weather and subgrade conditions. At the Laurel, Miss. Airbase it was found necessary to use soil-cement or shut down construction on roads and storage areas. Through showers, low temperatures and excessive wet materials 60,000 sq. yd. of soil-cement were processed in 15 days elapsed time. However, all work was stopped on three days due to rain. The contractors were Taylor and Wheeless, Hattiesburg, Mississippi.

These highlights of construction accomplishments and the overcoming of apparently impossible construction conditions by engineers and contractors on Army and Navy work, illustrate in the paving field the same spirit shown by everyone in getting all parts of the war machinery into gear.

EMULSIFIED ASPHALT TREATED SUBBASE UNDER CEMENT CONCRETE PAVEMENT

By C. L. McKesson, *Director Engineering and Research, American Bitumuls Company*

SYNOPSIS

The phenomena of the warping of concrete pavements, particularly adjacent to joints and cracks, has long been recognized and has been the subject of many papers and discussions in the Proceedings of the Highway Research Board and other technical publications. The destructive effect of such warping is also well known.

Among the probable causes of distortion of slabs, there was enumerated in the 1938 report of the H. R. B. Committee on Warping of Concrete Pavement slabs, as external forces, nonuniform soil swell and frost action caused by water entering subgrade through cracks and joints and nonuniform shrinkage of soil caused by moisture loss. As internal forces, there was enumerated vertical moisture and temperature differentials and unequal deposition of crystalline matter in top and bottom of the slab.

In 1934 the writer, believing that high moisture content in the bottom of the slab due to contact with saturated subgrade and lower moisture content in the surface of the slab where exposed to evaporation was a substantial factor in producing warping, began tests to determine differences in warping of slabs on a granular subbase containing a low clay content and an identical subbase rendered water-resistant by the admixture of 3 per cent of emulsified asphalt. When water was made available to these subbases, the untreated base became quickly saturated and warping resulted. On the treated subbase the absorption of moisture was insufficient to cause measurable warping. The concrete beams were allowed to remain in place for 10 yr. and in 1944 it was found that the 5-ft. long slab on the untreated subgrade had a permanent warp upward at the ends of between 0.20 and 0.25 in. The slab on the treated subbase showed no measurable warp.

In 1938 the cities of Oakland and Los Angeles, California, constructed projects of substantial size on which the subgrade was made water-resistant by the incorporation of a small quantity of emulsified asphalt (usually 3 per cent) admixed to a depth of 4 in. All of these projects at the present time, after about six years of service, are remarkable in their freedom from cracks, lack of warping at joints and in no case is there evidence of vertical movement at joints. These projects are more fully described in this report.

It appears that the reasons for the successful performance on these projects may be: (a) Uniformity of moisture content in top and bottom of slab on a treated base due to the reduced rate at which moisture passes upward from the subgrade

investigations herein reported. On Eastern Avenue, with 6-in. plain concrete, shrinkage cracks appeared in over five years in only about 15 per cent of the 33 ft. long panels. On Olympic Blvd. with 8-in. plain concrete there are no shrinkage cracks after five years although panels are 35 ft. long. (No dummy joints were provided on any of these projects.)

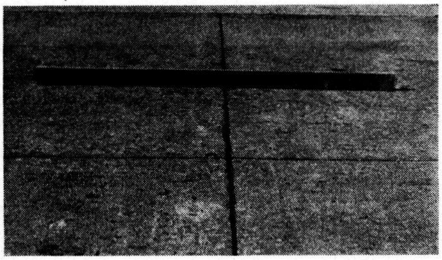

Figure 11. Eastern Ave. 6-in. plain concrete, treated base, shown in background Figure 5. Expansion joints and longitudinal joints wide open, never sealed. No steel in joints. No evidence of warping or vertical movement after five years.

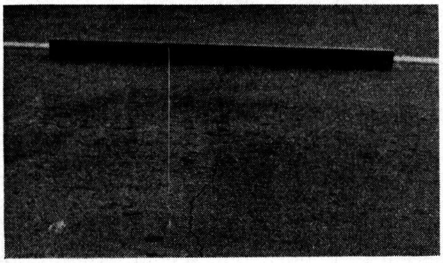

Figure 12. Eastern Ave. 6-in. plain concrete, treated base, in background Figure 5, was laid with expansion joints 33 ft. apart. No dummy or contraction joints. Contraction cracks after five years: near center of about 15 per cent of panels like one shown here. No warping shown under straight edge and no evidence of vertical movement at cracks or joints although no cracks or joints have ever been sealed.

Leakage through Joints and Cracks

While surface water can leak through joints with treated as with untreated subbase, resultant damage from leakage appears to be entirely eliminated. With warping substantially prevented and a uniform moisture content maintained in the subsoil, the slab remains in contact with the base at all times. Water cannot pass through the base to the subgrade to produce swelling or softening under the joints or cracks.

In the present field study the moisture content is substantially the same in the treated base and subsoil beneath open expansion joint in Test "A" (Figure 8) as under the center of the same panel over 16 ft. from an expansion joint (see Tests "A" and "B", Table 4).

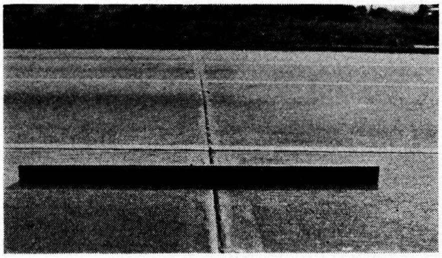

Figure 13. Olympic Blvd. Pavement on treated base (foreground in Figure 9). Joints are all open, never having been sealed. No warping or evidence of vertical movement at joints. Although plain concrete and panels 35 ft. long without dummy joints, no transverse shrinkage cracks have appeared.

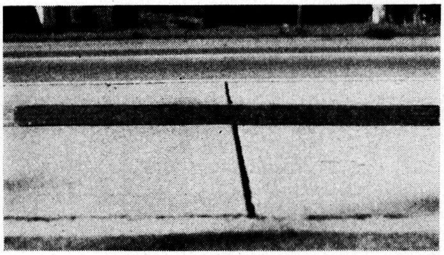

Figure 14. Olympic Blvd. Pavement on 12-in. untreated selected granular subbase (background in Figure 9). Pavement shows inequalities and warping at many joints, as above, of 0.2 in. to 0.3 in. under 6 ft. straight edge.

The Report of the Committee on Warping of Concrete Pavement Slabs (1) shows with untreated subbase or soil that moisture content is greater at joints than under the center of slabs. This Committee Report (1) also states: "Distortions can be prevented by any treatment which insures uniform moisture content in the soil under the slab."

Elimination of Shrinkage and Swell in Subsoil

The construction of a moisture resistant base not only prevents saturation, swelling and softening of subsoil adjacent to joints and cracks but also retards shrinkage of subsoil due to the escape of moisture at joints, cracks and from under panels during dry weather. The moisture content of subsoil under treated base (Table 4) is apparently stabilized after 5 yr. at below the moisture content of "Plastic Limit," even under open joints. The swelling of subsoil can produce powerful disruptive force. Derleth (6) reported a pressure of 880 p.s.i. developed by confined clay soil while 12 per cent of water was being absorbed in 4 days. The same report (6) shows the destructive effect of subsoil swell and shrinkage on concrete pavements and repeately urges the measures which will prevent fluctuations in subsoil moisture.

TABLE 4
FIELD MOISTURE CONTENT, BASE AND SUBSOIL WHEN BEARING VALUE TESTS MADE (FIGURE 10)

Test	Base				Subsoil Moisture, %	
	Treated[a] Moisture, %		Untreated[b] Moisture, %			
	Top Inch	Aver.	Top Inch	7-8 in. Depth	Top Inch	7-8 in. Depth
A	8.5	9.5	No Subbase		15.8	24.9
B	6.4	8.2	No Subbase		20.3	26.6
C	No Base		No Subbase		16.0	23.8
D	9.2	8.0	No Subbase		15.4	15.9
E	No Base		10.6	8.6	Not Sampled	

[a] 4-in. thick emulsified treated base.
[b] 12-in. thick selected granular untreated subbase.

Nonswelling Subsoil and Subbase

Flexing and break up at joints is less pronounced with subsoils or untreated subbases which have low plastic properties but such nonswelling soils do absorb moisture and become less stable with saturation. Aldrich and Leonard report (7) that concrete pavement over a crushed stone base on adobe soil failed under traffic before failure of identical sections placed directly on the same "adobe" soil. It is a matter of common knowledge that slab breaks do occur frequently at joints and cracks even on sandy subsoil or subbase, where joints and cracks are not kept thoroughly sealed. A granular subbase on dense saturated clay subgrade may even act as a reservoir when surface water reaches it through cracks and joints and from the edges of the pavement. That vertical movement of slab corners does occur on untreated granular subbase is shown in Figure 15.

Support at Joints and Cracks

The uniform moisture content in a treated base and in the subsoil beneath insures uniform support under the entire slab as well as at joints and cracks. The reduction in warping due to moisture control in concrete and soil, and elimination of swell and shrinkage in the subsoil, prevents the ends or corners of slabs from being upwardly stressed by swelling subsoil and then being left to act as cantilevers, with no support, when the soil shrinks from loss of moisture.

In the example shown in Figure 4 a base course bearing value of more than 500 p.s.i.

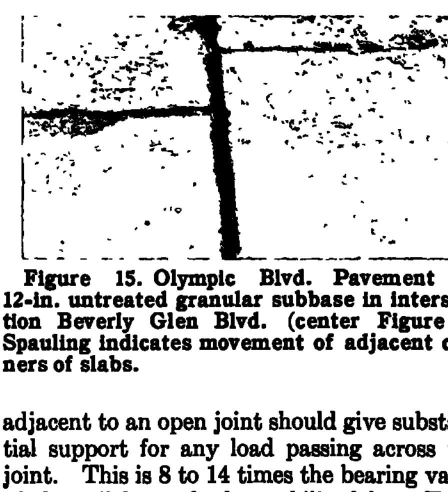

Figure 15. Olympic Blvd. Pavement on 12-in. untreated granular subbase in intersection Beverly Glen Blvd. (center Figure 9). Spauling indicates movement of adjacent corners of slabs.

adjacent to an open joint should give substantial support for any load passing across the joint. This is 8 to 14 times the bearing value of the soil beneath the stabilized base Tests "A," "B" and "D" and 8 times the bearing value directly beneath the slab where the slab rests directly on the subsoil as in Test "C" (See Figure 10). The average of bearing values of treated base in Tests "A," "B" and "D" is at least 3 times that of the untreated granular subbase in Test "E."

Uniform Support of Slab Between Joints

With uniform moisture content in treated base and subbase and no volume changes in subsoil, uniform support should be provided throughout the length of the panel and under unexpected transverse shrinkage cracks should these occur. The bearing value of over 800 p.s.i. in Test "B" (Figure 10) is a very substantial addition to the total load supporting strength of the pavement. With uniform support assured under a slab and at ends, the mathematical considerations for thickness design should be simple indeed.

Design and Construction of Treated Bases

The same considerations are involved as for similarly treated bases under bituminous surfacings. This writer has discussed this subject fully in previous published papers (8), (9), (10) and further comment here is unnecessary.

RECOMMENDATIONS

Based on extensive experience with emulsified asphalt treated bases, the writer suggests:

1. That subgrade be built as carefully as if pavement was to be laid directly thereon.
2. That the thickness of the treated base be a minimum of 4 in. for light traffic, 6 in. for heavy traffic, with a possible increase to a maximum of 8 in. under taxi strips and warming up aprons where very heavy planes are to be served. If the designing engineer believes more thickness is required than that of the slab plus recommended thickness of treated base, then additional selected material should be placed on the subgrade beneath the treated base,—never between base and slab where it could become saturated by surface or shoulder leakage.
3. That the treated base be carried out under shoulders or well beyond the edge of the slab to prevent moisture loss from subsoil under the edges of the pavement.

CONCLUSIONS

Based on the observation of a number of projects 5 and 6 yr. old and disclosures in the literature, the following conclusions appear fully warranted.

An emulsified asphalt treated base:

1. Insures uniformity of moisture content beneath the concrete slab.
2. Substantially eliminates warping and contraction of concrete pavement insofar as these are due to moisture.
3. Provides uniform and continuous support under slabs and at joints and cracks.

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