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Load-Carrying Capacity of Frost-Affected Roads

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Load-Carrying Capacity of Frost-Affected Roads

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Department of Maintenance

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Superintendent of Operation and Maintenance
New York State Department of Public Works

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Contents

Report of Committee on Load-Carrying Capacity Of Roads as Affected by Frost Action

C. L. MOTL, Maintenance Engineer,
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THIS report includes additional information furnished by Oregon, new information furnished by Nebraska and Indiana. In the five reports issued previous to this one and covering activity of the committee during 1948, 1949, 1950, 1951, and 1952, information was furnished by Iowa, Michigan, Minnesota, New Hampshire, New York, North Dakota, Ohio and Oregon. It is believed that information gathered is adequate to provide a basis on which a final and all inclusive report of the committee can be prepared.

The purpose and objective of the project is to determine the loss of strength that may occur in highways after being subjected to freezing and thawing action. While the accumulation of a large volume of bearing-value data is necessarily a part of this research project, it is not the purpose or objective of this project to suggest these for use in road design, since many other factors also affect the bearing values of subgrade materials.

Additional information submitted by Oregon in this report supports the information previously submitted by that state, indicating a substantial loss of bearing value due to frost action. At some locations the loss of bearing value was as much as 80 percent, and it would appear that a part of this loss might be attributed to the serious damaging of the road surface structure by overloads before the plate-bearing tests were applied. Oregon data further support the findings of other cooperating states, except one, which indicate loss of bearing value in road subgrade soils due to frost action.

New information submitted by Nebraska, gathered from 240 test sites, discloses losses from 0 to 65 percent, with an average of 29.4 percent. This state reports, however, that during the cycle year in which the tests were taken there was no severe winter weather, and therefore, the frost penetration was moderate. This state will continue testing through another cycle year, with the expectation that frost penetration will be greater than has been experienced heretofore.

Attention is called to load-bearing data accumulated in Canada by the Province of Ontario during the past 5 years and summarized in the report "Proceedings of the Sixth Canadian Soil Mechanics Conference, Winnipeg, December 15 & 16, 1952—Technical Memorandum No. 27." This report likewise discloses loss of carrying capacity due to frost action.

To those who may be interested in reports submitted by this committee during previous years, attention is called to the following HRB publications: Proceedings, Vol. 28; Research Report 10-D; Bulletin 40; and Bulletin 54.

Nebraska

A STUDY of the load-carrying capacity of bituminous-surfaced roads was initiated by the Nebraska Department of Roads and Irrigation in May of 1952. A full schedule of plate-bearing tests was started in August of that year. This progress report contains data accumulated between August 26, 1952, and October 15, 1953. The investigation has been confined to the use of "quickie" plate-bearing tests because of the large number of sites required to obtain a true representation of all the situations encountered in this state. Limitations of personnel precluded the possibility of an enlarged investigation.

The test apparatus consists of a tandem drive, six-wheel International tractor and semitrailer. The trailer (Figure 1) was fabricated from an old gasoline-transport running gear, using two 12 WF 72 steel beams. The two 24-foot beams were spaced at 32 inches, center to center, and 10-foot sections of reinforced concrete were poured at each end integrally with the steel beams. The concrete slab extended to a height of 8 inches above the tops of the beams and to a width of 7.5 feet. A tool box was placed in the center 4-foot section, and under this an 8 WF 32 beam was mounted on rollers on

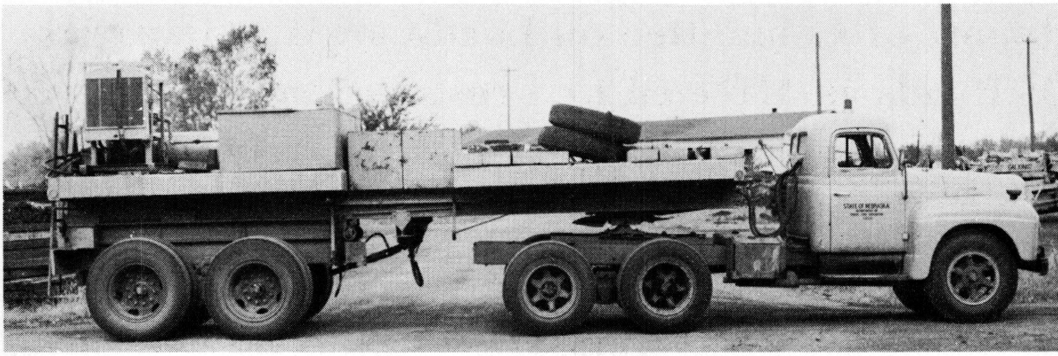

Figure 1. Tractor-trailer unit used for Nebraska plate-bearing tests.

the bottom flanges of the two 12 WF 72 beams. The ram assembly, (Figure 2) which was patterned after that used by Minnesota, was attached to the 8-inch beam. Figure 3 shows the assembly in traveling position. Originally an aluminum beam supported on three legs was built to hold the Ames dial indicator, but this proved to be unstable in strong winds, and a setup using four legs, the two rear legs of which were adjustable, was built. After much experimentation a method of supplying sand to the test site was developed which has proven satisfactory. The bottom of a 5-gallon paint can was cut out and a large funnel was attached in its place. A lid with overhanging edges was coated with No. 2 Permatex on the inside and fastened to the container with springs. The container was mounted on the side of the trailer and a hose was attached to convey the sand to the road surface. The fine sand used is oven dried and then passed through a No. 4 and No. 10 sieve in order to break up any aggregations in the material. Any small aggregations which remain after the screening operation readily break up during the process of smoothing the sand under the bearing plate.

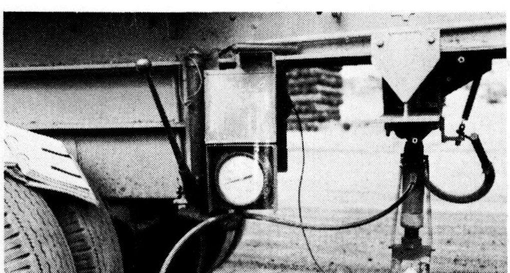

Figure 2. Jack and ram assembly in testing position.

It is believed that the moisture content of the subgrade and the temperature of the mat and subgrade exert considerable influence on the bearing value, hence data on these two factors are being accumulated. The moisture samples are obtained from the subgrade immediately under the base course. A pneumatic drill (Figure 4) with a 2-inch concrete core drill is used to go through the mat and base course, after which a soil auger is used to obtain the sample. Temperatures of the subgrade are then taken in this hole with a pyrometer. A record of time intervals between increments of load application is being kept to determine the relationship, if any, between time and deflection.

Originally, 325 test sites were set up and complete data pertinent to the construction and maintenance of the highways at these sites were obtained. Approximately 85 sites were subsequently eliminated, either because of duplication of existing conditions or because they were located at a dangerous point with respect to traffic. The location of the test sites throughout the state is shown in Figure 5. All test sites were plainly marked with yellow traffic paint to insure that repetitive tests would be made at the same location. A complete cycle of tests over the entire state takes approximately five weeks to complete and the schedule setup is rigidly followed, except when severe weather conditions or equipment breakdowns prevent its accomplishment.

The crew consists of three men: an

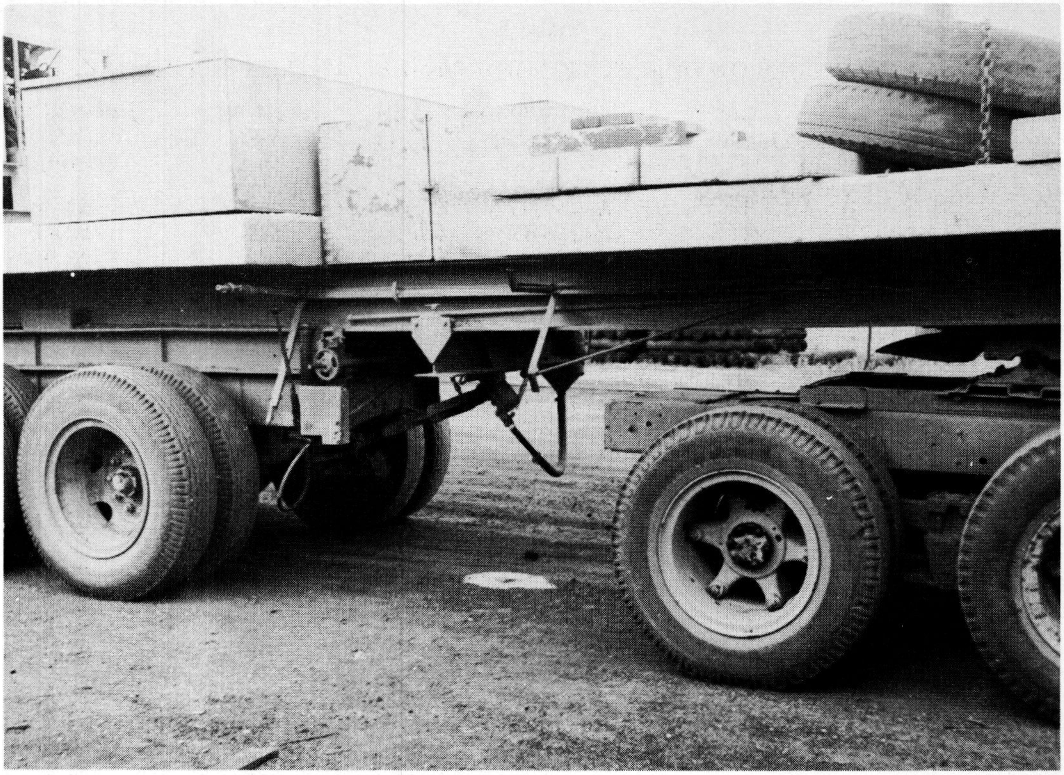

Figure 3. Jack and ram assembly in traveling position.

engineer who conducts the test and also drives the truck, a man to obtain the moisture sample and temperatures and a flagman. It has been found that a flagman not only provides much better control of traffic than any combination of signs, barricades and flags, but also saves time in the test operation.

The analysis of the data thus far accumulated has proceeded at a relatively slow pace due to the shortage of competent personnel. Statistical analysis has been run on the results obtained up to February 1953. This has included seven factors which were felt to have the greatest influence on bearing, namely: thickness of mat, thickness of base course, subgrade soil type, subgrade moisture, temperature of the air, day of the year, and the traffic count. Graphs showing some of these relations are included in this report. No correlation could be found between the air temperature and the bearing values obtained. Figure 6 shows the bearing strength of the flexible-type pavements, based on a statistical analysis, as compared to the thickness of surfacing, to the soil type and the moisture in the subgrade. Table 1 shows the loss in the bearing strength of the flexible pavement at each test site, together with other pertinent data. The losses range from 0 to 65 percent with

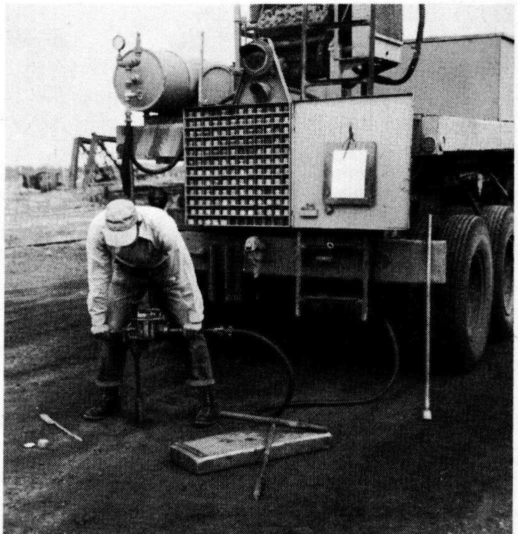

Figure 4. Moisture-sampling equipment.

TABLE 1

BEARING AT 0.2 INCHES OF DEFLECTION IN 1,000-LB., 12-INCH-DIAMETER PLATE

Site	Mat Inches	Base Inches	Subgrade (BPR Class)	Fall 1952	Spring 1953	Percent of Fall Bearing
307	5	2	A-7-6(17)	11	5	45.5
26	3	2	A-7-6(19)	13	7	53.8
33	3	2	A-7-6(12)	16	7	43.8
55	1	4	A-7-6(14)	12	7	58.3
138	3	5 Clay Surf	A-6(8)	20	7	35.0
22	5	5	A-6(12)	15	8	53.3
47	6½	2½	A-6(10)	13	8	61.5
56	4	5	A-6(11)	15	8	53.3
29	1½	7½	A-6(10)	13	9	69.2
35	3	3	A-6(12)	15	9	60.0
42	4	3½	A-7-6(11)	24	9	37.5
44	4	4	A-7-6(20)	14	9	64.3
46	4½	5	A-7-6(10)	13	9	69.2
133	4	2	A-7-6(20)	17	9	52.9
205	6	-	A-7-6(16)	20	9	45.0
208	2¾	3¾	A-6(10)	15	9	60.0
60	2¾	4	A-6(9)	16	9	56.3
7	3¼	3½	A-7-6(11)	13	10	76.9
20	3	4	A-6(10)	19	10	52.6
27	1	2	A-7-6(15)	14	10	71.4
34	3	3	A-6(12)	17	10	58.8
48	3	3	A-7-6(11)	15	10	66.7
53	4	5	A-7-6(11)	19	10	52.6
66	1	2½	A-4(8)	17	10	58.8
92	9	3	A-4(3)	17	10	58.8
131	2¼	2¾	A-6(10)	13	10	76.9
181	2½	3	A-4(7)	20	10	50.0
204	3	5 Rock	A-7-6(16)	13	10	76.9
207	4	3¼	A-7-6(18)	17	10	58.8
211	1	4	A-6(11)	19	10	52.6
263	2¾	2¾	A-4(8)	17	10	58.8
300	6	-	A-6(11)	13	10	76.9
228	4	-	A-6(10)	17	11	64.7
3	1¼	2¼	A-7-6(12)	23	11	47.8
24	2¾	1¾	A-6(7)	16	11	68.8
31	3	3	A-6(9)	17	11	64.7
68	3	-	A-4(8)	20	11	55.0
78	5½	-	A-4(4)	15	11	73.3
86	4½	2 Clay Surf	A-2-4(0)	25	11	44.0
119	4	-	A-6(6)	25	11	44.0
188	7	2	A-7-6(15)	15	11	73.3
304	3	5	A-7-6(15)	17	11	64.7
305	4	3	A-7-6(15)	17	11	64.7
308	6	2	A-6(12)	16	11	68.8
262	3½	2½	A-4(8)	20	12	60.0
2	1¼	2¼	A-6(10)	25	12	48.0
4	4	3	A-7-6(12)	22	12	54.5
30	3	2	A-6(9)	16	12	75.0
58	7	3	A-6(11)	21	12	57.1
206	6	-	A-7-6(19)	21	12	57.1
216	5	-	A-4(8)	19	12	63.2

Table 1(continued)

Site	Mat Inches	Base Inches	Subgrade (BPR Class)	Fall 1954	Spring 1953	Percent of Fall Bearing
223	4	4	A-6(11)	21	12	57.1
251A	1	1½	A-6(8)	19	12	63.2
251B	1	1	A-6(9)	15	12	80.0
254	3	-	A-4(3)	17	12	70.6
268	2½	3½ Rock	A-4(4)	23	12	52.2
278	5	1½ Rock	A-4(8)	28	12	42.9
282	3½	4½ Clay Surf	A-2-4(0)	25	12	48.0
253	3	4 Gravel	A-6(9)	19	13	68.4
183	3	2	A-6(10)	14	13	92.9
215	5	-	A-7-6(13)	15	13	86.7
1	1½	2	A-6(10)	19	13	68.4
6	7¼	2¼	A-7-6(11)	29	13	44.8
8	4	3	A-7-6(13)	21	13	61.9
12	2½	4½	A-6(10)	18	13	72.2
16	7	5 Sand	A-4(6)	26	13	50.0
23	1½	3	A-6(10)	19	13	68.4
40	3	3	A-4(4)	24	13	54.2
45	3½	3½	A-6(9)	20	13	65.0
62	5¼	3	A-7-6(11)	21	13	61.9
67	2½	2¾	A-4(8)	25	13	52.0
71	4½	3¾	A-4(4)	21	13	61.9
96	5	2½	A-2-4(0)	25	13	52.0
130	1½	3	A-7-6(20)	17	13	76.5
137	3	-	A-4(8)	21	13	61.9
147	3	3 Rock	A-6(8)	21	13	61.9
154	2½	1½	A-7-6(9)	20	13	65.0
179	3	-	a-4(8)	17	13	76.5
276	5½	2	A-6(10)	18	13	72.2
9	4	3	A-4(8)	23	14	56.0
28	1½	4½	A-6(10)	19	14	73.7
36	3	6	A-6(11)	24	14	58.3
39	3½	4	A-4(5)	21	14	66.7
41	3½	4½	A-6(9)	24	14	58.3
49	6	6 Sand	A-7-6(11)	19	14	73.7
57	5	3½	A-6(10)	23	14	56.0
83	1	-	A-4(5)	23	14	56.0
156	2½	1½	A-6(9)	19	14	73.7
160	5½	-	A-2-4(0)	20	14	70.0
163	2	2	A-3(0)	28	14	50.0
178	3	3	A-2-4(0)	19	14	73.7
198	1	3	A-7-6(11)	21	14	66.7
200	4	4	A-7-6(14)	19	14	73.7
274	7½	-	A-6(8)	28	14	50.0
288	3	1½	A-4(7)	28	14	50.0
21	4	3	A-4(8)	23	15	65.2
32	3	4	A-7-6(12)	18	15	83.3
61	5½	12 Sand	A-6(12)	19	15	78.9
145	3¼	-	A-6(6)	23	15	65.2
222	6½	2½	A-7-6(14)	19	15	78.9
233	4	5	A-6(8)	29	15	51.7
236	3	3 Rock	A-7-6(11)	30	15	50.0
250	5	-	A-2-4(0)	26	15	57.7
289	3½	4	A-4(8)	37	15	40.5
186	4	3	A-7-6(14)	20	15	75.0

Table 1 (continued)

Site	Mat Inches	Base Inches	Subgrade (BPR Class)	Fall 1952	Spring 1953	Percent of Fall Bearing
229	2¼	1½	A-4(8)	17	15	88.2
43	4	5	A-4(2)	25	15	60.0
230	1	3	A-6(10)	16	16	100.0
13	2	5½ Soil Cem	A-7-6(11)	20	16	80.0
54	1	4	A-7-6(15)	23	16	69.6
69	2¼	3	A-6(8)	27	16	59.3
214	6	2	A-6(11)	26	16	61.5
226	5	-	A-4(8)	22	16	72.7
227	4	-	A-4(8)	25	16	64.0
231	1	3	A-4(8)	21	16	76.2
246	2½	2	A-4(8)	21	16	76.2
260	1	2	A-6(8)	20	16	80.0
271	4	13½ Gravel	A-7-6(12)	40	16	40.0
298	2½	2½	A-4(8)	17	16	94.1
299	4	3	A-4(8)	17	16	94.1
64	4½	3½	A-4(8)	25	17	68.0
70	4	4	A-6(11)	25	17	68.0
81	¾	-	A-4(2)	21	17	81.0
89	6	3 Clay Surf	A-2-4(0)	27	17	63.0
104	5	-	A-2-4(0)	23	17	73.9
149	7	1	A-6(7)	21	17	81.0
162	2½	-	A-2-4(0)	23	17	73.9
169	2	7½	A-3(0)	23	17	73.9
193	4½	-	A-4(4)	21	17	81.0
217	5	5	A-7-6(12)	25	17	68.0
229A	2	6 Rock	A-6(10)	21	17	81.0
247	2¼	-	A-4(7)	23	17	73.9
257	4	6	A-4(4)	27	17	63.0
301	2½	3½	A-4(6)	21	17	81.0
302	4	3½	A-4(8)	20	17	85.0
189	6	-	A-4(4)	21	17	81.0
221	5	2	A-7-6(15)	19	17	89.5
174	3	6 Sand	A-4(1)	19	17	89.5
252	1½	2¾	A-6(8)	17	17	100.0
255	6	3	A-4(8)	30	17	56.7
251	2½	2½	A-6(8)	26	17	65.4
38	3	3	A-4(8)	28	18	64.3
52	3½	4½	A-6(10)	27	18	66.7
82	1	2¼	A-2-4(0)	30	18	60.0
116	3	-	A-4(4)	24	18	75.0
151	2	-	A-4(2)	27	18	66.7
157	4	1	A-4(7)	23	18	78.3
158	2	1	A-2-4(0)	29	18	62.1
184	5	2	A-4(8)	26	18	69.2
192	6	3	A-6(8)	26	18	69.2
224	7	3	A-6(10)	26	18	69.2
228A	2	5 Rock	A-6(9)	28	18	64.3
264	4½	2½	A-4(8)	29	18	62.1
134	4	3	A-4(7)	23	18	78.3
244	2¾	3	A-6(9)	24	18	75.0
120	4½	2½	A-6(11)	26	18	69.2
170	5	-	A-3(0)	25	18	72.0

Table 1 (continued)

Site	Mat Inches	Base Inches	Subgrade (BPR Class)	Fall 1952	Spring 1953	Percent of Fall Bearing
213	4½	3	A-7-6(17)	22	18	81.8
218	3	5	A-7-6(14)	24	18	75.0
11	2	4	A-4(7)	33	19	57.6
17	6	7 Sand	A-4(8)	29	19	65.5
99	5½	-	A-4(4)	26	19	73.1
105	6	-	A-2-4(0)	27	19	70.4
112	4	-	A-2-4(0)	23	19	82.6
164	7	-	A-2-4(0)	25	19	76.0
165	2	5 Clay Surf	A-2-4(0)	25	19	76.0
238	2¾	4½ Rock	A-6(8)	26	19	73.1
128	3¾	-	A-4(5)	25	19	76.0
129	2	2½	A-7-6(19)	30	19	63.3
123	3	-	A-4(6)	31	20	64.5
125	3½	5 Rock	A-4(8)	34	20	58.8
126	4½	4 Rock	A-4(8)	33	20	60.6
280	2	-	A-4(8)	22	20	90.9
281	4½	-	A-4(2)	22	20	90.9
287	5	2	A-4(8)	26	20	76.9
291	5¼	-	A-4(4)	28	20	71.4
191	5½	7½	A-4(5)	21	20	95.2
245	3½	2	A-4(3)	28	21	75.0
243	6	3	A-6(8)	30	21	70.0
19	5	-	A-4(1)	26	21	80.8
37	3	6	A-4(8)	41	21	51.2
101	5	5 Clay Surf	A-3(0)	21	21	100.0
144	4	3 Rock	A-4(8)	37	21	56.8
249	3½	3½	A-4(8)	32	21	65.6
279	3	-	A-4(4)	24	21	87.5
241	2¼	2¼	A-4(8)	22	21	95.5
187	6	-	A-2-4(0)	31	21	67.7
296	1	3	A-4(4)	24	21	87.5
293	3½	2½	A-6(10)	30	21	70.0
146	4	-	A-4(8)	33	22	66.7
228C	4	5 Rock	A-4(8)	31	22	71.0
228D	2	7 Rock	A-6(9)	27	22	81.5
15	2	6	A-7-6(15)	27	23	85.2
73	4	4	A-4(8)	27	23	85.2
79	2¾	-	A-2-4(0)	37	23	62.2
150	1	11	A-4(2)	29	23	79.3
303	2½	3	A-7-6(14)	32	23	71.9
172	3	6 Clay Surf	A-2-4(0)	32	23	71.9
18	2½	5½ Soil Cem	A-4(5)	30	24	80.0
176	6	-	A-2-4(0)	32	24	75.0
212	1	4	A-4(5)	34	24	70.6
259	2¼	1½	A-4(2)	29	24	82.3
286	2½	3¼	A-4(2)	37	24	64.9
240	5	2	A-4(8)	27	24	88.9
14	3	6 Soil Cem	A-7-6(14)	41	25	61.0
74	2½	2	A-2-4(0)	29	25	86.2
100	4	5 Clay Surf	A-3(0)	29	25	86.2
155	4	3	A-6(8)	33	25	75.8
229C	2	5 Rock	A-6(9)	26	25	96.2

Table 1 (continued)

Site	Mat Inches	Base Inches	Subgrade (BPR Class)	Fall 1952	Spring 1953	Percent of Fall Bearing
234	5	2	A-6(8)	31	25	80.6
168	2	5 Soil Cem	A-2-4(0)	31	25	80.6
115	5	-	A-3(0)	27	25	92.6
235	2	2	A-4(8)	27	25	92.6
295	5	-	A-2-4(0)	32	26	81.3
306	2½	5½ Soil Cem	A-7-6(13)	38	26	68.4
258	2	-	A-2-4(0)	39	26	66.7
110	5	-	A-2-4(0)	29	26	89.7
148	3½	-	A-2-4(0)	33	27	81.8
173	7	-	A-2-4(0)	32	27	84.4
88	3½	3½ Clay Surf	A-3(0)	33	27	81.8
161	2½	4½	A-3(0)	36	27	75.0
108	3	5 Clay Surf	A-2-4(0)	33	27	81.8
297	1	2½	A-4(4)	29	28	96.6
261	3	6	A-4(1)	30	28	93.3
141	3	-	A-4(0)	39	28	71.8
102	10	-	A-3(0)	31	29	93.5
118	3	1½	A-4(0)	37	29	78.4
196	1	3	A-2-4(0)	33	29	87.9
103	3	-	A-3(0)	42	30	71.4
202	3	6 Soil Cem	A-4(2)	34	30	88.2
273	4	14 Gravel	A-6(9)	50	30	60.0
93	7	3½	A-2-4(0)	44	30	68.2
113	9	-	A-2-4(0)	33	30	90.9
143	3	4 Rock	A-4(8)	37	30	81.1
175	4	-	A-3(0)	35	31	88.6
285	4	-	A-2-4(0)	45	31	68.9
87	3	-	A-2-4(0)	44	32	72.7
90	3½	2	A-4(2)	41	32	78.0
272	3½	14 Gravel	A-4(2)	40	32	80.0
294	4	-	A-3(0)	47	32	68.1
201	2½	6½ Soil Cem	A-7-6(12)	33	33	100.0
127	3½	2½ Rock	A-4(1)	36	33	91.7
10	4	3	A-2-4(0)	40	33	82.5
97	6	-	A-2-4(0)	39	33	84.6
106	6	5 Clay Surf	A-2-4(0)	37	33	89.2
194	6	4	A-2-4(0)	35	34	97.1
95	2	4	A-2-4(0)	43	35	81.4
94	6	-	A-2-4(0)	47	35	74.5
277	3	-	A-2-4(0)	34	36	105.9
248	3½	-	A-2-4(0)	37	36	70.3
283	4	-	A-2-4(0)	50	36	72.0
269	3	6	A-1-b(0)	50	37	74.0
136	2	-	A-4(3)	45	41	91.1
265	3	2	A-4(1)	60	41	68.3
197	7	-	A-2-4(0)	55	45	81.8
266	1	2½	A-4(1)	60	50	83.3
25	3	1½	A-2-4(0)	68	51	75.0
121	3	-	A-4(8)	60	60	100.0

NOTE: All values over 40,000 Lb. are extrapolated.

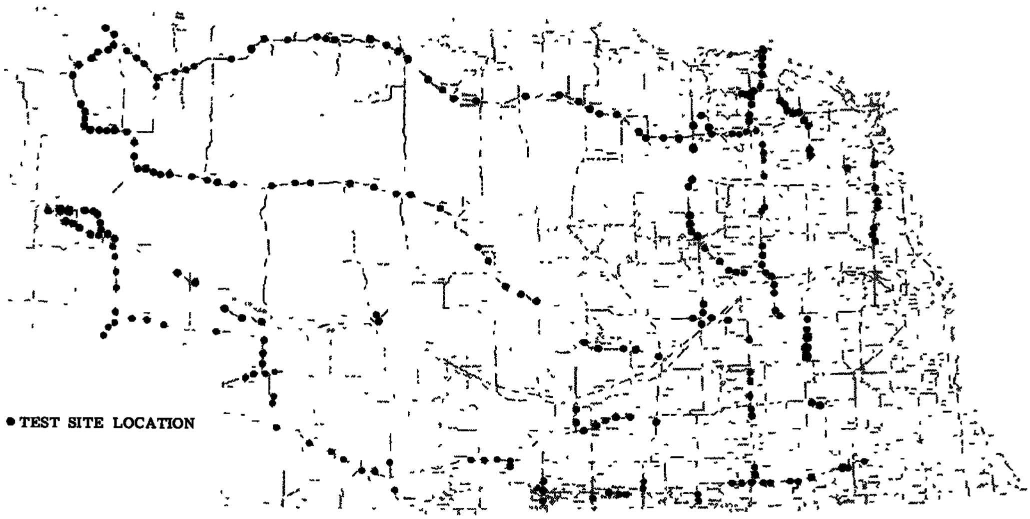

Figure 5. Test site locations in Nebraska.

an average of 29.4 percent. This is slightly higher than that obtained from the graph in Figure 7 for the reason that the maximum loss at individual sites did not occur during the same month. This loss of bearing strength is lower than that reported by other states and is probably due to the very dry fall and extremely mild winter of 1952-53. The reason for the high values obtained in April is not, at this time,

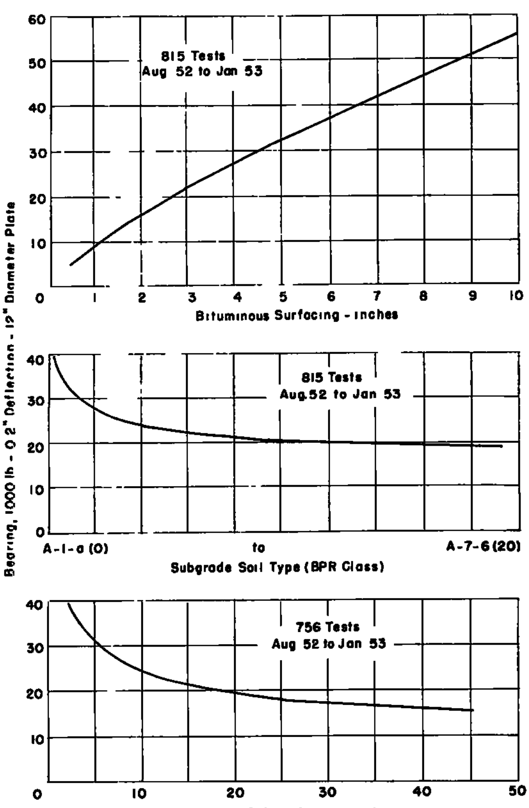

Figure 6.

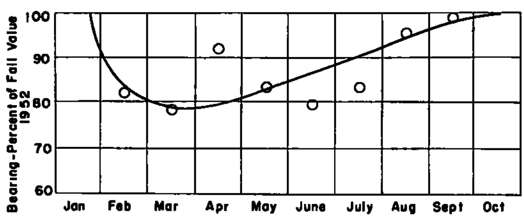

Figure 7.

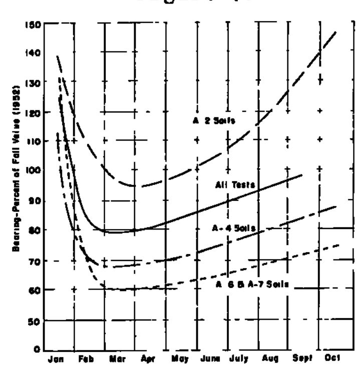

Figure 8.

apparent. There was a slight decrease in subgrade moisture during the month, but it is not believed that this was responsible for the pronounced gain in strength shown.

The comparison of the loss in strength and the recovery of strength for the major soil groups encountered in Nebraska through the 1953 loading cycle is shown in Figure 8.

The tests are scheduled to continue until the fall of 1954, and it is thought that, if the approaching winter should be severe and the normal amount of spring breakup takes place, a much greater amount of useful information will be obtained.

Indiana

CARL E. VOGELGESANG, Chief Engineer,
State Highway Commission of Indiana

● ALTHOUGH Indiana has been a member of this committee since its inception, we have not been in position to carry on a large-scale program of plate loadings until later this summer (1953).

Our truck was completed in 1949 and has been used numerous times on special projects. We found it was particularly well suited for inplace C. B. R. testing and was used extensively for this purpose during the construction of our US 41 test road in 1949.

The trailer and other component parts were completed late in 1951.

The completed unit has been used on several small projects and was extensively used on two special test roads constructed on US 31 during the summer of 1953. A total of 83 plate loadings were made on subgrades, subbases, bases, and finished surfaces on these two projects. Results on the flexible test pavement can be utilized by this committee.

During the summer of 1953, the final selection of sites for determining the load-carrying capacity of flexible pavements as affected by frost was decided upon. Actual determination of plate bearings at these sites began in September 1953.

Although a total of 33 sites were selected, two of these were discarded and final loadings were made at 31 locations. It was realized that the selection of such a large number of sites involved an ambitious program. The locations were selected to cover a range of subgrade soils and various types and thicknesses of pavement constructed throughout Indiana.

The initial phase of testing, (the determination of plate bearing values for the pavement's maximum strength) was completed before the fall rains began. These test results will be used as the base for comparison with future tests.

This report describes the equipment, test sites, tests, test results and outlines a proposed schedule for future testing.

EQUIPMENT

The loading unit consists of a GMC Model 450 truck with a trailing axle and a Trailmobile Model 662. The design is similar to that of Minnesota and Ohio. The truck is ballasted with five concrete blocks and the trailer by four cast iron blocks. The resulting axle loads are as follows:

Truck	Lb.
Front axle	5,200
Front tandem axle	11,600
Rear tandem axle	9,000
Total	25,800
Trailer	
Front axle	12,700
Rear axle	12,300
Total	25,000
Total	50,800

Loads are applied to the bearing plate through a jack column by means of a 20-ton Blackhawk Porto Power hydraulic ram. The 20-ton ram limits the maximum total load applied through the jack column to 40,300 lb. To produce this load requires a gauge reading of 8,000 psi. This maximum load applied to a 12-inch plate develops a unit load of 357 psi. on the surface being tested.

The truck and trailer unit is shown in Figure 1 while Figure 2 shows the equipment in operating position.

TEST SITES

A total of 33 test sites was selected throughout the state, eight of which are located in the southern half of the state and 25 in the northern half. At the time the tests were being made it was decided that Sites 12 and 14 in the northern circuit should be discarded. No tests will be run at these two locations.

Sites were selected to represent a wide variety of pavement and base design and subgrade soil types. The location and a description of each site follows. Figure 3 shows the location of each site on a map of Indiana.

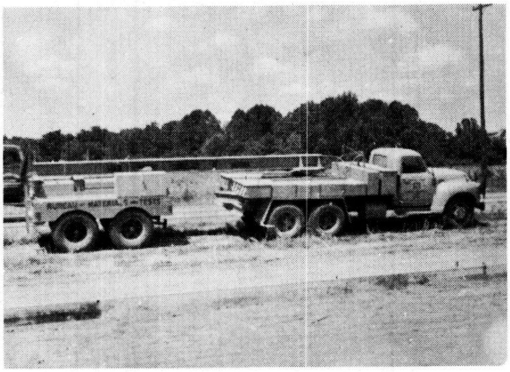

Figure 1. Truck and trailer unit used for plate-bearing tests.

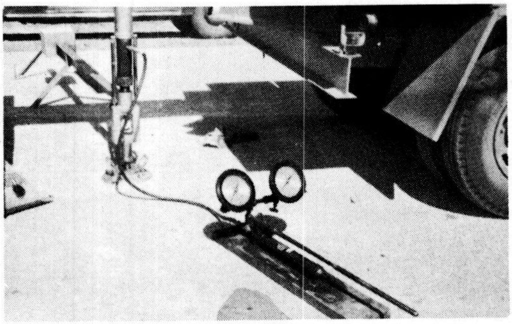

Figure 2. Equipment in operating position.

Southern Circuit

Site 1. Indiana 59, 6.2 miles north of the junction with Indiana 67, in a long uniform fill. Original construction, 6 inches of crushed stone base and bituminous dust palliative. Thickness of present surface, 1 inch. Present total thickness, 7 inches. Subgrade soil, clay loam.

Site 2. Indiana 159, 2.2 miles north of the junction with Indiana 67, in a fill. Original construction, 8 inches of waterbound macadam base and 3/4 inches of surface and seal. Thickness of present surface, 2 1/2 inches. Present total thickness, 10 1/2 inches. Subgrade soil, silty loam.

Site 3. Indiana 257, 8.3 miles south of the junction with US 150, in a low area at approximate grade. Original construction, 6 inches of crushed stone base (upper 3 inches of bituminous stabilized). Thickness of present surface, 1 inch. Present total thickness, 7 inches. Subgrade soil, silty loam.

Site 4. Indiana 256, 4.1 miles west of the junction with US 31, in a flat upland area in a very light fill. Original construction, 6 inches of crushed stone with bituminous seal. Thickness of present surface, 3/4 inch. Present total thickness, 6 3/4 inches. Subgrade soil, silty clay loam.

Site 5. Indiana 256, 5.8 miles west of the junction with US 31, in a low fill in lowland area. Original construction, 6 inches of crushed stone with bituminous seal. Thickness of present surface, 3/4 inch. Present total thickness, 6 3/4 inches. Subgrade soil, clay.

Site 6. Indiana 256, 7.2 miles west of the junction with US 31, in a low fill in lowland area. Original construction, 6 inches of crushed stone with bituminous seal. Thickness of present surface, 3/4 inch. Present total thickness, 6 3/4 inches. Subgrade soil, clay.

Site 7. Indiana 203, 1.0 miles south of the junction with Indiana 256, in a cut. Original construction, 3 inches of traffic bound stone and 3 inches of bituminous stabilized stone with bituminous seal. Thickness of present surface, 2 inches. Present total thickness, 8 inches. Subgrade soil, clay loam.

Site 8. Indiana 203, 2.4 miles south of the junction with Indiana 256, on flat, high ground grade at approximate ground line. Original construction, 3 inches of traffic bound stone and 3 inches of bituminous stabilized stone with bituminous seal. Thickness of present surface, 1 1/2 inches. Present total thickness, 7 1/2 inches. Subgrade soil, clay.

Northern Circuit

Site 1. Indiana 75, 0.2 miles south of Cutler, in a deep cut. Original construction, 9 inches of compacted aggregate (upper 3/4 inches bituminous stabilized and sealed). Thickness of present surface, 2 inches. Present total thickness, 11 inches. Subgrade soil, sandy loam.

Site 2. Indiana 75, 0.2 miles north of Wildcat Creek, in a fill. Original construction, 9 inches of compacted aggregate with a bituminous dust palliative. Thickness of present surface, 1 inch. Present

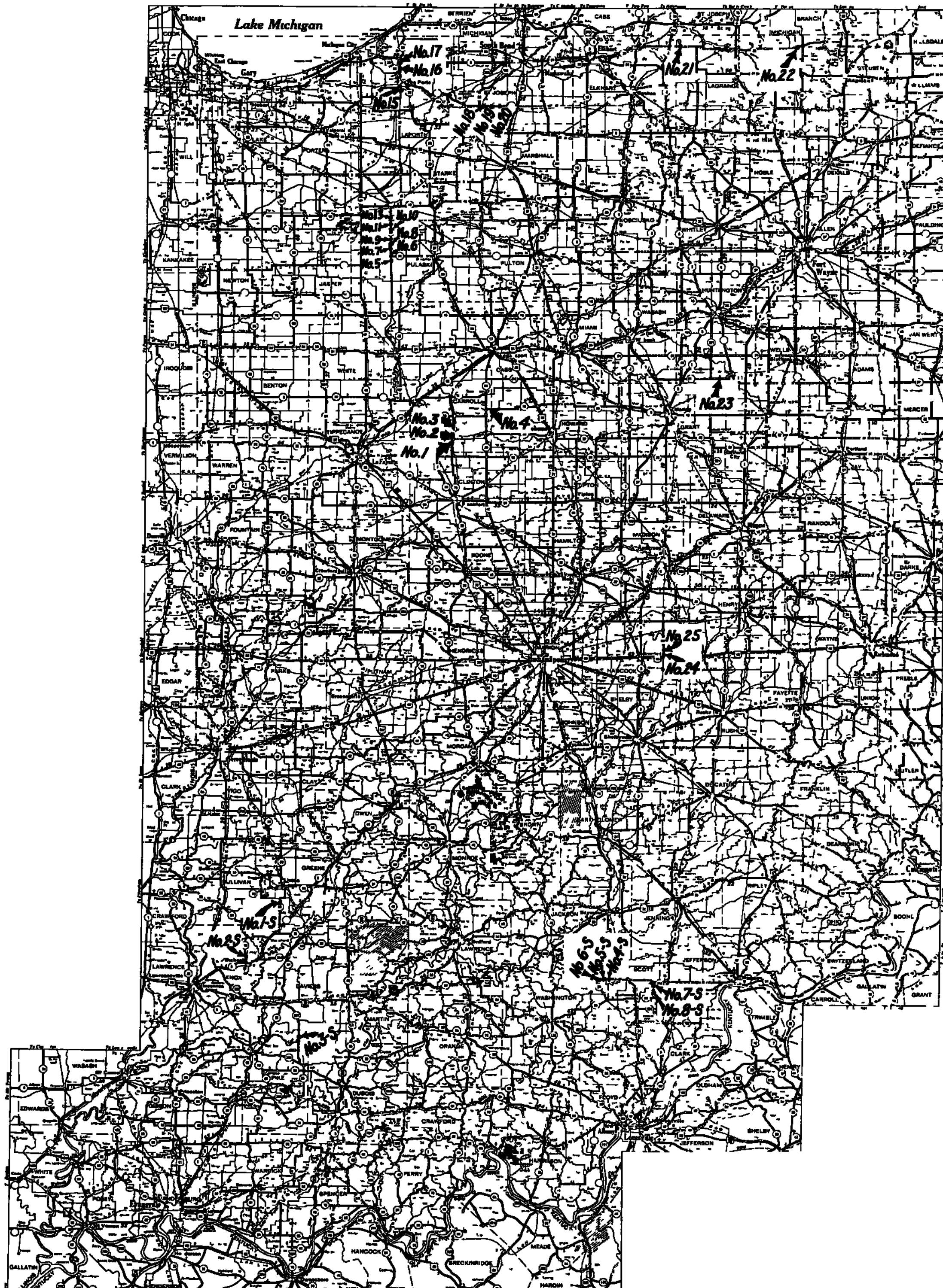

Figure 3. Location of sites for plate bearing tests.

total thickness, 10 inches. Subgrade soil, sandy loam.

Site 3. Indiana 75, 1.0 miles north of Wildcat Creek, in a cut. Original construction, 9 inches of compacted aggregate with a bituminous dust palliative. Thickness of present surface, 1 inch. Present total thickness, 10 inches. Subgrade soil, sandy loam.

Site 4. Indiana 18, 0.2 miles east of the junction with Indiana 29, in a very light fill. Original construction, 6 inches of crushed stone. Thickness of present surface, 3 inches. Present total thickness, 9 inches. Subgrade soil, sandy loam.

Site 5. Indiana 39, 0.5 miles south of the junction with Indiana 14, in a light fill. Original construction, 8 inches of compacted aggregate with seal. Thickness of present surface, 1 inch. Present total thickness, 9 inches. Subgrade soil, sandy loam.

Site 6. Indiana 39, 0.3 miles north of the junction with Indiana 14, in a fill. Original construction, 6 inches of crushed stone. Thickness of present surface, 3 inches. Present total thickness, 9 inches. Subgrade soil, sand.

Site 7. Indiana 39, 1.2 miles north of the junction with Indiana 14, in a cut. Original construction, 6 inches of crushed stone. Thickness of present surface, 3 inches. Present total thickness, 9 inches. Subgrade soil, sand.

Site 8. Indiana 39, 1.7 miles north of the junction with Indiana 14, in a fill. Original construction, 6 inches of crushed stone. Thickness of present surface, 3½ inches. Present total thickness, 9½ inches. Subgrade soil, sand.

Site 9. Indiana 39, 2.6 miles north of the junction with Indiana 14, in a light fill. Original construction, 6 inches of crushed stone. Thickness of present surface, 3½ inches. Present total thickness, 9½ inches. Subgrade soil, sand or sandy loam.

Site 10. Indiana 39, 5.6 miles north of the junction with Indiana 14, in a fill. Original construction, 6 inches of crushed stone. Thickness of present surface, 3½ inches. Present total thickness, 9½ inches. Subgrade soil, sand or sandy loam.

Site 11. Indiana 39, 6.4 miles north of the junction with Indiana 14, in a fill. Original construction, 6 inches of cement stabilized base ("windblown" sand) and approximately 1 inch bituminous surface. Thickness of present surface, 2 inches. Present total thickness, 8 inches. Subgrade soil, sand.

Site 13. Indiana 39, 7.7 miles north of the junction with Indiana 14, in a cut. Original construction, 6 inches of cement stabilized base ("windblown" sand) and approximately 1 inch bituminous surface. Thickness of present surface, 2 inches. Present total thickness, 8 inches. Subgrade soil, sand.

Site 15. Indiana 39, 0.2 miles south of the junction with Indiana 2, in a cut. Original construction, 8 inches of compacted aggregate with a bituminous dust palliative. Thickness of present surface, 5¾ inches. Present total thickness, 13¾ inches. Subgrade soil, sandy loam.

Site 16. Indiana 39, 1.2 miles south of the junction with US 20, in a cut. Original construction, 9 inches of compacted aggregate (upper 1 inch bituminous stabilized). Thickness of present surface, 1¾ inches. Present total thickness, 10¾ inches. Subgrade soil, clay loam.

Site 17. Indiana 39, 0.3 miles south of the junction with US 20, in a cut. Original construction, 9 inches of compacted aggregate (upper 1 inch bituminous stabilized). Thickness of present surface, 1 inch. Present total thickness, 10 inches. Subgrade soil, sandy loam.

Site 18. Indiana 4, 0.7 miles east of the junction with Indiana 23, in a fill. Original construction 9 inches of compacted aggregate (upper 1 inch bituminous stabilized). Thickness of present surface, 1¼ inches. Present total thickness, 10¼ inches. Subgrade soil, sandy loam.

Site 19. Indiana 4, 2.4 miles east of the junction with Indiana 23, in a cut. Original construction, 9 inches of compacted aggregate (upper 1 inch bituminous stabilized). Thickness of present surface, 1 inch. Present total thickness, 10 inches. Subgrade soil, silty loam.

Site 20. Indiana 4, 3.8 miles east of the junction with Indiana 23, in a cut. Original construction, 9 inches of compacted aggregate (upper 1 inch bituminous stabilized). Thickness of present surface, ¾ inch. Present total thickness, 9¾ inches. Subgrade soil, clay loam.

Site 21. Indiana 120, 2.2 miles east of the junction with Indiana 13, in a cut. Original construction, 8 inches of compacted aggregate and a 1 inch bituminous surface. Thickness of present surface, 1 inch. Present total thickness, 9 inches. Subgrade soil, sand and gravel.

Site 22. Indiana 120, 6.5 miles east of the junction with Indiana 3, in a cut. Original construction, 6 inches of stone. Thickness of present surface, 3 inches. Present total thickness, 9 inches. Subgrade soil, sand and gravel.

Site 23. Indiana 218, 1.8 miles west of the junction with Indiana 5, in a light fill. Original construction, 7½ inches of compacted aggregate and a 1½ inch bituminous surface. Thickness of present surface, 1½ inches. Present total thickness, 9 inches. Subgrade soil, sandy loam.

Site 24. Indiana 209, 0.2 miles north of the junction with US 40, grade at approximate ground line. Original construction, 3 inches of stone and 3 inches of bituminous stabilized stone with a seal. Thickness of present surface, 1¼ inches. Present total thickness, 7¼ inches. Subgrade soil, clay loam.

Site 25. Indiana 209, 0.7 miles north of the junction with US 40, in a light fill. Original construction, 3 inches of stone and 3 inches of bituminous stabilized stone with a seal. Thickness of present surface, 1¼ inches. Present total thickness, 7¼ inches. Subgrade soil, clay loam.

Classification of Soils

Textural classification of subgrade soils was made by field identification of samples obtained from one boring at each site. Additional borings will be made at each site to establish detailed soil profiles. At the same time soil samples will be taken for laboratory analysis and classification. Laboratory analysis may make some slight changes in the final textural classification.

TESTS

Due to other commitments the testing equipment and operating personnel were not available for this project until late September 1953. Because of this late start and the number of sites to be tested it was decided that time, and probably unfavorable weather, would not permit completion of detailed tests of the surface, base, and subgrade at all sites. Therefore, for this initial phase bearing tests were run only on the surface of the pavements. At least one test was run at each site using the 12-inch plate. At 23 of the sites there were two tests run; at two sites there were three tests run; at one site there were four tests run; at the remaining five sites only one test was run. The procedure was to run the regular test at each site. Any additional tests that were run were the "quickie" type.

No attempt was made to determine densities at this time. Moisture samples of the subgrade were taken at the time of testing. Where possible a 2-inch-diameter pointed steel pin was driven through the pavement and base and moisture samples removed with a 1½-inch soil auger. At locations where the pin could not be driven or the soil couldn't be removed with the auger a hole was dug in the shoulder at the edge of pavement and to a depth equal to that of the pavement and base. The sample was then removed from under the edge of the pavement.

TEST RESULTS

The test results thus far obtained are shown in Tables 1, 2, and 3. Sites located in the southern part of the state are indicated by the letter S following the site number. All other sites are located in the northern circuit. The three tables contain the same information, merely being arranged in different order. This was done to try to show more clearly the effect of various factors upon the bearing values. However, the bearing values depend on a combination of factors: thickness and type of base and surface, type of subgrade soil, and moisture and density of pavement and subgrade soil. Therefore, careful consideration of those factors is necessary in order to ascertain any general trend in the results.

It appears that the bearing values tend to increase for a given soil type with increasing thickness of base and surface and decreasing subgrade moisture contents. Also, for a given type and thickness of pavement there appears to be an increase in the surface bearing value as the subgrade soils range from clays to nonplastic granular materials.

Figure 4 shows typical bearing value curves. One is for the regular method of test and the other for the "quickie" method, both at Site 8-S.

Figure 5 shows typical bearing value curves for a plastic subgrade, granular subbase, base courses, binder and surface for a section of our test road constructed on US 31, during the past season. These

TABLE 1

SUMMARY OF BEARING VALUES
(Results arranged in order of increasing values)

Site No.	Bearing Value Psi	Ave	Present Thickness (inches) Base	Surface	Total	% Moisture (Subgrade)	Soil Type (Subgrade)	Type of base
5-S	88 & 84	86	6	¾	6¾	20.2	Cl	Traffic bound stone
6-S	79 & 97	88	6	¾	6¾	24.9	Cl	" " "
8-S	103 & 108	106	6	1½	7½	17.3	Cl	Traffic bound stone & bit.stab.stone
4-S	134 & 146	140	6	¾	6¾	17.1	SiClL	Traffic bound stone
24	147 & 141	144	6	1¼	7¼	22.8	ClL	Traffic bound stone & bit.stab.stone
3-S	158 & 141	149	6	1	7	16.7	SiL	" " " " " "
7-S	154 & 161	157	6	2	8	10.4	ClL	" " " " " "
1-S	158 & 162	160	6	1	7	12.7	ClL	Traffic bound stone
2-S	174 & 180	177	8	2½	10½	18.3	SiL	Waterbound macadam
20	167 & 187	177	9	¾	9¾	10.7	ClL	Traffic bound gravel
23	176 & 185	180	7½	1½	9	14.4	SL	" " stone
1	180 & 191	185	9	2	11	8.0	SL	" " "
25	189 & 191	190	6	1¼	7¼	21.0	ClL	Traffic bound stone & bit.stab.stone
16	175,200 & 202	192	9	1¾	10¾	12.1	ClL	Traffic bound gravel
3	216 & 197	206	9	1	10	10.1	SL	" " stone
4	215 & 210	212	6	3	9	7.2	SL	" " "
17	237 & 231	234	9	1	10	10.4	SL	" " gravel
2	260 & 277	268	9	1	10	5.9	SL	" " stone
15	270 & 273	272	8	5¾	13¾	8.7	SL	" " "
18	273 & 275	274	9	1¼	10¼	8.0	SL	" " gravel
5	268 & 282	275	8	1	9	10.0	SL	" " stone
9	288 & 277	282	6	3½	9½	12.1*	S or SL	" " " *Questionable Val.
19	266,299 & 312	292	9	1	10	7.7	SiL	" " gravel
10	344	344	6	3½	9½	6.6	S or SL	" " stone
22	361 & 348	354	6	3	9	7.6	S & G	" " "
6	328,387 & 363	359	6	3	9	4.5	S	" " "
7	387	387	6	3	9	5.3	S	" " "
8	396	396	6	3½	9½	7.9	S	" " "
21	420 & 396	408	8	1	9	5.1	S & G	" " gravel
11			6	2	8	5.0	S	Soil-cement
13			6	2	8	5.1	S	" "

Cl - Clay; ClL - Clay Loam; SiClL - Silty Clay Loam; SiL - Silty Loam; SL - Sandy Loam; S - Sand; S&G - Sand & Gravel

TABLE 2

SUMMARY OF BEARING VALUES
(Results grouped by soil types)

Soil Type (sub-grade)	Site No.	Bearing Value Psi	Ave.	% Moisture (Subgrade)	Present Thickness (inches) Base	Surface	Total	Type of Base
Cl	5-S	88 & 84	86	20.2	6	¾	6¾	Traffic bound stone
	6-S	79 & 97	88	24.9	6	¾	6¾	" " "
	8-S	103 & 108	106	17.3	6	1½	7½	Traffic bound stone & bit.stab.stone
SiClL	4-S	134 & 146	140	17.1	6	¾	6¾	Traffic bound stone
SiL	3-S	158 & 141	150	16.7	6	1	7	Traffic bound stone & bit.stab.stone
	2-S	174 & 180	177	18.3	8	2½	10½	Water bound macadam
	19	266,299, 312	292	7.7	9	1	10	Traffic bound gravel
ClL	24	147 & 141	144	22.8	6	1¼	7¼	Traffic bound stone & bit.stab.stone
	7-S	154 & 161	158	10.4	6	2	8	" " " " " "
	1-S	158 & 162	160	12.7	6	1	7	Traffic bound stone
	20	167 & 187	177	10.7	9	¾	9¾	" " gravel
	25	189 & 191	190	21.0	6	1¼	7¼	Traffic bound stone & bit.stab.stone
	16	175,200, 202	192	12.1	9	1¾	10¾	Traffic bound gravel
SL	23	176 & 185	180	14.4	7½	1½	9	" " stone
	1	180 & 191	186	8.0	9	2	11	" " "
	3	216 & 197	206	10.1	9	1	10	" " "
	4	215 & 210	212	7.2	6	3	9	" " "
	17	237 & 231	234	10.4	9	1	10	" " gravel
	2	260 & 277	268	5.9	9	1	10	" " stone
	15	270 & 273	272	8.7	8	5¾	13¾	" " "
	18	273 & 275	274	8.0	9	1¼	10¼	" " gravel
	5	268 & 282	275	10.0	8	1	9	" " stone
S or SL	9	288 & 277	282	12.1*	6	3½	9½	" " " *Questionable Value
	10	344	344	6.6	6	3½	9½	" " "
S	6	328, 387, 363	359	4.5	6	3	9	" " "
	7	387	387	5.3	6	3	9	" " "
	8	396	396	7.9	6	3½	9½	" " "
	11			5.0	6	2	8	Soil-cement
	13			5.1	6	2	8	Soil-cement
S & G	22	361 & 348	354	7.6	6	3	9	Traffic bound stone
	21	420 & 396	408	5.1	8	1	9	Traffic bound gravel

Cl - Clay; ClL - Clay Loam; SiClL - Silty Clay Loam; SiL - Silty Loam; SL - Sandy Loam; S - Sand; S & G - Sand & Gravel

TABLE 3

SUMMARY OF BEARING VALUES
(Results grouped by type of construction)

Type of Original Construction	Site No.	Present Thickness (inches) Base	Surface	Total	Bearing Value Psi	Ave	% Moisture (Subgrade)	Soil Type (Subgrade)
1-3" course of #3 stone; 1-3" course of #10FF & #9 stone; with seal	5-S	6	¾	6¾	88 & 84	86	20.2	Cl
	6-S	6	¾	6¾	79 & 97	88	24.9	Cl
	4-S	6	¾	6¾	134 & 146	140	17.1	SiClL
1-3" course of #3 stone, traffic bound; 1-3" course of #3 stone bit. stabilized; with seal	8-S	6	1½	7½	103 & 108	106	17.3	Cl
	3-S	6	1	7	158 & 141	150	16.7	SiL
	7-S	6	2	8	154 & 161	158	10.4	ClL
6" of #3F & 10FF stone with dust pallative	1-S	6	1	7	158 & 162	160	12.7	ClL
1-3" course of #6 stone;1-3" course of #6 stone,bit.stabilized;with seal	24	6	1¼	7¼	147 & 141	144	22.8	ClL
	25	6	1¼	7¼	189 & 191	190	21.0	ClL
6" cement stabilized sand; 1" bit surface with seal	11	6	2	8			5.0	S
	13	6	2	8			5.1	S
6" crushed stone	4	6	3	9	215 & 210	212	7.2	SL
	22	6	3	9	361 & 348	354	7.6	S & G
2 - 3" courses of stone	9	6	3½	9½	288 & 277	282	12.1*	S or SL
*Questionable value	10	6	3½	9½	344	344	6.6	S or SL
	6	6	3	9	328,387, 363	359	4.5	S
	7	6	3	9	387	387	5.3	S
	8	6	3½	9½	396	396	7.9	S
1-3" course of salvaged road metal;2-3" courses of #63 stone,the upper 1½" being surface and seal	23	7½	1½	9	176 & 185	180	14.4	SL
2-4" courses of #63 stone,with seal	5	8	1	9	268 & 282	275	10.0	SL
	15	8	5¾	13¾	270 & 273	272	8.7	SL
1-3" & 2-2½" courses of #63 gravel, 1" bit. surface & seal	21	8	1	9	420 & 396	408	5.1	S & G
8" waterbound macadam with seal	2-S	8	2½	10½	174 & 180	177	18.3	SiL
3-3" courses of #63 stone, with seal	1	9	2	11	180 & 191	186	8.0	SL
	3	9	1	10	216 & 197	206	10.1	SL
	2	9	1	10	260 & 277	268	5.9	SL
1-3"course of salvaged road metal; 2-3"courses of #63 gravel with upper inch being an oil mat	20	9	¾	9¾	167 & 187	177	10.7	ClL
	16	9	1¾	10¾	175, 200, 202	192	12.1	ClL
	17	9	1	10	237 & 231	234	10.4	SL
	18	9	1¼	10¼	273 & 275	274	8.0	SL
	19	9	1	10	266, 299, 312	292	7.7	SiL

Cl - Clay; ClL - Clay Loam; SiClL - Silty Clay Loam; SiL - Silty Loam; SL - Sandy Loam; S - Sand: S & G - Sand & Gravel test values are not included in the summary tables of bearing values since this pavement, which is designed for heavy traffic and has a total thickness of 20 inches, is not comparable with other pavements tested.

at each site. Moisture content of the subgrade will also be determined at the same time. Immediately upon completion of this series of tests detailed tests will be run at certain sites. This will include bearing tests on the surface, base, and subgrade;

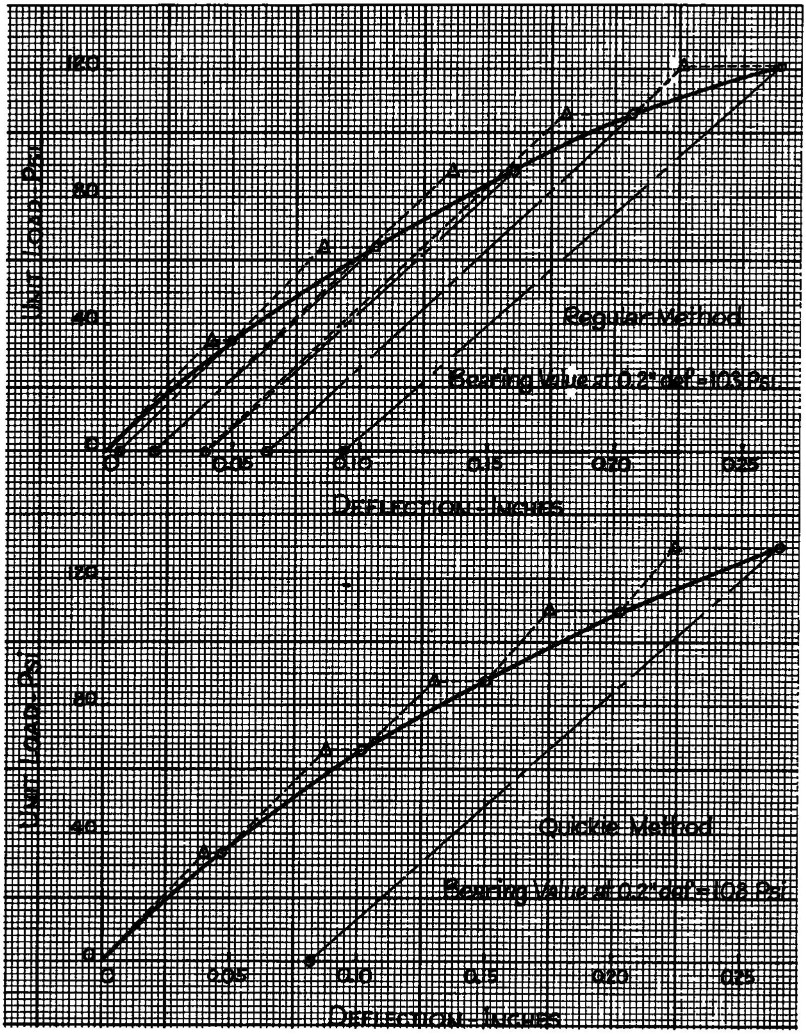

Figure 4. Typical bearing-value curves· Relation between regular and quickie methods. Tests run at Site 8-S. Construction was one 3-inch course of No. 3 stone, traffic bound; one 3-inch course of No. 3 stone, bituminous stabilized with seal, 1½-inch bituminous resurface, giving total thickness of 7½ inches. Subgrade soil was clay, moisture content 17.3 percent; 12-inch bearing plate was used.

FUTURE TESTING

Since there will not be time to run detailed tests on the surface, base, and subgrade at all 31 sites during the spring thawing period tests will be run on the surface

density and moisture content determinations of the base and subgrade; and sampling of the base and subgrade for laboratory testing to determine maximum density, optimum moisture, and physical analysis. As yet the sites for the detailed testing have not been selected.

A report covering the first complete cycle of our load bearing studies should be completed and submitted to the committee at the annual Highway Research Board meeting in 1955.

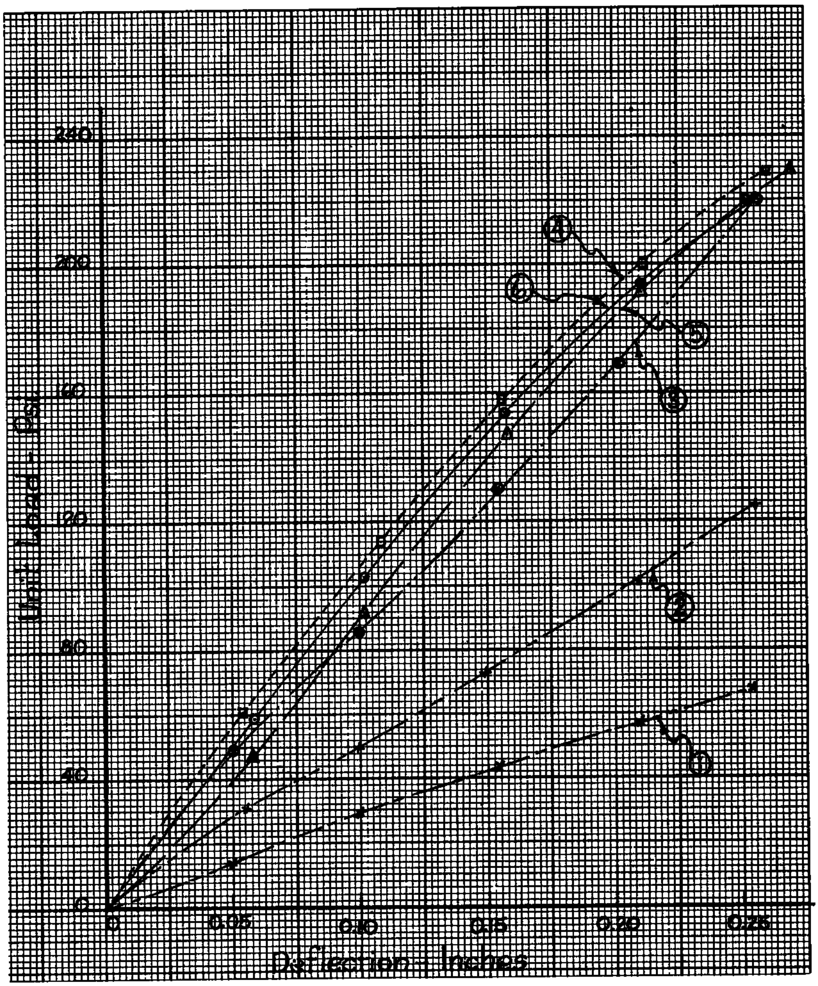

Figure 5. Typical bearing-value curves for US 31 test road· (1) subgrade, clay loam A4(4), (2) 7-inch Type I open-graded subbase; (3) 8-inch water-bound macadam base, (4) 2½-inch bituminous-concrete A.H. base, (5) 1½-inch bituminous-concrete binder, and (6) 1-inch bituminous-concrete A.H. Type B surface. The 12-inch bearing plate was used.

Oregon

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● THE third annual cycle of plate-bearing tests have been completed in Oregon. Tests have been continued on the 18 points with the same equipment and method of testing.

The winter of 1952-53 was mild in the area covered by the tests. No frost penetration of subgrade was observed at any of the test points in the vicinity of Madras, Groups A, B, C, and D. No serious reduction in strength was recorded in any of those groups. Curves with 1953 data added are shown in Figures 1 to 6. The test

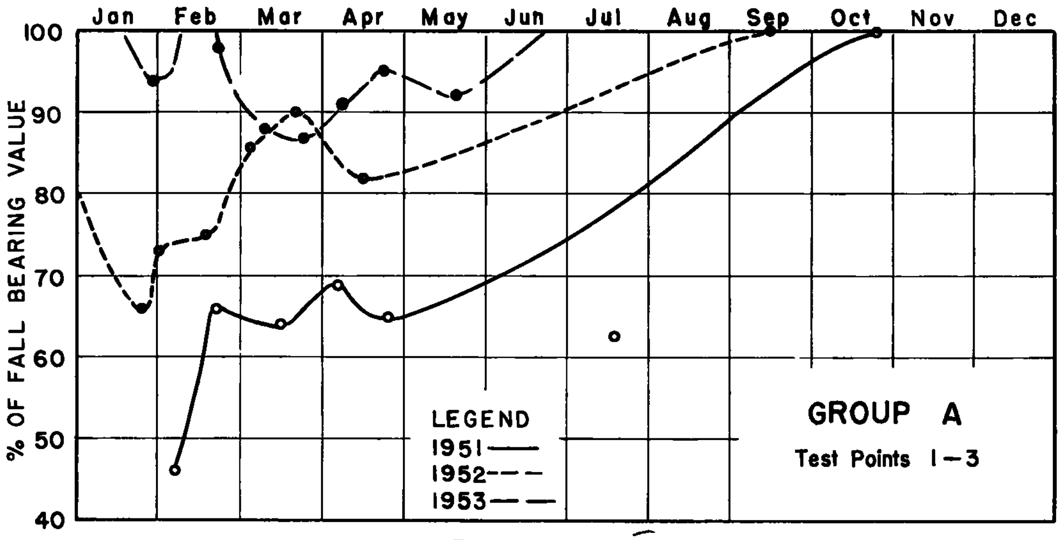

Figure 1.

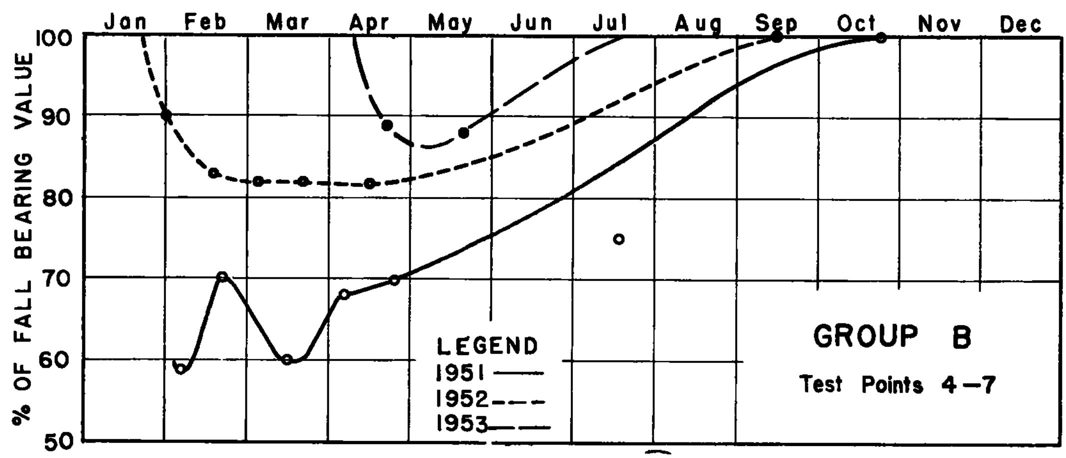

Figure 2.

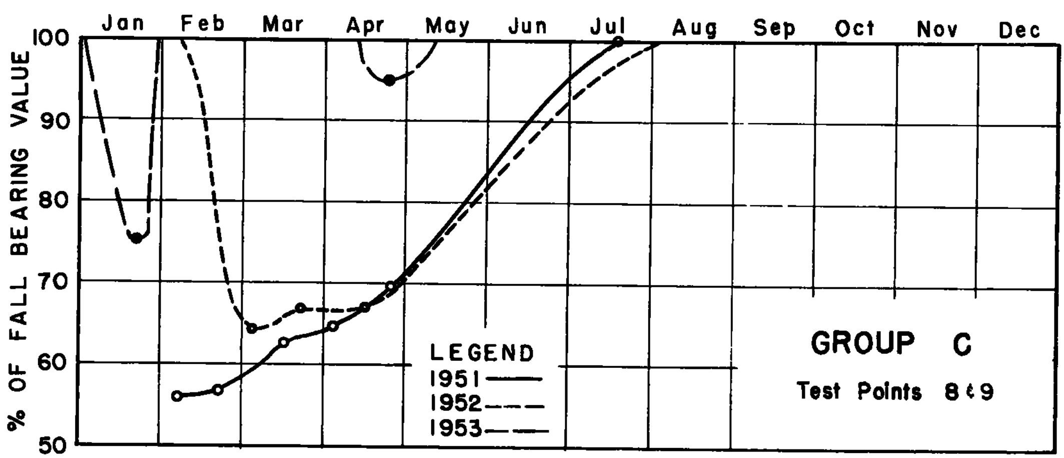

Figure 3.

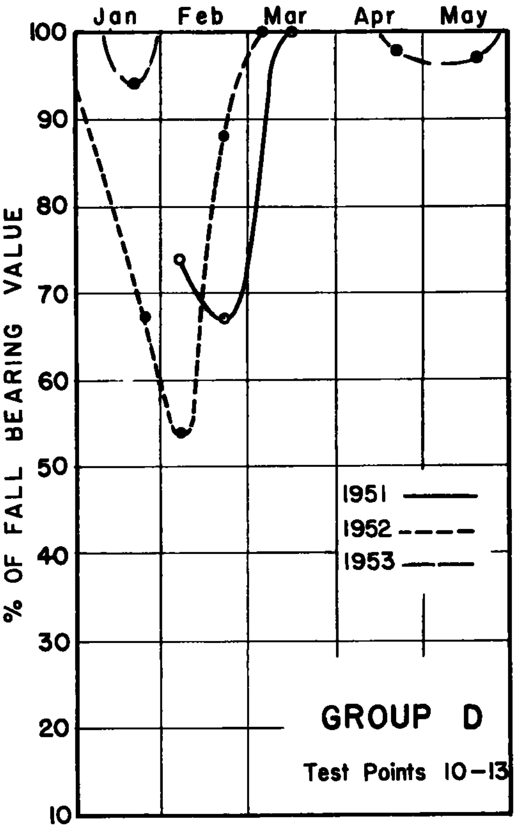

Figure 4.

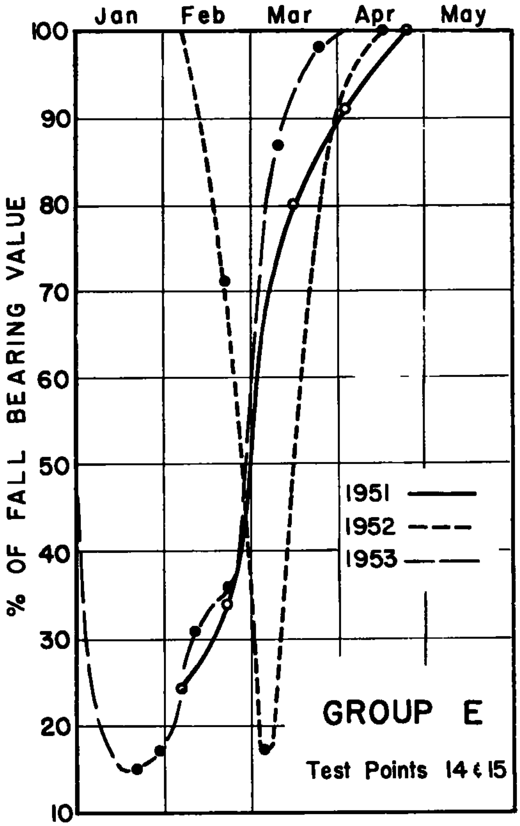

Figure 5.

TABLE 1
TEST POINT DATA

Test Point	Group	Surface		Base		Soil Classif	Cut or Fill	Year Completed	Avg January Temp			Max Frost Depth-1952
		Type	Thickness	Type	Thickness				Normal	1951	1952	
1	A	Bit. Mac.	3"	Gravel	12"	A-1-b	6' Cut	1948		28	26	13"
2	"	'	"	"	"	A-4	2' Fill	"		"	"	15"
3	"	"	"	Crushed Rock	6"	"	2' Fill	1945		"	"	12"
4 (1)	B	Oil Mat	1½"	"	"	"	4' Fill	1939	26	29	22	12"
5 (2)	"	"	"	"	"	"	1' Fill	"	"	"	"	12"
6 (3)	"	"	"	"	"	"	1' Fill	1948	"	"	"	14"
7 (2)	"	"	"	"	"	"	1' Fill	"	"	"	"	14"
8	C	Bit Mac	3"	"	18"	"	3' Fill	1950				26"
9	"	"	"	"	"	"	8' Cut	"				26"
10	D	Oil Mat	1½"	Grav & Cr R	6"	"	2' Fill	1947	30	32	27	10"
11	"	"	"	"	8"	"	10' Fill	"	"	"	"	8"
12	"	"	"	Crushed Rock	5"	"	Grade	"	"	"	"	11"
13	"	"	"	"	"	A-2-4	12' Fill	"	"	"	"	10"
14	E	"	"	Cinders	7"	A-2-5	3' Fill	1948	25	24	22	20"
15	"	"	"	"	"	"	3' Fill	"	"	"	"	20"
16	F	"	¾"	Crushed Rock	6"	A-1-b	4' Cut	1939	"	"	"	24"
17	"	"	"	Gravel	"	"	3' Cut	"	"	"	"	24"
18 (4)	"	Bit Mac	3"	Crushed Rock	12"	"	5' Fill	1949		25	23	20"

(1) 6" Crushed Rock and 1½" Oil Mat placed over 1939 construction in 1950
(2) 1½" Oil Mat placed over 1939 and 1948 construction in 1950
(3) 4" Asphaltic Concrete placed over 1948 construction in 1950
(4) 1949 construction placed over 1939 construction as at Test Point 17

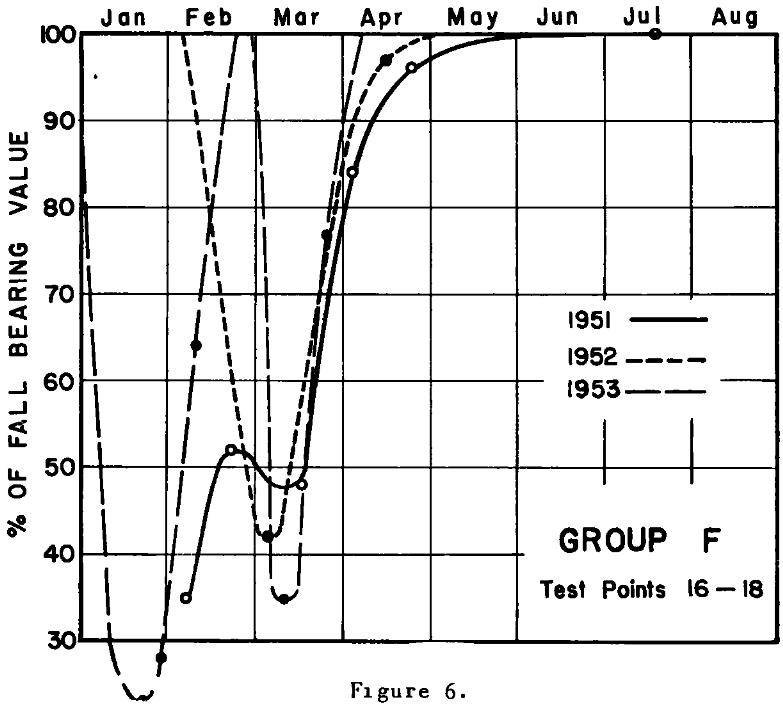

Figure 6.

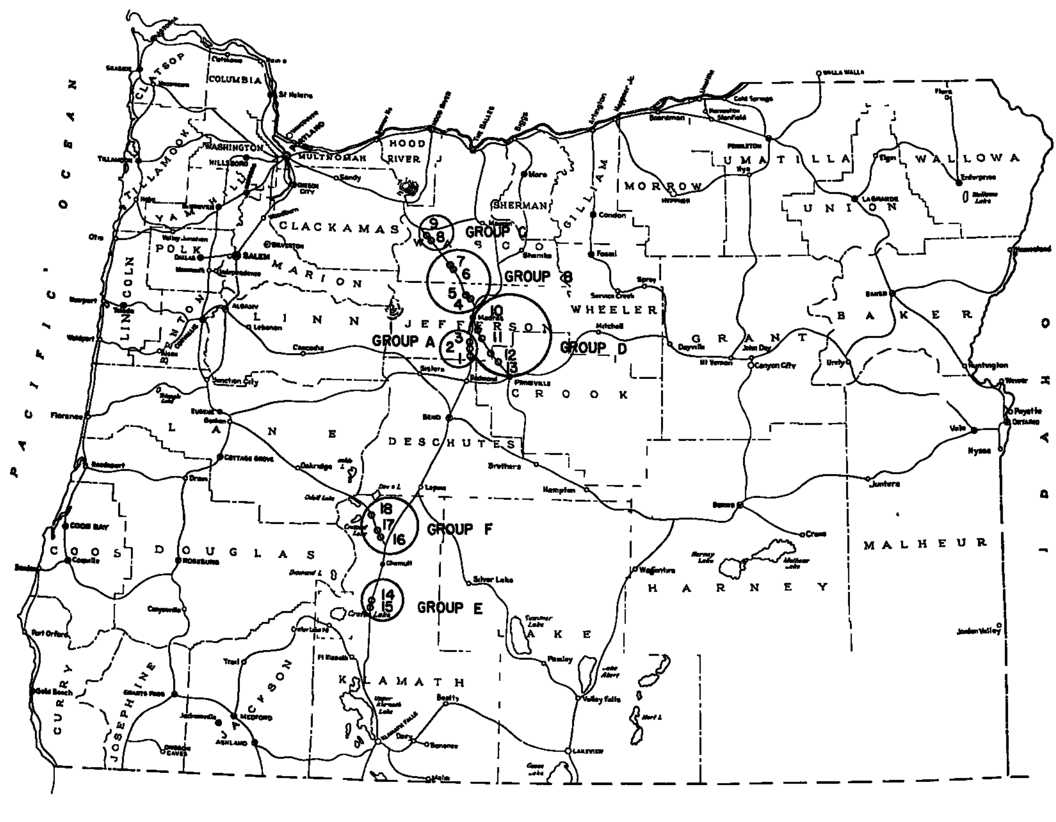

Figure 7. Test-point locations.

point locations and data are shown in Figure 7 and Table 1.

Groups E and F (Fig. 7) in the vicinity of Chemult showed strengths lower than any previously recorded even with comparatively mild weather for the area and no observation of frost penetration of the subgrade to a depth of more than 3 or 4 inches.

New fall high strengths were recorded in all groups except Group B in October 1953. These strengths averaged 25 percent higher than any previous fall readings.

No explanation has been discovered for the low spring strength in Groups E and F or for the new high strengths in October 1953.

Tests will be continued through the coming winter.

Some HRB Publications Relating to Frost

Bibliography 3: FROST ACTION IN SOILS, $.45

Bulletin 40: LOAD CARRYING CAPACITY OF ROADS AS AFFECTED BY FROST ACTION (1951) 42 pp. $.75

Introduction; Iowa; Michigan; Minnesota; New York; North Dakota; Ohio: The Effect of Temperature on the Bearing Value of Frozen Soils, Miles S. Kersten and Allen E. Cox.

Bulletin 54: LOAD CAPACITY OF ROADS AFFECTED BY FROST (1952) 21 pp. $.30

Introduction; Iowa; North Dakota; Ohio; Oregon.

Bulletin 71: SOIL TEMPERATURE AND GROUND FREEZING (1953) 124 pp. $1.80

Cold-Room Studies of Frost Action in Soils, A Progress Report, James F. Haley; Frost Design Criteria for Pavements, Kenneth A. Linell; Soil-Temperature Comparisons Under Varying Covers, George A. Crabb, Jr., and James L. Smith; Calculation of Depth of Freezing and Thawing Under Pavements, Harry Carlson and Miles S. Kersten; Discussion—Harl P. Aldrich, Jr., and Henry M. Paynter; Frost-Action Research Needs, A. W. Johnson and C. W. Lovell, Jr.

Special Report 1: FROST ACTION IN ROADS AND AIRFIELDS, A REVIEW OF THE LITERATURE, 1765-1951, (1952) 288 pp. $3.00

Presents a detailed study and review of all available writing on the subject. Includes 242 illustrations, a complete bibliography, and a subject index.

Special Report 2: FROST ACTION IN SOILS, A SYMPOSIUM (1952) 385 pp. $3.75

Foreword; Major Soil Profiles and Their Relationship with Climate; Climate Aspects of Frost Heave and Related Ground Frost Phenomena; Soil Temperature, A Review of the Literature; Field Measurements of Soil Temperature in Indiana; An Absolute Method of Determining Thermal Conductivity and Diffusivity of Soils; The Thermal Conductivity Probe; Discussion of Soil Temperature; Methods for Measuring the Moisture Content of Soils Under Field Conditions; The Measurement of Soil Moisture and Temperature by Heat-Diffusion Moisture Cell; The Measurement of Soil Moisture and Density by Neutron and Gamma-Ray Scattering; Water in Highway Subgrades and Foundations; Soil Moisture Under Concrete Pavement of an Airport; Distribution of Capillary Moisture at Equilibrium in Stratified Soil; Moisture Conditions Under Flexible Airfield Pavements; Heat Transfer and Temperature Distribution in Soils for Transient Heat Flow Due to Cylindrical Sources and Sinks; Thermal Properties of Soils; Relation of Frost Action to the Clay Mineral Composition of Soil Materials; A Theory of Ice-Blocked Drainage as a Principal Factor in Frost Heave, Slump, and Solifluction; Soil Instability on Slopes in Regions of Perennially Frozen Ground; Calculation of Depth of Thaw in Frozen Ground; Interpretation of Permafrost Features from Airphotographs; Cold Room Studies of Frost Action in Soils; The Nature and Extent of Damage to New Hampshire Highways from Frost Action; Frost Action and Spring Breakup in Colorado; Frost Action in Michigan; Frost Damage to Roads in Great Britain; Load-Carrying Capacity of Roads Affected by Frost Action; Frost-Action Studies of Thirty Soils in New Jersey; Investigation of the Effect of Frost Action on Pavement Supporting Capacity; Calcium Chloride Treatment of Frost Action; Controlling the Effects of Frost Action in Michigan; Remedies and Treatments for the Frost Problem in Nebraska; Remedies and Treatments by the Connecticut Highway Department; The Influence of Frost on Highway Foundations; The Norwegian State Railways' Measures Against Frost Heaving; Results of a Questionnaire on Needed Research; Needed Research Pertaining to Frost Action and Related Phenomena; Discussion on the Frost Symposium.

Research Report 10-D: COMMITTEE REPORT AND MANUAL OF RECOMMENDED TESTING PROCEDURES ON LOAD CARRYING CAPACITY OF ROADS AS AFFECTED BY FROST ACTION (1950) 19 pp. $.45

Foreword; Report of Committee on "Load Carrying Capacity of Roads as Affected by Frost Action, C. L. Motl; Manual of Recommended Testing Procedures, C. L. Motl.

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