sawing, consequently some reflection cracking had occurred.

Sawing and sealing procedures were identical with those described for Project 1.

OBSERVATIONS

A thorough inspection of the overlay on Project 1, Norwalk, was made prior to sawing, and existing reflection cracks were noted. A further detailed inspection was made on December 16, 1958. Only 7 ft of cracks in addition to those observed prior to sawing were found. It is of interest to note that some cracks observed at the time of sawing showed a tendency to knit together, despite night temperatures at or below freezing. Figures 1 and 2 show controlled and uncontrolled joint cracking on December 3, 1958.

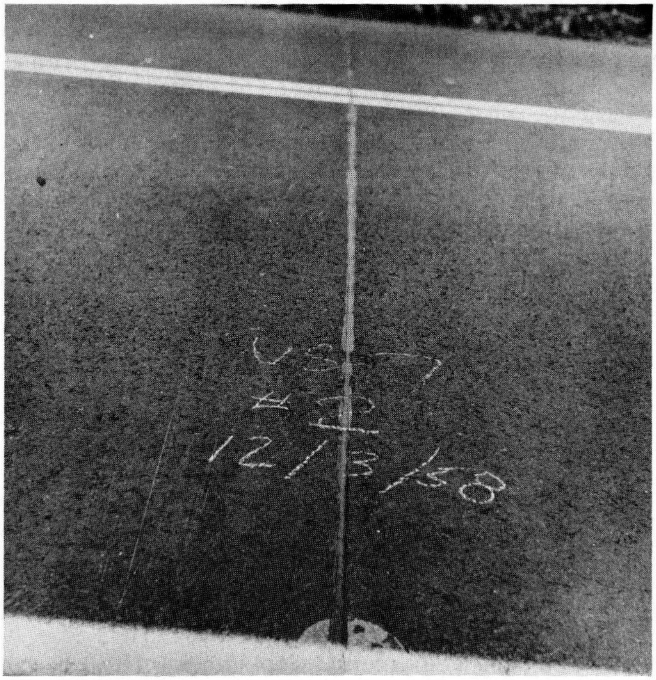

Figure 1. Controlled Joint Crack Project No. 1—Route US 7, Norwalk, December 3, 1958.

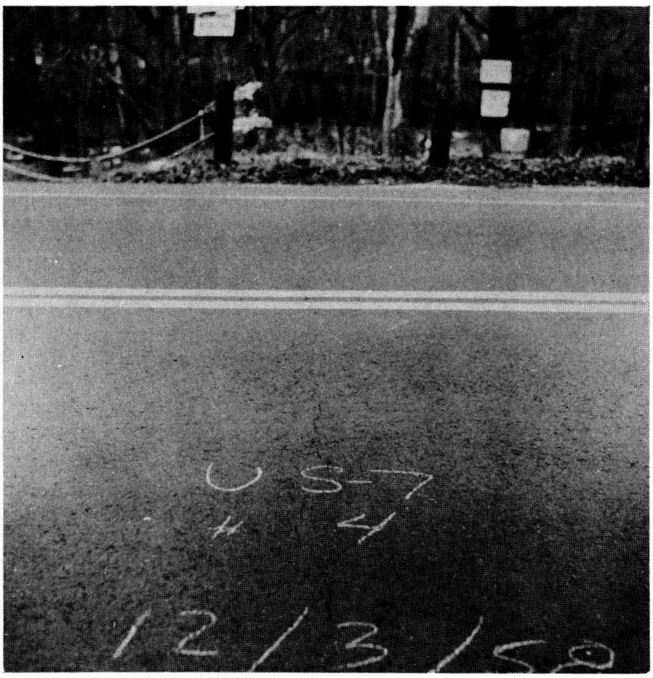

Figure 2. Uncontrolled Joint Crack Project No. 1—Route US 7, Norwalk, December 3, 1958.

TABLE 2

OBSERVED REFLECTION CRACKS AND ADHESIVE FAILURES

Date of Inspection	Project 1		Project 2	
	Reflection Crack[1] (ft)	Adhesive Failure[2] (ft)	Reflection Crack[1] (ft)	Adhesive Failure[2] (ft)
Oct. 1958	216		No obs.	No obs.
Dec. 16, 1958	223	Slight	No obs.	No obs.
Feb. 3, 5, 1960	-	-	65	359
Mar. 11, 1960	55	28	-	-
June 11, 19, 1960	41	17	-	-
July 6, 8, 1960	-	-	66	117
Mar. 13, 1961	58	1172	-	-
Mar. 16, 1961	-	-	52	743
Aug. 17, 22, 1961	4	813	-	-
Aug. 16, 1961	-	-	60	403

[1]Over transverse joint.
[2]Any failure $\frac{1}{4}$ in. or more in depth.

Project 2 in East Haven was not observed to the same extent as Project 1 during the sawing and sealing operations. Limited observations indicated a condition similar to Project 1.

Semiannual inspections have been made on Projects 1 and 2 starting during the winter of 1959-60. The joints still retain their original good appearance, and there is very little spalling or raveling except where cracking had occurred prior to sawing and sealing. As might be expected, a greater amount of adhesive failure of the sealer is detected during the winter inspections. Expansion of the underlying rigid pavement tends to close the joints in hot weather and this creates the impression that the sealer regains some adhesion. It is suspected, however, that this is at best a very temporary effect.

As expected, successive inspection reports indicate an increase in the amount of adhesive failure. For example, the February 1960 inspection stated "adhesive failure appears to be very narrow and very shallow," whereas the March 1961 inspection report stated "adhesive failure varied in depth from ¼ in. to over 1 in." The August 1961 inspection report noted a reduction in adhesive failure; the depth of the remaining adhesive failure, however, remained at ¼ in. to over 1 in. Table 2 gives the amount of reflection cracking and adhesive failure observed in each inspection.

Inasmuch as reflection cracking has occurred over 100 percent of the joints in the control sections, a tabulation thereof is omitted. Other research on the durability of bituminous concrete indicates age deterioration, or hardening, of the bituminous concrete to be much more advanced adjacent to cracks then in unbroken surfaces. For this reason the cracks in the control sections should have some attention now. Undoubtedly, routing and sealing of these cracks would cost at least as much as sawing and sealing at the initial stage.

Routing and sealing of open cracks over centerline joints has been tried on a limited experimental basis. It appears to be a satisfactory method of sealing such reflection cracks. Sawing and sealing of longitudinal cracks along the centerline and edges of the original pavement was not attempted on the two experimental projects described.

Figure 3. Controlled Joint Crack Project No. 1—Route US 7, Norwalk, May 12, 1960.

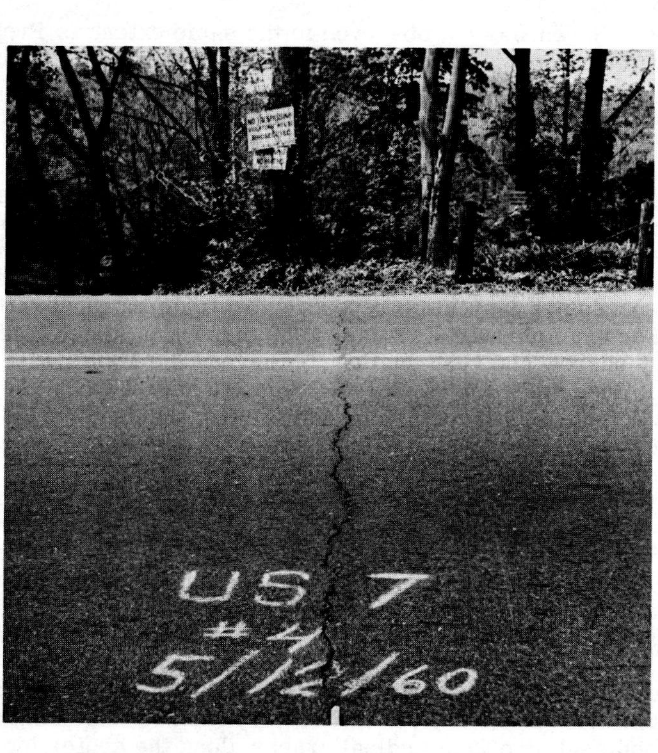

Figure 4. Uncontrolled Joint Crack Project No. 1—Route US 7, Norwalk, May 12, 1960.

Figure 5. Controlled Joint Crack Project No. 1—Route US 7, Norwalk, October 18, 1961.

ADDITIONAL EXPERIMENTAL WORK

The 1959-1960 winter inspections showed such a marked difference in the appearance of the test and control sections that three additional installations were scheduled for 1960 construction. Figures 3 and 4 show the condition in May 1960 of the joints shown earlier. Figures 5 and 6 show the joints in October 1961. The change in numbers reflects the identification now used for inspection of the joints. There is some doubt that Joint 28A is the same joint identified as No. 4 in previous figures.

The 1960 construction, however, involved some further experimentation. Reports on the work by Egons Tons (2) relating the joint shape to sealer performance raised a question as to the necessity of a 1¾-in. deep joint in a 2½-in. overlay. Thus several different joint shapes were tried in the 1960 construction (Fig. 7). The purpose was to determine (a) the depth of cut required to insure that the controlled crack would occur over the joint in the original pavement, and (b) the effect of various joint shapes on the performance of the sealer.

These test installations were plagued by delays to a greater extent than the original test installations. Two of the three projects were paved in late September and mid-November, respectively. One project was paved in mid-July. Due to delays in sawing and sealing, all three projects developed reflection cracks prior to sawing, the most severe occurring in the late season projects.

Because it is too early to draw valid conclusions from the 1960 tests, it can only be stated that the ⅜- by ½-in. joint appears to control the location of the reflection crack

Figure 6. Uncontrolled Joint Crack Project No. 1—Route US 7, Norwalk, October 18, 1961.

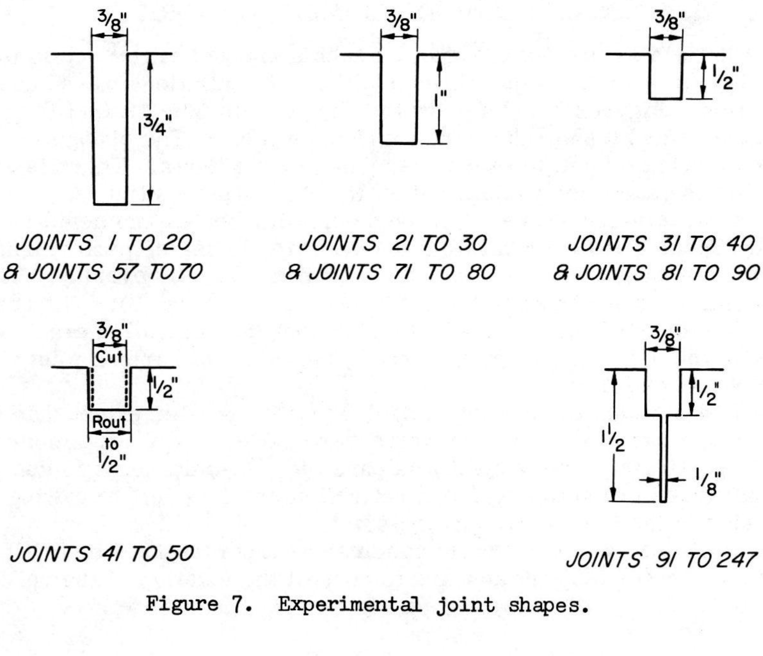

Figure 7. Experimental joint shapes.

as efficiently as the other shapes. Considerable variation in adhesive failure between replicate sections of the same joint shape raises the question of influences other than the joint shape. Figure 7 shows the system of replicate sections.

There is no information available on the experience elsewhere in controlling reflection cracks by sawing and sealing other than that reported by Egons Tons.

COST DATA

The installations to date have been experimental, consequently cost records are not conclusive. In 1961 there was one overlay project by contract in East Hartford that contained an item for sawing and sealing 10,500 ft of crack control joints. The contractor bid \$0.45 per ft for sawing and sealing joints. The configuration of this joint is 3/8 by 1/2 in. with the center saw cutting to a depth of 1 1/2 in. On the basis of a 10- by 40-ft slab the additional cost is approximately \$0.10 per sq yd.

CONCLUSIONS

Based on the admittedly limited experience, both as to extent and age of the experimental projects, and with the procedures used, the following conclusions are believed warranted:

1. Crack control joints are anticipated to provide from 5 to 10 years of maintenance-free service.
2. The 3/8- by 1/2-in. joint shape is considered adequate to control crack formation in a 2 1/2-in. overlay.
3. Further experimentation is needed to determine the required curing period for the overlay material to achieve most efficient sawing operation at various seasons of the year.
4. Relative efficiency of abrasive disks and diamond saws in forming crack control joints remains to be evaluated.
5. A need for experimentation with other sealers is indicated.

ACKNOWLEDGMENTS

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REFERENCES

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