SUMMARY REPORT

EFFORTS TO REDUCE REFLECTIVE CRACKING OF BITUMINOUS CONCRETE OVERLAYS OF PORTLAND CEMENT CONCRETE PAVEMENTS

by

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SUMMARY

Studies of efforts in Virginia to reduce the incidence of reflection cracking when portland cement concrete pavements or bases are overlayed with asphaltic concrete are reported. The methods of reflection crack reduction discussed are: (1) The use of sand as a bond breaker between portland cement concrete pavements and asphaltic overlays, (2) the use of a high tensile strength fabric as a stress relieving layer between two asphaltic concrete overlays of an old portland cement concrete pavement on a weak subbase, and (3) the use of two types of fabric as stress relieving layers between asphaltic layers and a concrete base on a very strong subbase and subgrade.

The following conclusions were drawn.

1. Neither sand as a bond breaker nor high strength fabrics as stress relieving layers are effective in reducing reflection cracking where vertical joint movement (differential deflection) is a significant factor.
2. When differential deflections are greater than about 0.002 in. (0.05 mm) reflection cracks form early. Such cracking is delayed for lower differential deflection but may occur as the magnitude and frequency of wheel loadings increase.
3. Both an asphalt impregnated polypropylene fabric and an unwoven, spun-bonded nylon fabric, when placed to span joints in portland cement concrete base and covered with an asphaltic concrete overlay, are able to sustain the formation of reflection cracking in the overlaying layer without undergoing damage.
4. An asphalt impregnated polypropylene fabric spanning the joints in portland cement concrete pavements, and placed between the pavement and an asphaltic overlay, may be effective in reducing the infiltration of surface water to pavement sub-layers. There is some evidence that pavement pumping may be reduced by this method.
5. Both an asphalt impregnated polypropylene fabric and an unwoven, spun-bonded nylon fabric can delay the formation of reflection cracking. There is strong evidence, however, that such cracking is fatigue in nature and will eventually develop under the application of repetitive wheel loadings.

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INTRODUCTION

Transverse joints in rigid pavements commonly reflect through bituminous concrete overlays in a short period of time. Many highway engineers believe that these cracks are detrimental to pavement riding quality, while others believe that they are generators of future maintenance problems because they provide ready access of surface water to subsurface pavement layers.(1) Recent studies provide some basis for the latter belief in that a crack only 0.035 in. (0.9 mm) wide is reported to admit 70% of the surface water falling on a pavement sloped 1.25% under a 2 in. (50 mm) per hour precipitation rate.(2)

Numerous efforts to reduce reflection cracking have been reported in the literature. A discussion of the many methods tried would be voluminous, but a good summary of those which have been at least partially successful is given in NCHRP Synthesis No. 9 on Pavement Rehabilitation.(3) In that document most methods attempted are grouped into 4 general classifications: (1) Increased thickness of asphaltic concrete overlay, (2) special treatment of existing portland cement concrete pavement, (3) special condition in asphaltic concrete overlay design, and (4) treatment of joints and cracks.

In Virginia, most of the methods in categories 1 through 3 have been rejected for economic or other reasons. The category 4 methods employed in Virginia all consist of some means of breaking the bond or otherwise relieving the stress between the PCC and the bituminous concrete overlay. The first efforts to provide a bond breaker were reported by Hughes, who found that a thin layer of sand spread on either side of the PCC pavement joints before application of a bituminous concrete overlay was of only partial success in reducing reflection cracking.(4) In his studies, an asphalt emulsion tack coat was applied at the rate of 0.05 to 0.10 g/y^2 (0.23 to 0.46 l/m^2) for a distance of 9 to 12 in. (225 to 300 mm) on either side of transverse joints. Class A sand sieved to pass a 3/8 in. (9.5 mm) sieve was applied over the tack coat at a thickness of approximately 1/4 in. (6 mm). An asphaltic concrete overlay (85/100 penetration grade asphalt) of from 100 lb./y^2 (59 Kg/m^2) to 175 lb/y^2 (95 Kg/m^2) was applied over the pavement surface and the sanded joints. Joint spacings were 30 ft. (9 m). Of 3 projects treated in such a manner, only 1 showed any indication of fewer reflection cracks on joints treated with sand. No reason for a difference in performance between the 3 projects was determined although after 9 years some of the joints still had not reflected through the best performing project, which is located on Route 13 in Northampton County.

The next significant effort to reduce reflection cracking, also reported by Hughes, involved the use of an unwoven polypropylene fabric spanning the reflection cracks on a previously overlaid concrete pavement on Route 460 in Sussex County.(5) The polypropylene had high tensile strength and was purported to prevent horizontal overstressing of the overlay. Supposedly, at points of stress concentration such as transverse joints or cracks, the material would prevent reflection cracking. Again, the joint spacing was 30 ft. (9 m) and the fabric was applied with approximately 0.25gal/y^2 (1.1 l/m^2) of CAE2 tack coat. The fabric was applied in 3 ft. (0.9 m) wide strips approximately centered on the cracks and running lengthwise with the cracks. A total of 99 joints, all with discernible cracking in the previous overlay, were treated in this manner. An asphaltic concrete (85/100 penetration grade asphalt) overlay of 125 lb./y^2 (68 Kg/m^2) was applied after the fabric had been under traffic for some 12 hours.

The performance of the fabric treated section, like that of the sanded sections, was disappointing when it was noticed, after three months under traffic, that many of the joints had reflected through the second overlay. However, the cracking in an adjacent section where no fabric had been used was somewhat more frequent.

As a result of the above partially successful experiments, studies were undertaken in 1972 to determine through field testing the mechanism of reflection cracking on overlays of jointed portland cement concrete pavements. The present report summarizes these studies and concludes with several recommendations concerning the future handling of such cracking.

FIELD STUDIES

Route 460 Project

Horizontal Joint Movements

Prior to placing the second overlay on the Route 460 project both control and test sections were chosen for horizontal joint movement studies. It was hoped that by monitoring the horizontal hydrothermal movements of typical joints on both the section with fabric reinforcement and a control section without reinforcement it would be possible to determine the effect of such movement on the ability of the fabric to reduce reflection cracking. Five consecutive joints in both the control and the test sections were located prior to placement of the overlay on the control section and the fabric and overlay on the test section. After the overlay was in place in both sections, gage points were embedded in the overlay such that a nominal 10-in. (250 mm) gage length would span the area subject to reflection cracking. These gage points were established at each of the 10 previously selected joints. Initial readings of the exact measurements between gage points were taken on August 25, 1971, the day after the overlay was placed. At the same time, readings were taken on reference (calibration) points embedded in the asphaltic concrete where no cracking was expected to occur. Thus, measurements spanning reflection cracks could be corrected for the length change occurring in a 10-in. (250 mm) segment of uncracked pavement. A realistic measure of crack movement was anticipated through this adjustment.

Readings of both the test and calibration points were taken at monthly intervals for 30 months subsequent to the overlay. During the first 3 months of this period reflection cracks developed between the gage points at 3 locations in each section. At 1 location in each section a reflection crack developed outside the limits of the gage points. At the end of the 30-month period 1 joint in each section had not reflected through the overlay. The results of these studies are indicated graphically in Figure 1 where curves show the behavior of the reflection cracks and of the 10-in. (254 mm) long pavement segments where cracking was expected but did not occur. On the ordinate of this figure a positive number indicates joint opening while a negative number indicates joint closure. It is apparent that the fabric reinforced test section and the control section behaved similarly and there is no evidence from these tests that the stress relieving layer provided any advantage in preventing reflection cracking. Once the cracks formed, their behavior was somewhat as would be expected for the first year, the seasonal movements being clearly evident. The author offers no explanation for the strange behavior of the measurements after the first year. Obviously, the indication that

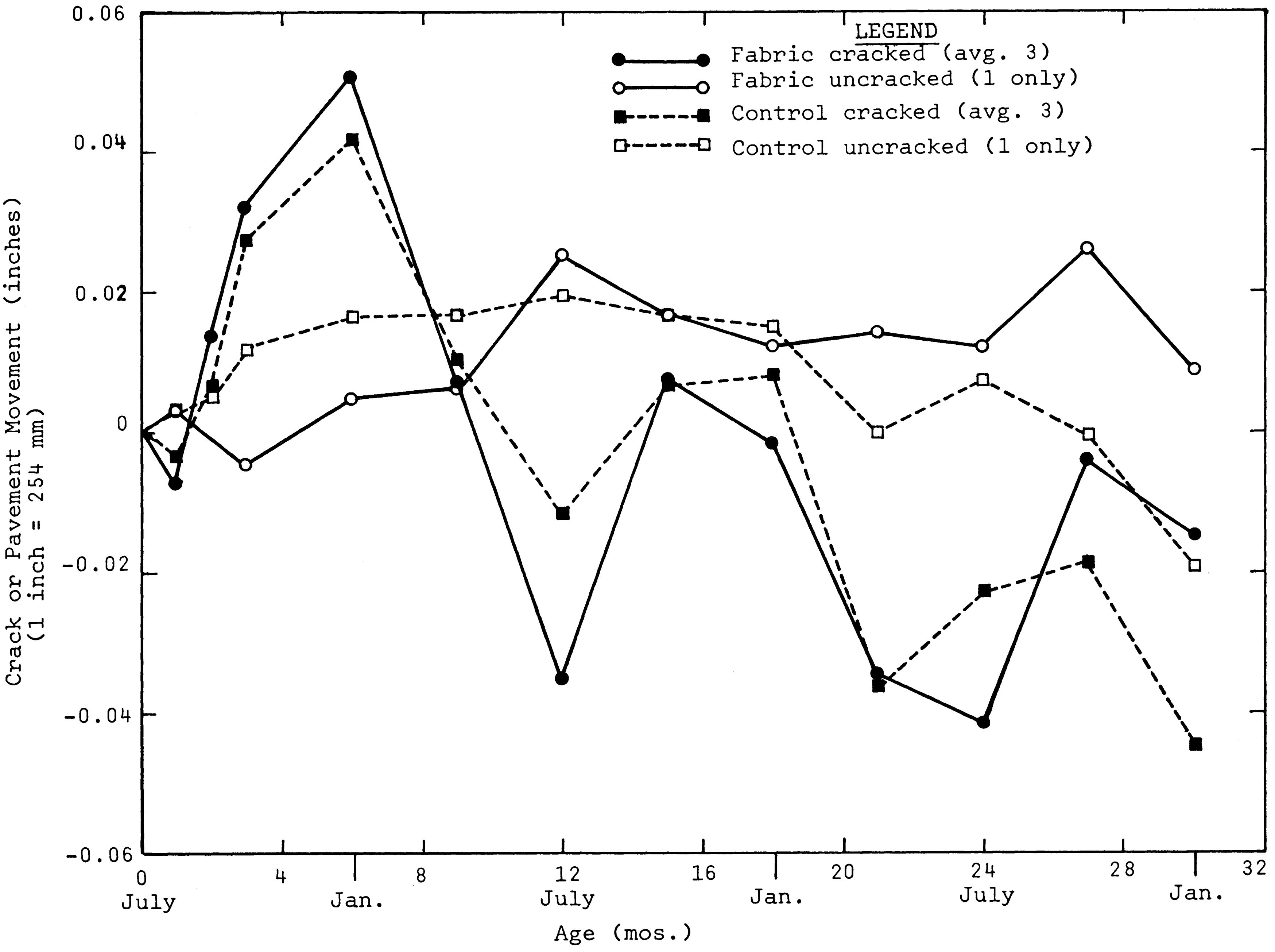

Figure 1. Crack movement with age.

the cracks (which were clearly visible) took on negative width values is ridiculous. It is evident that for unknown reasons the distances between gage points became something less than the nominal 10 in. (254 mm) originally established. This anomaly is believed to be related to a "humping" effect noted at many transverse reflection cracks in Virginia. In such cases, a gradual upheaval or accumulation of asphaltic concrete at the reflection cracks results in noticeable roughness.

Vertical Joint Movements

The realization that most reflection cracking in the Route 460 project had occurred during the first 3 months when measured horizontal movements had been minimal led to a consideration of other factors which might contribute to the cracking. Since the pavement under study showed significant evidence of joint faulting and pumping it was considered likely that vertical movement of the joints might be such a factor.

In April 1972 joint deflection tests were conducted on both the fabric reinforced and the control sections. The procedure for these tests is indicated in Figure 2. A Benkelman beam (A in Figure 2) was placed on the shoulder of the road with its point near the edge of a reflection cracked joint or of a joint which had not reflected through. A dump truck loaded to 18,000 lb. (8165 kg) on its rear axle was positioned on the opposite side of the joint. At this point (point 1, Figure 2) an initial beam reading was taken. The truck was then driven slowly across the joint while beam readings were taken as points 2 and 3 were traversed. The edge deflection for point 2 gives an indication of the deflection when the wheel load is directly at the joint. The comparison between readings for points 1 and 2 gives an indication of the load transfer efficiency while the reading for point 3 is used to ensure that the Benkelman beam, still located at point 2, is no longer within the area of influence of the wheel load.

The results of these tests are indicated in Table 1 where, in addition to the deflection data, the number and percentages of cracked and uncracked joints are given for the control and the fabric treated sections. The deflection data include that for the case when the wheel load is on the opposite side of the joint from the Benkelman beam (D_1),the case where wheel load is directly at the Benkelman beam (D_2) and the differential deflection ($d = D_2 - D_1$). Here d could be interpreted as a function of the load transfer capability of the joint; i.e., if the load transfer is 100%, $d = 0$.

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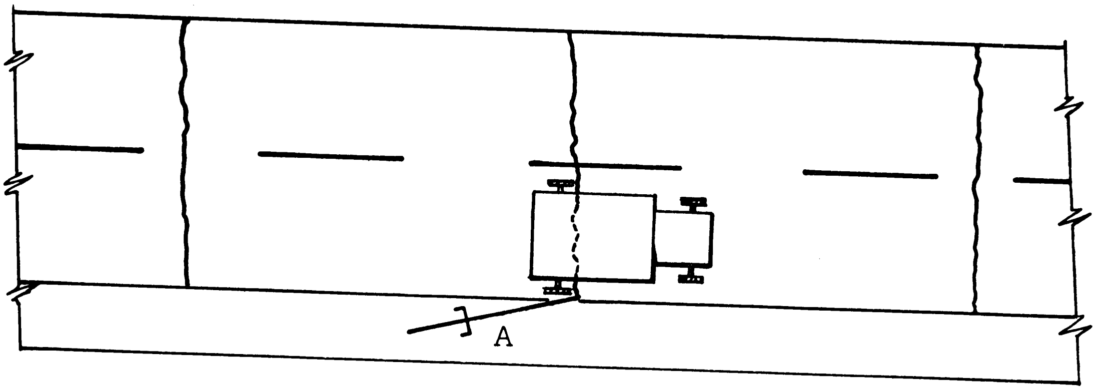
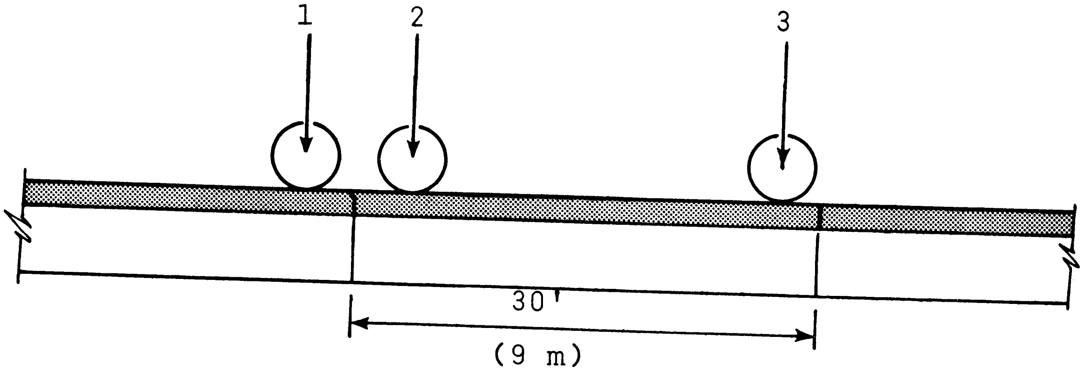


Typical location of Benkelman Beam (A).



Typical wheel locations during deflection tests.

Figure 2. Schematic showing deflection testing procedure.

Table 1

Cracking and Deflection Data
(April 1972)

Section	Cracked Joints		Average Deflections (in.)*		
	No.	%	D_2	D_1	$d = D_2 - D_1$
Fabric — cracked	57	58	0.014	0.009	0.005
— uncracked	42	42	0.009	0.008	0.001
Control — cracked	90	73	0.015	0.010	0.005
— uncracked	34	27	0.012	0.010	0.002

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*1 inch = 25.4 mm.

It should be pointed out here that when these tests were run the overlay was approximately 8 months old. Also, traffic records show that the test sections sustain an average of more than 600 vpd in the 2 axle-6 tire or larger truck and bus categories.

Note that Table 1 shows that there was somewhat of a reduction in reflection cracking on the fabric treated section as indicated by the cracking percentages of 58 and 73 for the fabric and control sections, respectively. A later survey (September 1974) showed 61% and 75% cracked in the same order. As can also be seen in Table 1 the net joint deflection (D_2) may have some influence on the cracking as the deflection for uncracked joints averages somewhat lower than for the cracked joints in both the fabric and the control sections. More descriptive, however, is the differential joint deflection (d) where it can be seen that uncracked joints have very low average values of 0.001 in. to 0.002 in. (25 μm to 50 μm) while the cracked joints average 0.005 in. (125 μm) in both sections.

An analysis of the distribution of d values is given in Table 2, where cracking frequency is given as a function of differential deflection in increments of 0.002 in. (50 μm) (the least reading of the Benkelman beam used). Note that when the differential deflection is zero (load transfer = 100%) the fabric had a marked effect on reflection cracking as seen by the fact that of 20 treated joints none were cracked, while for the control section

4 joints out of 9 were cracked. Similarly, but less dramatically, when d = 0.002 in. (50 μm) the joints having reflection cracks were 29% and 54% for the fabric and the control sections, respectively. Finally, when d was over 0.008 in. (200 μm) all joints had reflection cracking in both the control and the fabric reinforced sections.

Table 2

Cracking and Differential Deflection
(Route 460)

Differential Deflection d (in.)*	No. Joints Cracked		No. Joints Uncracked		% Joints Cracked	
	Fabric	Control	Fabric	Control	Fabric	Control
0	0	4	20	5	0	44
0.002	7	20	17	17	29	54
0.004	23	35	3	12	88	74
0.006	15	11	2	0	88	100
0.008	12	20	0	0	100	100

*1 inch = 25.4 mm.

Clearly, when joints have essentially 100% load transfer capability, the reason for the absence of reflection cracking could be that the joints simply are not functioning. In such a case no stress concentrations or cracking would be expected. This may well explain the absence of cracking at the 5 untreated joints (Table 2) where the differential deflection was zero. The 4 untreated joints where cracking did occur may be working joints where load transfer is fully effective. Thus, it is likely that many of the 20 uncracked treated joints where there was no differential deflection were working joints where the fabric served its intended purpose of reducing overlay stresses to the point where no cracking occurred. Conversely, it is likely that when joints had higher differential deflections the fabric, a thin sheet, had no ability to distribute sheer stresses and was unable to significantly reduce reflection cracking.

If the above hypothesis is accepted, it follows that much, if not most, of the reflection cracking on the treated joints was the result of sheer stress concentrations induced as wheel loads traversed the joints and caused differential deflections. Luther, et al. have since established that reflection cracking of asphaltic overlays is multimodel fatigue fracture.(6) Their paper, based on laboratory model studies, states in part:

> It was observed that these (reflection) cracks propagate, from the surface under mixed mode conditions arising from compressive bending stresses and high sheer stresses induced by differential vertical movement between the underlying rigid concrete layer.

If, as seems to be the case, reflection cracking is fatigue in nature and differential vertical movements are a major cause, it is reasonable to assume that the rate of crack development would be a function of the frequency of wheel loadings and of the magnitude of vertical movement, or differential deflection, caused by these loadings. This concept seems to have been substantiated on the Route 460 project, where with some 600 heavy loads per day a 3% increase in cracking was noted between April 1972 and September 1974. At the time of the later survey it was observed that the joints having very low differential deflection in 1972 still were uncracked in 1974.

Core Studies

During the September 1974 crack survey five 4-inch (100 mm) diameter cores were removed from the Route 460 pavement. Each core was at a reflection crack in the fabric treated section and was located so as to intercept the crack approximately as a core diameter. These 5 cores were returned to the laboratory for study. The findings of these studies are indicated in the photograph given in Figure 3, where it can be seen that the core through both asphaltic concrete layers is held together by the polypropylene fabric. The reflection crack is plainly visible both above and below the fabric. Efforts to separate the asphaltic concrete from the fabric showed that all were firmly bonded together so that some effort was required to remove either layer. When the asphaltic concrete had been removed it was found that the fabric showed no evidence of damage. A slight wrinkle in the fabric corresponded with the location of the reflection crack.

The observation that there was no tear or other evidence of elongation of the fabric was taken as further evidence that the reflection cracking had been caused primarily by vertical joint movements.

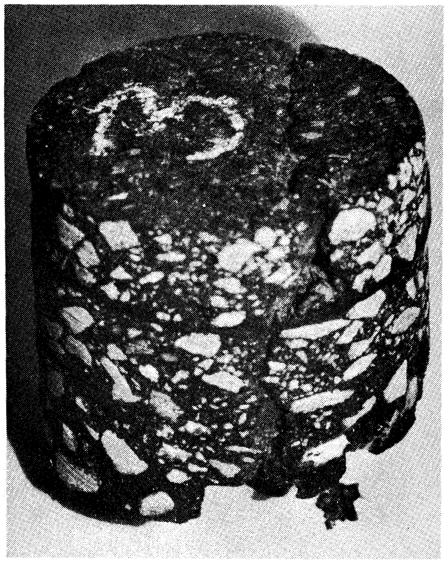

Figure 3. Core through new overlay (top), Petromat, and old overlay. Route 460 project.

Joint Pumping Studies

As a coincidence of the 1972 and 1974 reflection crack surveys it was noted that the polypropylene fabric spanning transverse joints may have been beneficial in reducing pumping. In both cases some 15% of the joints in the control section were determined, on the basis of the ejection of fines from the subbase or subgrade, to be pumping. No case of pumping was observed in the fabric treated section during either survey. It may be conjectured that the fabric, which was asphalt impregnated during its manufacture and was applied with a heavy tack coat of liquid asphalt, served as a barrier to surface water entering the joints such that pumping was eliminated. Since joint pumping had not been a consideration early in the study no data are available on the incidence of pumping before the fabric was applied. For this reason, no firm conclusions can be offered on this matter and further studies in another location are anticipated.

Route 13 Project

Vertical Joint Movements

The apparent relationships between vertical joint movements and the effectiveness of the stress relieving layer on the Route

460 project led to speculation that such movements might be of significance where sand had been used as a bond breaker between an asphaltic concrete overlay and a jointed portland cement concrete pavement. Since, as noted earlier, the sand had been partially successful on the Route 13 project, it was decided to conduct joint deflection tests at this site. These tests were conducted, in the manner described earlier, in June 1972 when the test section was 6 years old. At that time, of 60 control or untreated joints 100% exhibited reflection cracking while of 232 sanded joints 155, or 66%, had such cracking.

The results of these joint deflection tests are summarized in Table 3, where descriptions similar to those used for Table 2 are employed.

Table 3

Cracking and Differential Deflection
(Route 13)

Differential Deflection d(in.)*	Number of Joints Cracked		Number of Joints Uncracked		Percentage of Joints Cracked	
	Sanded	Control	Sanded	Control	Sanded	Control
0	4	1	13	0	24	100
0.002	58	15	43	0	57	100
0.004	66	28	19	0	77	100
0.006	27	14	2	0	93	100

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*1 inch = 25.4 mm.

Note that while the sand layer can be effective in reducing reflection cracking, the degree of this effectiveness is strongly influenced by the magnitude of the differential deflection. For example, the sand layer appears to have been 76% effective after 6 years where there is no differential deflection while during the same period of time it was only 7% effective where the differential deflection is as much as 0.006 in. (150μm).

A recent survey of cracking on this project showed that after 9 years 93.5% of the sanded joints exhibited reflection cracking. Thus, it appears that the fatigue nature of reflection cracking is again shown on this project, where traffic volumes include an average of 335 vpd in the 2-axle 6-tire or larger truck and bus categories.

Route 95 Project

As a result of the above reported studies indicating that stress relieving layers could be effective in delaying reflection cracking where differential vertical joint movements were minimized, the researchers, in July 1972, placed several test sections on a segment of Interstate 95 under construction in Northern Virginia. This project, called the "Mixing Bowl," is a part of the multi-lane Pentagon highway network and was constructed with a composite pavement overlying a very rigid foundation. The pavement design features are as follows:

Surface — 100 lb/yd^2 (54 kg/m^2) bituminous concrete, Type S-5

Binder — 250 lb./yd.^{2} (136 kg/m^2) bituminous concrete, Type B-3

Base — 8 in. (400 mm) plain portland cement concrete

Subbase — 8 in. (400 mm) cement stabilized subbase material

On this pavement it was expected that the extremely rigid base and subbase layers would reduce vertical joint motions to a minimum so that the provision of a stress relieving layer between the bituminous concrete layer and the portland cement concrete base would reduce the incidence of reflection cracking of the shrinkage cracks in the concrete base. Plans called for the installation of 2 fabric stress relieving materials, each on approximately 100 shrinkage cracks.

The details of installation have been reported earlier by McGhee and Hughes.(7) Some of the more important features are summarized below along with the results of 3 years of performance studies.

Materials and Application

The materials applied were:

(1) Petromat — an asphalt impregnated unwoven polypropylene fabric manufactured by the Philips Petroleum Company.

(2) Chemstrand (403) — an unwoven, spun-bonded nylon manufactured by the Monsanto Co.

Sometime before the application of bituminous concrete layers but after the concrete base was old enough to develop shrinkage cracks at approximately 30 ft. (9 m) intervals, the cracks were located for installation of the stress relieving materials. In all cases the cracks were located with respect to a permanent reference point on the roadway or median. Prior to placing the materials each crack was tacked for its full length (a 12 ft. (3.6 m) lane width) and for 18 in. (0.45 m) to either side with approximately 0.25 gal/yd.^{2} (1.1 $^1/m^2$) of CAE-2. After the tack had cured for from 1 to 3 hours, the fabric was broomed into place to assure good adhesion. It was noted that the Petromat appeared to absorb the tack better and to adhere more uniformly to the base course than did the Chemstrand.

Due to numerous problems outlined in the earlier report,(7) many of the fabric treated cracks were not suitable for evaluation by the time the bituminous concrete layers had been placed. Since the overlay, many of the treated cracks have been under traffic volumes of more than 40,000 vpd so that no evaluation has been possible. The result is that at present only 2 test sections and 1 control (no fabric) section are available for evaluation. These are summarized in Table 4 and shown schematically in Figures 4, 5, and 6.

Table 4

Fabric Reinforced Cracks Available for Study
(September 1975)

Site	Location	Number of Cracks			Date Overlayed
		Petromat	Chemstrand	Control	
3*	NBL-Rt. 27	22	—	—	9-18-72
4	SBL-I95	25	25	8	9-18-72
5	SBL-I95	—	—	29	10-31-72
	Total	47	25	37	

*Numbers refer to previous report on this study.(7)

Note that the three sections were overlayed in September and October 1972. Note also that Site No. 4 had both types of fabric and a few untreated control cracks.

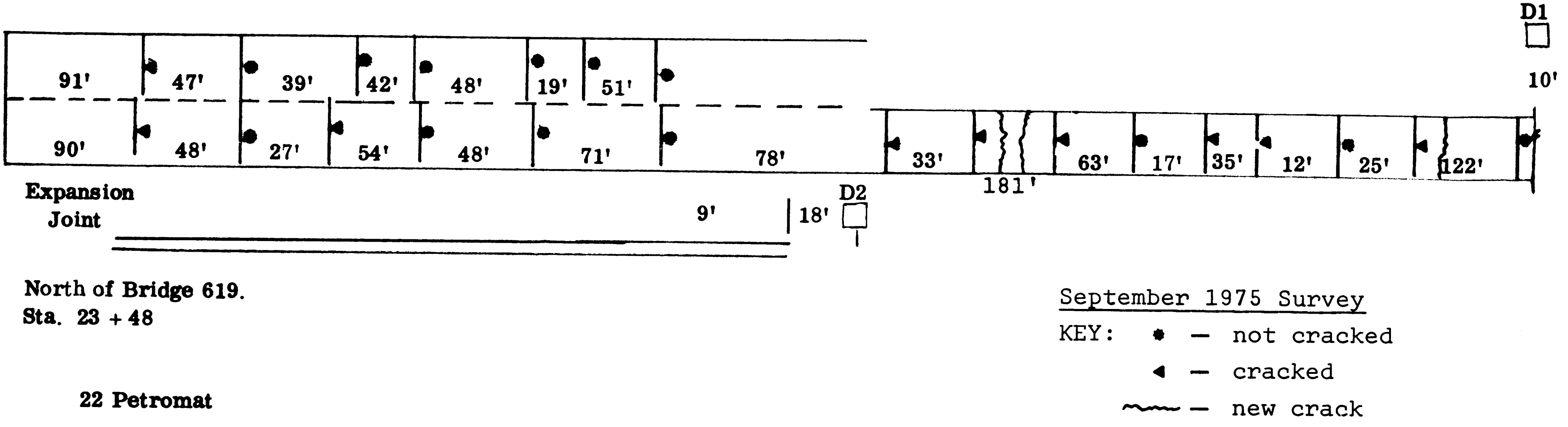
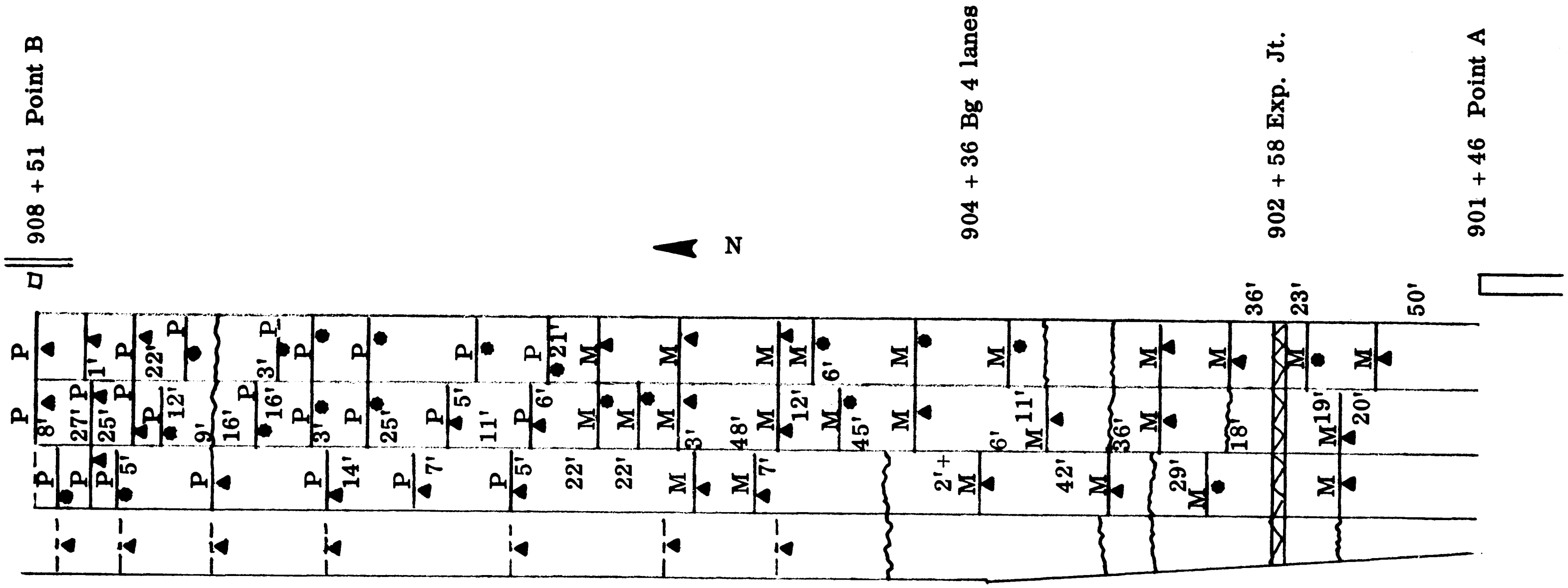


Figure 4. Site #3 — Roadway C northbound. (Not to scale.)



Point A is northeast corner of Bridge 616.

Point B is top of electrical junction box 20' north of beginning of retaining wall right of southbound lane.

M indicates crack covered with Monsanto Chemstrand. Total = 25.

P indicates crack covered with Petromat. Total = 25.

Dashed line indicates uncovered crack. Total = 8.

<u>September 1975 Survey</u>

KEY: ● — not cracked

◄ — cracked

~~~~ — new crack

Figure 5. Site #4 — Southbound I-95. (Not to scale.)
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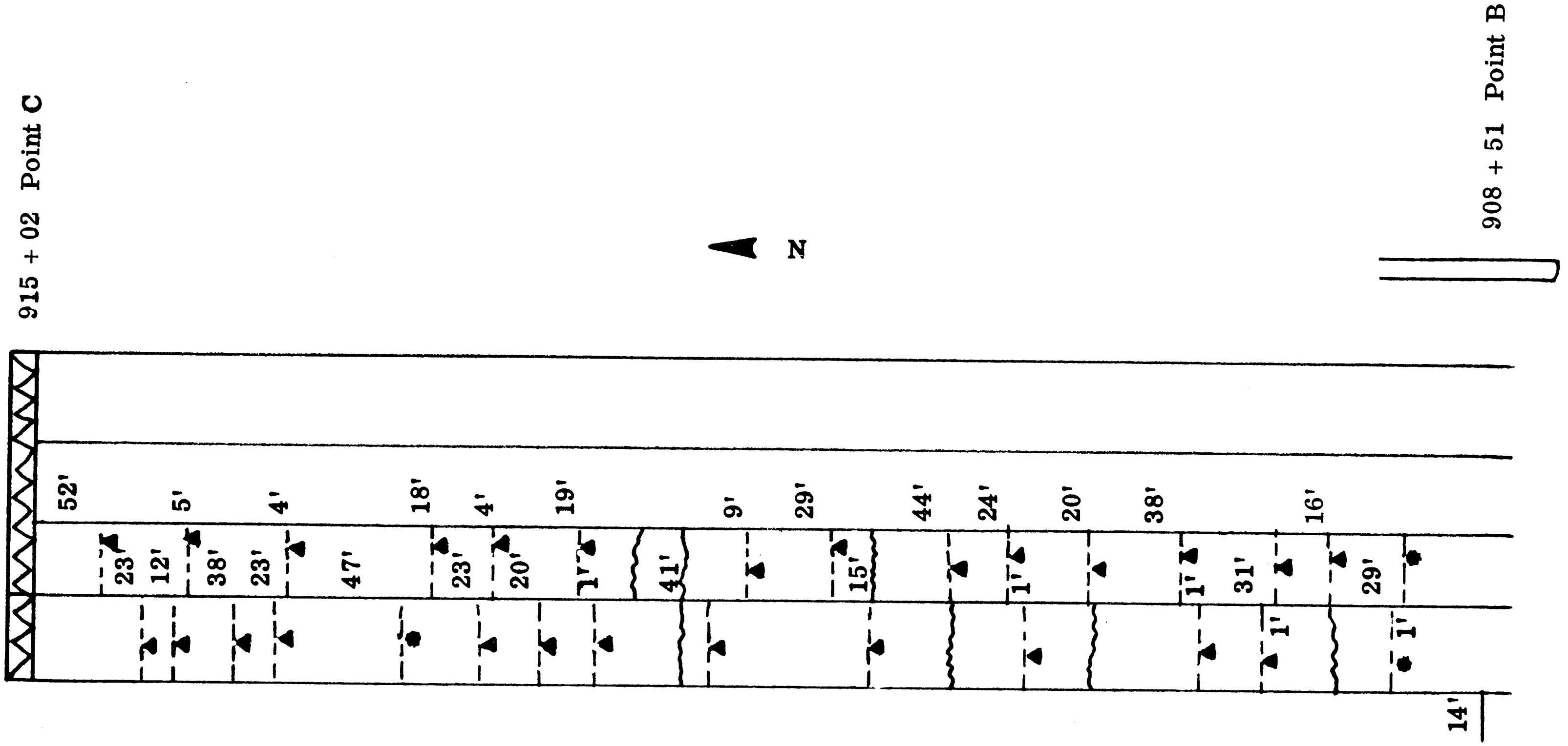

Point B is top of electrical junction box. **20' north of beginning of retaining wall right of southbound lane.**

Point C is expansion joint south of Bridge 621.

Dashed line indicates uncovered crack. Total cracks = 29

September 1975 Survey

KEY: ● — not cracked
◄ — cracked
〰 — new crack

Figure 6. Site #5 — Southbound I-95. (Not to scale.)

Results

Periodic studies of the 3 test sites showed an early difference in the number of reflection cracks detected. For example, in February 1973, when little traffic had used the sites, there were 0, 5, and 16 reflection cracks detected in the binder course on sites 3, 4, and 5, respectively. Thus, there was a clear indication that the fabric on sites 3 and 4 was somewhat effective in reducing the incidence of reflection cracking at an early overlay age. In April 1973, soon after the final surface had been applied, no cracks could be detected in either of the 3 sections. No significant cracking developed in the surface course during the summer of 1973. However, during the winter of 1973-74, when hydrothermal pavement movements could be expected to be most conducive to reflection cracking, numerous cracks began to develop in the control section and in site No. 4. It also became clear during this period of time that additional cracks were developing in the unreinforced concrete base and were in turn being reflected through the asphaltic concrete surface. As a result, by July 1974 there were a total of 32 reflection cracks in the control section (site 5) while there were 45 cracks in site 4, many of which were newly developed at the base course level. At the same time, there were only 2 cracks in site No. 3.

Also, in July 1974 deflection tests were conducted on all cracks visible in sites 4 and 5 at that time. Similar to the finding in the studies reported earlier, the average differential deflection on visible cracks was 0.002 in. (50 μm).

Cores removed from site 4 during July 1974 showed results similar to those reported above for the Route 460 project. For both the Petromat and the Chemstrand cases cores taken at the location of reflection cracks showed that the cracks lie directly above cracks in the portland cement concrete base, but that the fabric is still intact and shows no evidence of distress. Photographs of cores through both fabrics are shown in Figures 7 and 8.

Final detailed studies of the cracking on the I-95 project were conducted in September 1975. Again, there were a number of cracks which had developed in the base concrete and reflected through the bituminous layers since the test sections were installed. However, based on the original cracking in the 3 test sites, Table 5 was developed in an effort to show the relative effectiveness of the stress relieving layers. The data in Table 5 are given in detail in Figures 4, 5, and 6.

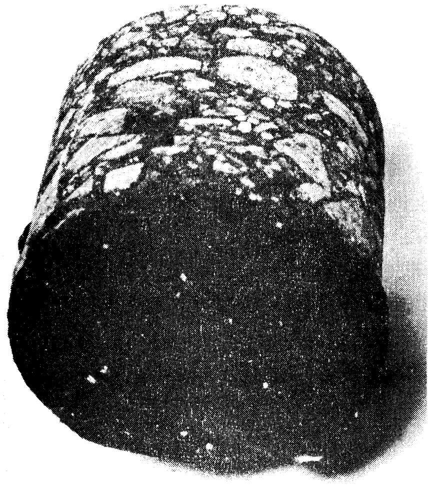

Figure 7. Core through bituminous layers and Petromat, Route 95 project.

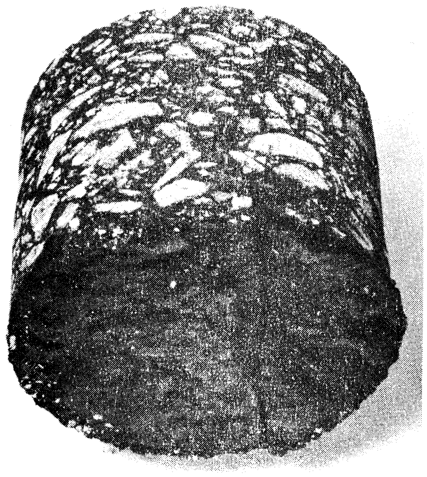

Figure 8. Core through bituminous layers and Chemstrand, Route 95 project.

Note that for site 3 forty-one percent of the cracks had reflected through the Petromat in approximately 3 years. In the same time, on site 4 forty-four and sixty-eight percent of the cracks had reflected through the Petromat and the Chemstrand, respectively, while all the untreated cracks had reflected. Similarly, for site 5 ninety percent of the control cracks had reflected by September 1975. Clearly, both fabrics were somewhat effective in at least delaying the reflection cracking. There is also some evidence that the Petromat was more effective than the Chemstrand. The traffic characteristics given in Table 5 are indicative of service conditions but cannot be used to establish a relationship between traffic volume and reflection cracking. While site 3 has been subjected to the indicated traffic for most of the 3-year period sites 4 and 5 have had only sporadic traffic due to construction related detours.

Table 5

Cracking and Traffic
(September 1975)

Site	Truck Traffic (vpd)*	Total Traffic (vpd)	Percentage Cracks Reflected		
			Petromat	Chemstrand	Control
3	270	19,000	41	—	—
4	3,050	42,500	52	68	100
5	3,050	42,500	—	—	90

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*2-axle 6-tire or larger trucks and buses.

However, the influence of traffic volumes (and fatigue) on the rate of development of the reflection cracking is found in a detailed study of site 5, where it can be seen that the frequency of reflection cracking is greatest in the lanes subject to the most traffic, particularly trucks. Table 6 has been developed from a study of this site, where the outermost lane has been designated as the acceleration lane, the second as the traffic lane, the third as the middle lane, and the innermost as the passing lane. Clearly truck traffic will be heaviest on the acceleration and traffic lanes.

Table 6

Cracking and Traffic Lane
(Site 5, September 1975)

Lane	Percentage Cracks Reflected		
	Petromat	Chemstrand	Control
Acceleration	—		100 (8/8)
Traffic	71 (5/7)*	83 (5/6)	—
Middle	55 (5/9)	67 (6/9)	—
Passing	33 (3/9)	60 (6/10)	—

*Numbers in parentheses show actual number of reflection cracks as a fraction of the total number of treated cracks in the portland cement base.

Note that in addition to the marked decrease in reflection cracking for the lanes where trucks would be less frequent there is also a significant difference in cracking for the Petromat and the Chemstrand treated cracks. The author has no explanation for this difference in performance. Finally, as indicated earlier, all untreated cracks in the acceleration (control) lane have reflected through.

CONCLUSIONS

The following conclusions appear to be warranted from the studies reported above:

1. Neither sand as a bond breaker nor high strength fabrics as stress relieving layers are effective in reducing reflection cracking where vertical joint movement (differential deflection) is a significant factor.

2. When differential deflections are greater than about 0.002 in. (0.005 mm) reflection cracks form very early. Such cracking is delayed for lower differential deflection but may occur as the magnitude and frequency of wheel loadings increase.

3. Both an asphalt impregnated polypropylene fabric and an unwoven, spun-bonded nylon fabric, when placed to span joints in portland cement concrete pavements or cracks in portland cement concrete base and covered with an asphaltic concrete overlay, are able to sustain the formation of reflection cracking in the overlaying layer without damage to themselves.

4. An asphalt impregnated polypropylene fabric spanning the joints in portland cement concrete pavements, and placed between the pavement and an asphaltic overlay, may be effective in reducing the infiltration of surface water to pavement sub-layers. There is some evidence that pavement pumping may be reduced by this method.

5. Both an asphalt impregnated polypropylene fabric and an unwoven, spun-bonded nylon fabric can delay the formation of reflection cracking. There is strong evidence, however, that such cracking is fatigue in nature and will eventually develop under the application of repetitive wheel loadings.

RECOMMENDATIONS

The following recommendations are offered for consideration by the Department.

1. Stress relieving layers of thin fabric used to reduce reflection cracking are not recommended where there is any appreciable differential vertical movement of joints or cracks to be overlayed.

2. The asphalt impregnated polypropylene is recommended for installation on an experimental basis for either of the following uses:

   (a) To reduce reflection cracking in instances where truck traffic will not be a factor.

   (b) To reduce the infiltration of surface water into transverse cracks in instances where it is not feasible to provide a positive subsurface drainage system.

3. Since reflection cracking has been shown to be a shear-fatigue phenomenon it is reasonable to assume that a thick cushioning layer of a relatively fluid material would serve to distribute stresses such that the cracking would be prevented. The purpose of such a material might be served in Virginia by the "B-2" bituminous concrete, which is open-graded and contains a softer asphalt than used in other mixtures. The installation of a test section containing B-2 as a cushioning layer between jointed portland cement concrete pavement and a conventional overlay is recommended.

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