TESTING OF SUBMERGED BITUMEN-SAND MIXTURES BY SLOW REPETITIONAL LOADING

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SYNOPSIS

An extensive investigation performed in 1943–46 for the Technical Development Service of the Civil Aeronautics Administration at Princeton University revealed the fact that granular soils were particularly susceptible to deformation and (or) compaction both by vibratory and by slow-repetitional loading. The results of this study were described in papers published in the 1944 and the 1946 Proceedings of the Highway Research Board.

The present paper describes a cooperative preliminary investigation performed by Princeton graduate students for the purpose of determining to what extent asphalt admixtures were liable to decrease the deformations of granular materials under repetitional loading. The slow repetitional soil plunger testing machine described in the earlier papers on the subject was used to test submerged bitumen-sand mixtures.

Diagrams are presented which illustrate the findings made. The beneficial effects of admixtures of aniline-furfural to sand-asphalt specimens tested in a submerged condition are demonstrated. Plunger penetrations after 10,000 load repetitions on submerged specimens treated in this manner were found: (1) not to exceed 66 percent of the plunger penetrations recorded on submerged specimens for which 4 percent of RC-2 asphalt was admixed to the sand, without addition of aniline-furfural; (2) not to exceed 22 percent of the plunger penetrations recorded on specimens of submerged sand without any admixtures.

A brief discussion is given of possible practical applications of these findings.

The investigation described in References (*2, 3, and 4*)[1] revealed the fact that coarse grained soils are particularly susceptible to deformation and to compaction both by vibratory and by slow repetitional loading. The number of load repetitions was found to be one of the essential and governing factors. Under all types of load the deformations of submerged sands were much greater than the deformations of dry sands of equal density.

Some field data has recently become available which appears to provide supporting evidence for our laboratory findings. Information provided by Mr. E. C. Ely, District Soils Engineer of the New Jersey State Highway Department, showed that on certain highway sections with concrete pavement underlain by natural sandy soil, so-called "turtle backs" were found to have developed after several years service; that is, the concrete slabs had settled more at the joints and had developed a corresponding curvature which was particularly pronounced on old roads and on the heavily travelled lanes.

[1] Italized figures in parentheses refer to list of references at the end of the paper.

This brings up some interesting points. First will be mentioned the possibility of increased plastic flow of concrete as a result of load repetitions. Some studies recently performed in France have indicated that plastic flow of concrete due to rapid repetitional axial loading might be greater than plastic flow resulting from a steady application of load. A few preliminary experiments performed during the past year at Princeton with slow repetitional loading of small concrete beams gave similar indications so that this whole question appears to provide good opportunities for further study.

The present paper is however mainly concerned with the preliminary results of another study which was undertaken for the purpose of finding the means for decreasing the sensitivity of coarse-grained soils to repetitional loading.

Such repetitional loading should not create problems beneath flexible pavements if the traffic is normally distributed. This is usually the case and the resulting compaction of coarse-grained subgrades, or of inadequately compacted base courses, is then also distributed without resulting pavement damage (*1*).

In the case of concrete pavements the situation is different. No matter how the traffic is distributed the base course and the subgrade are liable to be subjected to higher pressures beneath the joints than beneath the central portions of an uncracked concrete panel. A method which would decrease the sensitivity of coarse-grained soils to vibratory and to slow-repetitional loading might therefore find practical application in such cases. In a discussion of (*2*), Mr. L. A. Palmer of the Bureau of Yards and Docks had suggested the possibility of using asphalt for the purpose (*1*).

An admixture of four percent of rapid curing No. 2 asphalt was selected for our tests; further, to some specimens were added 0.04 per-

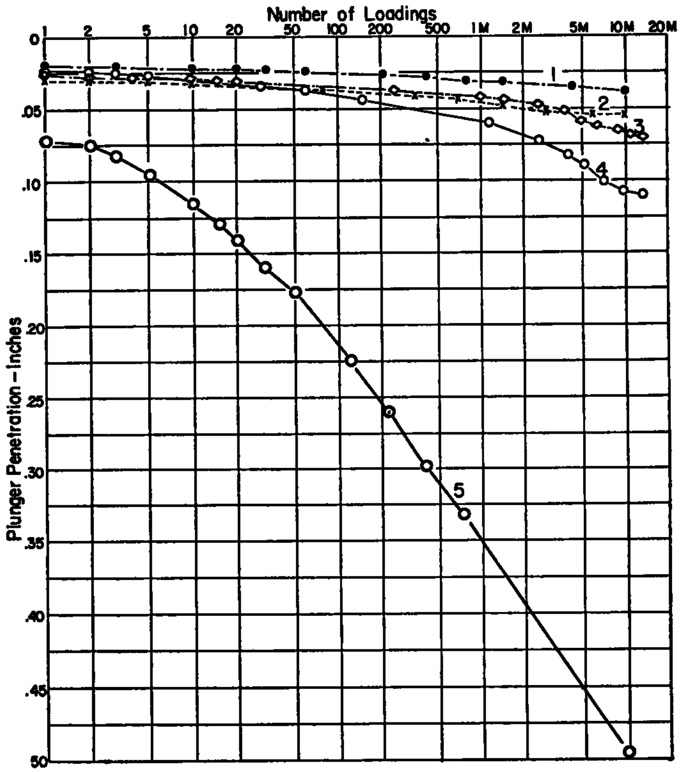

Figure 1. Slow Repetitional Test

Curve No:	(*1*)	(*2*)	(*3*)	(*4*)	(*5*)
Material	**Sand "A" and Admix. listed below**				
Condition of Saturation	**Dry**	**Dry**	**Submerged**	**Submerged**	**Submerged**
Compaction Method, Static, ***psi.***	**2000**	**2000**	**2000**	**2000**	**2000**
Void Ratio "e"	**.530**	**.505**	**.543**	**.518**	**.508**
Dia. of Container, ***in.***	**6**	**6**	**6**	**6**	**6**
Area of Plunger, ***sq. in.***	**3**	**3**	**3**	**3**	**3**
Surcharge, ***lb.***	**12.3**	**12.3**	**12.3**	**12.3**	**12.3**
Frequency, ***cycles per min.***	**1**	**1**	**1**	**1**	**1**
Plunger weight, ***lb.***	**95**	**95**	**95**	**95**	**95**
Counter weight, ***lb.***	**95**	**95**	**95**	**95**	**95**
Admixture					
4% RC-2 Asphalt	**Yes**	**Yes**	**Yes**	**Yes**	**No**
.04% Aniline	**No**	**Yes**	**Yes**	**No**	**No**
.02% Furfural	**No**	**Yes**	**Yes**	**No**	**No**
Curing Time	**8 days**	**9 days**	**11 days**	**13 days**	

cent of aniline and 0.02 percent of furfural in order to prevent stripping of the asphalt when the sand is saturated with water.

The effectiveness of aniline-furfural admixtures to asphaltic bitumen is due to a number of different factors. The aniline, as a derivative of ammonia is easily adsorbed on negatively charged hydrophilic minerals. The furfural resinifies the aniline and prevents its removal from the mineral surfaces (*5*). The synthetic resin consisting of two parts of aniline and one part of furfural is one of the most weather resistant materials known (*6*).

The aniline, the furfural, and the resinous products derived from their combination, all possess strong bactericidal and fungicidal properties. Since it has been proven that soil bacteria can strip bituminous materials from mineral aggregate, the bactericidal properties of aniline-furfural are of great practical importance with respect to permanency of the anti-stripping effect.

The testing itself was performed by means of a slow repetitional (one-cycle per min.) six-bank plunger soil testing machine which is shown on Figure 20 of Reference (*3*) and on Figure 53 of Reference (*4*).

The first series of tests was performed on specimens of sand which is referred to as "Sand 'A'" in References (*3*) and (*4*), and in the manner described in these references. The CBR type plungers were loaded to an intensity of 31.7 lb. per sq. in. (2.27 T. per sq. ft.) whereby the counterweight equaled the plunger weight. The results of this series of tests are summarized in Figure 1 and Table 1. It may be seen that for specimens tested in a submerged condition the addition of asphalt to the sand was beneficial for a single loading and to an only slightly greater extent for repetitional loading. For a single loading the plunger penetrations were reduced to one third of the values recorded on sand only; for the following 10,000 load repetitions the plunger penetrations were reduced to one fifth of the values recorded on sand only. The beneficial effects of the addition of aniline-furfural to the sand-asphalt mixture became particularly apparent for the repetitional loading—for a single loading the plunger penetrations remained approximately equal to one third of the values recorded on sand only; but for the following ten thousand load repetitions the plunger penetrations were reduced to one tenth of the values recorded for sand only.

TABLE 1
COMPARISON OF PLUNGER PENETRATIONS LOADED TO A UNIT PRESSURE OF 2.27 T per sq. ft.
(See Fig. 1)

	Soil (Tested Submerged)	*Penetration After* (a) First Loading	(b) 10,000 Load Repetitions	(c) = (b) — (a)
(1)	Sand Only	0.070in.	0.495in.	0.425in.
(2)	Sand + 4% RC-2 Asphalt	0.023in.	0.108in.	0.085in.
(3)	Sand + 4% RC-2 Asphalt + .04% aniline + .02% furfural	0.025in.	0.068in.	0.043in.
(4)	$\frac{(2)}{(1)} \times 100$	33%	22%	20%
(5)	$\frac{(3)}{(1)} \times 100$	36%	14%	10%
(6)	$\frac{(3)}{(2)} \times 100$	108%	63%	50%

TABLE 2
COMPARISON OF PLUNGER PENETRATIONS LOADED TO A UNIT PRESSURE OF 3.97 T per sq. ft.
(See Fig. 2)

	Soil (Tested Submerged)	*Penetration after* (a) First Loading	(b) 10,000 load repetitions	(c) = (b) — (a)
(1)	Sand Only	0.240in.	0.950in.	0.710in.
(2)	Sand + 4% RC-2 Asphalt	0.033in.	0.305in.	0.272in.
(3)	Sand + 4% RC-2 Asphalt + .04% aniline + .02 furfural	0.040in.	0.200in.	0.160in.
(4)	$\frac{(2)}{(1)} \times 100$	14%	32%	38%
(5)	$\frac{(3)}{(1)} \times 100$	17%	21%	22%
(6)	$\frac{(3)}{(2)} \times 100$	120%	66%	59%

A second series of tests was performed under higher intensities of plunger loading equal to 55.0 lb. per sq. in. (3.97 T. per sq. ft.) whereby the counterweight equalled the plunger weight. The results of this series of tests are summarized on Figure 2 and Table 2, and are similar to the results of the first series of tests. The increased intensity of loading appears to result in an increase of the beneficial effects of both types of admixtures insofar as the first loading is concerned; but in a slight decrease—

in the same proportion for both types of admixtures—of such beneficial effects for repetitional loading.

aniline-furfural to sand-asphalt specimens subjected to repetitional loading have thus been demonstrated. Such treatment of granular soils therefore appears to provide an effective means for decreasing their sensitivity to vibratory or to slow repetitional loading. Treatment by this method of granular base courses

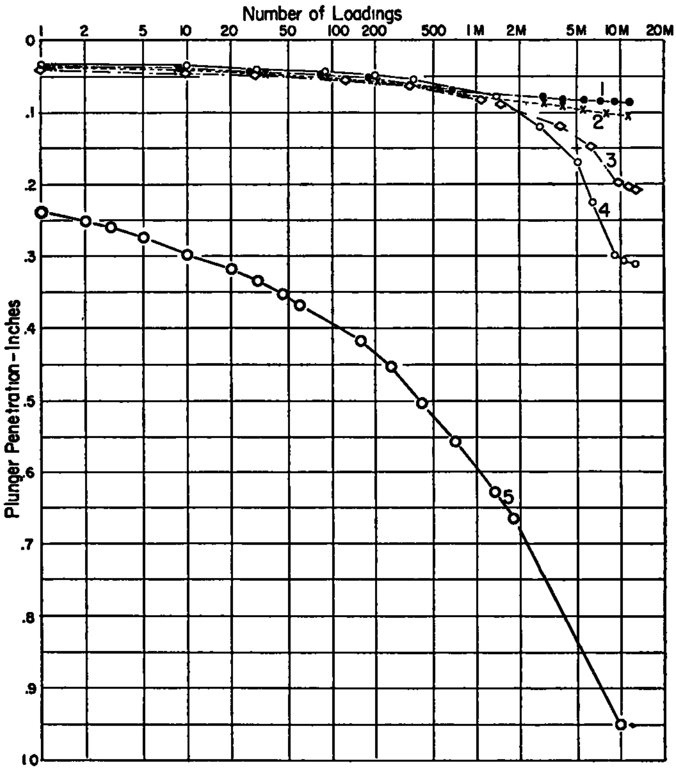

Figure 2. Slow Repetitional Test

Curve No:	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Material	**Sand "A" and Admixture listed below.**				
Condition of Saturation	**Dry**	**Dry**	**Submerged**	**Submerged**	**Submerged**
Compaction Method, *psi*.	**2000**	**2000**	**2000**	**2000**	**2000**
Void Ratio "e"	**.505**	**.483**	**.555**	**.527**	**.591**
Dia. of Container, *in*.	**6**	**6**	**6**	**6**	**6**
Area of Plunger, *sq. in*.	**3**	**3**	**3**	**3**	**3**
Surcharge Load, *lb*.	**12.3**	**12.3**	**12.3**	**12.3**	**12.3**
Frequency of Loading, *cpm*.	**1**	**1**	**1**	**1**	**1**
Plunger Weight *lbs*.	**165**	**165**	**165**	**165**	**165**
Counter Weight *lbs*.	**165**	**165**	**165**	**165**	**165**
Admixture					
4% RC-2 Asphalt	**Yes**	**Yes**	**Yes**	**Yes**	**No**
.04% Aniline	**No**	**Yes**	**Yes**	**No**	**No**
.02% Furfural	**No**	**Yes**	**Yes**	**No**	**No**
Curing Time	**8 days**	**10 days**	**12 days**	**13 days**	

Further tests may be required for a detailed evaluation of the effect of changes in the variables involved; but it can be definitely stated now that the beneficial effects of admixtures of and even of coarse-grained subgrades beneath joints of concrete pavements may prove advisable on sections with heavy traffic.

CONCLUSIONS

1. The admixture of 4 percent RC-2 asphalt to sand decreases its sensitivity to repetitional loading in a submerged condition and the resulting deformations to approximately one third of the values obtained on the same sand without any admixtures.

2. The admixture of 4 percent RC-2 asphalt and of 0.04 percent aniline with 0.02 percent furfural prevents stripping of the asphalt from the submerged sand grains and further decreases the sensitivity of the sand to repetitional loading in a submerged condition and the resulting deformations to approximately one fifth of the values obtained on the same sand without any admixtures.

3. The bactericidal properties of aniline-furfural prevent the stripping of asphalt by bacteria action. Therefore, over long periods of time in the field, the use of this admixture may be even more beneficial than is indicated by the results of the present purely mechanical study.

ACKNOWLEDGEMENTS

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