INVESTIGATION OF CONCRETE PAVEMENT PUMPING

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SYNOPSIS

This paper describes the investigation of the pumping at transverse joints in concrete pavement slabs on a project 4.39 miles in length on U.S. 52 in Scioto County, Ohio, near the village of Franklin Furnace.

The soils survey made prior to grading operations showed that on some sections the predominating soil was high in silt content and could be classified in the A-4 group. It was considered necessary to cover these areas with suitable granular material to a depth of 18 inches and provide tile drainage.

The pavement was built without reinforcing or load transfer devices. Records are also included on a short project built in 1941 in which complete reinforcing and load transfer devices were used. Observations were made of slab deflections under moving loads on both projects.

Pumping was found to be much more extensive and severe over the areas where no granular material was used. On the plain concrete section pumping was more severe at contraction joints of the premolded type. The severity on the reinforced section was about the same for expansion and contraction joints. On the plain concrete slabs without granular sub-base, 2 per cent of the expansion joints and 52 per cent of the contraction joints were pumping. On the plain concrete slabs placed on granular sub-base 1.5 per cent of the expansion and 16 per cent of the contraction joints were pumping. On the reinforced section, 71 per cent of the expansion joints and 91 per cent of the contraction joints were pumping.

On most of the work, the gradation of the backfill for the tile drains was from the 3/4-inch to No. 4 sizes. It was observed that these drains silted up badly. On one section 3/8 inch to No. 8 material was used and only a small amount of silting was observed.

The conclusions of observations on these projects are as follows:
1. A sub-base composed of suitable granular material will appreciably reduce the pumping at joints in concrete pavements. 2. The use of small size backfill aggregate will extend the useful life of tile drains.
3. The use of load transfer devices prevents excessive permanent deformation at the joints between concrete slabs after pumping starts.

GENERAL DESCRIPTION

It is the purpose of this paper to describe the investigations that were made and the conclusions and recommendations that resulted in connection with transverse joint pumping on S.N. Federal Aid Project No. 626-H(1) and S.N. Federal Aid Project No. 240-A(3) located on U.S. Route 52 in Scioto County, Ohio near the village of Franklin Furnace.

The length of the project is 4.39 miles and the plans provided for the placing of a Portland Cement concrete wearing surface 24 ft. wide and nine in. thick. It was further provided that the "concrete pavement shall be placed and finished in single lane widths as separate operations and the longitudinal joint separating lanes thus placed shall be a key joint".

Because of wartime restrictions the pavement was designed without reinforcing steel or load transfer bars at any of the joints. The use of Portland Cement containing vinsol resin was required in amounts so that the reduction in weight of the concrete of from four to eight pounds per cu. ft. would be effected.

Most of this project is on new grade and alignment. As a consequence a considerable quantity (230,000 cu. yds.) of earthwork was involved, more than 60 per cent of which was to be secured from roadway, structure and channel excavation. A soil profile was prepared by the Highway Testing Laboratory which set forth the information obtained from the analysis of 112 samples taken throughout the length of the project. An inspection of this profile shows that the predominant soil types are silt soils, P.R.A. Classification A-4, S.H.T.L. Classifications 8, 9 and 11 (See page 57). Since these soils are subject to detrimental capillarity and subsequent frost heave it was decided that, wherever this material would be encountered at subgrade elevation, it would be removed to a depth of at least 18 in. and replaced with a suitable granular material. Deep longitudinal drainage was provided adjacent to these backfilled areas leading to the nearest convenient disposal points. This treatment was provided for seven areas which covered 7858 lin. ft. measured along the center line.

Over one area of 2250 lin. ft. where clay, P.R.A. Classification A-7, S.H.T.L. Classification 16, was encountered a bituminous impregnated paper insulation course was provided.

Actual construction work was started on August 25, 1942 when excavating operations were begun at a point approximately one-half mile south of the northern extremity of the project. Cross road culvert and underdrainage work was begun on September 1, 1942, and the first classified embankment material was placed the following day.

Approximately 20 per cent of the 9 in. Portland Cement concrete pavement was placed between October 8, 1942 and November 12, 1942 when paving work was suspended due to unfavorable weather.

The grading work was vigorously prosecuted until November 28, 1942 when weather conditions made further progress impractical. At that time approximately 50 per cent of the excavation and borrow materials were in place (See Table 1 for Mechanical analysis of borrow pit materials) and nearly 60 per cent of the classified embankment was completed.

It was possible to continue the installation of underdrainage until late in December at which time approximately 90 per cent of this work was completed.

The weather during the first four months of 1943 was unsuitable for the prosecution of construction work. Flood waters partially covered the project three times.

During the first flood period observations were made between Sta. 254+ 0 and Sta. 261+0 where the east half of the pavement slab was in place. Numerous air bubbles were in evidence at the transverse joints and along the edges of the pavement slab. The number gradually decreased until they had entirely disappeared. Subsequent floods failed to cause a repetition of this condition. This may be due to the fact that the first flood exceeded subsequent ones by approximately four feet.

TABLE 1. SUMMARY OF TESTS OF BORROW PIT SOILS FOR S.N.F.A.P. No. 626-H(1) S.N.F.A.P. No. 240-A(3)

Proj. Sample No.	Depth Sampled in Inches	Liquid Limit	Plasticity Index	Proctor Compaction: Max. Dry Wt. Lbs. per Cu. Ft.	Proctor Compaction: Optimum Moisture Content	Mechanical Analysis, Percentage of: Sand +0.05 mm	Silt 0.05-0.005 mm	Clay -0.005 mm
S-1	6 to 48	20.1	2.7	115.2	13.6	19.6	39.9	13.2
S-2	48 to 96	24.2	6.6	113.0	14.2	19.2	47.5	21.7
S-3	6 to 24	24.4	6.0	107.0	15.8	36.0	37.2	26.8
S-4	24 to 72	29.7	7.7	101.5	20.2	5.6	61.6	32.8
S-14	18 to 30	23.8	3.4	107.9	15.8	11.0	66.8	22.2
S-15	30 to 36	24.7	3.5	107.2	16.4	15.0	66.2	18.8
S-16	132 to 144	19.6	Non Plastic	100.8	16.8	63.0	26.4	10.6
S-17	96 to 108	21.1	Non Plastic	105.9	14.6	70.0	20.8	9.2
S-18	48 to 60	21.0	4.5	110.1	15.2	50.0	30.8	19.2
S-22	12 to 96	26.7	2.4	100.9	17.6	1.4	85.4	13.2
S-23	12 to 120	21.6	5.1	116.8	13.2	40.0	40.2	19.8
S-25	12 to 36	21.5	2.9	114.8	12.8	29.2	55.0	15.8
S-26	12 to 36	26.0	9.4	111.1	15.8	19.8	47.2	33.0
S-27	12 to 36	31.3	13.3	107.8	15.4	9.5	45.3	44.6
S-28	12 to 36	20.7	3.5	117.6	11.6	43.0	39.6	17.4

Studies show that a considerable portion of this project was subjected to at least partial flooding during the early part of 1943.

Grading operations were resumed on June 1, 1943 and pavement placing followed in approximately two weeks. Except for ordinary delays caused by weather, equipment failures, etc., the work continued until the completion of paving operations on November 12, 1943.

SLAB PUMPING OBSERVATIONS

After the pavement had been opened to traffic for a period of between two and three months the first evidences of pumping became apparent. During this time the weather had been relatively mild and exceedingly dry. Within 30 days after the first pumping was observed this action had increased at such an alarming rate that it was decided to determine the extent to which it had progressed and to investigate any and all contributing factors.

In order to compare the action of pavement of this design with that built with reinforcing steel and load transfer bars at all joints the investigation was made to include Federal Aid Grade Crossing Project No. 240-A(2) which adjoins this project and which was placed during the late fall of 1941.

For purposes of easy identification the originally described project will be referred to as the "Plain-slab" project.

The investigation was begun by locating all transverse joints on each project. This work was done on March 27 and 28, 1944 after a series of rains made pumping joints easily identifiable. While it might seem that results observed at this time would represent extreme conditions subsequent observations indicate that average conditions prevailed. Each joint was listed as to type and condition and the results plotted. Figure 1 shows a typical section with legend markings.

As a general statement it may be said that pumping was much more extensive and severe where the pavement slab was placed on soil subgrade. It was noted that where pumping did occur over classified embankment areas the large portion of this action was confined to the low side of superelevated curves on which edge curbs were used. The water was carried to sod gutters spaced at frequent intervals and directed across the berm. During the construction of this project the sod gutters were placed one inch below the pavement edge. It was thought that this would be sufficient to allow for ordinary growth and fluffing of the sod and still have drainage away from the pavement. It was observed, however, that the sod built itself up to such an extent that, combined with an accumulation of ice control material, drainage was impeded so that water was ponded along the gutter line. This ponding with resultant splashing under traffic could have set up a condition which caused the pumping to develop.

Table 2 shows the results of this investigation. It will be observed that on the plain slab project the highest percentage of pumping occurred at the contraction joints regardless of the type of subgrade material. Pumping on the reinforced slab project is generally more severe at all types of joints. Following the usual Department policy some latitude was allowed in the choice of the type of transverse joint. Figure 2 shows the types of joints that were used on each project. Although surface sealing was not required State Maintenance forces went over the plain slab project during the fall of 1943 and performed this operation along the longitudinal center joint and along the transverse construction and expansion joints beginning at the south end of the project and extending to Sta. 244+0. When, on March 27 and 28, 1944,

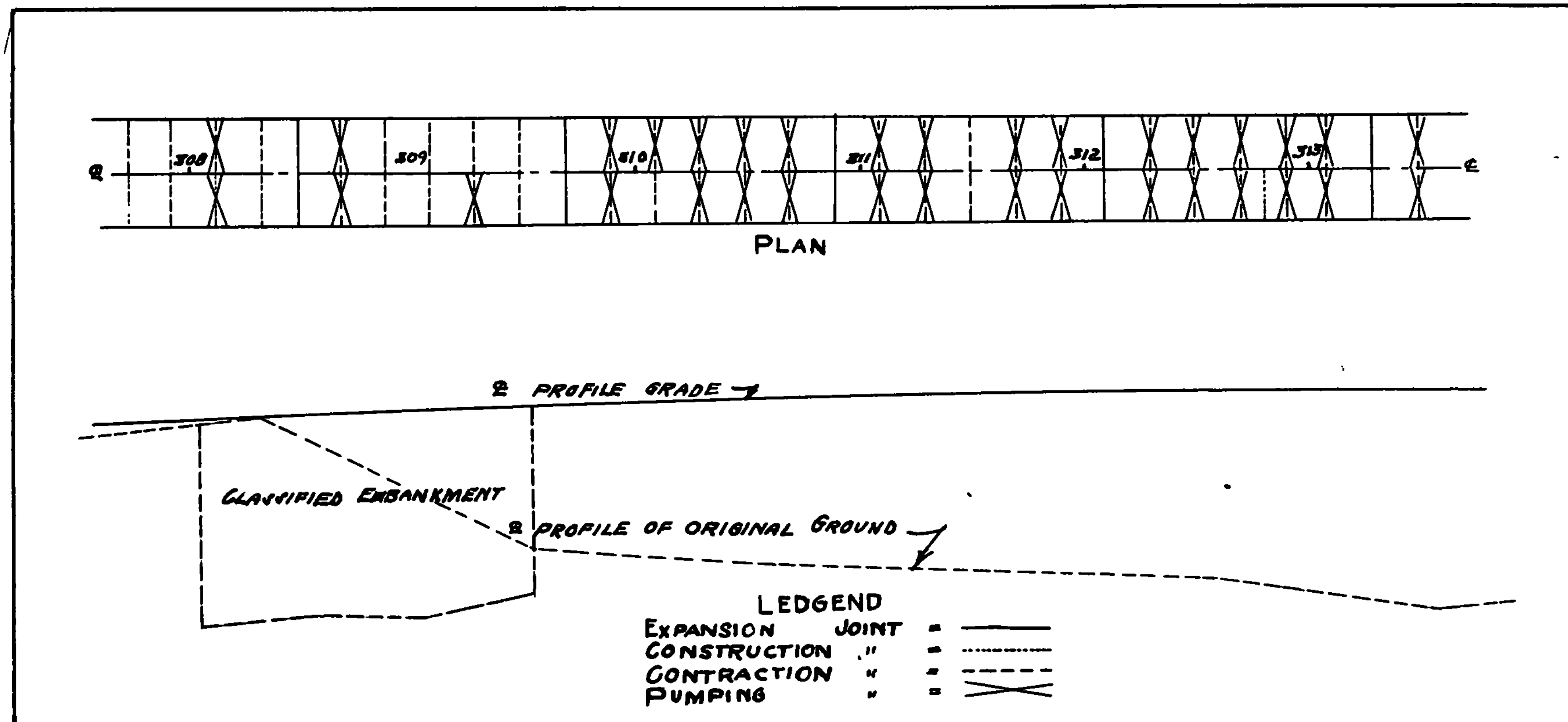

FIG. 1. SHOWING METHOD OF PLOTTING TRANSVERSE JOINTS

the location of the transverse joints was determined, it was observed that the surface seal was, generally, in good condition and showed evidence of having been well applied. Inquiry developed that asphaltic filler having a softening point of 75+ and a penetration range of 30 to 45 was used and applied when heated to a temperature that permitted easy flow of the material.

SLAB DEFLECTION OBSERVATIONS

On April 20, 21 and 26, 1944 a series of observations were made to determine the deflection of the pavement slab under traffic. The device used consisted of a metal stake and bracket to which two Ames gauges were attached. The metal stake was driven at such locations that one of the gauges was in contact with each of the pavement slabs adjacent to the transverse joint. At each joint where observations were made the gauges were placed near the pavement edge (See Fig. 3) and near the junction with the center line joint.

An attempt was made, at first, to observe the slab deflections resulting from the passage of each vehicle over the joint. It soon became apparent that the movement under passenger cars and light trucks was so slight that it could not be measured on the dial of the Ames gauge. Observations were, therefore, confined to the action resulting from the passage of medium and heavy trucks and buses at normal operating speed of approximately 35 miles per hour. In certain instances trucks were stopped and asked to proceed at very slow speed, and it was observed that greater deflections resulted than when normal speeds were allowed.

In making these tests all traffic was routed over the half of the pavement under observation and dial readings were recorded on both the forward and rear slabs as determined by the direction in which the vehicle is moving. Table 3 shows the summary of pavement deflections. While the amount of the individual deflection is small there is every reason to believe that over a period of time serious trouble will develop. This is substantiated by observations on the reinforced slab project. In the two years that this pavement has been in place serious spalling has occurred at some transverse joints. Reference to Table 3 will show that the movement here is comparable to that on the plain slab project. That the repetition of these small deflections has affected the relative positions of the individual slabs was demonstrated as follows:

It was known that at the time work was completed on the plain slab project all pavement irregularities in excess of specification limit (1/4 inch in 10 ft.) had been removed. On May 1, 1944 the smoothness of the pavement was again tested by means of a hand profilometer. It was found that irregularities in excess of the specification limit existed at 111 transverse joints. This represents approximately 10 per cent of the total number of transverse joints on the project. The distribution of these irregular joints was fairly even throughout the length of the project.

In order to obtain specific subgrade information, samples were taken one foot from the pavement edge where slab deflections had been measured. The results of tests of these samples are shown in the last column of Table 3. It is interesting to note that at Sta. 417+68 where the most deflection was recorded and where very bad pumping was observed the silt content was lower than at transverse joints where less movement and pumping were in evidence.

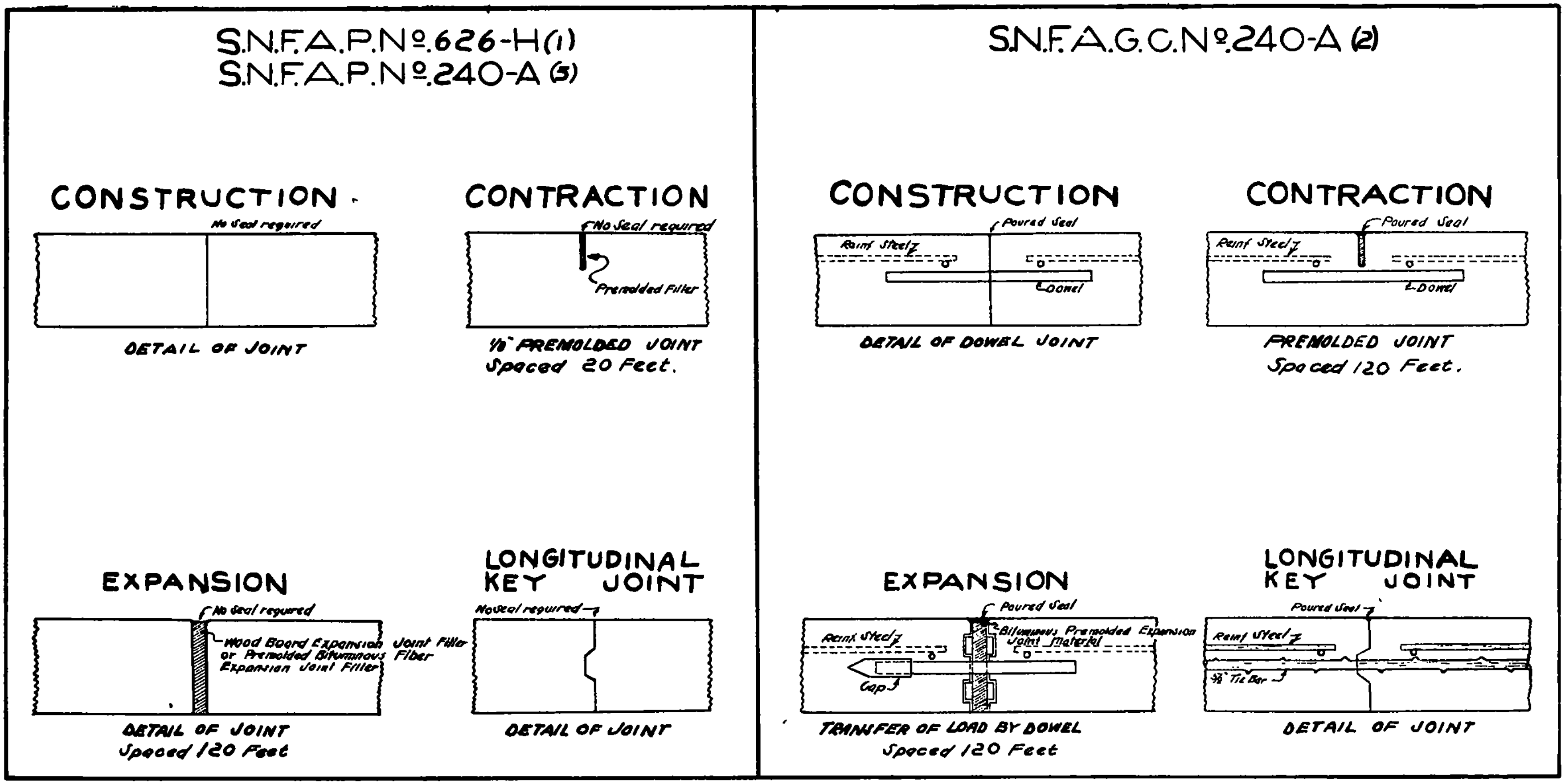

FIG. 2. PAVEMENT JOINTS

TABLE 2. SUMMARY OF TRANSVERSE JOINT INVESTIGATION FOR S.N.F.A.P. No. 626-H(1)
S.N.F.A.P. No. 240-A(3)
F.A.G.C.P. No. 240-A(2)

EXPANSION JOINT			CONSTRUCTION JOINT			CONTRACTION JOINT		
Total No.	No. Pumping	% Pumping	Total No.	No. Pumping	% Pumping	Total No.	No. Pumping	% Pumping
PLAIN CONCRETE SLAB PROJECT SOIL SUBGRADE								
130	3	2.31	29	7	24.14	622	325	52.25
PLAIN CONCRETE SLAB PROJECT CLASSIFIED EMBANKMENT SUBGRADE								
67	1	1.49	9	0	0.0	335	52	15.52
REINFORCED CONCRETE SLAB PROJECT SOIL SUBGRADE								
21	15	71.43	1	1	100.00	24	22	91.25

TABLE 3. SUMMARY OF PAVEMENT DEFLECTION UNDERMOVING WHEEL LOADS S.N.F.A.P. No. 626-H(1)
F.A.G.C.P. No. 240-A(2)
S.N.F.A.P. No. 240-A(3)

Station	Location	Number of Vehicles	Average Deflection in Inches: Forward Slab	Average Deflection in Inches: Rear Slab	Maximum Deflection in Inches: Forward Slab	Maximum Deflection in Inches: Rear Slab	Condition of Joint	Subgrade Material
313+68	6" from W. Edge	14	.0039	.0039	.011	.010	Medium Pumping	P.R.A. Class A-4 S.H.T.L. " 9
313+68	6" W. of ℄	7	.0093	.0077	.019	.015	" "	With 48.6% Silt
319+08	6" from E. Edge	8	.0043	.0055	.017	.014	Bad "	P.R.A. Class A-4 S.H.T.L. " 8
319+08	6" E. of ℄	12	.0074	.0106	.015	.021	" "	With 54.9% Silt
350+88	6" from E. Edge	7	.0004	.0007	.001	.001	No "	P.R.A. Class A-5 S.H.T.L. " 12
350+88	6" E. of ℄	10	.0005	.0004	.001	.001	" "	With 49.8% Silt
417+68	6" from E. Edge	10	.0092	.0095	.025	.025	Very Bad "	P.R.A. Class A-7 S.H.T.L. " 16
417+68	6" E. of ℄	12	.0015	.0024	.004	.010	" " "	With 33.2% Silt
435+06	6" from E. Edge	7	.0003	.0003	.002	.002	No "	S.S. 112 Grading 2
435+06	6" E. of ℄	8	.0010	.0008	.003	.003	" "	With 5.2% Passing #200 Sieve
478+96	6" from E. Edge	8	.0011	.0009	.003	.002	Bad "	P.R.A. Class A-7 S.H.T.L. " 15
478+96	6" E. of ℄	8	.0051	.0055	.011	.012	" "	With 48.3% Silt

SUBGRADE INVESTIGATIONS

The plans for the plain slab project contained the following note: "Excavated material, of which the grain size is of 50 per cent or more between 0.05 mm. and 0.005 mm. (S.H.T.L. Classification 8), shall be placed at least three feet below the pavement when used in embankment". The Soil Profile indicated that a number of areas from which roadway excavation material was to be obtained contained more than the maximum allowable amount of S.H.T.L. Classification 8. Table 1 shows the amounts of this type of material contained in borrow pit soils.

Because of the limitations set forth by the note quoted above and the presence of S.H.T.L. Classification 8 material in both the excavation and borrow material it was decided to sample the subgrade soil of the completed project. The results of tests of these samples are summarized in Table 4. While a number of the samples (Nos. 9, 13, 24) indicate an excess of undesirable material in embankment areas, the amount of pumping does not seem to be particularly affected thereby. This may be due to the relatively high percentages of compaction that were obtained on this project. An average of 99.75 per cent compaction was obtained from 299 tests completed during the construction operations. The three other samples (Nos. 6, 17, 18) which contain an excess of S.H.T.L. Classification 8 material seem to bear out the statement that the amount of pumping is not particularly affected by its presence. These latter samples are all from within excavation areas.

The limitations for fineness of classified embankment material is that not more than 15 per cent shall pass a No. 200 opening. Table 5, which is a summary of tests of samples of classified embankment in place, indicates that in a number of places this limitation is exceeded. In all probability this is caused, for the most part, by the mixing of some of the berm material in the sample and to the unavoidable combining of earth with the classified embankment material during construction operations. These contentions are further borne out by Table 6 which shows the mechanical analysis of samples taken from the pit which was the source of the classified embankment material. Sample numbers 1, S-24 and 34 were taken before and during construction operations and sample numbers 40 and 41 were taken recently. The gradation of the material represented by the two sets of samples are closely comparable. But regardless of the cause of the presence of an excessive amount of fine material in the classified embankment material, the amount of pumping does not seem to be affected thereby.

The limitations of the General Specifications provided the control of the type of material and its manipulation in the embankment on the reinforced slab project. Since practically all of this project consisted of embankment to be obtained from borrow pits a soil profile was not needed. Table 7 shows a summary of the tests of material obtained from these pits. Subgrade samples taken during April 1944 conform generally to that shown in the Table. It is interesting to note that only one of the borrow pit samples and none of the subgrade samples indicate the presence of more than 50 per cent silt. From 311 tests completed during the construction of this project an average of 102.4 per cent compaction was indicated. However, pumping is prevalent throughout the project to a very high degree. The presence of edge curbs and the steepness of the grade which caused considerable longitudinal flow of water over the pavement slab may be a contributing factor to the pumping especially since the bituminous seal at the transverse joints was rather poorly maintained.

TABLE 4. SUMMARY OF TESTS OF * SUBGRADE SOILS AS BUILT FOR SN.F.A.P. No. 626-H(1)
SN.F.A.P. No. 240-A(3)

Proj. Sample No.	Location	Depth Taken in Inches	Liquid Limit	Plasticity Index	Mechanical Analysis Percentage of Sand +0.05mm	Silt 0.05-0.005mm	Clay -0.005mm	Classification P.R.A.	S.H.T.L.
1	1' Lt. Pavt. Sta. 232+85	12 to 36 Fill	21.5	4.9	32.2	29.5	9.1	A-4	Class 9
2	1' Rt. " " 237+41	" " " "	24.6	6.5	23.0	46.7	26.9	A-4	" 9
3	1' Rt. " " 246+60	" " " "	22.9	4.4	33.6	42.6	23.8	A-4	" 9
4	1' Lt. " " 246+00	" " " "	21.9	4.2	33.0	43.2	23.8	A-4	" 9
5	1' Lt. " " 254+60	" " " "	27.9	8.2	20.8	46.4	32.8	A-4	" 9
6	1' Rt. " " 263+40	" " " Cut	32.4	9.8	6.1	56.4	34.8	A-4	" 11
9	1' Lt. " " 275+20	" " " Fill	36.9	13.0	7.4	53.2	39.1	A-4	" 11
13	1' Lt. " " 287+60	" " " "	31.9	9.4	6.7	57.7	35.3	A-4	" 11
17	1' Rt. " " 302+12	" " " Grade	26.3	7.2	13.3	50.4	34.0	A-4	" 8
18	1' Lt. " " 321+48	" " " Cut	26.3	7.5	16.2	55.5	27.1	A-4	" 8
24	1' Rt. " " 352+28	" " " Fill	38.7	12.2	4.0	53.9	41.0	A-4	" 8
25	1' Lt. " " 326+68	" " " "	35.5	11.8	4.6	47.6	47.8	A-7	" 15
26	1' Rt. " " 372+08	" " " Grade	35.4	13.0	1.6	45.4	52.8	A-7	" 15
31	1' Lt. " " 414+88	" " " "	45.1	19.5	3.2	30.0	66.8	A-7	" 16
32	1' Lt. " " 425+08	" " " Fill	36.3	13.1	6.1	43.5	50.0	A-7	" 15
36	1' Lt. " " 457+42	" " " "	30.2	11.4	16.1	45.3	34.1	A-4	" 11
42	1' Rt. " " 456+00	" " " "	25.7	8.3	19.3	49.1	25.7	A-4	" 9

*These Tests represent Subgrade exclusive of areas where Classified Embankment Material was used. See Table 5 for this summary.

TABLE 5. SUMMARY OF TESTS OF CLASSIFIED EMBANKMENT MATERIAL IN PLACE FOR SN.F.A.P. No. 626 H(1) SN.F.A.P. No. 240 A(3)

Proj. Sample No.	Location	Depth Taken in Inches	Liquid Limit	Plastic Index	Mechanical Analysis Total % Passing 2"	1"	1/2"	#10	#200
7	6" Lt. Pavt. Sta. 268+00	12 to 42	14.9	3.1	100.0	100.0	92.1	52.3	15.3
8	" " " " 270+80	" " "	16.9	3.2	100.0	100.0	93.6	56.9	14.7
10	" " " " 281+60	" " "	15.6	2.1	100.0	100.0	94.2	54.8	12.9
11	" Rt. " " 283+60	" " "	15.4	2.5	100.0	100.0	91.5	47.1	10.0
12	" Lt. " " 284+60	" " "	19.4	5.2	100.0	100.0	93.8	56.5	22.2
14	" " " " 387+80	" " "	19.4	4.2	100.0	100.0	99.6	63.5	26.6
15	" Rt. " " 291+00	" " "	17.1	3.5	100.0	100.0	85.5	26.3	8.5
16	" Lt. " " 293+40	" " "	17.9	3.5	100.0	100.0	98.0	64.8	22.2
19	" " " " 320+88	" " "	16.9	4.2	100.0	100.0	93.6	56.8	14.9
20	" Rt. " " 324+68	" " "	18.8	4.8	100.0	100.0	98.3	73.3	37.9
21	" Lt. " " 330+00	" " "	18.5	5.2	100.0	100.0	97.4	64.9	27.7
22	" " " " 338+00	" " "	18.5	4.4	100.0	100.0	93.9	57.9	20.4
23	" Rt. " " 342+28	" " "	18.5	4.7	100.0	100.0	90.2	55.2	20.1
27	" " " " 377+00	" " "	13.2	2.0	100.0	100.0	88.2	53.1	12.7
28	" " " " 390+00	" " "	14.6	2.6	100.0	100.0	95.2	52.7	8.9
29	" " " " 400+00	" " "	17.7	3.9	100.0	100.0	95.7	56.3	14.6
30	" Lt. " " 407+00	" " "	Non Plastic		100.0	100.0	98.0	51.8	4.5
33	" Rt. " " 431+08	" " "	17.4	4.2	100.0	100.0	94.9	56.9	4.2
34	12"Lt. " " 440+08	" " "	16.4	4.8	100.0	100.0	93.0	55.2	12.9
35	6" Rt. " " 444+28	" " "	16.4	2.9	100.0	100.0	95.1	54.5	8.8

TABLE 6. SUMMARY OF TESTS OF CLASSIFIED EMBANKMENT MATERIAL FOR SN.F.A.P. No. 626-H(1) SN.F.A.P. No. 240-A(3)

Proj. Sample No.	Location	Depth Taken in Inches	Liquid Limit	Plastic Index	Mechanical Analysis Total % Passing 2"	1"	1/2"	#10	#200
1	Borrow Pit	12 to 42	Non Plastic		100.0	100.0	95.3	47.2	1.5
S-24	" "	" " "	"	"	100.0	100.0	89.7	42.5	1.0
34	" "	" " "	"	"	100.0	100.0	92.8	43.9	3.2
40	" "	" " "	"	"	100.0	100.0	96.2	54.4	5.4
41	" "	" " "	"	"	100.0	94.4	86.4	48.0	3.9

TABLE 7. SUMMARY OF TESTS OF BORROW PIT SOILS FOR SN.F.A.G.C.P. No. 240-A(2)

Proj. Sample No.	Depth Sampled in Inches	Liquid Limit	Plasticity Index	Proctor Compaction Max. Dry Wt. Lbs. Per Cu. Ft.	Optimum Moisture Content	Mechanical Analysis Percentage of Sand +0.05 mm	Silt 0.05-0.005 mm	Clay -0.005 mm
S-1	6 to 40	29.2	8.5	111.0	16.4	18.9	48.6	32.3
S-2	6 to 40	32.0	10.6	107.6	17.6	9.8	46.8	43.4
S-3	6 " 120	35.4	12.5	105.8	17.2	11.6	39.1	43.5
S-4	6 " 120	30.0	9.3	107.1	18.2	16.4	50.4	33.2
S-5	6 " 48	34.2	12.7	103.4	20.6	12.2	48.6	39.2
S-6	6 " 48	36.3	12.4	107.5	18.0	12.7	31.2	36.8
S-7	6 " 48	36.3	10.6	104.1	21.4	13.5	31.1	36.8
S-8	6 " 48	33.4	18.8	108.3	17.8	15.0	42.6	36.2
S-9	6 " 48	33.0	12.2	107.6	16.4	15.0	41.6	38.2
S-10	6 " 48	40.3	16.6	102.9	21.8	14.9	32.8	43.4
S-11	6 " 48	34.3	12.0	114.9	14.8	25.8	23.7	41.4
S-12	6 " 84	38.9	16.4	101.0	20.4	4.0	39.6	56.4
S-13	6 " 48	35.2	13.7	105.8	18.0	11.2	38.4	50.4
S-14	6 " 48	37.8	14.3	103.0	20.4	10.4	27.1	45.7

BERM AND UNDERDRAINAGE INVESTIGATIONS

On the left of Sta. 294+50 is located a sod gutter for disposal of pavement surface water. In an effort to check the movement of water through the subgrade one-half of this sod gutter was dug out for the width of the berm and to a depth of the thickness of the pavement slab. It was not possible to check the movement of the water, but it was observed that the bottom of the trench was damp one week after it was opened.

A trench of similar depth was dug through the berm on the left of Sta. 314+25 at the end of a contraction joint. Clear water ran from beneath the pavement slab when the trench was opened. The bottom of the trench was damp one week later.

On the left of Sta. 417+68 where a trench was cut through the berm, water was being worked from beneath a contraction joint by traffic one week later. Figure 4 shows this trench. This location is at the transverse joint where the greatest deflection was observed as shown by Table 3.

In order to check the functioning of the No. 46 size (3/4 in. to No. 4) porous backfill material that was used over the longitudinal roadway drainage pipe placed adjacent to classified embankment areas, the material was removed at one location down to the top of the pipe and more or less vertical faces of undisturbed material were exposed. Figure 5 shows one such vertical face on the left of Sta. 337+10. At this location it was observed that eight inches of heavily silted aggregate was in place immediately above the top of the pipe. Above this was approximately 20 in. of aggregate with a very small amount of silt. Above this was a layer, approximately 12 in. thick, composed of predominately silty material. The flow line of the ditch has been raised approximately six inches by silt depositing in it during the five month period that has elapsed since the contract work was completed on this project. While the porous backfill is apparently functioning satisfactorily at the present time, it is doubtful whether it will do so indefinitely with the continuance of the depositing of silt.

Excavation on the left of Sta. 290+20 showed the same general characteristics with regard to the silt deposited in and above No. 46 size porous backfill aggregate.

On the left of the center line between Sta. 431+0 and Sta. 445+0 it was planned to install roadway drainage pipe with No. 46 size porous backfill material adjacent to a classified embankment area. During the course of construction operations it became necessary to change the design to the following: The open joints in the line of pipe were wrapped with burlap and No. 6 size porous backfill aggregate was placed around the pipe and up to a point 6 in. above the top of the pipe. From here to the flow line of the ditch classified embankment material was used. An examination was made of one section, and it was found to be functioning satisfactorily with very little silt having filtered into the porous material. It was observed, however, that the flow line of the ditch was built up with deposited silt to a greater extent than in the two previous places that were examined where No. 46 size aggregate was used.

An examination was made of the outfall end of all pipe underdrains on this project, and they were all apparently doing the job for which they were intended after having been in place from seven to twelve months.

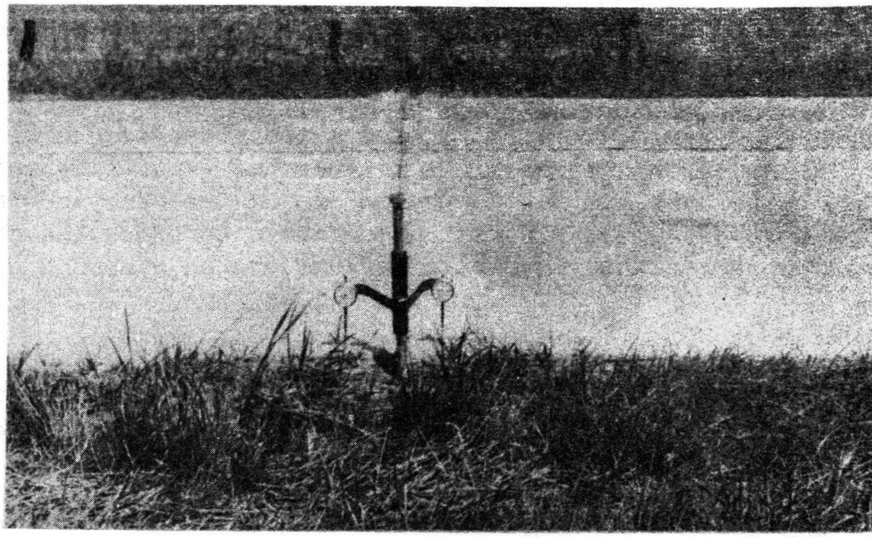

FIGURE 3. AMES DIAL GUAGE IN POSITION TO MEASURE SLAB DEFLECTIONS.

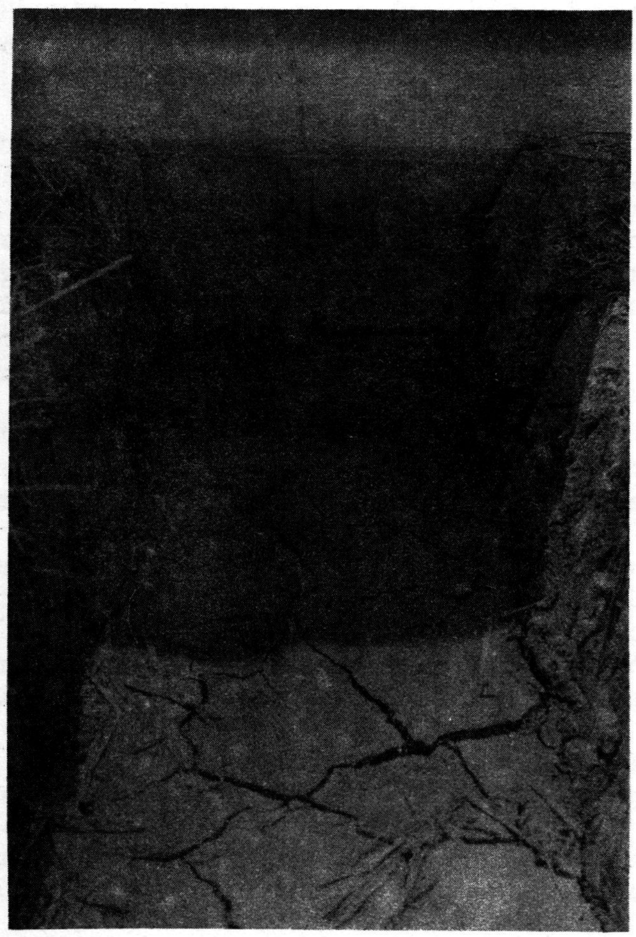

FIGURE 4. TRENCH CUT THROUGH BERM FROM PAVEMENT EDGE. WATER RAN FROM BENEATH THE PAVEMENT JOINT WHEN TRENCH WAS OPENED.

FIGURE 5. VERTICAL FACE OF #46 POROUS BACKFILL OVER PIPE. NOTE HEAVY SILT CONTENT FOR APPROXIMATELY 8" OVER PIPE.

CONCLUSIONS

As a result of the previously described tests and observations the following conclusions are reached and recommendations are made. It should be borne in mind that conditions were observed and tests made on only the two projects and the conclusions and recommendations may not be universally applicable. They will be presented in the reverse order from that in which the description was written.

When using gravel for porous backfill over pipe underdrainage, it is recommended that the size be not larger than No. 6 (3/8 in. to No. 8). Despite the high coefficient of permeability (187.5 ft. per day) that was obtained from tests of the No. 46 porous backfill material taken from immediately above the underdrainage pipe, heavy silting has occurred and will eventually reach a point where the functioning of the system will be greatly impaired if not entirely invalidated. It is further recommended that the open joints of the underdrainage pipe be wrapped with burlap to prevent the finer particles of the porous backfill material from being carried through these joints.

The plans for the plain slab project provided that the porous backfill material extend upward to the flow line of the ditch indicating that it was the intention to dispose of the surface run-off through the porous backfill material. Heavy silt deposits have, at least partially, sealed the flow line so that the surface water must travel longitudinally along the ditches for some distance to the nearest inlet or cross road culvert. The gradients of the ditches are not sufficient to prevent further depositing of silt during the longitudinal flow of the water. The build-up in the elevation of the flow line of the ditches previously described has resulted.

It is recommended that, especially where S.H.T.L. Classification 8 material is encountered, the top of the porous backfill material be at a point approximately six inches below the flow line of the ditch and that some type of impervious material be used above this point. The gradient of the ditch should be not less than 0.5 per cent and suitable vegetation should be provided to prevent erosion.

The advisability of using classified embankment material for subgrade treatment has been clearly demonstrated by the prevalence of pumping over areas where it was not used and the comparative freedom from pumping in areas so treated. Reference to Table 3, particularly to the last column, would seem to indicate that classified embankment material should be used in all roadway excavation areas where silt in excess of 25 per cent or more is encountered at subgrade elevation. The limitations regarding the use of excavated materials provided by the plans for the plain slab project should be altered to read "Excavated material, of which the grain size is 25 per cent or more between 0.05 mm. and 0.005 mm. shall be placed at least three feet below the pavement when used in embankment".

Based on the successful functioning of the classified embankment on this project up to the present time and on the mechanical analysis of samples taken from the project, it would appear that the fineness limitations of the specifications might be exceeded without causing harmful results. This statement should be further qualified by application only when bank run aggregate is used. No recommendation is made as to the ultimate fineness of material that might be used since opportunity was not afforded for any tests on which to base a statement.

The drainage difficulties caused by the fluffing and natural growth of the sod indicate, that on sections where edge curb is used, some other method of disposing of the water that accumulates on the surface of the pavement should be used in place of sod gutters. Because of the prevalence of pumping on the reinforced slab project where catch basins were spaced at approximately 350 ft. it is recommended that disposal units be placed at not to exceed 250 ft. to prevent a detrimental accumulation of water on the pavement surface.

By far, most of the pumping occurred at the contraction joints where the premolded or "ribbon" type was used. On the assumption that a more positive seal can be maintained it is recommended that the alternate provided by most plans, the impressed joint, be used. It is also recommended that a surface seal be required for all types of joints, since, regardless of the amount of care that is exercised during construction some variation will be obtained in the depth of the top of the joint material beneath the pavement surface.

The roughness of the plain slab pavement project at the present time proves the advisability of providing dowels and tie bars at transverse and longitudinal joints respectively.

It is hoped that the foregoing conclusions and recommendations may prove to be beneficial in avoiding on future projects the difficulties that were encountered on the projects under observation.

Very helpful assistance and cooperation was extended by The Highway Testing Laboratory during these investigations and appreciation is herewith expressed.

DISCUSSION ON INVESTIGATION OF CONCRETE PAVEMENT PUMPING

MR. H. E. MARSHALL, OHIO DEPARTMENT OF HIGHWAYS: The author's careful observation and analysis of the performance of the two adjoining sections of new pavement on U.S. Route 52 east of Portsmouth, Ohio are particularly valuable since they represent a study of a project made by the same individuals who were responsible for its construction. The intimate knowledge of the project which is gained by the engineer in charge of its construction can rarely be entirely built up by the outside investigator who attempts the study of the performance of a project at some time more or less remote from its completion.

A number of very important conclusions have been drawn by the author from his observation of this project of which the most gratifying is the marked improvement in the condition of the pavement constructed on a granular subbase over that constructed on the raw soil subgrade. The author's principal conclusions appear to be entirely justified on the basis of observations made on these two projects; however, there are several points which he makes that are not borne out by experience on other projects throughout Ohio. These points are briefly discussed below.

A note on the plans for this project provided that "Excavated material of which the grain size of 50 per cent or more is between 0.05 and 0.005 mm. (silt) shall be placed at least 3 ft. below the pavement when used in embankment." This note has been used on the plans for a number of projects in Ohio where a considerable quantity of material high in silt was likely to be encountered in excavation. The objection to the presence of these soils closer to the pavement than about 3 ft. is that they are frequently elastic and rubbery due to the prepomderance of the uniform sized silt particles and that they are very difficult to compact. Further these soils are very susceptible to frost heaving. The author proposes that the restriction on the soil used in the upper 3 ft. of embankment be extended to include all materials which contain more than 25 per cent silt. Study of Table 4 indicates that this restriction would exclude all materials similar to those taken from the soil subgrade on this project from the upper 3 ft. of embankment. Such a note would restrict the upper portion of all fills to either materials so granular or so high in clay as to have less than 25 per cent silt. This restriction in the writer's opinion would be neither justifiable nor desirable. Present day traffic does not warrant the use of selected predominantly granular material in depths as great as 3 ft. on the usual soil types encountered in Ohio and the use of non-granular soil so high in clay as to contain less than 25 per cent silt would afford a subbase no better and very probably somewhat worse than would be obtained if soils high in silt were used.

Referring now to the author's comments concerning the permissible quantity of fines in the classified embankment material, he states that "it would appear that the fineness limitation of the specification can be exceeded without causing harmful results. This statement should be further qualified by application only when bank run aggregate is used." The grading specification to which he refers is as follows:

Sieve Size	Per cent Passing		
	Grading 1	Grading 2	Grading 3
3 in.	100	100	
2 in.			100
1 in.	30-70	75-100	
½ in.		50- 90	
No. 10	0-25	25- 70	50-100
No. 200		0- 15	0- 15

Although the observations made on this project apparently justify the above general statement concerning the effect of soil fines slightly in excess of the 15 per cent limitation of the specification, this has not been found to be true throughout the State. It has been frequently observed that materials which contain the maximum or slightly in excess of the maximum permissible quantity of passing the No. 200 mesh sieve material are by no means as free draining as material for this course should be. In a number of instances free water has been observed ponded on top of these materials after they have been spread and compacted on the subgrade and prior to the placement of the pavement. Low permeability of the subbase is also indicated by the seepage of water from joints on the low sides of superelevated curves which the author reports on this project and has also been observed on a number of other projects where the classified embankment material was known to contain a considerable fraction of passing the No. 200 mesh soil fines. One of the most important functions of this type of subbase material is the speedy removal of water entering it either from the surface through joints and cracks or from the subgrade and the quantity of passing the No. 200 mesh soil fines has a very important effect on the permeability of the material. Recognizing this fact the Ohio Department of Highways in November of 1944 revised the specification for classified embankment material./1 The revision consisted principally of decreasing the quantity of fine sand and soil fines permitted in the course.

/1 - See Table 5, page 62 of this publication.