PAVEMENT DISPLACEMENT DUE TO WATER AND FROST

F H Eno

Ohio State University, Columbus, Ohio

In 1920 the writer began a series of observations upon pavement displacement Two concrete roads leading into Columbus, Ohio, were selected, and the worst soil condition upon either road was picked for trial The method for obtaining the displacement was discussed at some length The measurement from a piano wire base line was discarded as soon as suggested, for three very good reasons First, the inevitable sag of the wire, second, the interference with traffic, and, third, the impracticability of obtaining permanent, fixed supports for the wire that would not be disturbed by the traffic, frost, or other factors The precise level was discarded because of the slowness of operation, the danger of injuring a valuable instrument that would have to be carried back and forth over the highway so much, and the lack of such an instrument immediately at hand The semi-precise level was accepted as sufficiently accurate, when carefully used, to secure results well within any movement that would be injurious to the pavement

Permanent, unmovable bench marks were required, and for these, concrete piers 3½ feet long were set inside of two lengths of vitrified 15-inch sewer pipe set into the ground at one side of the right-of-way The sewer pipe prevented the soil from resting against the bench mark pier and lifting the concrete when frozen during the winter A cover was put over the pipe and sod thrown over that, so that frost never affected these bench marks

But few levels were ever taken on these two sites because the organization was disrupted in 1921 and nothing done until the co-operative scheme between the Ohio State University and the U S Bureau of Public Roads became active late in 1924

Beginning nominally on September 15, 1924, but actually not until December 6, 1924, the Co-operative Subsoil Survey was established As a part of this research, the observations upon pavement displacement were again actively begun in February, 1925 Thirty-one stations were established, from Washington County, on the southeast, to Geauga County in the northeastern portion of the State Each station was selected because of some peculiar soil or condition Most of the stations were upon brick or concrete pavements, four only were upon surface treated or bituminous macadam

Each station consisted of two or more lines of observation points at right angles to the center line of the road Usually there were three points in a line, one about six to eight inches in from each edge and one at the center line of the pavement At one station where a well-defined center joint occurred, due to the road having been built at one time and widened to double width later, each line contained four points In a number of cases where a transverse crack or a joint existed, a line of points was placed on either side of the crack or joint

In the case of brick or concrete pavements the level point was a conical depression cut in the pavement and made so as to hold a steel ball-bearing ball, 17 mm in diameter The level rod was held upon the ball, insuring a practically uniform bearing for the rod in all cases These proved very satisfactory

Upon the macadam roads three methods were used. plain 60-penny wire spikes, driven flush with the surface of the pavements, railroad spikes having a cone beveled into the head of the spike into which the ball could rest, and nipples of ⅜-inch gas pipe set flush in holes drilled into the pavement, the nipples set in cement mortar The latter method proved the most satisfactory for use

The bench marks used for these levels were either cones cut in the wings or abutments of concrete culverts or bridges or else railroad spikes driven into telegraph poles, leaving about 1½ inches of the head sticking out

Eight or ten of the stations have not produced satisfactory data due to several causes, such as the resurfacing of the pavement, removal and relaying of the brick, removal and replacing of the telegraph pole holding the bench mark, and the bungling in taking the levels

Due to the press of other work in the research, levels were not taken as frequently as would have been desirable It would have been much better if levels could have been taken every 15 to 20 days each year, at least from October through until the last of March This would have enabled us to establish more nearly when the pavement began to rise in the fall and at what time the spring breakup permitted it to begin dropping back again In the case of two or three pavements that attained their maximum elevation in the late spring or mid-summer it would have enabled us to determine how soon after excessive wet weather the pavement began to rise

Hard, deep sheet ice prevented the obtaining levels on two or three times during the winter This, however, can be avoided in future work by driving line posts on either side of the roadway and measuring from them to the level points This definite location will enable us to economically chop through ice to the point without injury to the point

From the study given to these levels, it is the writer's opinion that the observations should be continued through another winter and spring and that for a few stations at least more frequent levels should be taken from October to May, inclusive

A plan or drawing of the road surface to scale showing the location of the level points and of all cracks and joints covering a length of the road at least 20 feet each way from the level sections should be made this coming October, and a similar drawing in May or June, 1927

A comparison of these will show any injurious effect that may have occurred during two major movements of the pavements

The appended tabulations show the results at a few typical stations, giving the elevations with the downward movements marked (—) and the upward movements marked (+)

The maximum difference in elevation of the pavement from extreme high to extreme low is shown, also the variation from period to period between levels There are a few cases where error in observation is undoubtedly shown, but in the great majority of the readings the accuracy of this method of measuring displacement is evidenced in the remarkable agreement under normal conditions

In a number of stations where the road was tending toward destruction, the erratic changes in elevation between the various level points of the station preshadow the ultimate breaking up, this is shown particularly in stations Nos 72 and 60x of these special illustrated sheets and in stations 22 and 21y not shown in detail

Station No 127 gave some very peculiar results From July to September, 1925, the pavement dropped rather uniformly about 0 007 feet From September 28 to January 18, 1926, it rose from 0 037 feet to 0 041 feet along the north edge of the road, 0 047 feet along the center line and 0 098 feet along the south edge. From January 18 to March 10, 1926, the north edge fell 0 022 feet, the center line fell from 0 015 feet to 0 021 feet, while the south edge raised from 0 028 feet to 0 045 feet From March 10 to April 8th the north edge fell from 0 003 to 0 010 feet, the center line fell from 0 018 to 0 022 feet, while the south edge fell from 0.108 feet to 0 122 feet From April to May the road continued to fall slowly, but only from 0 002 feet to 0 007 feet The soil at this station is about 22 per cent sand, 35 per cent silt and 43 per cent clay There is a shallow weed grown ditch along the north side of the roadway, some 6 or 8 feet away, but one that did not seem to be always wet and full of water On the south side there is a well-shaped ditch some 24 to 30 inches below the road and 3 to 4 feet from its edge, and during these observations it was kept clean It nearly always showed water in the south ditch

In collecting soil moisture samples, water was nearly always found at 20 to 24 inches below the shoulder of the road The volumetric change of this soil is 20 9 per cent, rather above the normal This fact, with the other observed fact that the north ditch with less water was farther away from the edge of the road than the south ditch, probably accounts for the greater movement This is a concrete road The warping effect shown by the above movements are surely going to cause center and diagonal cracks before very long

In looking over the twenty stations discussed in this paper the average movement of the stations varied from 0 009 to 0 265 feet The average of all stations approximated 0 070 feet The maximum height of station as observed was reached at the following dates

1 station May 14, 1926
2 stations August 18-19, 1926
4 " in January 1925-1926
6 " March 11, 1926
7 " in February 1925-1926

A summary of the data is given in Table I, and a summary of the movements in comparison with soil characteristics in Table II A second comparison made by groups is shown in Table III

CONCLUSIONS

The following conclusions are drawn from a study of the data secured

1 No definite relationship appears to exist between the displacement of the pavement and the mechanical analysis of the soil, or with the various characteristics of the sub-soils The nearest possible chance of a relationship appears to be with capillary water Displacement seems to increase with increased capillarity

2 There appears to be greater irregularity of displacement of the pavement on bituminous and macadam roads than upon brick and concrete roads, also upon new roads than upon long used roads

3 The displacement is due both to moisture and freezing There is not sufficient data at present to evaluate the amount due to each cause In three cases at least the moisture caused the maximum movement, for they occurred in May and August Six times the minimum height occurred during February or March.

4 In Ohio under normal seasonal conditions, the displacement of the pavements is upward during the late fall and early winter and downward during the late winter, spring, summer and early fall Exceptions are noted in paragraph No 3 above.

5 The amount of displacement ranges from 0 025 to 0 265 of a foot, averaging about 0 063 feet in Ohio for the two seasons 1925 and 1926.

6 The rise and fall of the pavements upon long used roads were remarkably uniform for each year when the weather conditions fairly paralleled themselves The average difference at two widely separated periods upon 11 of the stations average less than 0 004 feet while upon 18 out of 20 stations compared, the average difference was 0 011 feet The wet, humid weather of August, 1926, made some rather marked differences in the movement of pavements in August of the two years 1925 and 1926

7. The maximum height of pavements occurred later in 1926 than in 1925, due evidently to different weather conditions The maximum height was reached later in the northern portion of the state in 1926 than in the southern portion.

8 This study seems to thrust one question prominently to the fore, viz what effect will this repeated rise and fall of pavements have upon non-flexible types of pavements? It seems certain that non-reinforced concrete slabs must be cracked and broken more and more each year due to the uneven stresses laid upon them by such movements as are indicated It is quite certain that there are more severe climates in the United States than in Ohio and that in more severe winters and wetter seasons greater movements of pavements will take place

TABLE I

SUMMARY OF LEVELS

August 23-24, 1926

Station	Route	Miles from town	Pavement	Levels from date to date	Max height	Min height	Difference	Average	Difference
17x	1	13 3 West of Zanesville	Brick	Feb 4, '25 to Aug 17, '26	Feb 21, 1925	Aug 25, '25	0 250 to 0 265	0 261	Diff Aug to Aug — 032 Diff Feb to Feb — 038
17x	1	13 3 West of Zanesville	Brick	Second year	Feb 9, 1926	Mar 25, '26	043 to 061	061	Mar to May less 001 Low to Low 018
17y	1	7 3 West of Zanesville	Brick	June 9, '25 to Aug 17, '26	Feb 9, 1926	Aug 25, '25	037 to 055	045	Diff Aug 1925 to Aug 1926 004
32	1	1 6 East of Cambridge	Brick	Feb 6, '25 to Aug 19, '26	Feb 6, 1925	Mar 25, '26	015 to 074	042	Diff Feb 1925 to Aug 1926 003 Diff Aug 1925 to Aug 1926 033
33	8	3 15 South of Cambridge	Concrete	Feb 5, '25 to Aug 17, '26	Feb 5, 1925	Mar 11 to 31, 1925	015 to 041	029	Diff Aug 1925 to Aug 1926 004
22	1	West Line Lloydsville	Brick	Feb 5, '25 to Aug 19, '26	Feb 5, 1925	Aug 19, '26	020 to 105	058	Diff Aug 1925 to Aug 1926 8 pts 014 lower 3 pts 007 higher
25	1	2 1 East Morristown	Brick	Feb 5, '25 to Aug 19, '26	Aug 19, 1926	Mar 13, '25	040 to 051	043	Diff Aug 1925 to Aug 1926 004 above high point
168	26	2 4 West of Marietta	Concrete	June 10, '25 to Aug 18, '26	May 14, 1926	June 10, '25	020 to 044	0315	Diff Aug 1925 to Aug 1926 025
119	26	3 5 West of Marietta	Concrete	June 10, '25 to Aug 18, '26	Aug 18, 1926	Nov 11, '25	004 to 013	009	Diff Aug. 1925 to Aug 1926 004
103-4	26	3 6 West of Marietta	Concrete	Feb 6, '25 to Aug 18, '26	Feb 6, 1925	Mar 26, '26	035 to 088	069	Diff Aug 1925 to Aug 1926 050
58	3	2 4 North of Amity	Brick	Feb 23, '25 to May 18, '26	Jan 18, 1926	Feb 23, '25	038 to 060	047	Diff Apr 1925 to Apr 1926 0066
000	10	1 2 East Hayesville	Brick	Feb 23, '25 to May 18, '26	Jan 18, 1926	May 18, '26	067 to 098	081	Diff Quite variable
127	5	12 0 East Wooster	Brick	Ju y 20, '25 to May 18, '26	Jan 18, 1926	Sept 28, '25	037 to 143	0735	Diff July 1925 to May 1926 002
60x	19	West Line Louisville	Brick	Feb 23, '25 to May 18, '26	Feb 23, 1925	May 18, '26	079 to 172	112	Diff Apr 1925 to Apr 1926 020
72	91	S Line Hudson	Brick	Feb 23, '25 to May 18, '26	Mar 11, 1926	May 19, '26	102 to 136	114	Diff Sept 1925 to May 1926 0005 Diff Apr 1925 to Apr 1926 003
76	15	2 4 Mi East of Huntsville	Macadam	Feb 24, '25 to May 19, '26	Mar 11, 1926	May 12, '25	043 to 115	070	Diff Irregular
85	85	3 15 Mi N E Chardon	Concrete	July 21, '25 to May 19, '26	Mar 11, 1926	May 19, '26	022 to 101	073	Diff Sept 1925 to May 1926 024
78	85	5 0 Mi W Chardon	Macadam	Feb 24, '25 to May 19, '26	Mar 11, 1926 Mar 20, 1925	Sept 29, '25	057 to 083	061	Diff Sept 1925 to May 1926 005
54	81	W Line Brecksville	Concrete	July 22, '25 to May 19, '26	Mar 11, 1926	Sept 29, '25	053 to 086	066	Diff Sept 1925 to May 1926 014
71	18	4 1 Mi East Medina	Concrete	Feb 25, '25 to May 19, '26	Mar 11, 1926	1926 all above 1925	019 to 081	060	Diff Apr 1925 to Apr 1926 012

TABLE II

SUMMARY OF LEVELS WITH ANALYSES

August 23–24, 1926

Soil No	Sand	Silt	Sus-pended clay	Total clay	Moisture			Volume change	Average changed elevation	Maxi-mum change	Date of maximum height	Difference—low to low
					Capillarity	Capacity	Equivalent					
17x	0 3	51 0	3 7	48 7	32 3	53 6	27 3	19 3	0 261	0 265	Feb 21, 1925	0 017
17y	5 4	43 2	1 7	51 4	21 5	38 4	14 8	11 9	045	055	Feb 9, 1926	0 004
32	5 1	23 9	7 2	71 0	24 4	39 7	17 7	12 4	042	074	Feb 6, 1925	0 003
33	0 3	29 1	6 6	70 6	36 0	50 6	27 6	24 0	029	041	Feb 5, 1925	0 004
22	24 3	30 2	1 1	45 5	29 0	40 5	20 4	6 5	058	105	Feb 5, 1925	Quite variable
25	26 6	15 7	2 8	57 7	27 6	40 3	18 0	12 5	043	051	Aug 19, 1926	0 004, high to high
168	28 2	23 5	2 9	48 3	24 1		16 8	18 5	0315	044	May 14, 1926	Aug , 1925, to Aug , 1926, 0 025
119	9 6	29 5	6 3	60 9	31 1	49 0	21 6	22 8	009	013	Aug 18, 1926	0 004
103–4	9 3	27 1	10 1	63 6	28 1	45 4	24 3	17 3	069	088	Feb 6, 1925	Aug , 1925, to Aug , 1926, 0 050
	11 3	29 9	8 2	58 8	30 3	46 7	23 1	17 7				
58	8 8	37 0	3 8	54 2	25 9	47 1	23 4	10 6	047	060	Jan 18, 1926	0 0066
59	17 2	39 1	5 5	43 7	26 4	38 6	19 6	15 7	081	098	Jan 18, 1926	Quite variable
127	22 2	34 9	9 3	42 9	29 1	51 4	21 2	20 9	0735	143	Jan 18, 1926	0 002
60x	19 8	36 6	6 8	43 6	29 3	42 9	21 3	14 8	112	172	Feb 23, 1925	0 020
72	16 9	26 2	6 7	56 9	31 6	43 2	20 4	21 2	114	136	Mar 11, 1926	Sept to May , 0 0005 Apr to Nov , 0 003
76	26 6	33 4	3 5	40 0	29 6	38 6	15 6	16 5	070	115	Mar 11, 1926	Irregular
85	26 1	21 4	5 5	52 4	28 9	45 7	22 1	21 7	073	101	Mar 11, 1926	Sept , 1925, t May, 1926, 0 024
78	20 6	24 6	4 0	54 8	29 4	40 3	18 7	14 9	061	083	Mar 11, 1926	Sept , 1925, to May, 1926, 0 005
54	12 2	19 1	1 3	68 7	29 4	45 2	22 4	21 3	066	086	Mar 11, 1926	Sept , 1925, to May, 1926, 0 014
71	15 1	26 4	4 1	58 5	25 4	45 1	21 6	25 4	060	081	Mar 11, 1926	Apr , 1925, to Apr , 1926, 0 012 May, 1925, to May, 1926, 0 012
113	18 4	27 6	4 9	54 0	30 6	39 2	20 7	18 3	068	146	Jan 9, 1925	Apr , 1924, to Aug , 1925, 0 006

TABLE III

COMPARISON OF GROUP LEVEL-CHANGES WITH OTHER PHENOMENA

August 24, 1926

Soil No	Diff in elev		Silt	Clay	Moisture			Vol change
	Average	Max			Capill	Capacity	Equiv	
119	0 009	0 013	29 5	60 9	31 1	49 0	21 6	22 8
33	029	041	29.1	70 6	36 0	50 6	27 6	24 0
168	0315	044	23.5	48 3	24 1		16 8	18 5
1 Aver	.023	033	27 4	59 9	30 4	50 ±	22 0	21 8
17y	045	053	43 2	51 4	21 5	38 4	14 8	11 9
32	042	074	23 9	71 0	24 4	39 7	17 7	12 4
25	043	051	15 7	57 7	27 6	40 3	18 0	12 5
58	047	060	37 0	54 2	25 9	47 1	23 4	10 3
2 Aver	044	060	30 0	58 5	24 8	41 4	18 5	11 8
71	060	081	26 4	58 5	25 4	45 1	21 6	25 4
54	066	086	19 1	68 7	29 2	45 2	22 4	21 3
78	061	083	24 6	54 8	29 4	40 3	18 7	14 9
103	069	088	28 5	61 2	29 2	46 0	23 7	17 5
3 Aver	064	0845	24 6	60 8	28 3	44 2	21 6	19 8
59	081	098	39 1	43 7	26 4	38 6	19 6	15 2
22	058	105	30 2	45 5	29 0	40 5	20 4	6 5
127	0735	143	34 9	42 9	29 1	51 4	21 2	20 9
76	070	115	33 4	40 0	29 6	38 6	15 6	16 5
85	073	101	21 4	52 4	28 9	45 7	22 1	21 7
4 Aver	071	1125	31 8	44 9	28 6	43 0	19 8	18 6
17x	106	116	51 0	48 7	32 3	53 6	27 3	19 3
60x	112	172	36 6	43 6	29 3	42 9	21 3	14 8
72	114	136	26 2	56 9	31 6	43 2	20 4	21 2
5 Aver	111	141	37 9	49 7	31 1	46 6	23 0	18 4

TABLE IV

STATION 17x, ROUTE 1

13 3 miles west of Zanesville

Date	A —W	Bn	Bc	Bs	C_1	C_2	C_3	D_1	D_2	D_3
1925										
Feb 4	8 953	9 163	9 212	9 111	9 214	9 243	9 124	9 484	9 535	9 323
Difference	+ *150*	+ *148*	+ *157*	+ *158*	+ *158*	+ *151*	+ *148*	+ *167*	+ *160*	+ *159*
Feb 21	9 103	9 311	9 369	9 269	9 372	9 394	9 272	9 651	9 695	9 482
Difference	− *215*	− *214*	− *217*	− *218*	− *219*	− *214*	− *215*	− *217*	− *214*	− *214*
Mar 11	8 888	9 097	9 152	9 051	9 153	9 180	9 057	9 434	9 481	9 268
Difference	+ *001*	− *003*	+ *004*	− *003*	− *002*	− *002*	− *005*	− *008*	− *000*	− *003*
Mar 31	8 889	9 094	9 156	9 048	9 151	9 178	9 052	9 426	9 481	9 265
Difference	− *013*	− *005*	− *013*	(− *009*)	− *052*	− *009*	− *009*	− *002*	− *005*	− *008*
Apr 4	8 876	9 089	9 143	9 039	9 099	9 169	9 043	9 424	9 476	9 257
Difference	+ *019*	+ *016*	+ *016*	+ *017*	+ *060*	+ *017*	+ *019*	+ *015*	+ *014*	+ *017*
Apr 22	8 895	9 105	9 159	9 056	9 159	9 186	9 062	9 439	9 490	9 274
Difference	− *013*	− *008*	− *014*	− *011*	− *008*	− *016*	− *011*	− *008*	− *013*	− *018*
Apr 25	8 882	9 097	9 145	9 045	9 151	9 170	9 051	9 431	9 477	9 256
Difference	− *038*	− *042*	− *034*	− *036*	− *038*	− *032*	− *036*	− *040*	− *034*	− *031*
June 6	8 844	9 055	9 111	9 009	9 113	9 138	9 015	9 391	9 443	9 225
Difference	+ *004*	+ *001*	+ *003*	+ *000*	+ *001*	+ *003*	+ *001*	+ *003*	+ *000*	+ *000*
June 9	8 848	9 056	9 114	9 009	9 114	9 141	9 016	9 394	9 443	9 225
Difference	− *006*	− *003*	− *007*	− *005*	− *007*	− *009*	− *008*	− *007*	− *006*	− *007*
Aug 25	8 842	9 053	9 107	9 004	9 107	9 132	9 008	9 387	9 437	9 218
Difference	− *002*	+ *004*	− *001*	+ *001*	+ *002*	− *000*	+ *005*	+ *004*	− *001*	+ *004*
Oct 17	8 840	9 057	9 106	9 005	9 109	9 132	9 013	9 391	9 436	9 222
Difference	+ *004*	+ *001*	+ *003*	+ *000*	+ *002*	+ *003*	+ *001*	+ *000*	+ *002*	+ *002*
Nov 25	8 844	9 058	9 109	9 005	9 111	9 135	9 014	9 391	9 438	9 224
Difference		+ *073*	+ *065*	+ *062*	+ *071*	+ *066*	+ *065*	+ *067*	+ *061*	+ *058*
1926										
Feb 9		9 131	9 174	9 067	9 132	9 201	9 079	9 458	9 499	9 282
Difference	+ *014*	− *061*	− *050*	− *046*	− *056*	− *051*	− *051*	− *053*	− *044*	− *043*
Mar 25	8 858	9 070	9 124	9 021	9 126	9 150	9 028	9 405	9 455	9 239
Difference	+ *001*	+ *000*	+ *001*	+ *003*	+ *000*	+ *001*	+ *000*	+ *001*	− *000*	− *001*
May 13	8 859	9 070	9 125	9 024	9 126	9 151	9 028	9 406	9 455	9 238
Difference	+ *006*	+ *010*	+ *006*	+ *009*	+ *009*	+ *008*	+ *013*	+ *012*	+ *034*	+ *010*
Aug 17	8 865	9 080	9 131	9 033	9 135	9 159	9 041	9 418	9 489	9 248
Difference										
Maximum difference	*263*	*258*	*263*	*265*	*265*	*262*	*264*	*264*	*259*	*264*

TABLE V

STATION 17y, ROUTE 1

7 3 miles west of Zanesville

Date	Aw	B_1	B_2	B_3	C_1	C_2	C_3	D_1	D_2	D_3	E_1	E_2
1925												
Feb 21	0 481	0 795	0 904	0 725	0 841	0 956	0 795	1 496	1 614	1 475	1 619	1 686
Difference	− *002*	− *002*	− *004*	+ *002*	− *006*	− *001*	− *000*	− *003*	− *005*	− *004*	− *004*	− *002*
Apr 4	0 479	0 793	0 900	0 727	0 835	0 955	0 795	1 493	1 609	1 471	1 615	1 684
Difference	*000*	+ *006*	+ *004*	− *004*	+ *008*	+ *002*	+ *002*	+ *002*	+ *000*	− *003*	+ *003*	− *001*
Apr 25	0 479	0 799	0 904	0 723	0 843	0 957	0 797	1 495	1 609	1 468	1 618	1 683
Difference	+ *006*	− *007*	− *002*	+ *002*	− *012*	+ *001*	− *001*	− *005*	+ *003*	+ *007*	− *005*	+ *007*
June 6	0 485	0 792	0 902	0 725	0 831	0 958	0 796	1 490	1 612	1 475	1 613	1 690
Difference	+ *003*	+ *002*	+ *005*	+ *002*	+ *009*	+ *002*	+ *005*	+ *005*	+ *007*	+ *005*	+ *004*	+ *002*
June 9	0 488	0 794	0 907	0 727	0 840	0 960	0 801	1 495	1 619	1 480	1 617	1 692
Difference	− *007*	− *005*	− *005*	− *006*	− *009*	− *003*	− *008*	− *007*	− *006*	− *009*	− *006*	− *006*
Aug 25	0 481	0 789	0 902	0 721	0 831	0 957	0 793	1 488	1 613	1 471	1 611	1 686
Difference	*000*	*000*	*000*	− *004*	+ *003*	+ *001*	+ *001*	− *004*	− *000*	− *003*	+ *002*	− *002*
Oct 17	0 481	0 789	0 902	0 717	0 834	0 958	0 794	1 484	1 613	1 468	1 613	1 684
Difference	*000*	+ *005*	+ *001*	+ *010*	+ *005*	+ *000*	+ *002*	+ *007*	− *001*	+ *003*	+ *000*	+ *001*
Nov 25	0 481	0 794	0 903	0 727	0 839	0 958	0 796	1 491	1 612	1 471	1 613	1 685
Difference		+ *034*	+ *043*	+ *045*	+ *030*	+ *044*	+ *050*	+ *032*	+ *043*	+ *046*	+ *035*	+ *048*
1926												
Feb 9		0 828	0 946	0 772	0 869	1 002	0 846	1 523	1 655	1 517	1 648	1 733
Difference		− *029*	− *040*	− *042*	− *025*	− *040*	− *044*	− *023*	− *038*	− *038*	− *024*	
Mar 25	lost	0 799	0 906	0 730	0 844	0 962	0 802	1 500	1 617	1 479	1 624	1 692
Difference		− *003*	− *001*	− *003*	− *001*	− *002*	− *003*	− *003*	− *000*	− *003*	− *002*	− *001*
May 13	lost	0 796	0 905	0 727	0 843	0 960	0 799	1 497	1 617	1 476	1 622	1 691
Difference		− *006*	− *001*	− *001*	− *006*	− *000*	− *000*	− *004*	− *001*	− *001*	− *006*	− *001*
Aug 17	lost	0 790	0 904	0 726	0 837	0 998	0 799	1 493	1 616	1 475	1 616	1 690
Max Diff		*039*	*046*	*055*	*038*	*043*	*053*	*039*	*046*	*049*	*035*	*050*
Diff Aug to Aug		+ *001*	+ *002*	+ *005*	+ *006*	*000*	+ *006*	+ *005*	+ *003*	+ *004*	+ *005*	+ *004*

TABLE VI

STATION 33, ROUTE 8

3 15 miles south of Cambridge

Date	A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3	D_1	D_2	D_3
1925												
Feb 5	9 316	9 367	9 250	9 310	9 369	9 266	0 139	0 170	0 037	0 152	0 132	0 058
Difference	− *038*	− *033*	− *039*	− *023*	− *028*	− *041*	− *012*	− *015*	− *032*	− *021*	− *016*	− *027*
Mar 11	9 278	9 334	9 211	9 287	9 341	9 225	0 127	0 155	0 005	0 131	0 166	0 031
Difference	+ *010*	+ *015*	+ *008*	+ *009*	+ *011*	+ *006*	− *010*	+ *002*	+ *001*	− *005*	− *002*	− *004*
Mar 31	9 289	9 349	9 219	9 296	9 352	9 231	0 117	0 157	0 006	0 126	0 164	0 027
Difference	+ *004*	+ *005*	+ *006*	+ *008*	+ *009*	+ *006*	+ *015*	+ *009*	+ *006*	+ *014*	+ *012*	+ *011*
Apr 22	9 292	9 354	9 225	9 304	9 361	9 237	0 132	0 166	0 012	0 140	0 176	0 038
Difference	+ *003*	+ *002*	+ *006*	+ *002*	+ *002*	+ *003*	+ *010*	+ *011*	+ *009*	+ *011*	+ *007*	+ *005*
June 9	9 295	9 356	9 231	9 306	9 363	9 240	0 142	0 177	0 021	0 151	0 183	0 043
Difference	− *004*	− *008*	− *003*	+ *002*	− *010*	− *000*	− *003*	− *011*	− *003*	− *003*	− *006*	− *000*
Aug 20	9 291	9 348	9 228	9 308	9 353	9 240	0 139	0 166	0 018	0 148	0 177	0 043
Difference	− *006*	− *001*	− *003*	− *010*	− *001*	− *007*	− *014*	− *010*	− *006*	− *014*	− *009*	− *009*
1926												
Feb 8	Ice											
Mar 25	9 285	9 347	9 225	9 298	9 352	9 233	0 125	0 156	0 012	0 134	0 168	0 034
Difference	+ *003*	+ *001*	+ *001*	+ *003*	+ *003*	+ *002*	+ *008*	+ *008*	+ *004*	+ *012*	+ *007*	+ *005*
May 14	9 288	9 348	9 226	9 301	9 355	9 235	0 133	0 164	0 016	0 146	0 175	0 039
Difference	+ *001*	− *002*	+ *001*	+ *001*	− *003*	*000*	*000*	− *004*	− *002*	*000*	− *004*	− *001*
Aug 19	9 289	9 346	9 227	9 302	9 352	9 235	0 133	0 160	0 014	Cor broken	0 171	0 038
Maximum difference	*038*	*033*	*039*	*023*	*028*	*041*	*022*	*015*	*032*	*026* Av	*018* *029*	*031*
Difference Mar, 1925 to May, 1926	*000*	− *001*	+ *007*	+ *005*	+ *003*	+ *004*	+ *016*	+ *007*	+ *010*	+ *020* Av	+ *011* + *008*	+ *012*

TABLE VII

STATION 33, ROUTE 8

3 15 miles south of Cambridge

Date	A	A	A	B	B	B	C	C	C	D	D	D
1925												
Feb 5	9 316	9 367	9 250	9 310	9 369	9 266	0 139	0 170	0 037	0 152	0 182	0 058
Difference	− *038*	− *033*	− *039*	− *023*	− *028*	− *041*	− *012*	− *015*	− *032*	− *021*	− *016*	− *027*
Mar 11	9 278	9 334	9 211	9 287	9 341	9 225	0 127	0 155	0 005	0 131	0 166	0 031
Difference	+ *010*	+ *015*	+ *008*	+ *009*	+ *011*	+ *006*	− *010*	+ *002*	+ *001*	− *005*	− *002*	− *004*
Mar 31	9 288	9 349	9 219	9 296	9 352	9 231	0 117	0 157	0 006	0 126	0 164	0 027
Difference	+ *004*	+ *005*	+ *006*	+ *008*	+ *009*	+ *006*	+ *015*	+ *009*	+ *006*	+ *014*	+ *012*	+ *011*
Apr 22	9 292	9 354	9 225	9 304	9 361	9 237	0 132	0 166	0 012	0 140	0 176	0 038
Difference	+ *003*	+ *002*	+ *006*	+ *002*	+ *002*	+ *003*	+ *010*	+ *011*	+ *009*	+ *011*	+ *007*	+ *005*
June 9	9 295	9 356	9 231	9 306	9 363	9 240	0 142	0 177	0 021	0 151	0 183	0 043
Difference	− *004*	− *008*	− *003*	+ *002*	− *010*	− *000*	− *003*	− *011*	− *003*	− *003*	− *006*	− *000*
Aug 20	9 291	9 348	9 228	9 308	9 353	9 240	0 139	0 166	0 018	0 148	0 177	0 043
Difference	− *006*	− *001*	− *003*	− *010*	− *001*	− *007*	− *014*	− *010*	− *006*	− *014*	− *009*	− *009*
1926												
Feb 8	Ice											
Mar 25	9 285	9 347	9.225	9 298	9 352	9 233	0 125	0 156	0 012	0 134	0 168	0 034
Difference	+ *003*	+ *001*	+ *001*	+ *003*	+ *003*	+ *002*	+ *008*	+ *008*	+ *012*	+ *004*	+ *007*	+ *005*
May 14	9 288	9 348	9 226	9 301	9 355	9 235	0 133	0 164	0 016	0 146	0 175	0 039
Difference	+ *001*	− *002*	+ *001*	+ *001*	− *003*	*000*	*000*	− *004*	− *002*	*000*	− *004*	− *001*
Aug 19	9 289	9 346	9 227	9 302	9 352	9 235	0 133	0 160	0 014	Cor broken	0 171	0 038
Maximum difference	*038*	*033*	*039*	*023*	*028*	*041*	*022*	*015*	*032*	*026* Av	*018* *029*	*031*
Difference Mar, 1925 to May, 1926	*000*	− *001*	+ *007*	+ *005*	+ *003*	+ *004*	+ *016*	+ *007*	+ *010*	+ *020* Av	+ *011* + *008*	+ *012*

TABLE VIII
STATION 168, ROUTE 26
25 miles west of Zanesville

Date	A_1	A_2	A_3	B_1	B_2	B_3	
1925							
June 10	0 204	0 154	0 011	0 135	0 108	9 986	
Difference	*+ 001*	*000*	*+ 007*	*− 004*	*− 004*	*− 002*	
Aug 20	0 205	0 154	0 018	0 131	0 104	9 994	
Difference	*000*	*+ 006*	*+ 008*	*− 005*	*+ 002*	*+ 002*	
Nov 11	0 205	0 160	0 026	0 126	0 106	9 998	
Difference	*+ 024*	*+ 028*	*+ 029*	*+ 020*	*+ 023*	*+ 023*	
1926							
(Probably Feb 10)	0 229 Ice	0 188 Ice	0 055 Ice	0 146 Ice	0 129 Ice	0 021 Ice	Core-lip 0 158
Difference	*− 001*	*− 002*	*− 003*	*− 001*	*− 001*	*− 002*	*− 002*
Mar 26	0 228	0 186	0 052	0 145	0 128	0 019	0 156
Difference	*± 003*	*+ 002*	*+ 003*	*+ 001*	*+ 001*	*+ 006*	*+ 003*
May 14	0 231	0 188	0 055	0 146	0 129	0 025	0 159
Difference	*− 004*	*− 003*	*000*	*− 004*	*− 002*	*− 002*	*− 002*
Aug 18	0 227	0 185	0 055	0 142	0 127	0 023	0 157
Maximum difference	*027*	*034*	*044*	*020*	*025*	*039*	*Av 0 0315*

TABLE IX
STATION 60x, ROUTE 19
West limits of Louisville, Ohio

Date	A_1	A_2	A_3	B_1	B_2	B_3
1925						
Feb 23	8 168	8 487	8 275	8 064	8 310	8 233
Difference	*− 065*	*− 114*	*− 105*	*− 052*	*− 082*	*− 066*
Mar 19	8 103	8 373	8 170	8 012	8 228	8 167
Difference	*+ 004*	*+ 009*	*− 022*	*+ 003*	*+ 008*	*+ 001*
Apr 7	8 107	8 382	8 148	8 015	8 236	8 168
Difference	*− 008*	*− 009*	*− 009*	*− 002*	*− 007*	*− 008*
May 11	8 099	8 373	8 139	8 013	8 229	8 160
Difference	*− 004*	*− 003*	*− 002*	*− 010*	*− 004*	*− 007*
July 20	8 095	8 370	8 127	8 003	8 225	8 153
Difference	*− 005*	*− 006*	*− 004*	*− 003*	*− 004*	*− 001*
Sept 28	8 090	8 364	8 123	8 000	8 221	8 152
Difference	*+ 078*	*+ 097*	*+ 078*	*+ 094*		
1926						
Jan 18	8 168	8 461	8 201	8 094	Too dark	
Difference	*− 047*	*− 056*	*− 072*	*− 076*		
Mar 10	8 121	8 405	8 129	8 018	8 238	8 177
Difference	*− 020*	*− 045*	*− 006*	*− 033*	*− 020*	*− 029*
Apr 8	8 101	8 360	8 123	7 985	8 218	8 148
Difference	*− 038*	*− 014*	*− 020*	..		
May 18	8 063	8 346	8 103	Relaid		
Maximum difference, 1925	*078*	*123*	*152*	*064*	*088*	*081*
Maximum difference, 1926	*105*	*115*	*098*	*Difference only to May 18*		

TABLE X

STATION 72, ROUTE 91

South line of Hudson, Ohio

Date	Ac	B_1	B_2	B_3	C_1	C_2	C_3	D_1	D_2	D_3
1925										
Feb 23	7 390	6 646	6 730	6 830	6 631	6 701	6 798	5 761	5 887	5 961
Difference	− *039*	− *006*	− *018*	− *033*	+ *008*	− *014*	− *029*	− *029*	− *043*	− *053*
Mar 19	7 351	6 640	6 712	6 797	6 639	6 687	6 769	5 732	5 844	5 908
Difference	+ *002*	− *007*	− *011*	− *010*	− *011*	− *010*	− *011*	− *006*	− *008*	− *007*
Apr 8	7 353	6 633	6 701	6 787	6 628	6 677	6 758	5 726	5 836	5 901
Difference	*000*	− *003*	− *000*	− *005*	− *007*	− *003*	− *004*	− *006*	+ *001*	− *006*
May 12	7 353	6 630	6 701	6 782	6 621	6 674	6 754	5 720	5 837	5 895
Difference	+ *010*	+ *009*	+ *009*	+ *012*	+ *006*	+ *010*	+ *011*	+ *018*	+ *010*	+ *027*
July 21	7 363	6 639	6 710	6 794	6 627	6 684	6 765	5 738	5 847	5 922
Difference	− *013*	− *005*	− *014*	− *014*	− *004*	− *013*	− *013*	− *016*	− *014*	− *013*
Sept 29	7 350	6 634	6 696	6 780	6 623	6 671	6 752	5 722	5 833	5 909
Difference	+ *051*	+ *052*	+ *047*	+ *050*	+ *047*	+ *055*	+ *050*	+ *067*	+ *064*	+ *060*
1926										
Jan 19	7 401	6 686	6 749	6 830	6 676	6 726	6 802	5 789	5 897	5 969
Difference	+ *063*	+ *055*	+ *050*	+ *052*	+ *051*	+ *049*	+ *053*	+ *060*	+ *067*	+ *076*
Mar 11	7 464	6 741	6 799	6 882	6 727	6 775	6 855	5 849	5 964	6 045
Difference	− *108*	− *106*	− *101*	− *098*	− *102*	− *100*	− *100*	− *119*	− *123*	− *215*
Apr 9	7 356	6 635	6 698	6 784	6 625	6 675	6 755	5 730	5 841	5 830
Difference	− *004*	− *003*	− *003*	− *004*	− *003*	− *005*	− *005*	− *007*	− *009*	
May 19	7 352	6 632	6 695	6 780	6 622	6 670	6 750	5 723	5 832	*5 940
Max diff 1925	*040*	*016*	*034*	*050*	*010*	*030*	*046*	*041*	*054*	*066*
Max diff 1926	*112*	*109*	*104*	*102*	*105*	*105*	*105*	*126*	*132*	
Difference Apr to Apr	+ *003*	+ *002*	− *003*	− *003*	− *003*	− *002*	− *003*	+ *004*	+ *005*	− *071*

* Broken up

SUB-BASE TESTS ON ROUTE 26, WASHINGTON COUNTY, OHIO

F H Eno

Ohio State University, Columbus, Ohio

In October and November, 1924, a series of sub-base experimental sections was constructed upon the Marietta-Athens road known as State Aid Route 26 These sections varied from 100 to 200 feet in length The sub-base construction was 2, 4 or 6 inches in thickness, and was constructed of sand, gravel, slag or an admixture of 5 per cent Portland cement, by volume, mixed with the top 2, 4 or 6 inches of the natural sub-base Adjoining sections of the natural soil base were left at either end of the three divisions of this test work for comparison The sand and gravel were dredged out of