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EVALUATION OF WELDED WIRE FABRIC IN BITUMINOUS CONCRETE RESURFACING

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This paper describes an experimental project undertaken in Illinois to determine the effectiveness of welded wire fabric in the prevention or retardation of reflection cracking in bituminous concrete resurfacing on an old portland cement concrete pavement. "Reflection" cracks are those cracks that commonly appear in bituminous resurfacing immediately over cracks and joints in the portland cement concrete serving as a base.

Various methods have been employed by highway agencies in attempts to prevent or minimize reflection cracking. Among these methods are the use of a granular cushion coarse, subsealing or mud-jacking of the concrete slabs, extra-thick overlays, welded wire fabric, and others.

This study is concerned with one type of welded wire fabric as the dependent variable in the experiment, as to its presence or absence and to its effective width, with all other factors considered to be essentially the same.

Illinois for many years has been engaged in an extensive construction program of rehabilitating many miles of existing portland cement concrete pavement by widening when necessary and resurfacing with bituminous concrete. Some form of rehabilitation had become necessary owing to poor riding quality and high maintenance costs. The rehabilitation program has not only made possible the restoration of the riding quality of these pavements but has extended substantially the service lives of existing highway facilities. Many more miles of existing pavement each year can be rehabilitated by widening and resurfacing than would have been possible if complete reconstruction were attempted.

Although the performance of nearly all resurfaced pavements has been satisfactory, it has been demonstrated that reflection cracking occurs after only relatively short periods of service life, particularly on routes carrying high volumes of heavy truck traffic. The reflection cracks occur not only over the cracks and joints that exist in the original pavements, but also over the longitudinal joint formed when widening strips are used to furnish a wider base for resurfacing. Reflection cracks in themselves do not appear to affect the riding quality of a pavement to any great extent, but experience has shown that these cracks progress to a stage of distress known as belt cracking (a pair or series of closely spaced parallel cracks) and ultimately to the spalling or dislodgement of material between these cracks. The advanced state of deterioration seriously affects the riding quality, reduces the potential service life of a resurfaced pavement, and intensifies the maintenance problem.

Engineering literature indicates that the installation of welded wire fabric in a bituminous resurfacing over concrete probably was introduced in Texas in 1946. Numerous other installations of the kind have been placed since that time, both before and after the Illinois installation in 1958. These installations have included various sizes and configurations of wire mesh reinforcing. In some instances the reinforcing has been placed over the entire pavement surface, while in others, strips have been placed only over joints, cracks, and deteriorated areas. The location of the reinforcement in reference to a horizontal plane has been varied, sometimes being at the old pavement surface and at others being between the layers of the bituminous concrete resurfacing.

Encouraging reports from many of the earlier projects led to the establishment of the study involving the use of welded wire fabric in an experimental construction project of bituminous concrete resurfacing in Illinois. Experimental observations were conducted by the Illinois Division of Highways with the cooperation of the U.S. Department of Commerce, Bureau of Public Roads.

The Illinois installation, after five years under traffic, is showing superior performance at locations where the fabric was used.

DESCRIPTION AND LAYOUT OF PROJECT

This experimental installation was incorporated in the widening and resurfacing of Section 12RS-1, SBI Route 13, Jackson County for the rehabilitation of an old portland cement concrete pavement. The project is located about 60 miles north of the southernmost tip of Illinois, shown in Figure 1, between Murphysboro and Carbondale, Illinois. <u>Fig. 1</u>

The annual precipitation at the site averages about 44 inches, with little variation in the average monthly rainfall throughout the year. In the winter, the soil seldom remains frozen for any extended period, and there are relatively few freeze-thaw cycles. Normally, the average depth of frost penetration is less than 10 inches.

The topography at the site is typical of the upland, rolling portions of Jackson County and the surrounding areas of southern Illinois. The soils are light-colored and moderately slowly permeable, developed from thick to moderately thick loess. Silty loam soils of the A-6 group predominate.

The original improvement was constructed in 1925, with the then-current practice of light cut-and-fill sections. The pavement was placed directly upon the silty loam soils.

The original pavement was constructed of plain concrete 18 feet wide and to a 9-6-9-inch cross section. No transverse joints were used except for construction stops. Steel bars 3/4 inch in diameter were installed at each pavement edge. A full-depth metal plate was used to form a center longitudinal joint, with the adjoining slabs being tied by deformed steel bars. The pavement underwent extensive portland cement concrete patching and maintenance repair in the 1940's. At the time of resurfacing, it had numerous wide transverse cracks accompanied with serious spalling and faulting. Intermittent areas of scaling had occurred throughout the entire length, and many of the old patches were severely raveled.

A comprehensive condition survey of the existing pavement was made prior to resurfacing. A representative field survey sheet that is typical of the condition of the old concrete pavement is shown in Figure 2. Fig. 2

The 1958 rehabilitation consisted of widening the existing pavement to 22 feet by a 2-foot width of 8-inch thick portland cement concrete along each edge, and resurfacing of the entire width with a 3-inch thickness of bituminous concrete, Illinois subclass I-11. A typical cross section of the rehabilitated pavement structure is shown in Figure 3. Fig. 3

The experimental portion of the project consisted of two sections of welded wire fabric placement and two control sections without fabric. The two sections with fabric included a 2500-ft. section of continuous placement of fabric sheets of several different widths, and an 18,000-ft. section of intermittent placement in which sheets $10\frac{1}{2}$ feet in width were placed in the 11-ft. lanes at 19 severely distressed locations.

The 2500-foot section was subdivided into five equal lengths for placement of the different widths of fabric. In the first four subsections, the fabric was placed successively $3\frac{1}{2}$, $4\frac{1}{2}$, $5\frac{1}{2}$, and $10\frac{1}{2}$ feet wide in the westbound lane. A $10\frac{1}{2}$-foot width was placed in both the east and westbound lanes in the fifth subsection. In the 18,000-ft. section of intermittent placement where all sheets were $10\frac{1}{2}$ ft. in width, the lengths of fabric at the individual locations varied from 6 to 120 feet.

The two sections with no fabric installation included a 3500-foot length in which the interval between transverse cracks in the existing pavement averaged about 50 feet, and a 3900-foot section in which this interval was about 13 feet. The latter section was selected as the control section for the analysis of transverse reflection cracking because its 13-foot average crack interval was the same as that in the sections containing the fabric.

Details of the project layout are shown in Figure 4 and listed in Table 1. Fig.4 Table 1

CONSTRUCTION

All construction in the experimental area preliminary to the placement of the welded wire fabric was completed in September 1958. This work included the bituminous skin patch removal, the cleaning and resealing of joints and cracks, the construction of many full-depth concrete patches, the placement of the portland cement concrete widening, the application of the asphalt tack coat, and the placement of the leveling binder course.

The welded wire fabric conformed to AASHO Designation: M55 and consisted of 10-gauge longitudinal wires on 3-inch centers and 10-gauge transverse wires on 6-inch centers. The fabric was furnished in sheets 15 feet long and $10\frac{1}{2}$ feet wide, and were cut on the job site as needed into $3\frac{1}{2}$, $4\frac{1}{2}$, and $5\frac{1}{2}$-foot widths. The individual sheets of fabric were placed directly over the leveling binder course with the transverse wires in contact with the surface to prevent the tracks of the paving machine from snagging the fabric.

The bituminous concrete binder and surface course mixtures were produced in a hot-mix plant, and conformed to the Illinois specification for fine dense-graded aggregate type mixtures, subclass I-11. Each mixture was produced from two sizes of a crushed stone aggregate, a coarse sand, a fine blend sand, and a mineral filler (limestone dust) in combination with a 70-85 penetration grade paving asphalt. All material of the binder-course mixture was required to pass a 1-inch sieve opening; all of the surface-course mixture was required to pass a 3/4-inch opening. The leveling binder mixture was the same as the surface mixture.

The mix designs were established by the Marshall method and conformed to Illinois standard design criteria which set a minimum stability value of 1500 and a flow value of 8 to 16. The mix formulas and tolerance limits are given in Table 2. <u>Table 2</u>

The contractor developed a special device for holding the wire fabric in place during the placement of the binder course mixture. The hold-down device, a three-runner sled of channel irons was placed between the tracks of the bituminous paver and pulled along over the fabric by chains attached to special brackets mounted on the paver. In addition, a nine-foot runner of light-weight railroad rail was pulled along outside of each track of the paver to hold the edges of the fabric firmly in place.

The sheets of fabric were placed a short distance ahead of the paver so that only the unloading truck needed to drive over them. The positioning of the fabric did not delay appreciably the paving operations.

Spot checks, made by temporary removal of small areas of the binder course to expose the fabric prior to the rolling operation, revealed that the fabric was tight against the leveling course. At some locations, the fabric was slightly embedded in the leveling course, apparently due to the heat and tamping during placement of the binder course.

Some distortion of the fabric occurred during the installation of the first few sheets of the $4\frac{1}{2}$-foot width. The inside edge of these sheets occasionally curled up between the outside and center runners of the hold-down sled. This curled edge snagged on the cross brace of the sled frame, humping the fabric and causing the spreading screw of the paver to further wrinkle it. This difficulty was eliminated by shifting the $4\frac{1}{2}$-foot width sheets inward a few additional inches beyond the normal three inches that other sheets were being set in from the edge of the base. This positioned the inner edge of the fabric under the center runner of the sled.

Occasionally, the sheets of fabric were skidded ahead and buckled between the wheels of the unloading truck, particularly on downgrades. This condition was remedied by applying less tension of the truck brakes while the paver pushed the truck during unloading operations. Little difficulty was encountered in placing the binder course over the isolated single pieces of fabric in the areas of intermittent placement.

TRAFFIC

The pavement involved (formerly Ill. Route 13) has carried a volume of traffic averaging approximately 1700 vehicles per day since resurfacing, including about 15 per cent of commercial vehicles. The volume and character of the traffic traveling in each direction appears to be about equal.

In an effort to present the data in a manner that reveals the most evidence of actual performance, the dependent variable has been compared with length of service and the accumulation of 18-kip equivalent single-axle loads representative of the mixed traffic loadings. Equivalency factors for converting single and tandem axle loadings into equivalent 18-kip single-axle application were derived from the AASHO Road Test performance equations. The volume and composition of traffic used in this conversion are given in Table 3. Details regarding the concepts for the application of the Road Test equations have been developed by relationships of actual Illinois performance trends.[1/] Table 3

OBSERVATIONS AND MEASUREMENTS

The observations and measurements that have been made for this study include (1) a condition survey of the existing concrete pavement made just prior to widening and resurfacing in 1958, (2) annual surveys of the conditions of the bituminous concrete resurfacing, for five consecutive years between 1959 and 1963, (3) rut depth

1/ Application of Road Test Formulas in Structural Design of Pavement, by W. E. Chastain, Sr., Highway Research Board Special Report 73, The AASHO Road Test: Proceedings of a Conference held May 16-18, 1962. St. Louis, Missouri.

measurements taken in the wheelpaths, and (4) road smoothness measurements taken with the BPR-type Illinois roadometer.

Special field sketch sheets were used for each condition survey to show transverse and longitudinal cracking. Prints of the pre-resurfacing survey sheets were used as underlays for the field sheets of the annual surveys of the resurfacing. Therefore, cracks could be tabulated as reflected or as occurring at previously uncracked locations.

Transverse cracks were tabulated and counted as reflection cracks if they extended half-way or more across the lane. Longitudinal reflection cracks were tabulated as continuous where the total length of short intermittent reflected cracks were at least half the potential crack length. The sketched lengths of longitudinal reflection cracking were tabulated to the nearest five-foot increment.

The road smoothness measurements were taken in conjunction with the fourth annual survey in 1962 and with the fifth survey in 1963.

Rut depth measurements were taken in the wheelpaths of both lanes in 1962 and 1963. In general, these measurements were made at 500-foot intervals.

ANALYSIS OF DATA

The condition survey of the old portland cement concrete pavement prior to resurfacing revealed numerous wide transverse cracks and associated spalling and faulting. There were two general transverse crack-intervals, one at nearly 50 feet, between Stations 51 and 86, and the other at approximately 10 to 15 feet, between Stations 86 and 230 (see Figure 4). No reason was found for the wide difference in crack interval between the two locations. <u>Fig. 4</u>

The existing pavement had required extensive full-depth patches during the 1940's. Many of these patches, all of which were of portland cement concrete, showed distress with wide areas of raveling. Intermittent areas of scaling were present throughout the entire length of the project.

The survey data on longitudinal reflection cracking over the longitudinal widening joints were summarized and analyzed for the two sections with fabric and for the two sections without fabric reinforcement. The progression of longitudinal reflection cracking over the widening joint for both the reinforced and nonreinforced sections is shown graphically in Figure 5. <u>Fig. 5</u>

Reflection cracking over the longitudinal widening joint in the areas containing the welded wire fabric was not apparent until the fourth survey in 1962, at which time 0.2 per cent of the total possible length had reflected. In 1963, after five years of service, the reflected amount was still less than one per cent. Reflection cracking over the widening joint in areas outside the fabric reinforcement, recorded in 1959 after one year service, amounted to 0.3 per cent of the total possible length. In 1960, the recorded value was approximately 10 per cent. This cracking distress progressed to 57 per cent in the third year of service, to 63 per cent in the fourth year, and to nearly 70 per cent by the fifth year (1963). During these years, single-axle loads accumulated at the rate of about 7,500 per year.

All widths of fabric reinforcement, varying from $3\frac{1}{2}$ to $10\frac{1}{2}$ feet, and placed 3 to 6 inches from the outer edge of the 2-ft. wide base widening, appear to be about equally effective in controlling cracking over the widening joint.

The analysis of transverse reflection cracking was limited to the two sections of pavement of initial long and short average joint and crack interval when no reinforcement was used, and to the reinforced sections having near-full-lane-width ($10\frac{1}{2}$ ft.) fabric. It will be recalled that the nonreinforced section of shorter joint and crack interval and the fabric-reinforced section initially had about the same average interval (13 ft.). The other nonreinforced section initially had an average joint and crack interval of about 50 feet. It did not seem appropriate to include the sections in which the shorter widths of fabric covered the original transverse joints and cracks only partially in this analysis. The progression of transverse reflection cracks, expressed as a per cent of the original number of transverse joints and cracks, with time and the accumulation of 18-kip equivalent axle loads is shown in Figure 6. Fig. 6

Referring to Figure 6, it will be seen that there has been a sharp growth of transverse reflection cracking where welded wire fabric was not used as compared with where it was used. The 50-foot crack-interval section data show 38 per cent had reflected the first year, with a steady increase to 98 per cent in the fifth year of service. The 13-foot crack-interval control section demonstrated a similar growth of 8 per cent the first year to 67 per cent by the fifth year. In the full-lane-width reinforced sections no appreciable amount of transverse reflected cracks was evident in the first year, and only 27 per cent reflected after the fifth year of service. As stated previously, 18-kip equivalent single-axle loads representative of mixed traffic accumulated at the rate of about 7,500 per year.

It is apparent that the welded wire fabric has been beneficial in reducing the growth of transverse reflection cracking up to the fifth year of service, with the per cent reflected being about one-fourth that in the 50-foot crack interval section, and less than one-half the value of the 13-foot crack interval control section.

It must be pointed out in comparing the two nonreinforced sections that the per cent of transverse cracks reflected is no indication of the over-all surface condition of the two areas of pavement, since these two areas differ greatly in the average length of uncracked sections. The average length of uncracked sections (crack-interval) after five years of service was 47 feet in the originally longer-crack-interval section, 20 feet in the control section, and 70 feet in the continuous full-lane reinforced sections.

Smoothness measurements recorded in 1962 and 1963 by the Illinois roadometer have indicated little variation in the riding quality throughout the project. The roughness indexes indicated subjective ratings of "slightly rough" in both reinforced and nonreinforced sections. There is no apparent correlation trend that would demonstrate the usefulness of fabric to retard depreciation in the riding quality, after five years of service. However, as the cracking progresses to spalling and dislodgement of surface particles, the control of reflection cracking demonstrated to date by the fabric reinforcement may be reflected in the riding quality.

Rut depth measurements up to the fifth year of service, with maximum values less than 0.1 inch on both reinforced and nonreinforced sections, offer no evidence to form an opinion regarding the effectiveness of fabric to resist rutting or shoving in the bituminous overlay.

DISCUSSION AND FINDINGS

Welded wire fabric can be incorporated in bituminous concrete resurfacing construction with conventional equipment and without appreciable difficulty. However, some type of hold-down device or a means of securing the fabric to the leveling binder course is required to prevent the tracks and augers of the paving machine from catching in the fabric. During paving operations, the truck driver should carefully control tension on the truck brakes, especially on downgrades, to avoid shifting of the wire fabric.

After five years of service under moderate traffic, the welded wire fabric has practically eliminated the formation of reflected cracks over the longitudinal widening joint; and has reduced substantially the reflection cracking over transverse cracks and joints.

It is reasonable to assume that the reflected cracks in the areas of no fabric will progress to more serious deterioration, as demonstrated by past performance of resurfaced pavements, and therefore will eventually affect the riding quality. The degree to which the fabric will be able to control or prevent this progression undoubtedly will provide a real measure of the benefits derived from the use of welded wire fabric in bituminous concrete resurfacing.

Although this experimental project might eventually provide some definite data regarding the long-term beneficial effects of welded wire fabric reinforcement, some considerations should be given in future research to incorporating reinforcement in bituminous concrete surfacing over pavements of various crack-intervals and stages of deterioration. The inclusion of control sections of various thicknesses of resurfacing to determine possible cost-benefit relationships should also be considered. (The cost of the welded wire fabric installation on this particular project was about the same as the cost of an additional inch of resurfacing thickness).

TABLE 1

LOCATIONS OF WELDED WIRE FABRIC
SBI Route 13, Sections 12 RS-1, Jackson County

Continuous Placement

Stations	Lane	Width of Fabric (ft.)	Length (ft.)
125+00 to 130+00	Westbound	3.5	500
130+00 to 135+00	Westbound	4.5	500
135+00 to 140+00	Westbound	5.5	500
140+00 to 145+00	Westbound	10.5	500
145+00 to 150+00	East and Westbound	10.5	500
		Total	- 2500 ft.

Intermittent Placement

Stations	Lane	Width of Fabric (ft.)	Length (ft.)
152+23 to 152+29	Westbound	10.5	6
153+72 to 154+18	Westbound	10.5	46
155+77 to 155+85	Westbound	10.5	8
157+15 to 157+31	Westbound	10.5	16
157+51 to 157+86	Westbound	10.5	35
161+79 to 162+00	Westbound	10.5	21
229+20 to 229+55	Westbound	10.5	35
151+50 to 151+64	Eastbound	10.5	14
152+10 to 152+46	Eastbound	10.5	36
152+80 to 153+16	Eastbound	10.5	36
153+57 to 154+77	Eastbound	10.5	120
155+44 to 155+70	Eastbound	10.5	26
156+54 to 156+71	Eastbound	10.5	17
156+95 to 157+45	Eastbound	10.5	50
157+58 to 157+86	Eastbound	10.5	28
159+02 to 159+37	Eastbound	10.5	35
160+63 to 160+69	Eastbound	10.5	6
219+42 to 219+57	Eastbound	10.5	15
227+25 to 227+70	Eastbound	10.5	45
		Total	- 595 ft.

TABLE 2

COMPOSITION OF BITUMINOUS CONCRETE MIXTURES

Sieve	Binder Course Mixture		Surface Course Mixture	
	Passing and Retained	Tolerance	Passing and Retained	Tolerance
	%	%	%	%
Passing 1-inch, retained on ½-inch sieve	34.5	± 5		
Passing ½-inch, retained on No. 10	32.3	± 5	61.5	± 3.0
Passing No. 10, retained on No. 200	25.0	± 3	28.9	± 3.0
Passing No. 200 sieve	4.2	± 3	5.0	± 1.5
Bitumen PA-6 (70-85 penetration)	4.0	± 0.3	4.6	± 0.3

TABLE 3

TRAFFIC VOLUME AND COMPOSITION

Year	Total Average Daily Traffic	Average Daily Truck Traffic Single Unit	Average Daily Truck Traffic Multi-Unit	Accumulated 18-Kip Equivalent Single-Axle Loads
1959	1650	290	10	7,500
1960	1650	290	10	15,045
1961	1700	240	10	21,580
1962	1700	240	10	28,115
1963	1700	240	10	34,650

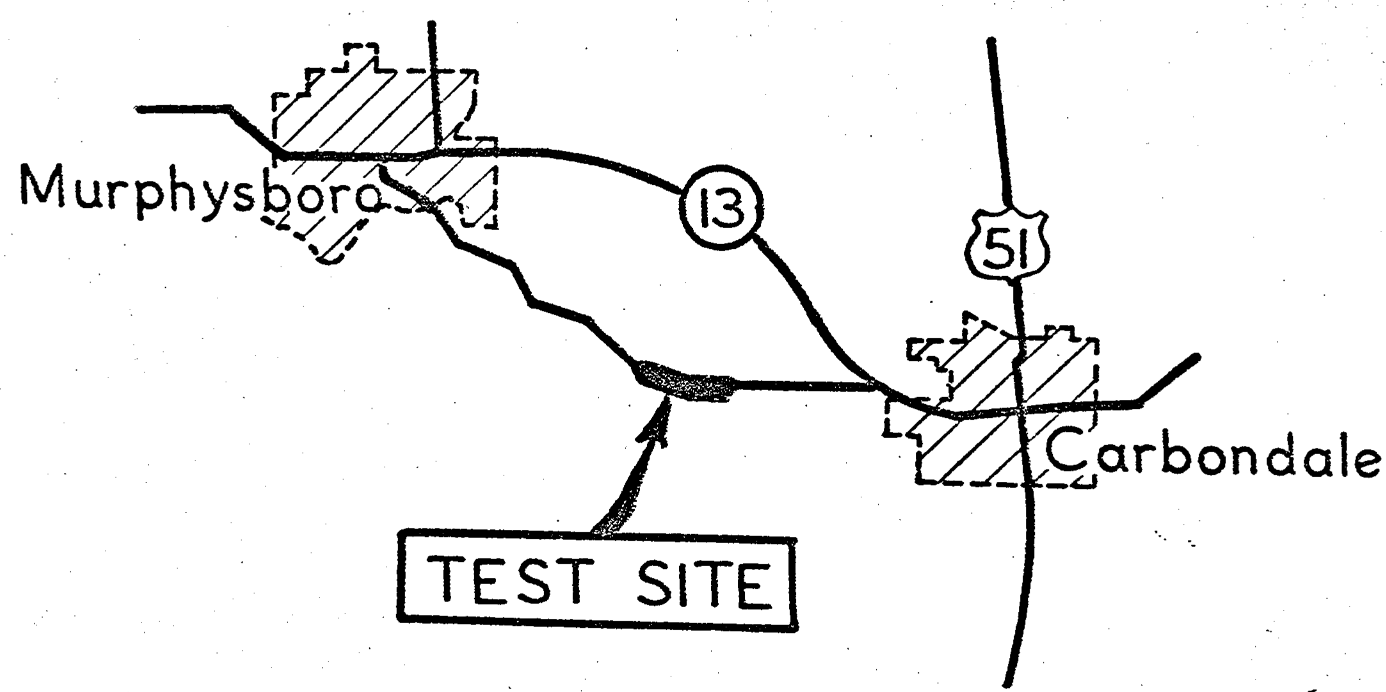

Figure I. General site location

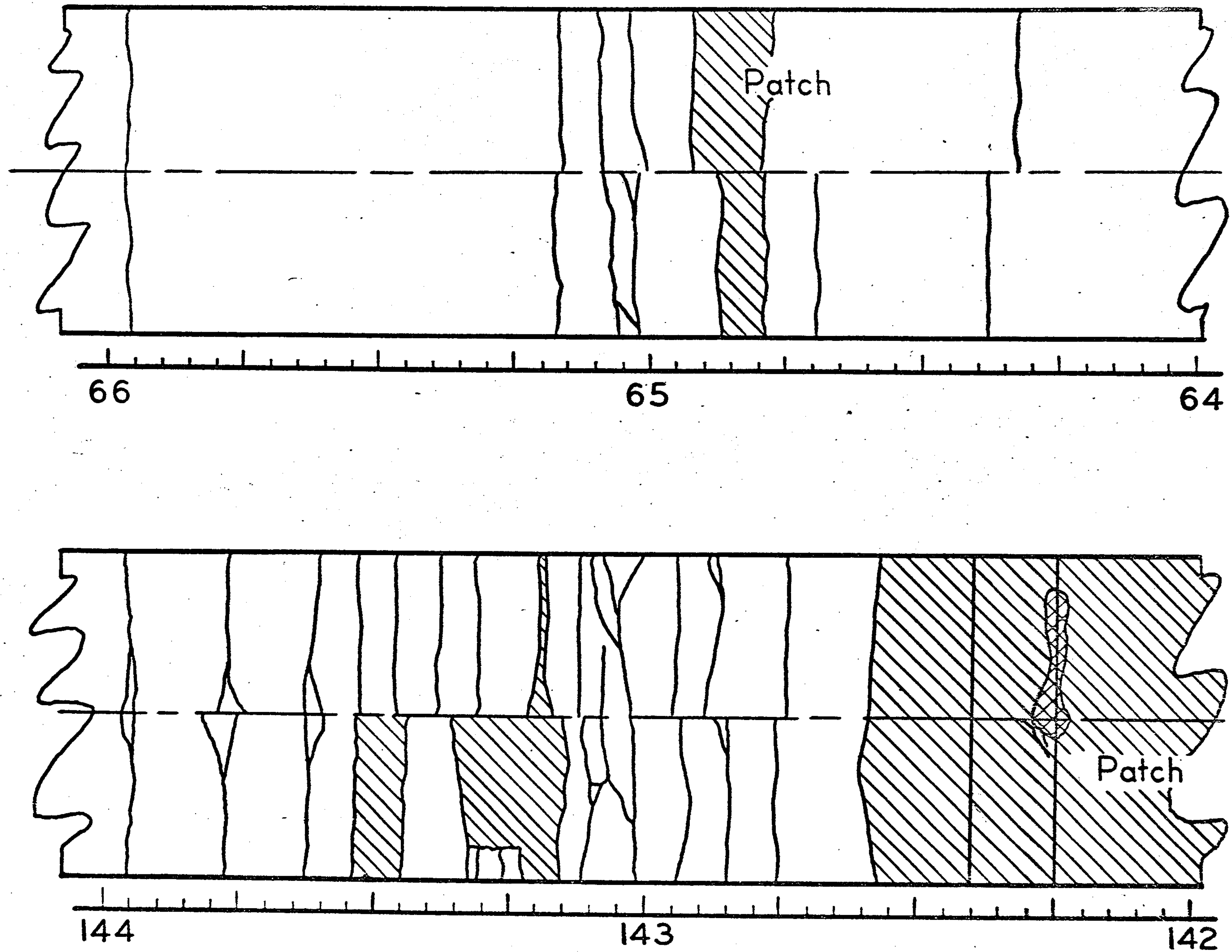

Figure 2 Typical Condition of Old Concrete Pavement

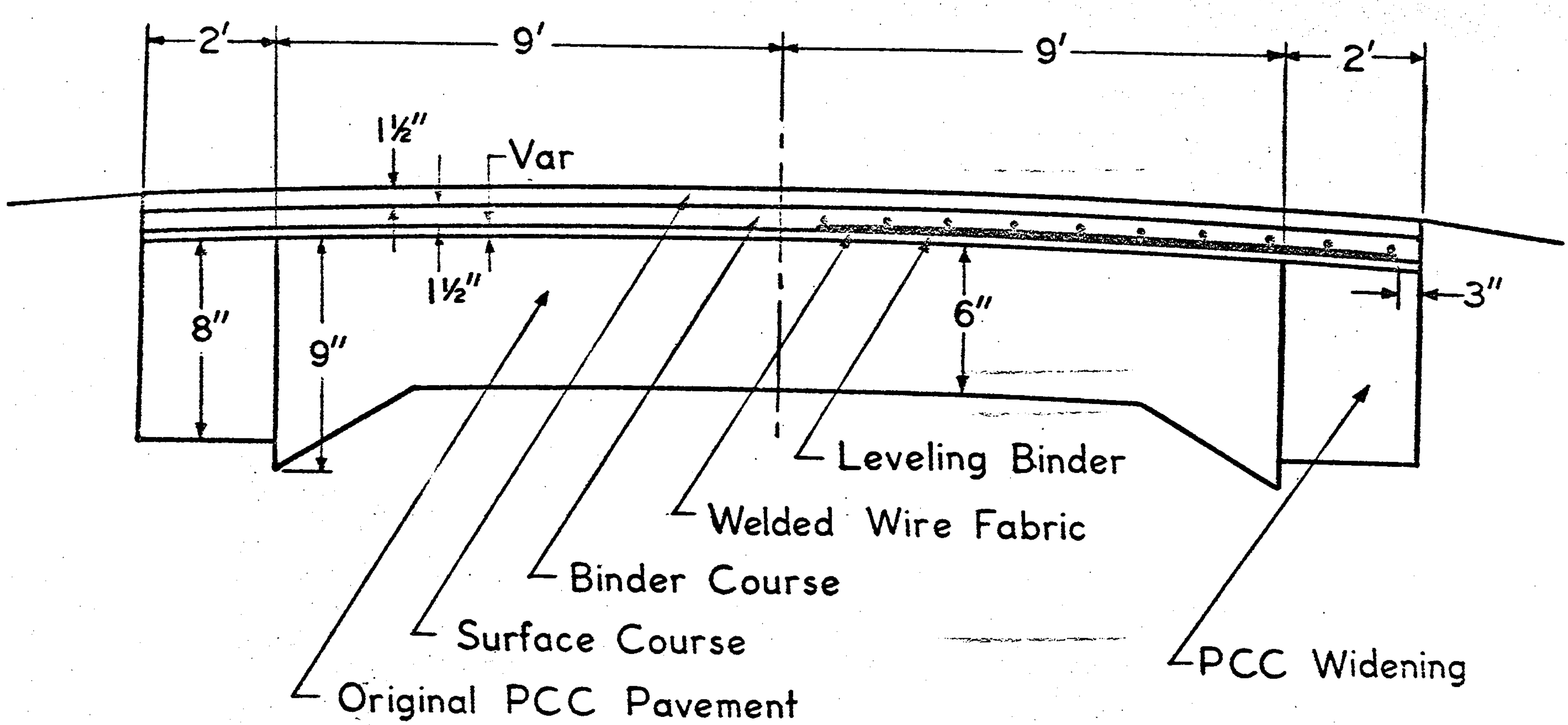

Figure 3 Typical Cross Section

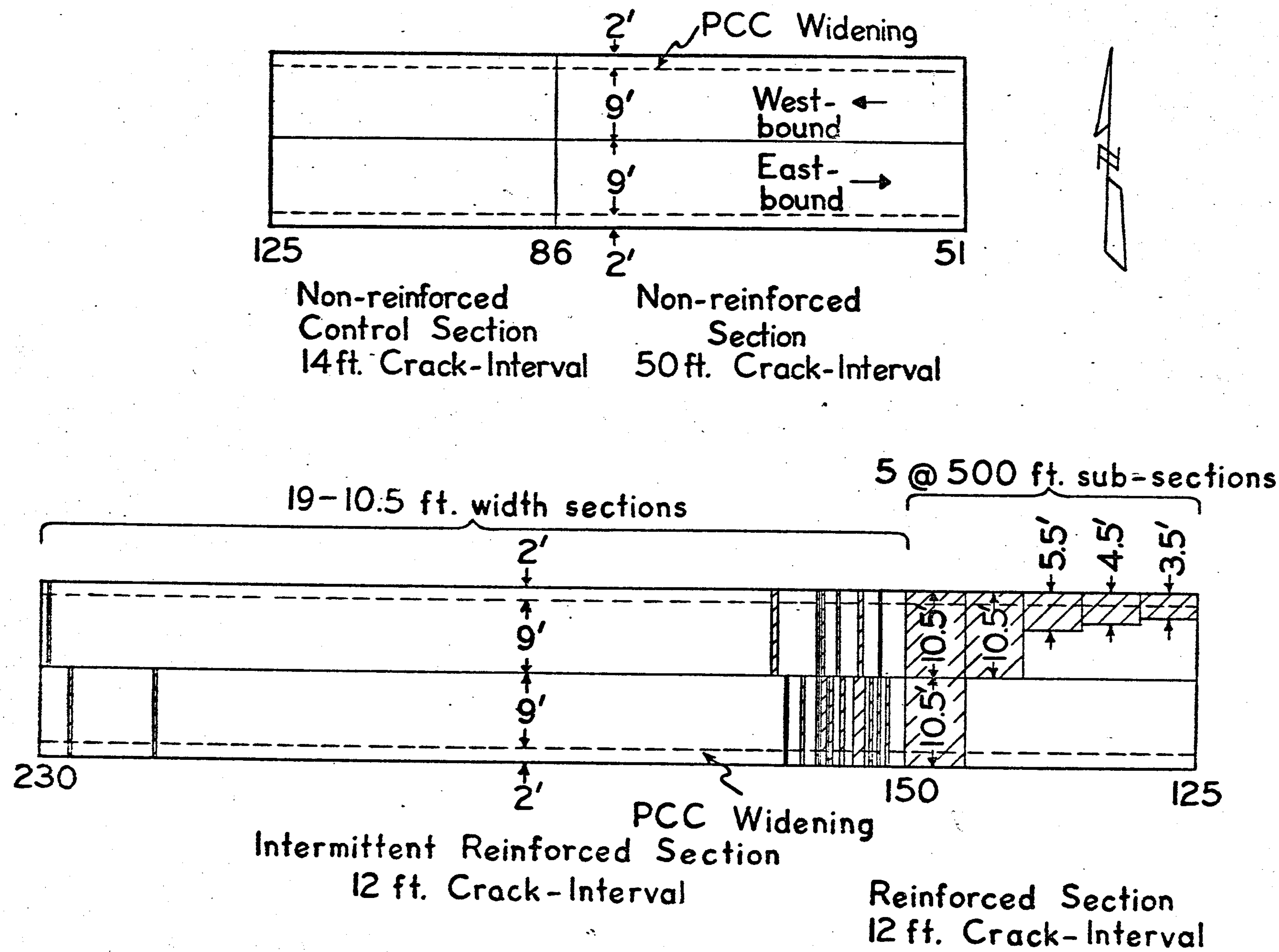

Figure 4. Details of project layout

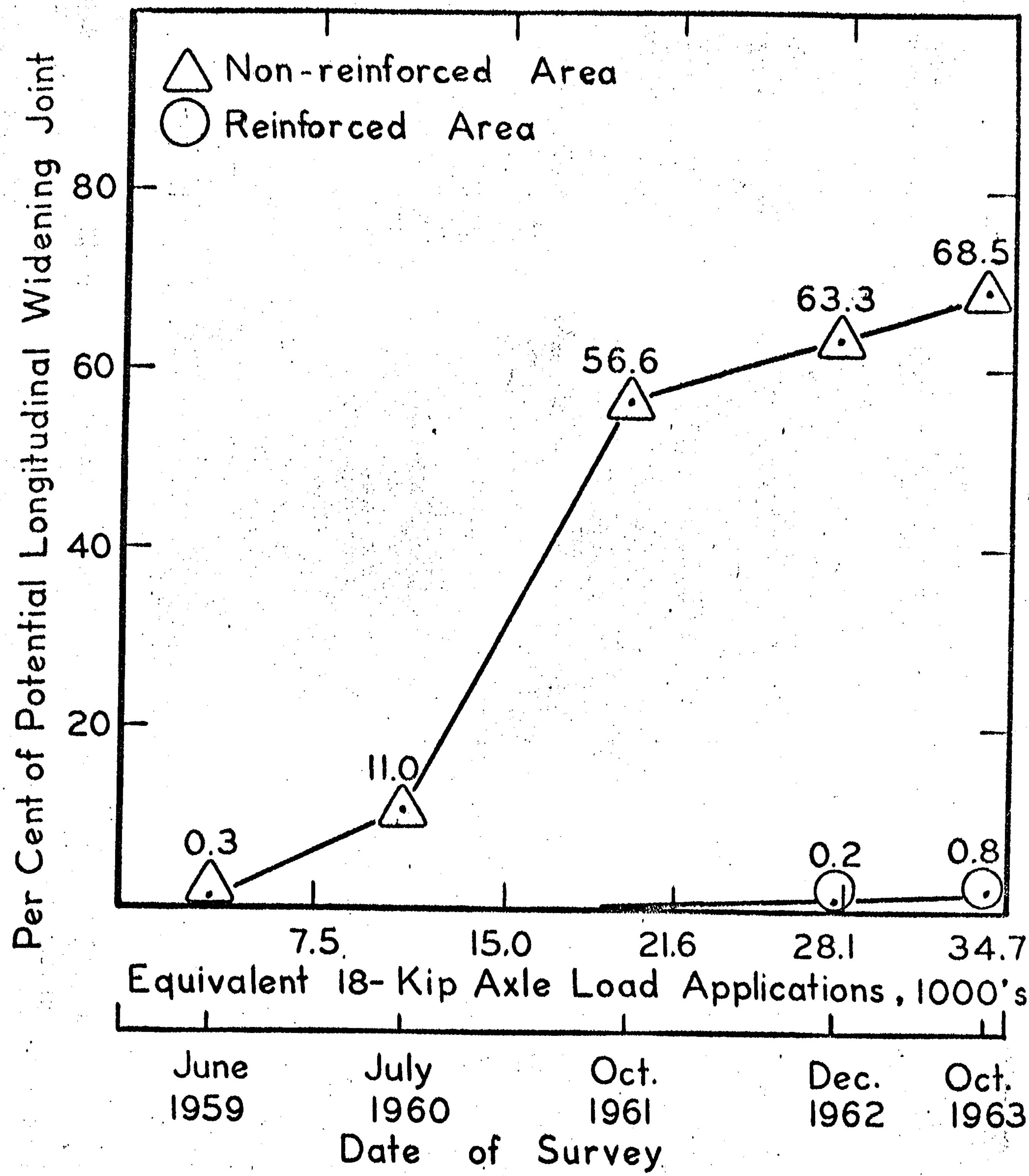

Figure 5. Progression of Longitudinal Reflection Cracking over Widening Joint.

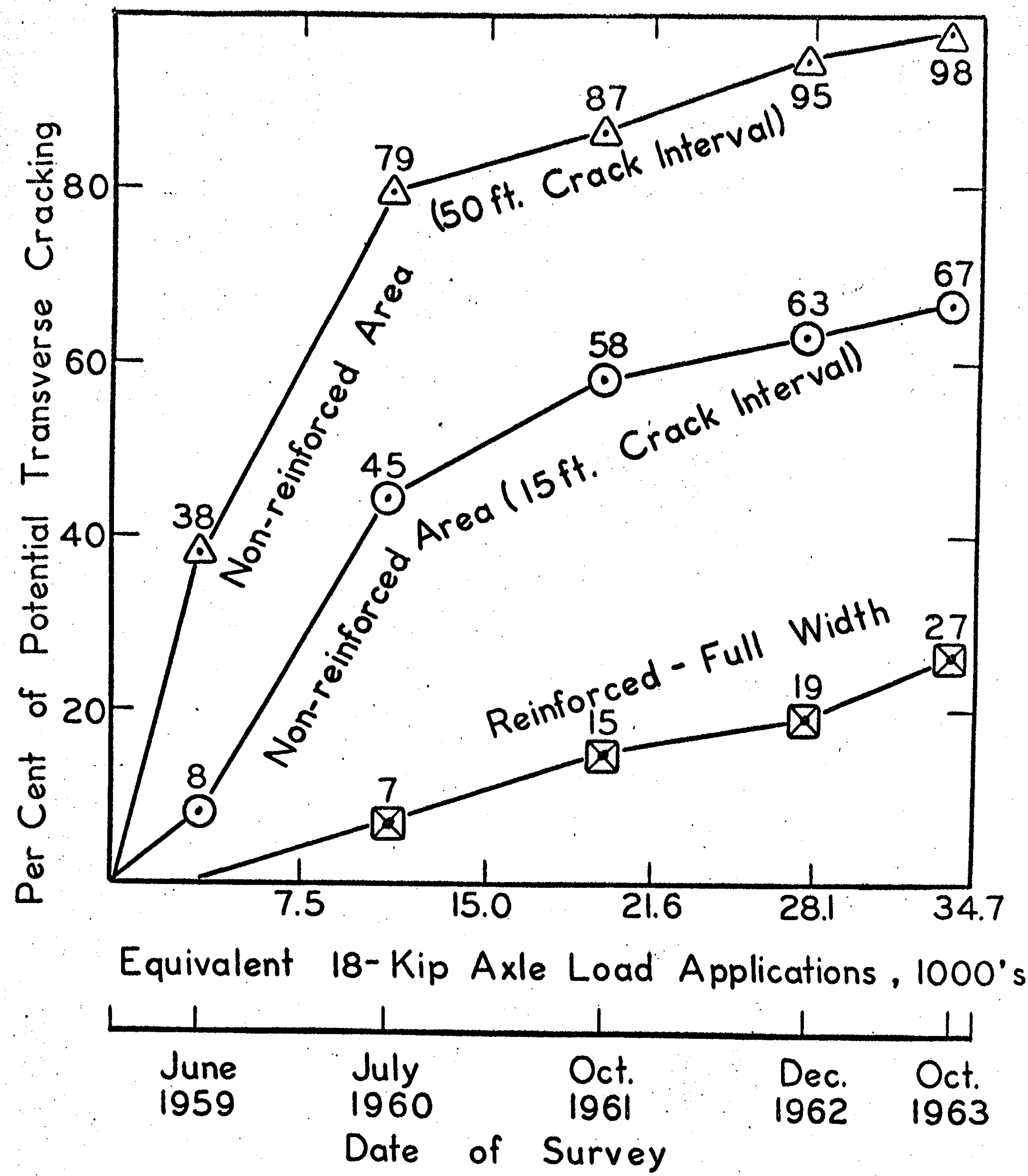

Figure 6. Progression of Transverse Reflection Cracking