Wire Mesh Reinforcement in Bituminous Resurfacing

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The problem of what to do about reflection cracks occurring in bituminous resurfacing blankets placed over old Portland cement concrete pavements has been a subject of much concern and paving engineers have long been seeking a satisfactory solution.

A number of methods have been used in an attempt to prevent or retard this type of cracking. Subsealing or mudjacking of the old concrete slabs has been tried, but has not eliminated the trouble. In many cases the old concrete has been covered with a cushion course of granular material of substantial thickness before placing the new surfacing. In other instances, the thickness of the new surfacing has been increased in an attempt to eliminate or minimize this cracking.

A more recent and promising method involves the use of some form of wire mesh, laid directly on the existing concrete surface and covered by a bituminous surfacing.

This paper describes an experimental project in which the California Division of Highways in 1954 placed several test sections for the purpose of comparing the relative merits of various types of wire mesh.

An old existing concrete pavement subjected to heavy truck traffic on highway US 40 and constructed in 1935 was selected for the test site. The pavement was badly cracked, had undergone extensive patching and was to be covered with a 4 inch contact blanket of plant mixed surfacing.

A total of eight experimental sections were placed, incorporating four types of expanded metal mesh, two types of so-called bituminous road mesh and two types of welded wire fabric.

The various experimental sections were separated by control sections containing no wire mesh thus permitting a direct and close comparison between reinforced and nonreinforced sections. Cost comparisons indicate the welded wire mesh to be the least expensive of the various types of reinforcement used.

The final answer as to the economical justification for placing wire mesh will depend upon the amount of retardation of cracking or prolonged life of the surfacing with the various types of reinforcement when compared to the control sections.

●THE problem of what to do about reflection cracks occurring in bituminous resurfacing blankets placed over old P. C. C. pavements has been a subject of much concern and paving engineers have long been seeking a satisfactory solution. These cracks not only present an unsightly appearance, but often develop subsequent spalling which presents a difficult maintenance problem. The cracks may appear at any time from a month up to a few years after construction depending upon the condition of the underlying concrete pavement. Vertical movement of the slabs, commonly referred to as rocking slabs, is the most common cause. Other contributing factors are the type and volume of traffic, particularly heavy truck traffic, the thickness of the new blanket and probably to a lesser degree, at least in California, the temperature differential of the seasons. Figure 1 shows typical reflection cracking of a thin bituminous blanket placed over old concrete pavement on one of our main roads. This picture bears out the fact that reflection cracking is not entirely due to horizontal movements caused by temperature changes in the underlying concrete, as evidenced by the absence of cracking in the lighter traveled passing lane. In this case it is obviously caused by vertical movements of the slabs under heavy traffic.

A number of methods have been used in an attempt to prevent or at least retard reflection cracking. Subsealing or mudjacking of the old concrete pavement slabs prior to blanketing has been tried and although this process greatly reduced the amount or intensity of cracking, it has not completely eliminated the trouble.

In many cases particularly when the old concrete pavement is badly faulted or broken and structurally inadequate to carry the traffic loads, a blanket of granular material 4-to-8 inches in thickness is placed and covered with 3-to-4 inches of new surfacing. However, existing curbs and gutters or structures and the additional cost of raising shoulders very often discourage such a substantial increase in thickness.

In other instances, the thickness of the new asphaltic surfacing has been increased in an attempt to eliminate or minimize this cracking. Even the so-called open graded mixes of the macadam type possessing somewhat more flexibility than dense graded mixes have been tried but still have not completely solved the problem.

From the varying degree of success obtained by any of the above-mentioned methods it appears that prevention of the vertical movement of slabs caused by the passage of heavy trucks is the most important step towards eliminating or delaying the appearance of reflection cracks. In recent years it has been the standard practice of the California Division of Highways to subseal with asphalt before blanketing any concrete pavements showing signs of movement or pumping of the slabs.

It is of interest to note that bituminous blankets placed over many miles of old broken concrete pavements which were built in the early 20's without expansion or contraction joints (but which during the years of service have developed random cracks) are usually free from reflection cracking. This is also true of the pavements covered with the granular cushion courses.

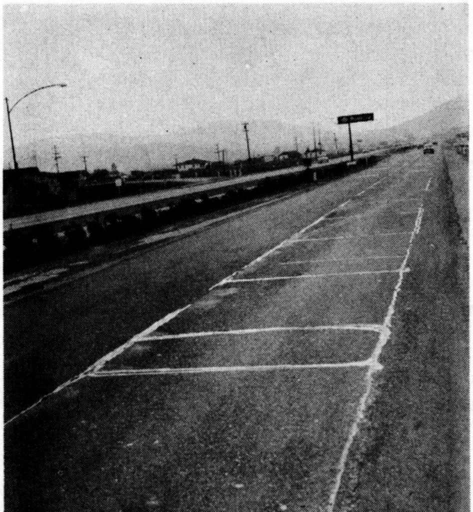

Figure 1. Typical reflection cracking. Both lanes resurfaced June 1954, with 1-inch thick bituminous mix. Note absence of cracks in passing lane at left. Cracks began to appear after 1 month. US 40 near Fairfield.

One of the more recent and promising proposals for eliminating or minimizing the number of reflection cracks is the use of some type of wire mesh reinforcing laid directly on the concrete slab or placed between the leveling and surfacing courses of the bituminous blanket. Although the first attempt to use such material was apparently made in Michigan in 1937, it was not until after the last World War that the use of some form of wire mesh became more widespread. In 1946 the State of Texas placed two projects involving the use of so-called wire fabric and reports from Texas engineers indicate that this method apparently reduced crack formation. Since that date numerous experimental installations of welded wire fabric have been placed in various states and reports in general indicate favorable results in suppression of reflection cracking.

Another form of wire mesh is expanded metal sheets of small diamond size mesh which are used to cover only individual joints and cracks in the existing concrete pavement. This method of treatment was developed in England, where a number of test sections were placed in 1951. Reports received in 1953 indicate that this application shows a definite promise of delaying or materially reducing the amount of cracking.

It might be well to outline briefly the types of wire mesh that have been used in the various trial installations both in the United States and England.

The two primary types of wire mesh are known as expanded metal mesh and welded wire fabric. The expanded metal mesh is produced by feeding stock sheets into a machine

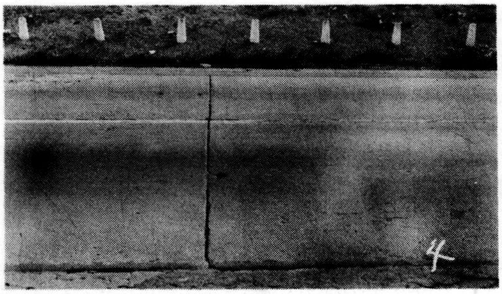

Figure 2. District X-Sol-7-G, condition of old concrete pavement. Note hole for sub-sealing.

Figure 3. Random cracks.

which cuts and expands the solid sheet into a diamond shaped mesh. The diamonds vary in size from ¼-by 1-inch to 6-by 12-inches and the gauge of metal can also be varied. The sheets with the smaller sized diamonds are usually cut into 4- by 8-foot size and are used in building construction for open partitions, door panels, shelving, etc. The larger sized diamond mesh is used for reinforcement in concrete construction work and may be secured in sheets as large as 12- by 16-feet. The small diamond mesh sheets are normally produced with the long dimension of the diamond parallel to the long axis of the sheet, whereas the large diamond mesh is produced with the long dimension of the diamond at right angles to the long dimension of the sheet. Welded wire fabric is produced by spot welding wires to form rectangles. These sheets may have openings of 3- by 6-inches or 6- by 6-inches or any other dimension desired by the consumer. The gauge of the wire may also be varied, and rolls containing up to 300 feet in length are available. However, the majority of the installations have been laid using sheets 11 feet -6 inches wide by 8-feet long.

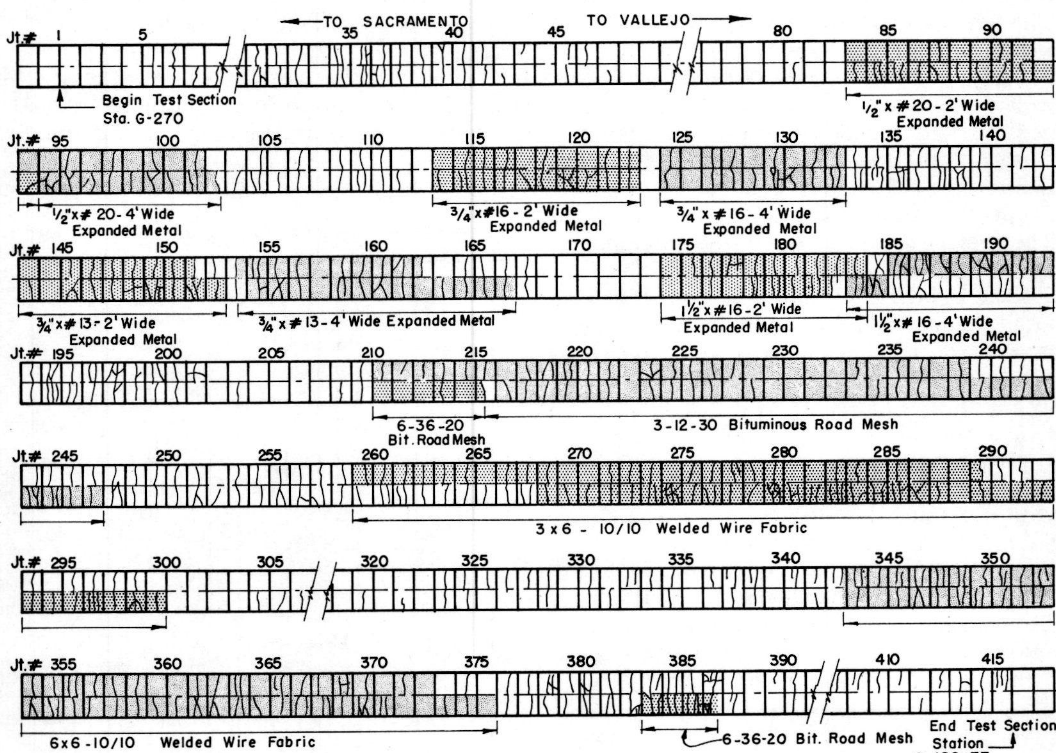

Figure 4. Layout of test section-X-Sol-7-G.

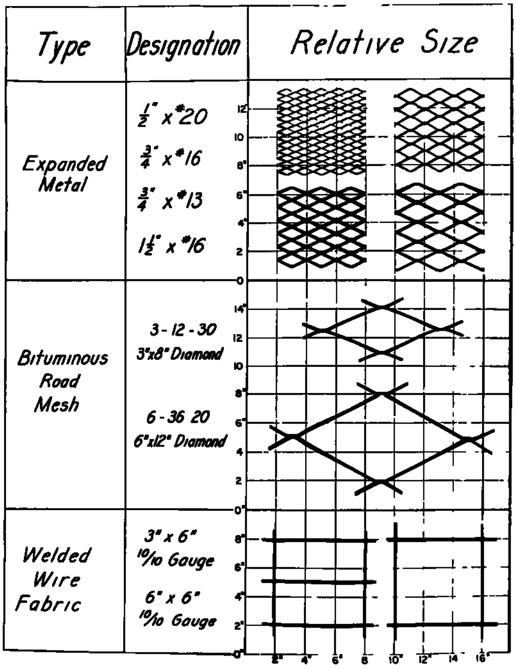

Figure 5.

This paper describes three experimental projects which were installed by the California Division of Highways in three different highway districts using various types of wire reinforcement. The report describes primarily the installation and problems encountered in the major installation in District X where eight different types of wire mesh were used. The other two installations, in Districts V and VI are of a minor nature and mentioned briefly, in this report, involved the use of welded wire fabric only. The project in District VI used wire fabric in rolls each containing 200 feet which were placed in 6 foot, 12 foot, and 18 foot widths. The wire fabric installation in District V was covered with bituminous pavement varying in thickness from 2½ inches to 8 inches and thus should provide some information on the relation between reflection cracking and thickness of plant mixed surfacing. In all cases the wire mesh was placed directly upon the old concrete pavement.

ROAD X-SOL-7-G

The test section is located near the town of Vallejo on highway US 40, the main arterial between Sacramento and San Francisco, a heavily traveled four lane highway. The average daily traffic count is about 20,000 vehicles with about 15 percent consisting of heavy truck traffic.

This installation, involving a number of different types of wire mesh, was completed in June 1954 under Contract 55-10TC2. It is a rather complete test section in that all of the recommended types of wire mesh were placed under similar construction conditions and in areas where the existing pavement was of the same general nature in respect to amount and severity of cracking. The test sections involved the westbound travel and passing lanes only.

The existing 20 foot wide concrete pavement, constructed in 1935, had been mudjacked and later subsealed with asphalt and some bituminous patches had been placed by the maintenance department in past years.

As the old pavement showed signs of vertical movement, the contract provided for subsealing the existing slabs again with hot asphalt. Before resurfacing, the traveled way was widened with cement treated base to provide a standard 24 foot, cross-section with full paved shoulders. This widening resulted in a 2-foot shift of centerline. The resurfacing consisted of 3 inches of plant mixed surfacing, ½-inch maximum size aggregate, placed in two layers and topped with 1 inch of open graded mix, ½-inch maximum size aggregate. 85-100 penetration paving grade asphalt was used as the bituminous binder.

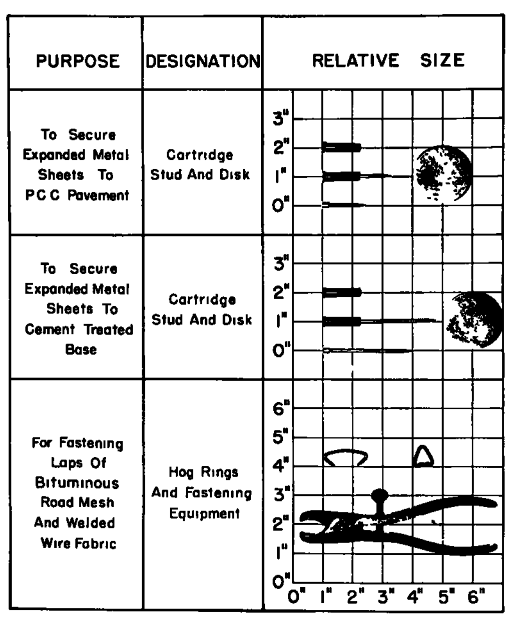

Figure 6.

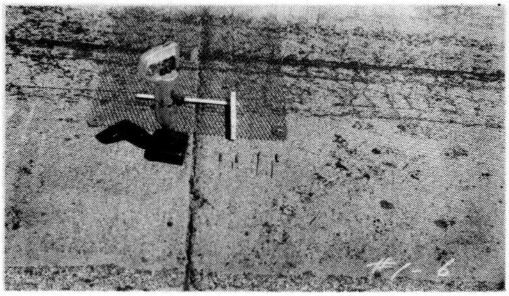

Figure 7. Stud driver used in fastening sheets to P.C.C. pavement.

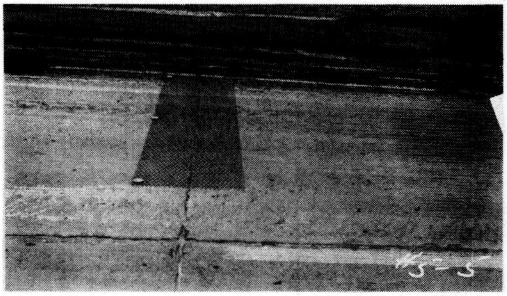

Figure 8. 2-foot wide sheet fastened along leading edge. Paver approaches from left.

The grading of the bituminous mix conformed to the specifications shown below:

	Percent Passing	
Sieve Size	Dense Graded	Open Graded
$\frac{1}{2}$ inch	95-100	100
$\frac{3}{8}$ inch	75-90	90-100
No. 4	50-70	35-50
No. 8	35-50	15-32
No. 16	-	0-15
No. 30	15-30	-
No. 200	4-7	0-3

A careful crack survey of the existing P. C. C. pavement was made and the location of the various test sections laid out. Alternate control sections without reinforcement but showing similar cracking were provided so as to permit ready comparison with each test section. Figures 2 and 3 are typical of the condition of the old concrete pavement and Figure 4 shows the general layout of the test sections.

The following forms of wire mesh were used in the test sections:

Type	Mesh Size
Expanded metal	$\frac{1}{2}$ inch by No. 20
	$\frac{3}{4}$ inch by No. 16
	$\frac{3}{4}$ inch by No. 13
	$1\frac{1}{2}$ inches by No. 16
Bituminous Road Mesh	3-12-30 (3- by 8-inch diamonds)
	6-36-20 (6- by 12-inch diamonds)
Welded Wire Fabric	3- by 6-inch -$^{10}/_{10}$ gauge
	6- by 6-inch -$^{10}/_{10}$ gauge

Figure 5 illustrates the comparative sizes of the various types of metal used.

Expanded Metal

The expanded metal was delivered to

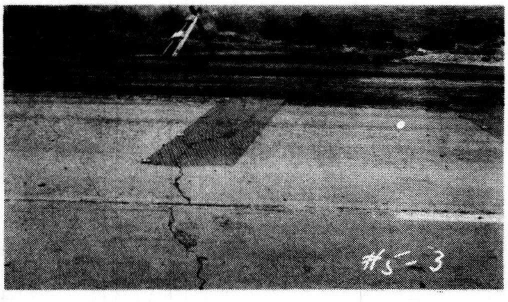

Figure 9. 2-foot wide sheet placed over random crack.

Figure 10. Typical expanded metal test section just prior to paving. Short section of longitudinal joint covered.

the job site in 2 and 4 foot wide strips by 8 feet long. As the expanded metal is rather expensive the two and four foot wide sheets were being tried in order to determine the most economical size which would prevent crack formation. The 8 foot long sheets were satisfactory for the passing lane as 8 feet of old concrete pavement remained due to a shift of the centerline. For the 12 foot wide travel-lane some sheets were cut in half and an 8 foot and 4 foot long sheet used, allowing an overlap of about 3 inches. All joints such as expansion and contraction joints and random cracks of the slabs were covered with the metal. Short sections of the longitudinal joints between the old concrete and new cement treated base were also covered with 2 foot and 4 foot wide sections of the metal, (see Figure 10).

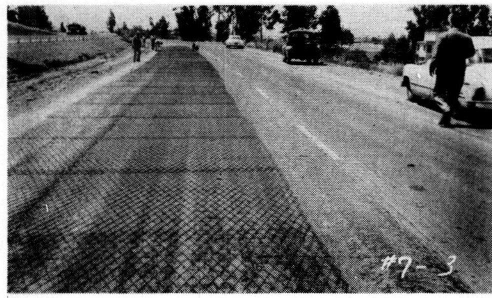

Figure 11. Test section with 3- by 8-inch diamond mesh. New centerline will be at inner edge of wire. On left, sheets cover 4 feet of cement treated base.

The variation in the random crack patterns, encountered mainly in the travel lane, required a great deal of fitting and cutting of the sheets. In a number of cases, a random crack could not be entirely covered with a 2- by 8-foot sheet and required the use of 4- by 8-foot sheets.

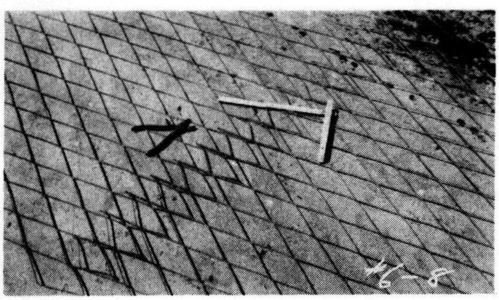

Figure 12. Lapping of sheets. Wires are tied with hog rings about every fifth diamond.

The sheets were securely fastened to the old pavement by means of a standard stud driver, (see Figure 7). In this operation a stamping disc, 2 inches in diameter was laid on the metal mesh, taking care to center the disc approximately in the center of the diamond. The operator, after loading the gun with the correct stud and cartridge, placed the gun over the disc and fired the charge. The stud penetrated the disc and concrete, and pulled the mesh into tight contact with the pavement. After a few trials it was decided that a stud having an over-all length of $1\frac{15}{32}$ inches was best suited. A heavy charge cartridge No. 832 was used in order to secure the required penetration. Satisfactory anchorage was obtained in the cement treated base by using a stud having an over-all length of $2\frac{31}{32}$ inches and a light No. 232 powder charge, (see Figure 6).

The $\frac{1}{2}$ inch by No. 20, 2-foot wide sheets were placed first to determine proper stud spacing. The 8-foot long sheet was fastened at both the leading and trailing edges with about 5 studs and also at a number of spots on either side of the joint.

On passage of the paver over the sheets it was noted that a definite vertical bow appeared in the sheet immediately after the paver treads moved onto the leading edge. It was not possible to determine if the sheet returned to its original shape after the paver moved past. There were no indications of distress caused by failure of the studs to hold the wire in place, as far as longitudinal movement was concerned.

Immediately after the first roller pass, transverse cracking appeared in the mix over the expanded metal sheets. This cracking became more severe on the final roller pass, although the metal was tight against the pavement as determined from

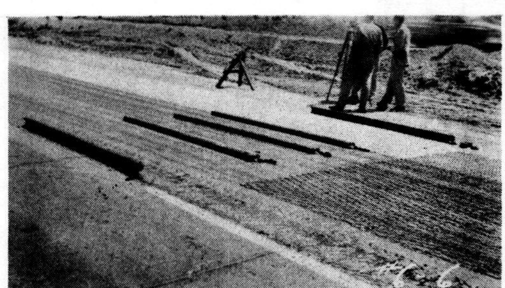

Figure 13. Sleds used to hold down road mesh and welded wire fabric.

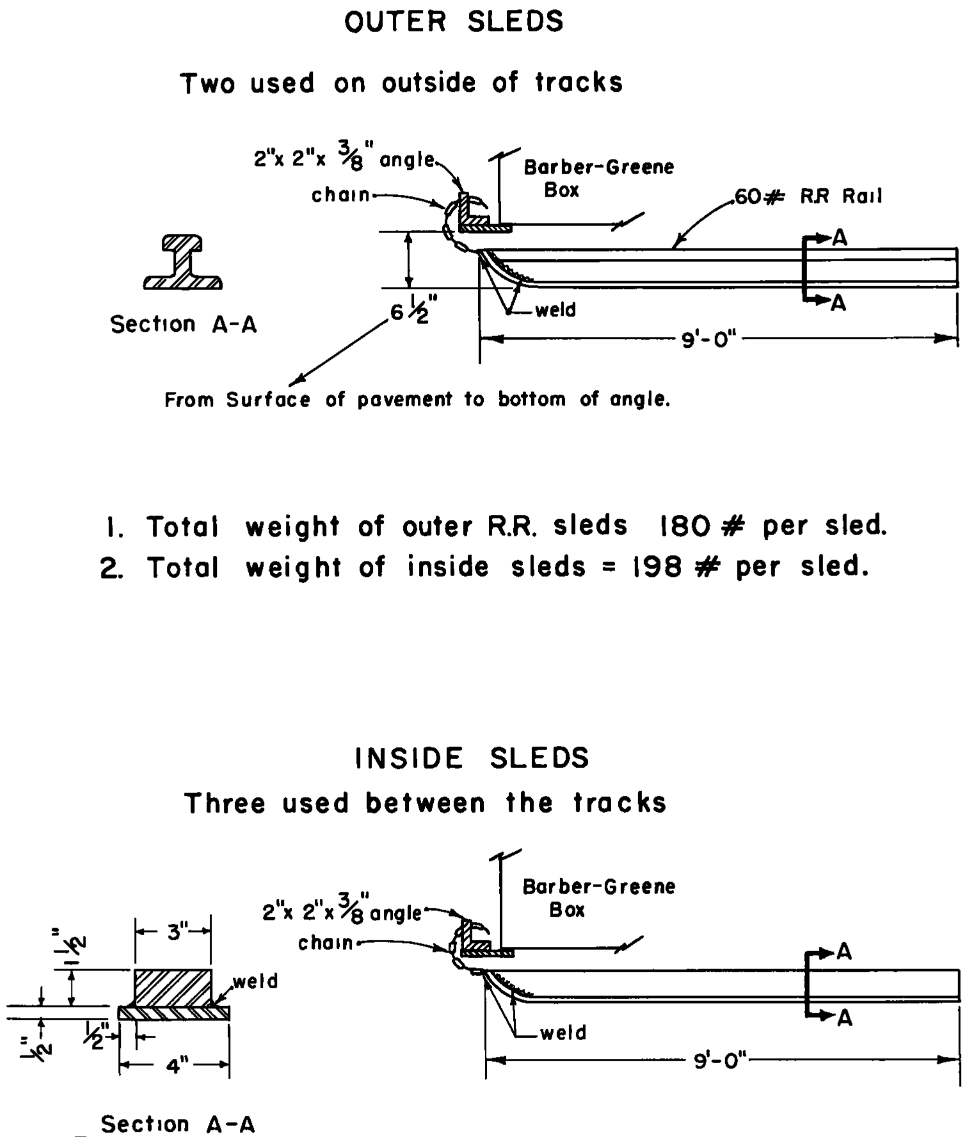

Figure 14. Wire mesh test sections. Details of sleds. X-Sol-7-G, June, 1954.

the protruding edge of the sheet. On a number of sheets a very definite bump was present, mainly at the leading edge. Generally cracks appeared over both the leading and trailing edges and in a number of cases there also were three or four transverse cracks spaced about 5 inches apart. However, the next morning after approximately fifteen hours of traffic most of the cracks had healed, although the leading and trailing edge cracks were still noticeable.

It was then decided to fasten the sheets only at the leading edge and to determine the least number of studs necessary to hold the sheet in place. Various numbers of studs were used including the absolute minimum for an 8- foot long sheet, one at each corner and one in the center of the leading edge, (see Figure 8). This proved to be satisfactory and resulted in a considerable saving as each stud in place costs about $. 25.

Stud driving operations proved quite successful in the passing lane, with very few failures due to shattering or excessive penetration. Some difficulties were encountered in the travel lane where the concrete appeared to exhibit marked variations in degree of hardness. In numerous instances the stud would penetrate only one-half of its normal

Figure 15. Close-up of paving operations. Note sled attachment on left.

Figure 16. Position of mesh after placing leveling course.

distance, or would bend or shatter the concrete, or the charge would drive the stud completely through the disc necessitating the driving of additional studs.

There was no difficulty in the paving operations in any of the expanded metal sections. None of the sheets, including those fastened at the leading edge with only three studs, were torn loose by either truck or paver movement. It was noted that some longitudinal movement on a large number of sheets occurred under the traction stresses of the paver. This movement was in the same direction as the forward movement of the paver and was about $\frac{1}{4}$ inch to 1 inch for the $\frac{3}{4}$-inch diamonds and 1 inch to $1\frac{1}{2}$ inches for the $1\frac{1}{2}$ inch diamonds. This movement undoubtedly was caused by the forward shifting of the entire sheet, until the studs which were fired in the center of the diamond encountered the edge of the metal.

The rather severe cracking following rolling as noticed in the beginning, where both leading and trailing edges were fastened, was not noted where only the leading edge was fastened. Paving and rolling operations were normal and very little cracking, following rolling, was noted.

The best size of diamond from the construction viewpoint, appears to be either the $\frac{3}{4}$ inch by No. 16 or the $\frac{3}{4}$ inch by No. 13. The lighter stocks were harder to handle and more difficult to fasten securely. The $\frac{3}{4}$ inch by No. 13 in both 2 and 4 foot wide sheets was easiest to lay and showed the least movement under paver traction forces. However, the $1\frac{1}{2}$ inch by No. 16 can be laid and if it retards the cracking as efficiently as the $\frac{3}{4}$ inch by No. 13 then the lighter metal would be the most advantageous from an initial cost standpoint.

Bituminous Road Mesh

The bituminous road mesh was delivered to the job in sheets measuring 11 feet -6 inches in width and 8 feet in length. The sheets (3- by 8-inch diamond) were laid along the median strip at various locations in the 600 foot test section and placed continuously on the pavement as needed. Due to widening of the pavement, as mentioned before, the wire mesh extended 4 feet over the cement treated base in the passing lane. Only 20 sheets of the large, 6- by 12-inch diamond mesh were placed.

The leading edge of the first sheet was

Figure 17. Paving over 3- by 8-inch mesh.

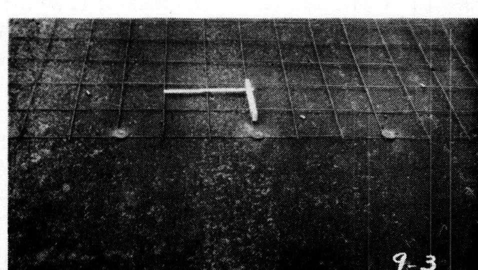

Figure 18. Fastening leading edge of first sheet.

securely fastened to the pavement by means of the stud driver, at about 1 foot intervals. All succeeding sheets were lapped one diamond, taking care that the sheets in place always overlapped the sheet being laid. The next operation was the fastening of the individual sheets to each other. This was done by two men, using medium sized hog rings and a hog ring clipper, (see Figure 6). About four to five rings were used at each lap, the wires being ties along the length of the diamond. The first diamond on each edge of the sheet was always fastened as well as two or three diamonds in between. The hog rings, when crimped into lock position, do not rigidly clamp the wires together and the rings could be freely moved in a longitudinal direction. Vertical movement, however, is restricted to a large extent. The 3-12-30 mesh laid very flat against the pavement and very little curl or raised areas were noted along the entire 600 foot section.

In order to pave over the large sheets it was necessary to provide sleds which forced the sheet to remain flat during movement of the paver. These sleds were fastened to the front of the paving machine and dragged over the sheets just in front of the auger feed. Figure 13 shows the sleds just before being attached to the paver. A total of five sleds were used, each 9 feet long. The sleds used on the outside of the Barber-Greene tracks consisted of regular 60 lb. railroad rails. The three sleds placed between the tracks were especially constructed from heavy bar stock to a total height of 2 inches in order to fit under the paving machine. See Figure 14 for details of sleds.

No particular difficulty was encountered with paving over the bituminous road mesh, except on a curve when due to the uneven traction of the paving machine a slight shifting of the mesh occurred and in one instance some of the wire for a distance of about 30 feet lifted suddenly out of the leveling course and had to be removed. After proper coordination of the truck driver and paving machine operator no further trouble was encountered. Occasional transverse cracks formed almost at once following the paver and in some cases after the first roller pass. Most of these cracks appeared at the laps of the sheets but were ironed out in the final rolling. However, the few that remained on opening the level course to traffic, had healed after overnight traffic. Some of the leveling course mixture was removed, after the rolling, in order to determine the location of the wire. The mesh in all cases was within ¼ inch of the concrete pavement.

Welded Wire Fabric

This material was delivered to the job in sheets measuring 11 feet- 6 inches wide and 8 feet long. Laying operations were the same as previously described for the bituminous road mesh. The fabric was laid so that for the 3- by 6-inch mesh the 3 inch spaced wires were transverse to the direction of travel and the longitudinal wires were uppermost. The 6- by 6-inch mesh was placed so that the longitudinal wires were also in the uppermost position. The first sheet was securely fastened to the pavement at about 1 foot intervals. Each sheet was overlapped 6 inches and tied on the longitudinal wires only with hog rings. These sheets, having a 1 inch projection of wire, seemed easier to lap than the bituminous road mesh and had less tendency to catch. Generally, the wire laid quite flat, although in some areas the sheets were raised from 3 to 4 inches due to warping of the wire above the pavement prior to paving operations. While laying this first section of welded wire fabric it was believed that the movement of the wire ahead of the paver would begin to accumulate enough forward longitudinal movement to cause buckling of the sheets. Therefore, as an experiment, it was decided to secure the leading edge of a sheet about every 150 feet. The overlapping sheet at this point was left free. The idea here was to take up all longitudinal forward movement of the previously laid sheets at this free joint. Close observations during paving operations did not disclose any marked movement of the sheets and any such small movement as occurred was taken up at the individual laps. We, therefore, concluded that this precaution would not be necessary in any future operations.

There were no difficulties in laying the mix over the section and the sleds appeared to iron down the mesh in an excellent manner. Cracking of the mix was very similar to that encountered with the bituminous road mesh. There were occasional transverse cracks, mainly at the laps, which appeared immediately after the mix was laid. Most

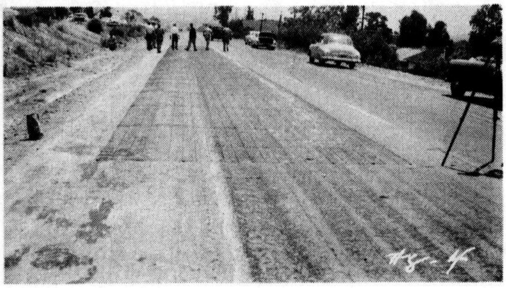

Figure 19. Laying 3- by 6-inch wire fabric. Left edge covers 4 feet of cement treated base.

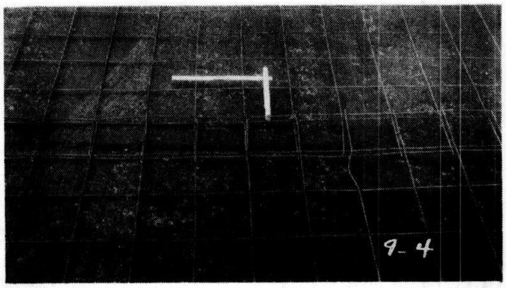

Figure 20. Lap of sheets. Longitudinal wires tied with hog rings every fifth to seventh square.

of these tended to iron out after the final roller pass and the remaining ones had healed after overnight traffic. Removal of the mix in numerous locations along the two 600 foot sections indicated that the fabric was about ½ to ¾ inches above the concrete pavement. The surface course was placed without any difficulties and no cracks of any kind were noticed.

Crack Survey

Three detailed surveys have been made of the job since its completion in June 1954. The first, in January 1955, revealed a few fine short transverse cracks in the nonreinforced control sections and none in any of the wire mesh sections. The second survey in May 1955, after eleven months of traffic, did not show any material change and no crack over 6 feet long. The latest survey, made in December 1955 revealed slightly more transverse cracking in the control sections, two cracks extending over the entire width of 20 feet of the old pavement. No transverse cracks of any kind were visible in the wire mesh sections. Therefore, as of this date no conclusions can be drawn except that so far there is no difference in the relative abilities of the various types of wire mesh to prevent or retard reflection cracking.

At this later survey, however, considerable longitudinal edge cracking was noticed in both the travel lane and passing lane. This cracking extended along the joint between the old concrete pavement and the newly laid widening strip of cement treated base. As none of the longitudinal edge along the travel lane was covered with wire mesh this cracking is irrelevant as far as the wire mesh is concerned. However, in the passing lane which is underlain only with an 8 foot width of old P. C. C. due to a shifting of centerline, the 8 feet long expanded metal sheets placed over the joints were laid to the edge of the old pavement only. The bituminous wire mesh and welded wire fabric, however, extended the full width of the new pavement and covered 4 feet of the new cement treated base. It was noted that no longitudinal cracking occurred over the joining edge which was covered with the bituminous road mesh or welded wire fabric. The total length of the project is 8, 320 feet. Of this distance, 6, 540 feet or 78. 6 percent consisted of the nonreinforced edge and 1, 780 feet or 21. 4 percent is covered with metal. Approximately 1, 200 feet comprising 18. 3 percent of the nonreinforced edge section has developed longitudinal cracking. It appears that up to this time the bituminous road mesh and welded wire fabric has definitely prevented longitudinal cracking.

Cost Analysis

It is difficult to present an accurate cost analysis where a number of relatively short test sections are involved. The installation of the various types of wire mesh was not part of the original contract and was performed under "extra work" and, therefore, no bid prices are available. However, an attempt has been made to present a cost comparison based on our observations during construction and cost figures supplied by the resident engineer. Labor costs, transportation and unloading costs and the price paid for construction and installation and of the sleds all tend to reflect somewhat higher prices due to the short test sections. The final analysis is based on the cost of mesh per square yard of pavement. This method was selected as the only way that a true cost comparison could be made between the small diamond sheets which covered the individual joints and cracks only, and the wire mesh which covered the entire pavement.

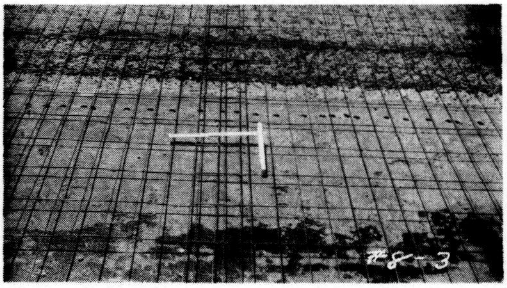

Figure 21. Lap in 3- by 6-inch mesh.

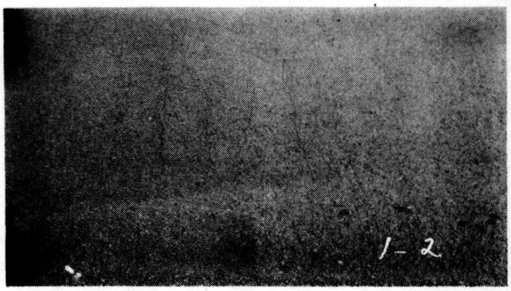

Figure 22. Typical transverse cracking of leveling course following first roller pass. Cracks were closed by traffic within 24 hours.

Three tables showing analyses for different conditions are presented. Table 1 shows the actual cost of the metal reinforcing on this job calculated on the basis of square yards of pavement covered. The 6- by 6-inch welded wire fabric appears the least expensive with the large diamond bituminous road mesh only slightly higher in cost. As the handling and installation of these two types of metals are similar, the final cost depends primarily upon the original price of the metal. The cost of the expanded metal per square yard of pavement is noticeably higher and is greatly influenced by the number of random cracks and the cost of fastening.

A direct cost comparison between the small diamond expanded metal sheets and the mesh which covers the entire pavement is difficult to make. On a pavement exhibiting little random cracking and where only the expansion and contraction joints would be covered, the cost of the expanded metal would be greatly reduced. A relative comparison may be obtained by assuming various conditions of the concrete pavement as shown in Table 2. In Case I the joints only are to be covered whereas Case II assumes the coverage of at least one random crack per 15 foot slab. The cost figures are based on the actual installation costs as shown in Table 1. The first assumed condition indicates that the 2 foot wide expanded metal sheets are less expensive than mesh which covers the entire slab. In the second assumed condition where one additional crack per slab is to be covered, the cost of the expanded metal is exactly doubled and exceeds the cost of the bituminous road mesh and welded wire fabric. The cost of the 4 foot wide sheets, of course, is considerably higher. As badly cracked concrete pavements very often have more than one random crack per slab it would appear from this analysis that the cost of covering these cracks with expanded metal sheets of either 2 foot or 4 foot widths would be prohibitive. On the other hand, the cost of the other two types of wire mesh which cover the entire pavement remains the same regardless of the number of random cracks.

In Table 3 a cost comparison, for the same specific conditions of the pavement as shown in Table 2, has been calculated in terms of cost per mile for a 24 foot width of pavement. For further comparison the cost of adding an increasing thickness of plant mixed surfacing is included at the bottom of the table. The cost of P. M. S. is based on average bid prices current in California. Roughly, the cost of either the large diamond bituminous road mesh or the 6- by 6-inch welded wire fabric is equal to the cost of 1½ inch thickness of plant mixed surfacing.

As stated, the cost comparisons presented are approximate only. There is little doubt that large scale installations of any of the wire mesh types described, together with experience gained by contractors, should show an appreciable reduction in cost.

TABLE 1

COST ANALYSIS FOR WIRE INSTALLATIONS ON CONTRACT 55-10TC2, X-Sol-7-G

Type of Metal		Expanded Metal		Expanded Metal		Expanded Metal		Expanded Metal		Bituminous Road Mesh		Welded Wire Fabric	
Size		1/2"x#20	1/2"x#20	3/4"x#16	3/4"x#16	3/4"x#13	3/4"x#13	1-1/2"x#16	1-1/2"x#16	3-12-30	6-36-20*	3"x6"	6"x6"
Width or Width and Length		2'	4'	2'	4'	2'	4'	2'	4'	11'-6"x8'	11'-6"x8'	11'-6"x8'	11'-5"x8'
Materials Costs													
Metal Sheets	$	128	256	143	286	203	406	115	230	860	489	665	478
Delivery and Unloading	$	26	26	26	26	26	26	26	26	52	52	52	52
Studs	$	46	46	46	46	46	46	46	46	3	3	3	3
Cartridges	$	24	24	24	24	24	24	24	24	2	2	2	2
Discs	$	6	6	6	6	6	6	6	6	(Included in cost of cartridges)			
Tie Supplies (Hog rings)	$	-	-	-	-	-	-	-	-	3	3	3	3
Sled Installation on Paver	$	-	-	-	-	-	-	-	-	40	40	40	40
Total Material Costs	$	230	358	345	388	305	508	217	332	960	589	765	578
Labor Costs		24	24	24	24	24	24	24	24	79	79	79	79
Grand Total	$	254	382	269	412	329	532	241	356	1039	668	844	657
Total Sq Yds of Pvt in Section		444	444	444	444	444	444	444	444	1701	1701	1701	1701
Cost/Sq Yd of Pvt Surface	$	0 57	0.86	0.61	0 93	0 74	1.20	0.54	0.80	0 61	0 39	0.49	0 38

*Only 20 sheets of 6-36-20 Bituminous Road Mesh were laid. The noted cost figures are theoretical values for laying an area equivalent to the 3-12-30 Bituminous Road Mesh and welded wire fabric sections

TABLE 2

COST OF VARIOUS TYPES OF WIRE REINFORCING BASED ON ONE SQUARE YARD OF PAVEMENT SURFACE COVERAGE

			Case I Joints only				Case II Joints plus one Transverse Crack Per Slab			
			Cost prorated per 180 sq.ft. of pavement Assumed that concrete is 12' wide with 15' joint spacing				Cost prorated per 180 sq.ft. of pavement Assumed that concrete is 12' wide with 15' joints and 1 transverse crack per slab			
Type	Designation	Width of Expanded Metal	Metal Cost	Installation Cost (4 Studs per 12' Sheet)	Cost Per Slab 15' long x 12' wide	Cost of Mesh per sq.yd. of Pavement	Metal Cost	Installation Cost (4 Studs Per 12' Sheet)	Cost Per Slab 15' long x 12' wide	Cost of Mesh per sq.yd. of Pavement
Expanded Metal	1/2"x#20	2'	$ 3.66	$ 1.52	$ 5.18	$ 0.26	$ 7.32	$ 3.04	$ 10.36	$ 0.52
		4'	7.32	1.52	8.84	0.44	14.64	3.04	17.68	0.88
Expanded Metal	3/4"x#16	2'	4.09	1.52	5.61	0.28	8.18	3.04	11.22	0.56
		4'	8.18	1.52	9.70	0.49	16.36	3.04	19.40	0.98
Expanded Metal	3/4"x#13	2'	5.79	1.52	7.31	0.36	11.58	3.04	14.62	0.72
		4'	11.58	1.52	13.10	0.65	23.16	3.04	26.20	1.30
Expanded Metal	1-1/2"x#16	2'	3.29	1.52	4.81	0.24	6.58	3.04	9.62	0.48
		4'	6.58	1.52	8.10	0.40	13.16	3.04	16.20	0.80
Bituminous Road Mesh	3-12-30 (3"x8" diamonds)		10.23	1.97	12.20	0.61	10.23	1.97	12.20	0.61
Bituminous Road Mesh	6-36-20 (6"x12" diamonds)		5.77	1.97	7.74	0.39	5.77	1.97	7.74	0.39
Welded Wire Fabric	3x6-10/10		7.91	1.97	9.88	0.49	7.91	1.97	9.88	0.49
Welded Wire Fabric	6x6-10/10		5.69	1.97	7.66	0.38	5.69	1.97	7.66	0.38

VI-KER-138-A, B

This installation involved the use of welded wire fabric, and was placed in May 1954 under Contract 55-6VC1. The job consisted of resurfacing 13 miles of old concrete pavement with 3 inches of plant mixed surfacing using 85-100 penetration grade paving asphalt. The old concrete pavement was very badly broken and had been extensively patched. Figure 25 shows a typical view of the old pavement.

Figure 23. Position of fabric after completion of leveling course.

The test sections involving the wire mesh consisted of a number of short sections varying in length from 100 feet to 500 feet and with varying width of wire fabric as shown in Figure 24.

The wire fabric used was 6- by 6-inch x $^{10}/_{10}$ gauge wire which was delivered to the job in 200 foot rolls 6 feet wide. Three different methods were used in placing the wire directly on the concrete prior to laying the leveling course, which was laid by means of spreader box and blade.

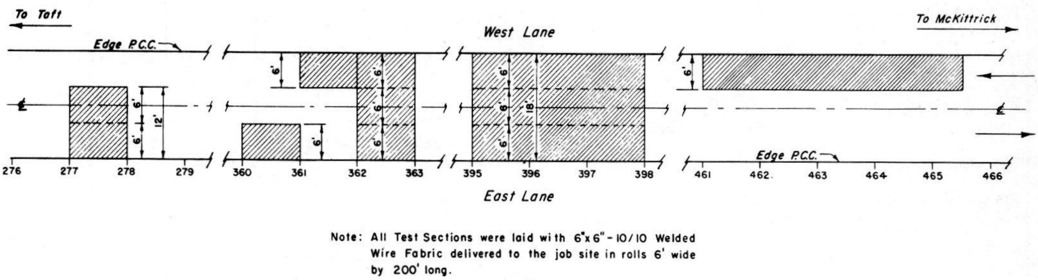

Figure 24. Wire mesh test sections. VI - Kern - 138 - A,B.

1. An entire roll was laid on the pavement and unrolled with the longitudinal wires uppermost. The leading edge was then tacked down with 1½ inch wire staples driven into the cracks. This method of fastening was not very successful. Only about ½ inch of penetration could be secured and many of the staples bent over. They also were easily forced out by movement of trucks over the wire.
2. A roll was cut into 16 foot lengths which were then overlapped one square and interlocked by bending over the cut ends of the mesh. A portion of this section was also stapled while the remainder was not fastened.
3. The roll was unrolled on the pavement and the leading edge was stapled to the pavement or fastened to the previously laid wire. The other end of the roll was placed between two 2- by 6-inch planks which were fastened together. A chain was attached to the planks and tied to a truck, which applied tension to the sheet during paving operations.

No material change was made in the spreader box, except to round the leading corners of the bottom plates. The trucks were backed over the wire mesh and hooked to the spreader box. All truck movements were at very slow speed especially during any turning movements on and off the mesh. After the windrow was laid a winged blade of 10 foot width was used to spread the mix. Two passes of the blade completed the spreading operations of the leveling course. The surface course was spread in the conventional manner with a Barber-Greene Paving Machine.

Of the three methods tried it appeared that the one involving the use of a tension device was the most satisfactory. This method also has been reported as giving good results on a recent large scale installation in Texas, involving the use of 300 foot rolls of 6- by 6-inch -$^{10}/_{10}$ welded wire mesh.

A survey made in December 1955 after 1½ years of traffic did not disclose any evidence of transverse cracking in the test sections nor adjacent control sections. However,

TABLE 3

COST PER MILE OF VARIOUS TYPES OF WIRE MESH FOR SPECIFIC CONDITION OF EXISTING CONCRETE PAVEMENT

Type	Designation	Width of Expanded Metal	Original Concrete Condition (12' Lane with 15' Joint Spacing)	
			Jts. Only No Cracks Cost/Mile for 24' Pvt. Width.	Jts. + 1 Transverse Crack Per Slab. Cost/Mile for 24' Pvt. Width
Expanded Metal	1/2" x #20	2'	$ 3,660	$ 7,320
		4'	6,196	12,392
Expanded Metal	3/4" x #16	2'	3,942	7,884
		4'	6,900	13,800
Expanded Metal	3/4" x #13	2'	5,068	10,136
		4'	9,152	18,304
Expanded Metal	1-1/2" x #16	2'	3,380	6,760
		4'	5,632	11,264
Bituminous Road Mesh	3-12-30 (3"x8" Diamonds)	-	8,588	8,588
Bituminous Road Mesh	6-36-20 (6"x12" Diamonds)	-	5,492	5,492
Welded Wire Fabric	3"x6"-10/10	-	6,900	6,900
Welded Wire Fabric	6"x6"-10/10	-	5,350	5,350

Cost/Mile of 1" of added thickness of P.M.S. for 24' Pavement = $ 3,878

Cost/Mile of 1½" of added thickness of P.M.S. for 24' Pavement = 5,817

Cost/Mile of 2" of added thickness of P.M.S. for 24' Pavement = 7,756

(Based on average cost price of $5.10 per ton in place)

there were signs of longitudinal cracking in some of the control sections, but none in the wire sections.

V-SB-2-D, C

This test section was laid in March 1955, on Contract 54-5VC12. On a portion of this contract a short section of the old existing P. C. C. pavement was covered with 8 inches of cement treated base and 4 inches of plant mixed surfacing. The adjacent pavement on either end was left in its existing condition, thereby requiring the construction of two tapered transitions involving a varying thickness of plant mixed surfac-

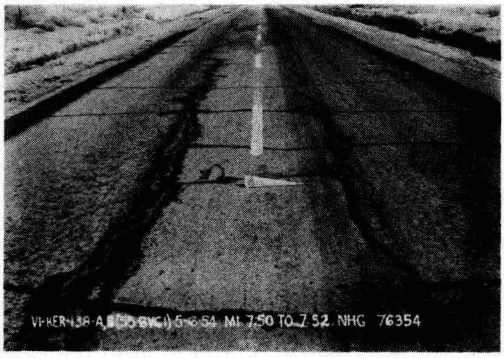

Figure 25. General view of pavement prior to blanketing.

Figure 27. Spreading leveling course.

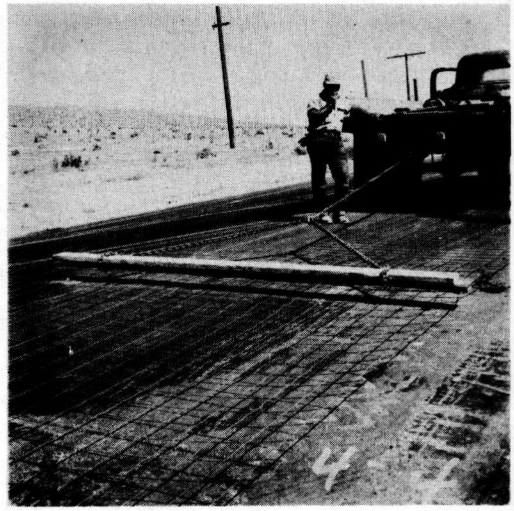

Figure 26. Method of applying tension to wire.

ing as shown in Figure 28.

A number of sheets of 6- by 6-inch - 10/10 gauge welded wire fabric were placed in both lanes of one of the transitions while the other was allowed to remain as a control. This trial section, although small, should provide some information on the relation between reflection cracking and thickness of plant mixed surfacing over the wire fabric. An attempt was made to secure the minimum thickness of plant mixed surfacing at one end of the tapered section by laying the wire up to the "feathering" point for the leveling course. This resulted in a minimum

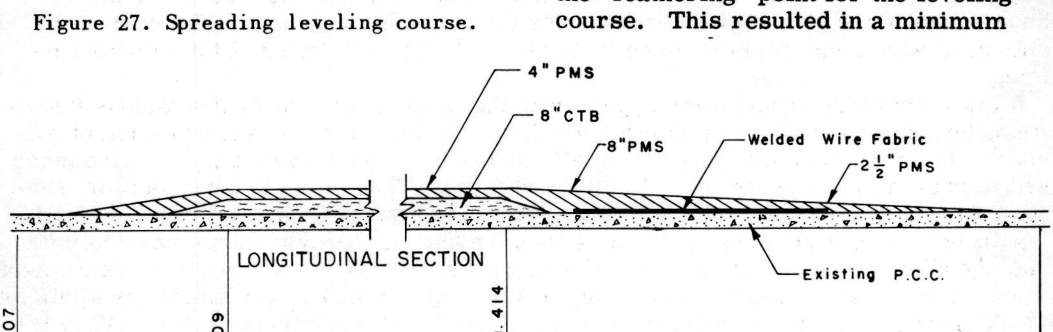

Figure 28. Welded wire fabric test section V - SB - 2 - D,C.

thickness of 2½ inches of surface course over the wire mesh.

The sheets were laid directly on the existing P. C. C. pavement and lapped one square and then tied with hog rings every fifth or sixth square. The leading edge of the first sheet was secured to the existing P. C. C. pavement by means of a stud driver in order to prevent the spreader box from catching. A light asphalt emulsion tack coat was placed after the wire was laid. However, the amount used was not sufficient to coat the wire and little protection from rusting may be expected.

The leveling course was laid with a spreader box and a blade. No difficulties were encountered, however, the equipment including trucks should be carefully handled while on the fabric. The surface course was laid in the conventional way with a Barber-Greene Paving Machine.

A survey was made in December 1955 after nine months of service. The tapered control section, containing no wire mesh, showed transverse cracking at the thin end over the first two joints. The other tapered section, containing the wire mesh, exhibited transverse cracking at all joints from the beginning of the taper to the start of the wire mesh where the pavement was about 2½ inches thick. No cracking was noticed in the wire section.

SUMMARY AND CONCLUSIONS

The three types of wire mesh used and described in this report can be laid and paved over by conventional construction equipment without undue difficulty. The expanded metal placed over joints and cracks only, required no modification of equipment. The bituminous road mesh and welded wire fabric required some type of hold-down device in order to press the wire flat against the old pavement and prevent the tracks of the paving machine from catching in the mesh. On pavements that are badly cracked or extensively patched it would appear that the use of wire mesh which covers the entire pavement would be more feasible and economical than the use of individual sheets placed locally over the joints and cracks only. Care should be taken in transporting and handling these sheets. The flatter the sheets, the less difficulty will be encountered with springiness and resulting cracking of the mix after placing. Any twisted or kinked sheets should be discarded. When paving on curves the paving machine operator should carefully control the traction of the paver so as to avoid shifting of the wire mesh.

The cost analysis indicates that the welded wire fabric is the least expensive of the various types of metal used. The large diamond bituminous road mesh can be considered competitive with the welded wire fabric and the 2 foot wide sheets of the expanded metal when placed over expansion or contraction joints only. The cost of the continuous wire reinforcement is equal to about 1½ inch thickness of bituminous surfacing.

A few transverse cracks have appeared in the control sections of the various installations but none in the wire reinforced sections. At this date there is insufficient evidence to form an opinion regarding the effectiveness of the various types of wire mesh used in preventing or retarding reflection cracking. There is, however, definite evidence that the wire reinforcement has prevented the formation of longitudinal cracks.

Although these experimental sections should eventually provide some very definite data regarding the beneficial effects, if any, of the various types of wire reinforcement to prevent or retard reflection cracking, it would appear that in any future installations thought should be given to incorporating one or two other variations such as: Vary the thickness of surfacing from perhaps 2 to 4 inches in the reinforced sections and in certain control sections increase the thickness of the bituminous mix so that the price per square yard of the nonreinforced portion is equivalent to that of the wire reinforced section. There is evidence that an increase in thickness of bituminous surfacing may not entirely prevent reflection cracking but the magnitude or severity of such cracking may be greatly delayed and reduced. This is demonstrated to some extent by the pavement represented by Figure 1 where a 1 inch blanket began to show reflection cracking after 30 days when compared to the District X job where the 4 inches of bituminous surfacing in the control sections has shown practically no reflection cracking so far. Traffic is similar in both cases. Another variation might be to place, prior to resuring, a cushion course of granular material varying perhaps in thickness from 4 inches to 6 inches over the old pavement and compare the cost and effectiveness with the wire reinforced sections. One other alternative might be to add rubber in various proportions to the bituminous mixture as a possible method of reducing reflection cracking.

ACKNOWLEDGMENTS

The work described herein was performed under the general direction of F. N. Hveem, Materials and Research Engineer, California Division of Highways. Excellent cooperation was extended by the Resident Engineers of the three test sections, L. E. Daniel of District X, N. H. Green, District VI, and C. L. Bunce of District V.

The writer wishes to especially acknowledge the efforts of John Skog who took care of most of the detailed work and assisted the resident engineers during the placing of the various wire test sections.

Discussion

EDWARD M. HOWARD, Field Engineer, Wire Reinforcement Institute—The presentation made by Mr. Zube of the California Highway Department at the recent Highway Research Board meeting was most interesting. His report of their experiences and results are quite similar to those which we have met with in corresponding construction in the central and eastern part of the United States with one exception. That exception is equivalent cost when comparing the cost of wire fabric with additional thickness of asphaltic concrete overlay.

Mr. Zube was quite explicit in stating that their costs were on a strictly research project and that for any comparison that point should be borne in mind. His statement was that the cost of mesh was equivalent to about an inch and one-half of additional thickness of overlay.

As was pointed out by J. W. Horn of Massachusetts Institute of Technology during the question period, the cost encountered on construction in the eastern part of the United States was equivalent to about three-quarters of an inch of asphaltic concrete overlay. Just half of the cost referred to by Mr. Zube.

This difference is accounted for by the fact that Mr. Zube's construction was strictly a carefully controlled research project, whereas the other comparison was to actual construction on a commercial scale.

My comment is offered to clear up any misunderstanding that might exist as to comparative costs, as there was no record made of the questions from the floor during the question period, nor of the answers given.

ERNEST ZUBE, Closure— Mr. Howard stated that during the discussion period J. W. Horn of the Massachusetts Institute of Technology pointed out that in the eastern part of the United States the cost of the welded wire fabric is equal to about ¾ inch of asphaltic concrete overlay against our cost of about 1½ inch of surfacing. Howard believes that such differences may be assigned to the experimental nature of our project.

Although the cost of our project may be a trifle high due to its experimental nature, I believe the main difference in the cost comparisons between eastern and western states lies in the price of the asphaltic concrete itself. The wire mesh is undoubtedly less expensive in the East than in the West. However, the price per ton of asphaltic concrete in the East is considerably higher than in the West.

As an example, using prices found in the paper entitled, "Welded Wire Fabric Reinforcement in Bituminous Resurfacing," by N. C. Smith of the District of Columbia, we noted an average bid price of $8.52 per ton of surfacing in place as against the California price of $5.10 per ton.

Using the California prices from Table 3 of $3,878 per mile per inch of surfacing and the cost of the 6- by 6-inch wire as $5,350 per mile we obtain

$$\frac{\$5,350}{\$3,878} = 1.4 \text{ inch thickness of surfacing equivalent to cost of 6-by-6 inch wire.}$$

Now, assuming that the cost of bituminous surfacing in the West was equivalent to that quoted by Smith, we arrive at

$$\frac{\$8.52}{\$5.10} \times 3,878 = \$6,500$$ cost per mile for 1 inch thickness of surfacing

and using our cost of installation for the 6- by 6- inch wire fabric we arrive at

$$\frac{\$5,350}{\$6,500} = 0.8$$ inch thickness of surfacing or about the same equivalent thickness as quoted by Horn.

Therefore, it would appear that the difference in equivalent thickness is primarily due to the cost per ton of the bituminous surfacing in the eastern and western parts of the United States.