No.L-7 OBSERVATIONS OF THE TEXAS STATE HIGHWAY DEPARTMENT ON THE SUBSEQUENT EFFECTS OF THE UNIFORMITY AND THE NON-UNIFORMITY OF FOUNDATION SOIL-TYPES ON PAVEMENTS; AND ALSO THE EFFECTS OF UNIFORMITY AND OF NON-UNIFORMITY OF MOISTURE CONTENT FLUCTUATIONS IN SOIL FOUNDATIONS OF HIGH VOLUMETRIC CHANGE

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A section of concrete pavement 1500 feet in length, laid during the winter and spring of 1931, on a clay soil foundation of high volumetric change, has been under close observation, since its completion. It was laid directly after a long period of slow rains. The soil foundation was perhaps expanded to approximately its maximum at the time pavement was laid. During a drought the following summer, the pavement receded in elevation as much as 0.4 of a foot at its edges, and 0.2 of a foot along its center-line. After slow winter rains of 1931-32, the pavement regained its original elevation, as shown in Fig. 1.

A bench mark set on a railroad spike driven into the trunk of a 6 inch diameter Bois D'Arc tree at edge of right-of-way, fluctuates in elevation, with the wet and dry seasons, as much as 0.3 of a foot, as shown at right side of Fig. 1.

Fig. 2 shows the profile of this section of pavement at the top of the figure. At the middle of the figure the elevation of the center-line of pavement at the time of its completion in May 1931, are represented by the horizontal line marked "0.00". The fluctuations that had occurred by August 1931 are represented by the lower line (at middle of sheet). It is noted that in May 1932, the pavement had practically regained its original elevations. The same data is shown for the edges of pavement in the lower part of the figure. Note the pavement did not fluctuate on the small hill at the right as much as elsewhere, on account of rain water running off more rapidly than at other places.

During droughts, the shoulder soil cracks open to depths of 10 feet or more, allowing dry winds and sun to rob the soil of its moisture. Fig. 3 shows one of these cracks 6 inches in width.

Also, during droughts, the shoulder soil recedes to 5 or 6 inches below the top of edge of pavement, as shown in Fig. 4. If these shoulders are built up with soil during summer dry weather, it will be that much too high after the winter rains.

Table I shows the soil "Constants" of this foundation, at different depths below the bottom of pavement, and also the moisture content of the soil samples at the time they were taken on March 1, 1934.

TABLE I

SAMPLES TAKEN FROM UNDISTURBED SOIL AT EDGE OF R/W 55' RIGHT OF STATION 497+50 ON HIGHWAY 14, IN NAVARRO COUNTY, MARCH 1, 1934.

Depth Below Surf. of Ground	LLL	LPL	PI	SL	LS from LLL	SR	FME	CME	Class	Soil Moisture Contents March '34
0"	84	25	59	9	27	1.97	41	56	A-7	33
2'	80	28	52	9	26	2.01	42	68	A-7	45
4'	79	26	53	10	25	2.02	45	74	A-7	39
6'	82	27	55	8	27	1.99	40	75	A-7	46
8'	87	28	59	10	27	1.94	39	71	A-7	39
10'	83	29	55	8	26	2.00	40	70	A-7	35
12'	83	28	55	10	26	1.91	47	67	A-7	38
14'	85	28	57	10	26	1.91	38	72	A-7	35
16'	97	28	69	11	28	2.00	48	82	A-7	34
18'	100	26	74	9	29	2.08	44	87	A-7	33

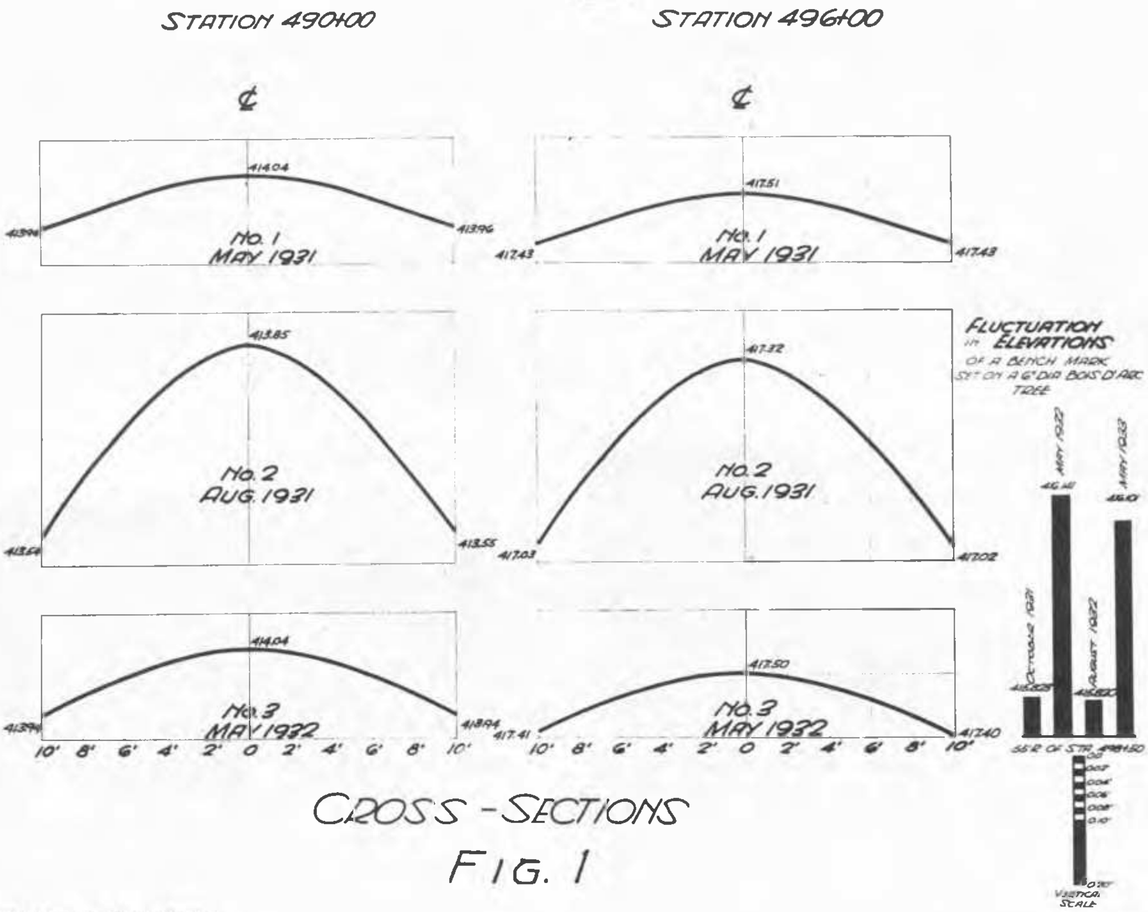
The concrete pavement shown in the foreground of Fig. 5 is the north end of the 1500 foot section that has been under observation and is designated as Project "A", which, as stated was laid on very wet and highly expanded native clay soil. Project "B", shown in the background, was laid shortly afterward on an 8 inch depth sand subgrade treatment. The white line across the pavement marks the junction expansion joint of the two projects "A" and "B".

Although the pavement of Project "A" has fluctuated in elevation as much as 0.4 of a foot as stated, the type of the soil and its moisture content fluctuation throughout its entire length have always been so uniform it all moves uniformly down and up with the seasons and no uncomfortable riding irregularities have ever developed. The same may be said for Project "B". However, at the end of the unusual drought of the summer of 1934, the slab-end of Project "A" had receded in elevation 2½ inches more than that of Project "B", at the expansion joint between the two, as shown in Fig. 6.

After the following winter and spring slow rains of 1934-35, the two slab-ends at this junction expansion joint were back to practically the same elevation, as shown in Fig. 7.

At the time the picture of Fig. 7 was taken the shoulder soil of the north slab of Project "A" was cut down to 2 inches below the bottom of edge of the slab. Free water immediately trickled from the soil under the pavement at many places, as illustrated in Fig. 8. No more moisture was found in the foundation soil at the expansion joints than elsewhere.

The data of Fig. 5, 6, 7, and 8 show one effect of an abrupt change in the subgrade soil-type, on the riding surface of a pavement.



CROSS - SECTIONS

FIG. 1

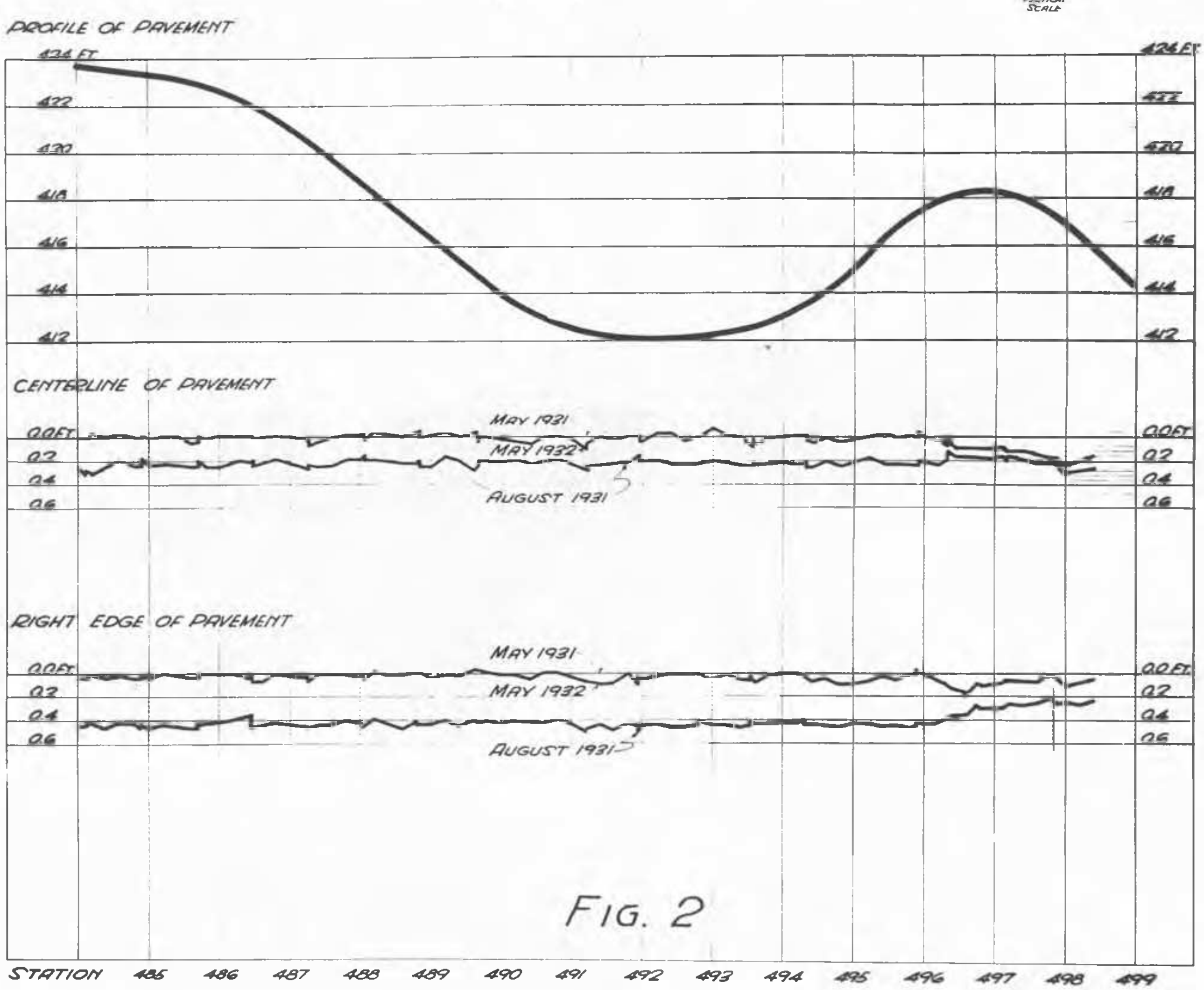


FIG. 2

FIG. 3

FIG. 4

FIG. 5

FIG. 6

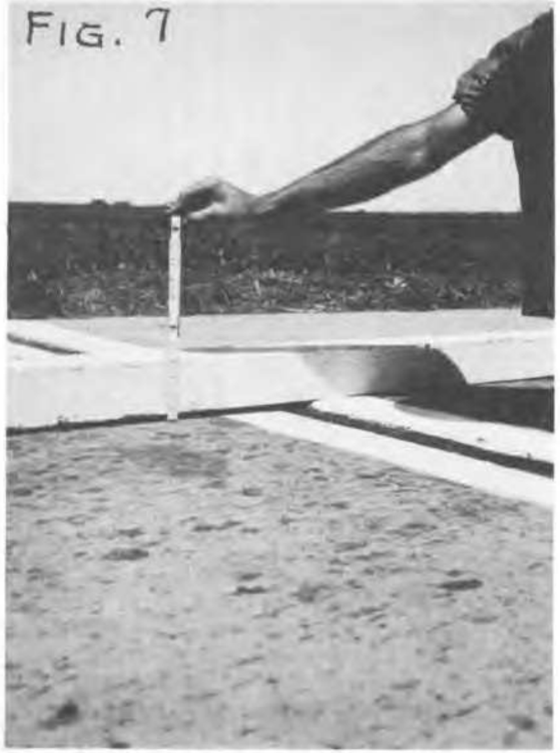


FIG. 7

FIG. 8

FIG. 9

In order to gain information on the depth (below the ground surface) that movements in the soil foundation extend, 9 steel rods, ranging from 2 to 20 feet in length were each lowered into a casing pipe set to the different depths in the natural undisturbed soil near the previously described fluctuating bench mark which was at the edge of right-of-way, opposite approximately Station 497. The rods were then driven into the ground at the bottom of the casings, to depths of 12 inches, as illustrated in Fig. 9. The elevations of the rod tops were all accurately determined at the time they were set in August 1934, during a prolonged drought . Elevations were again taken in January 1935, March 1935, June 1935, and April 1936, as shown in Table II.

TABLE II

SHOWING ELEVATIONS OF THE TOPS OF RODS OF DIFFERENT LENGTH SET IN THE GROUND 50 FEET R. OF STA. 497+50, NAVARRO COUNTY

Depth rod extends below ground surf.	Elevations of Rod Tops on different dates Aug. 1934	Jan. 1935	March 1935	June 1935	April 1936
1'	420.500	420.525	420.525	420.670	420.735
2'	420.500	420.515	420.515	420.580	420.615
3'	420.500	420.493	420.493	420.510	420.510
4'	420.500	420.530	420.530	420.530	420.505
5'	420.500	420.519	420.519	420.520	420.505
10'	420.500	420.519	420.519	420.510	420.500
15'	420.500	420.511	420.511	420.510	420.490
20'	420.500	420.511	420.511	420.510	420.500
25'	420.500	420.500	420.500	420.500	420.500

The moisture contents of the soil at the site of these rods have been determined from time to time, and are shown in Table III.

TABLE III

MOISTURE CONTENT SOIL SAMPLES FROM 50 R. OF STA. 497+50, IN NAVARRO COUNTY, NEAR RODS SET AT DIFFERENT DEPTHS IN NATURAL GROUND

Depth of sample below surf. of ground	Soil moisture contents on the dates as shown March 1934	Nov. 1934	June 1935	April 1936
0"	33	15		10
1'			37	
2'	45	20	36	34
3'			39	
4'	39	21	39	28
5'			36	
6'	46	22	37	27
7'			39	
8'	39	22	40	25
9'			37	
10'	35	22	37	24
11'			30	
12'	38	24	28	25
13'			27	
14'	35	27	29	27
15'			29	
16'	34	27	29	25
17'			29	
18'	33	29	29	27

Observations were also made on two other sections of a highway in Navarro County, laid in August 1930, on practically the same type of soil foundation as heretofore described for Project "A". Section "C" was laid on relatively dry soil, and Section "D" was placed on a soil foundation three weeks after it had been thoroughly wetted by jetting and ponding.

Fig. 10 shows that by August 1931, the soil foundation of Section "C", which was dry when pavement was laid on it in 1930, had irregularly gained moisture and expanded (more at expansion joints and cracks than elsewhere) and raised the pavement accordingly.

While on Section "C", by August 1931, the soil foundation which had been saturated with water just prior to the laying of pavement in 1930, had irregularly lost moisture, shrunk in volume and lowered the elevations of the pavement. It is noted that the pavement did not recede at expansion joints as much as elsewhere (perhaps due to leakage of rain water from time to time, through the joints to the underlying soil), as shown in Fig. 11.

Fig. 5, 6, 7 and 8 illustrate subsequent effects of uniformity and of non-uniformity of foundation soil-types on the riding surface of pavement; Fig. 1, 2, 3, 4, 9, 10 and 11 illustrate subsequent effects of uniformity and of non-uniformity of moisture content fluctuations in soil foundation of high volumetric change.

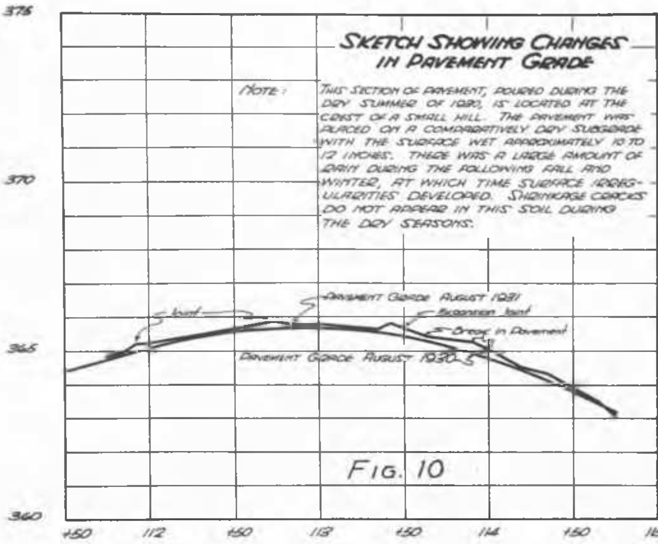


FIG. 10

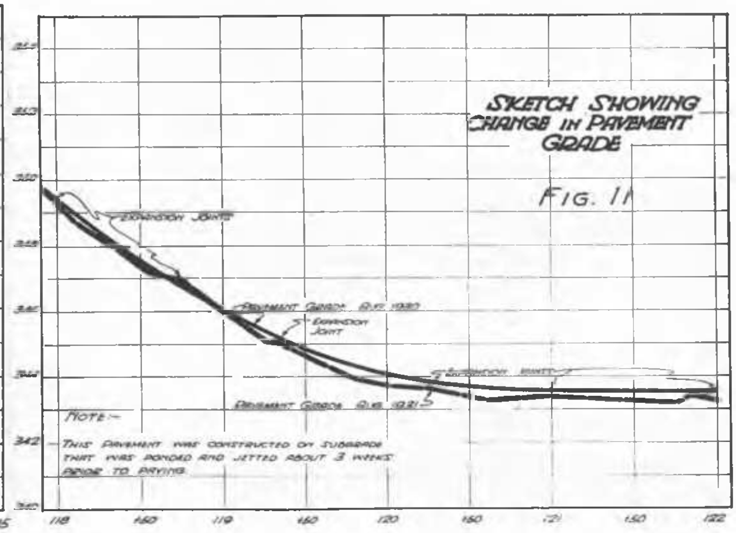


FIG. 11

No. L-8

PROGRESS REPORT ON AN INVESTIGATION OF FROST ACTION IN SOILS

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Investigations on Frost Action in Soils are in progress at the Graduate School of Engineering, Harvard University. The experiments are carried on in a cabinet which is in a constant temperature cold room. The cold room is approximately 7 ft square by $6\frac{1}{2}$ ft high, and is insulated on all sides with 4 in of corkboard. Fig. 1 shows a cross-section of this room and cabinet. The freezing cabinet is built with four removable drawers for samples, each drawer having a sample compartment 10 in square by 24 in deep. Provision is made for maintaining any desired water level in each sample and for observing the behavior during the test. The entire freezing cabinet, including the drawers, is also insulated with 4 in of corkboard.

In order to obtain the necessary differential in temperature between the room and the freezing cabinet and to maintain a required accuracy in temperature control, two separate and independently controlled refrigerating units are used. The temperature in the room is usually maintained at $+9^{\circ}$C which provides a satisfactory temperature gradient in the samples. The temperature in the cabinet can be lowered to -18°C with the present installation and controlled to $\pm \frac{1}{2}^{\circ}$C.

Equipment for temperature measurements. Foremost among the difficulties encountered in the preliminary tests was that of knowing exactly, at any time, the temperatures prevailing within the samples. After trying various methods the following one suggested by Dr. J. F. Downie Smith, Instructor at the Graduate School of Engineering, Harvard University, described in his article "Thermal Conductivity of Liquids", published in Industrial and Engineering Chemistry, Vol. 22, page 1246, Nov., 1930, was adopted and found very satisfactory. The essential parts of the set-up are shown in Fig. 2. A 6-volt storage battery supplies current to the slide wire resistance R3. In a circuit in series with this resistance are resistances R1 and R2. R1 is a plug in type resistance and may be set at 99 ohms, 999 ohms or 9999 ohms to give the desired ratio with R2 which is set at 1 ohm. The total voltage drop across R1 and R2 is given by a millivoltmeter with a guaranteed accuracy of 0.50 per cent of full range value, and having two scale ranges, 0 to 500 and 0 to 150 millivolts. From this the voltage drop across R2 is obtained. R2 is in circuit with a galvanometer, reversing switch, and thermocouples. With the circuit closed the current supplied through slide wire R3 is varied until the galvanometer shows no deflection and the millivoltmeter is read. The reversing switches in each circuit are then changed, the galvanometer brought to zero and the reading again taken, thus balancing out thermal effects. Copper and Constantan were used in making the thermocouples. The junction points were carefully spot welded in a carbon arc using borax for a flux, then each one was tested to see that the weld was satisfactory. Melting ice point is used for the temperature of the constant temperature junction. All equipment except the constant junction and thermocouples is located outside of the cold room. This set-up, when accurately calibrated, permits temperature determinations within $\pm 0.05^{\circ}$C to be made easily.