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Load-Carrying Capacity of Roads as Affected by Frost Action Final Report

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Load-Carrying Capacity of Roads as Affected by Frost Action Final Report

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Department of Maintenance

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

G. A. MESKAL, Chairman
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INTRODUCTION

Highway administrators situated in the Frost Belt area have for many years observed, with increasing concern, the rapidly mounting costs of restoring damaged highways after the spring thaw. This problem has always been one of particular concern to maintenance engineers, and it was their suggestion in 1947 that an investigation be undertaken to study the loss of load-carrying capacity suffered by roads because of frost action.

●AT the annual meeting of the American Association of State Highway Officials, held in New York City in September 1947, a resolution was passed recommending that the Highway Research Board undertake a study of the load-carrying capacity of roads as affected by frost action.

Accordingly, the Highway Research Board established Project No. 7, to be carried on under the direction and guidance of the Maintenance Department. The chairman of the Department appointed a special committee to organize, activate, and carry on the project and prepare and submit reports.

The following states lying within frost-affected areas agreed to take part in the research work: Indiana, Iowa, Michigan, Minnesota, Nebraska, New Hampshire, New York, North Dakota, Ohio, and Oregon. The Bureau of Public Roads was also represented. Because Minnesota had already done some research work on the problem and had initiated interest in the project, the Chief Maintenance Engineer of that state was appointed chairman of the special committee.

A full committee meeting was held in St. Paul, Minn., on April 13, 1948, during which the objectives and scope of the project were defined, testing procedures were adopted, and other matters of pertinent interest were discussed, which would promote uniformity of operation in the various states. Full details are given in HRB Research Report 10-D.

Beginning in 1948, a progress report was prepared and submitted at each annual meeting of the Highway Research Board up to and including 1955 — eight reports in all. These reports are referred to throughout this final report, with a brief summary of each given later herein.

As set forth in the objectives of the research project, its principal purpose was to determine, by actual field testing, the loss of load-carrying capacity (percentagewise) exhibited by highways during the time the frost is leaving and after the frost had left the ground. It already was an observed fact that highways were weakened by the thawing action, but the extent was not known. Other data pertinent to the research problem were to be gathered, so that the effect of such factors as the character of soil, moisture, densities, etc., might also be evaluated. The several annual reports present this information in detail.

To evaluate the carrying capacity of roads, heavy-duty, portable load-application equipment developed by Minnesota was adopted and quite generally used by the participants. This machine was self-propelled, easily portable, and capable of applying a reaction load up to 28,000 pounds. Eight of the ten participating states used the plate-bearing method of tests. Two states (Michigan and Iowa) used special testing devices.

STATE PARTICIPATION AND CONTRIBUTIONS

Indiana

A very comprehensive testing program was carried out by Indiana during 1953-1954 and 1955. Progress reports were made in 1954 and 1955. An excellent final report (October 1956) from this state, is included herein as Appendix B. The project in Indiana was broadened to include detailed soil investigations and measurements of load-carrying capacities of a range of pavement thicknesses, laid over a wide variety of soil types. The results of the plate bearing tests show a wide range of load-capacity loss due to frost action; pavements laid on fine-grained soils suffering the greatest damage.

Iowa

A substantial research project was carried on by Iowa during 1949-1950-1951, and detailed reports are given in HRB Research Report 10-D, and HRB Bulletins 40 and 54. Iowa conducted tests with load bearing equipment and a device known as a subgrade resistance meter. The plate tests disclosed substantial losses in load-carrying capacity from frost action, particularly in the fine-grained soils. No correlation was found between the results of the tests made with the resistance meter and those obtained in the plate-load tests. Likewise, there did not appear to be any consistent relation between the density of the soil and the plate-load test values.

Michigan

In Michigan the loss of load-carrying capacity was studied by three methods of testing: the ring shear, the North Dakota cone, and the Housel penetrometer. The results of these tests are presented in HRB Bulletin 40. Of particular interest are the comparative results given in Table 8 of that publication. The grand average of all tests shows strength loss due to frost action. The report calls attention to difficulties encountered in using bearing test devices where the subgrade soil is variable in character.

Minnesota

Field plate-bearing tests to investigate loss of load-carrying capacity from frost action were initiated by Minnesota in 1946 and continued through 1947-1948 and 1949. The data from the tests are presented in the first annual report of the committee (HRB Proc., 28:273;1948), and HRB Research Report 10-D and HRB Bulletin 40. Of particular interest are the strength-loss curves (Research Report 10-D) and the tabulation of extensive data on "quickie surveys" (Bulletin 40). Tests were made on extensive road mileages, of various thicknesses, built over a wide variety of soils. The tests showed substantial losses of strength by frost action, and confirmed and substantiated the earlier discoveries found in 1946 and 1947. Considerable data relating to rate of thawing, soils, moisture, densities, etc., are presented.

Nebraska

Field tests using a heavy duty plate-bearing machine were carried on by Nebraska from August 1952 to December 1954. Details of the tests and results obtained are presented in HRB Bulletin 96. Of particular interest are the extensive mileage covered and the tabulation of pertinent data obtained at 252 test points covering a wide variety of subsoil, base, and surfacing combinations. The tests revealed substantial strength losses due to frost action in the poor-grade soils, and lesser damage in the better soils.

New Hampshire

New Hampshire contributed some of the earliest data. Results of plate-bearing tests, made in the spring of 1948, are presented in the first annual report on the research project (HRB Proc., 28:273;1948) and in HRB Research Report 10-D. Of special interest is the graph showing the progressive loss of strength during the thawing period, and the graph showing the relationship of unit bearing values under plates of different diameters, for identical deflections. The information presented in these reports indicates definitely that road foundations are weakened by frost action.

New York

Plate-bearing and North Dakota cone tests were made during 1948-1949 and 1950. Reports of these tests, presented in HRB Research Report 10-D and HRB Bulletin 40, contain much interesting information. The detailed tabulation of the plate-load data is of special interest in that no consistent relationship is evident between bearing values, moisture content, and soil density. Load-capacity loss was much higher in lacustrine than in outwash soils. Cone-bearing tests also indicated that strength losses due to frost action do occur; however, the results were not in good agreement with those obtained from the plate tests.

North Dakota

An extensive program of work was carried on by North Dakota through 1948, 1949, 1950, and 1951, using the North Dakota cone device, a method of test that had a background of some ten years experience in the state. Reports of this work are given in HRB Research Report 10-D, Bulletin 40 and Bulletin 54. Testing was confined to subgrades only. Of particular interest are the numerous graphs that present a summary of the data obtained. The strength-loss curves are similar to those obtained from plate-bearing tests in some of the other states.

Ohio

Plate-bearing and North Dakota cone tests were carried on by Ohio during 1949-1950 and 1951. Work was limited to one location on a 22-in. thick flexible pavement. No loss in carrying capacity was found, as frost apparently did not penetrate into the soil subgrade. Cone-bearing tests were inconclusive. These tests are reported in HRB Bulletins 40 and 54. Of special significance is the comment in one of the reports, that during the spring of 1951 other roads in Ohio with less pavement thickness were breaking up during the spring thaw.

Oregon

Extensive plate-bearing tests were made by Oregon from February 1951 through July 1954, covering four complete frost-action cycles. Details of these tests and the data obtained are reported in HRB Bulletins 54 and 96, and in the fifth (see Appendix A) and seventh (HRB Proc., 34:439;1954) annual reports of the committee. Of special interest are the graphs and data tabulations, which show an increasing degree of strength-loss where the depth of frost penetration into the subgrade was greater. All test points show substantial percentage loss in carrying capacity from frost action. However, no testing was done on highways with heavy subbases where frost action damage was not eminent.

ANNUAL PROGRESS REPORTS

Six of the eight annual progress reports submitted on this project have been published elsewhere, the remaining two being included herein as Appendix A (Annual Report No. 5-1952) and Appendix B (Annual Report No. 8-1955).

In the interests of acquainting the reader with the content of the several reports, but at the same time eliminating extensive repetition of already published material, the following summaries are given:

Annual Report No. 1 — 1948
(HRB Proc., 28:273-281;1948)

Data gathered over the two-year period of field testing indicates there is a marked similarity in the behavior of roadway bases and subgrades on which tests have been applied; and with the exception of certain admixture types of stabilized bases, frost has a weakening effect on all other types of bases and subgrades.

It appears that many miles of highways now in the process of deteriorating under traffic very likely suffered their initial and serious damage during the spring of the year, even though it may not have been immediately apparent.

It is further indicated that the desired practice of a uniform load policy throughout the year in the Frost Belt may be economically unsound. With the possible exception of limited and extremely important mileages of highways, road investments could probably be more fully utilized by seasonal changes in load limits in harmony with the ability of soils and road bases to support the loads.

In this report it was hoped to direct attention to the general nature of this research project, the objectives of the committee, and the indications of the limited data so far assembled. Most of the work still lies ahead.

Annual Report No. 2 — 1949
(HRB Research Report 10-D; 1950)

This report covers the work of the Committee, and particularly the meeting held in June 1949, at which time the activities of the various states taking part in the project and contributing research data were reviewed and discussed. The reports submitted by the various active states at that time are briefly summarized insofar as they have a bearing on the objective of the project. Changes in research procedure, as agreed upon by the Committee, are also briefly discussed.

Research data gathered during the past year appear to point toward agreement with tentative conclusions reached in previous years, and continued full-scale plate-bearing tests, as well as instrument tests, confirm the loss of normal road strength, with subsequent recovery following the thawing out of frost. Some progress has been made in correlating instrument testing with plate-bearing testing, which is also one of the objectives of the project.

The report contains a number of graphs which summarize and compare test results. It also contains a number of pictures illustrating the equipment being utilized.

Annual Report No. 3 — 1950
(HRB Bulletin 40; 1951)

An arbitrary test procedure has been developed and tests on four different soils at a wide range of moisture contents and densities have been made at temperatures from about 0 F to above 32 F. The test was a penetration type similar in character to the California bearing-ratio test but using much smaller equipment.

The soils tested cover a wide textural range, viz., sand, sandy loam, silt loam, and clay. The following conclusions seem warranted:

1. The test procedure was sufficient to portray the effects of differences in density, moisture content, soil texture and temperature on stability. The numerical values of the bearing value are for comparative purposes only and are not considered directly applicable to other conditions.

2. The bearing power of frozed soils varies markedly with their temperature. The bearing value increases at the temperature decreases below approximately 32 F. The strength at 0 F may be several times that at 30 F.

3. The bearing power of a frozen soil at a given moisture content and temperature increases with an increase in density.

4. The bearing power of a frozen soil at a given temperature and dry density increases, in general, with an increase in moisture content. For thawed soils an increase in moisture content results in a decrease in bearing value.

5. The bearing power of frozen soils may vary considerably according to their texture. The order of strengths of the four frozen soils tested in this program from least to greatest was clay, silt loam, sandy loam, and sand. The bearing strength of ice as compared to the soils was greater than the clay, about the same as the silt loam and sandy loam, and less than the sand.

Annual Report No. 4 — 1951
(HRB Bulletin 54; 1952)

The 1951 results clearly reconfirm the large loss in subgrade bearing power which occurs during the spring thawing period.

A three-year accumulation of subgrade tests is now available for analysis. It is being studied to determine if any useful hidden information is present. While this data is incomplete and test work is still in progress, the available information is proving valuable to our department.

On the basis of the three-year study, it is apparent that atmospheric weather conditions greatly affect subgrade strengths in the northern climates where severe freezing-and-thawing cycles occur. Subgrade moisture content is also closely related to subgrade strength and performance. However, the extent of this relationship has not been able to be scientifically determined or correlated.

For accurate comparisons between bearing strengths in different years, it is recommended the comparisons be made on the basis of actual cone bearing values in pounds per square inch, rather than by the percentage method of fall values.

It is hoped that future tests and subgrade performance will continue to become more uniform, so definite design and performance information can be obtained from the results.

It is also hoped that a practical method can be established for determining the calendar dates for the start and end of the critical spring thawing period during which time load limits must be applied.

Ohio. Supplementing the report of November 15, 1950, the chart (Fig. 22) has been

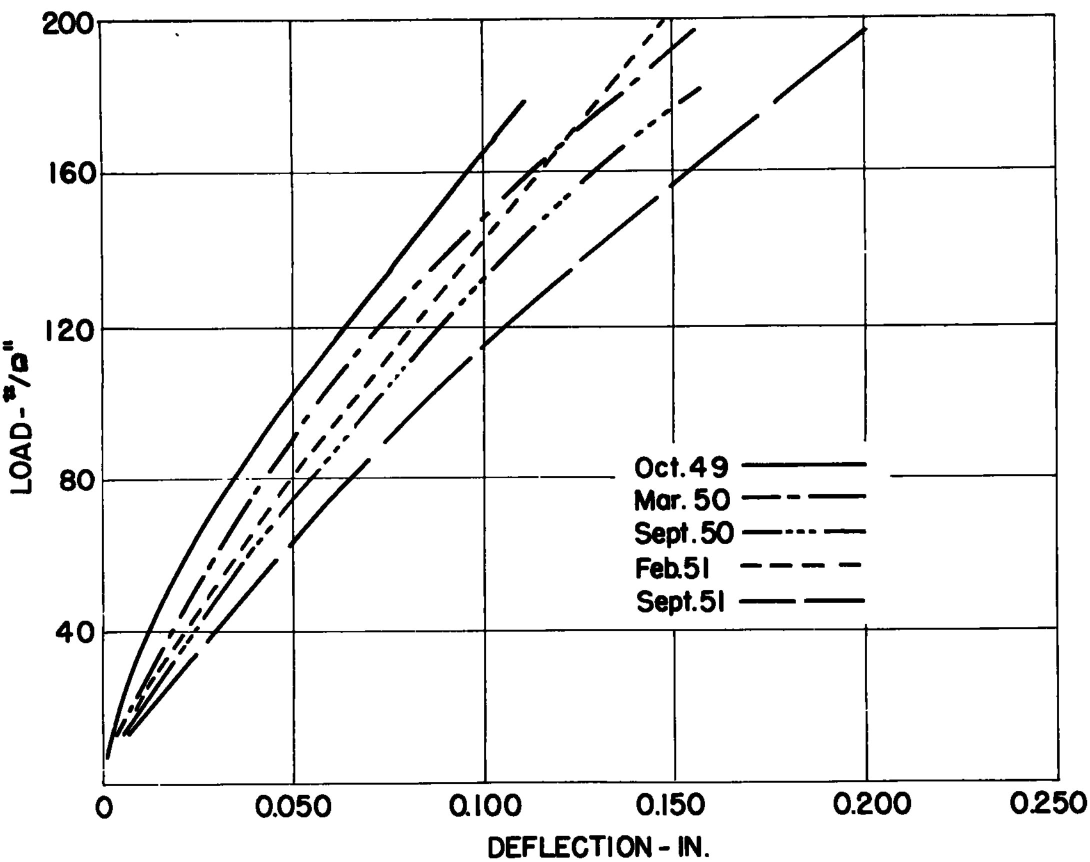


Figure 22. Average tests on surface, 12-in.-diameter plate.

brought up-to-date by including the plate bearing-test results obtained in February and September 1951 on the surface at the Delaware County test site. As previously reported, the pavement section at this test site is: 4-in. hot-mixed bituminous concrete, 8-in. waterbound macadam, and 10 ½ in. of classified embankment material.

It may be noted from the chart that the test results which were obtained in February 1951 are average by comparison to previous tests and consequently do not show a loss in strength even though these tests were made at a time when some other pavements (of less thickness) were showing considerable breakup from thaw and load.

The tests in September 1951 are lower than any of the previous tests on the surface of this pavement. It is felt that, in this series of surface tests, the variation in temperature of the 4-in. asphaltic-concrete surface course could be more responsible for the variation in results than any action due to frost.

Oregon. The Oregon test apparatus was completed in January 1951. Tests were started on 18 test points in central Oregon early in February, following the only severe weather of a generally mild winter. Tests were continued at intervals of about two weeks through the spring, and a set of midsummer readings were taken in July. All tests to date have been by the quickie method as recommended in Highway Research Board Research Report 10-D. Results vary from no apparent reduction in load-carrying capacity to readings as low as 20 percent of highest readings thus far observed.

Annual Report No. 5 — 1952
(See Appendix A)

This report includes, essentially, information supplied by the State of Oregon on research data gathered during the year 1952.

Information submitted in the Oregon report substantiated the information gathered in other states, which generally disclosed a loss of carrying capacity where frost penetration was of sufficient depth to reach the supporting soil in the subgrade. Although there is wide variation in the reported percentage loss of strength, there is nevertheless general agreement that freezing and thawing action does have a serious effect on the carrying capacity of subgrade soils.

Annual Report No. 6 — 1953
(HRB Bulletin 96; 1955)

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 and 16, 1952 — Technical Memorandum No. 27." This report likewise discloses loss of carrying capacity due to frost action.

Annual Report No. 7 — 1954
(HRB Proc., 34: 439-452; 1954)

This report includes final information by Oregon, and extensive information submitted by Indiana, which has started work on a project of considerable magnitude and has now completed the first cycle of tests.

All of the reports submitted to date contain information that discloses loss of carrying capacity by highways when subjected to substantial freezing and thawing action. The information submitted by Oregon and Indiana discloses the diminishing effect of frost action during mild winters when there is little frost penetration. Influence of frost action on carrying capacity of roads is not to be confused with surface disintegration caused sometimes by shallow freezing and thawing.

Annual Report No. 8 — 1955

This report, the final Report by Indiana (1956), is given in full in Appendix B.

SUMMARY

1. The results of the plate-load and other tests made by the states that participated in the investigation point conclusively to the fact that frost action reduces the ability of subgrade soils and pavements laid thereon to support load.
2. Fine-grained soils, including silts, silty clays, clay loams, plastic sandy loams, and clays, are affected more adversely by frost action than are soils of a granular nature. This adverse effect is dependent upon the severity of the frost action.
3. The loss in load supporting ability of soils as a result of frost action does not appear to be due to changes only in the moisture content or the density of the material. It is believed that the loss may be due in a greater degree to the manner in which the moisture is present in the soil or to the degree of saturation of the material (that is, the percent of voids filled with water).
4. The research work accomplished in the investigation indicates that the plate-load method of test may be used to develop information on load-carrying capacity of existing pavements and as a useful tool in the design of new pavements.
5. The tests executed by some of the states, as well as observations of the behavior or pavements in service, demonstrate that it is possible to build pavements of the flexible type that will not be affected appreciably by frost action.

Appendix A--Fifth Annual Report:1952

This report includes new material submitted by the State of Oregon, which completed its testing work in 1952.

Although the Oregon report continues to disclose that frost action penetrating into the subgrade soils weakens the carrying capacity of highways, it appears also to furnish some additional information which might indicate that there is some relationship between the percentage loss of carrying capacity and the depth of frost penetration. The data gathered so far are not sufficiently conclusive, but attention is nevertheless called to this phase of the Oregon information, which will be disclosed in more detail in the following report.

Oregon Progress Report No. 2 -November 1, 1952

W.W. STIFFLER, Assistant State Highway Engineer, Committee Member

Two annual cycles of plate-bearing tests on 18 test points have been completed in Oregon. The location of test points and test results are shown in accompanying figures. Test results are in general conformity with previous findings of others, except for some test points showing severe reduction with very rapid recovery.

Plate bearing tests were started in Oregon during the spring thaw of 1951 and were continued through the recovery phase to the fall high of that year. A second cycle of tests cover the thaw and recovery of 1952. All tests were conducted according to the procedure for the "quickie" test as specified in HRB Research Report 10-D, with soil moisture samples by drive-tube sampler added to the procedure in the 1952 cycle.

The Oregon test apparatus was pictured and described in detail in (Annual Progress) Report No. 1. It was assembled according to Minnesota plans and is similar in construction and operation to that used in Minnesota and Ohio.

TABLE 1

TEST POINT DATA

Test Point	Group	Surface Type	Surface Thickness	Base Type	Base Thickness	Soil Classif.	Cut or Fill	Year Completed	Avg January Temp. Normal	Avg January Temp. 1951	Avg January Temp. 1952	Max. Frost Depth-1952
1	A	Bit. Mac.	3 in.	Gravel	12 in.	A-1-b	6 ft Cut	1948		28	26	13 in.
2	A	Bit. Mac.	3 in.	Gravel	12 in.	A-4	2 ft Fill	1948		28	26	15 in.
3	A	Bit. Mac.	3 in.	Crushed Rock	6 in.	A-4	2 ft Fill	1945		28	26	12 in.
4[1]	B	Oil Mat	1 ¼ in.	Crushed Rock	6 in.	A-4	4 ft Fill	1939	26	29	22	12 in.
5[2]	B	Oil Mat	1 ¼ in.	Crushed Rock	6 in.	A-4	1 ft Fill	1939	26	29	22	12 in.
6[3]	B	Oil Mat	1 ¼ in.	Crushed Rock	6 in.	A-4	1 ft Fill	1948	26	29	22	14 in.
7[3]	B	Oil Mat	1 ¼ in.	Crushed Rock	6 in.	A-4	1 ft Fill	1948	26	29	22	14 in.
8	C	Bit. Mac.	3 in.	Crushed Rock	18 in.	A-4	3 ft Fill	1950				26 in.
9	C	Bit. Mac.	3 in.	Crushed Rock	18 in.	A-4	8 ft Cut	1950				26 in.
10	D	Oil Mat	1 ¼ in.	Grav. and Cr.R.	6 in.	A-4	2 ft Fill	1947	30	32	27	10 in.
11	D	Oil Mat	1 ¼ in.	Grav. and Cr.R.	8 in.	A-4	10 ft Fill	1947	30	32	27	8 in.
12	D	Oil Mat	1 ¼ in.	Crushed Rock	5 in.	A-4	Grade	1947	30	32	27	11 in.
13	D	Oil Mat	1 ¼ in.	Crushed Rock	5 in.	A-2-4	12 ft Fill	1947	30	32	27	10 in.
14	E	Oil Mat	1 ¼ in.	Cinders	7 in.	A-2-5	3 ft Fill	1948	25	24	22	20 in.
15	E	Oil Mat	1 ¼ in.	Cinders	7 in.	A-2-5	3 ft Fill	1948	25	24	22	20 in.
16	F	Oil Mat	⅝ in.	Crushed Rock	6 in.	A-1-b	4 ft Cut	1939	25	24	22	24 in.
17	F	Oil Mat	⅝ in.	Gravel	6 in.	A-1-b	3 ft Cut	1939	25	24	22	24 in.
18[4]	F	Bit. Mac.	3 in.	Crushed Rock	12 in.	A-1-b	5 ft Fill	1949		25	23	20 in.

[1] 6 in. Crushed Rock and 1 ¼ in. Oil Mat placed over 1939 construction in 1950.
[2] 1 ¼ in. Oil Mat placed over 1939 and 1948 construction in 1950.
[3] 4 in. Asphaltic Concrete placed over 1948 construction in 1950.
[4] 1949 construction placed over 1939 construction as at Test Point 17.

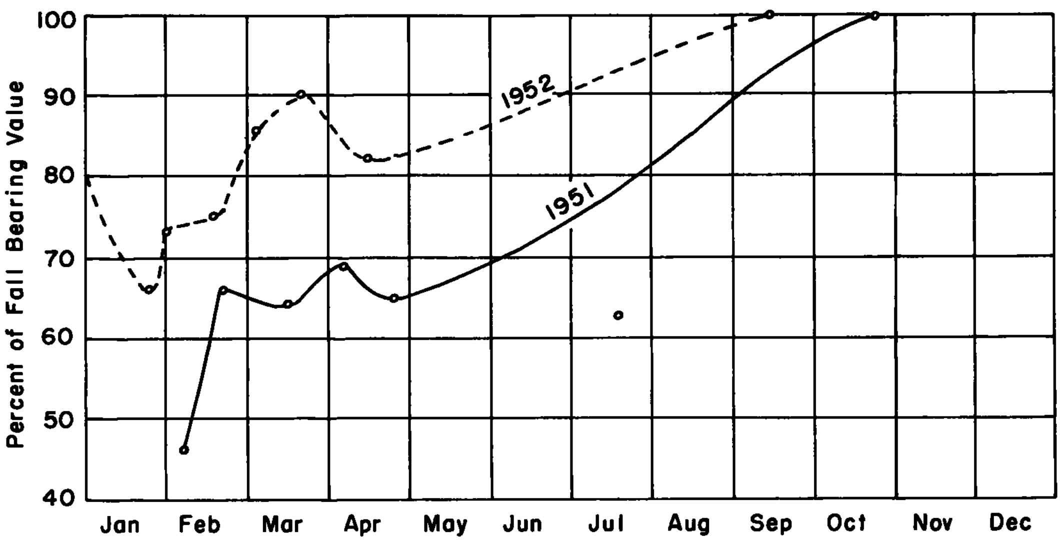


Figure 1. Group A Test Points 1 - 3.

The 18 test points were located in areas of Central Oregon subject to moderate to to severe freezing. Test points were selected to include bituminous macadam and oil mat treatment with all types of base construction commonly employed in the region. Test point locations are shown in Figure 7. General data on all test points are given in Table 1.

The highway at the specific location of each test point has served traffic satisfactorily without failure or major distress and without maintenance except for general light-oil treatments for re-seal and non-skid during the course of the tests except that points 6 and 7 were covered with a new asphaltic-concrete course as part of a general re-surfacing project as the tests were concluded.

Because of the difference in time of thaw and in recovery characteristics at the various test points, a composite curve for all test points would have little meaning. For this reason, results are presented in the form of curves for groups of points in the same vicinity with similar recovery characteristics. Curves for all groups for 1951 and 1952 are given in Figures 1 through 6. All data is based on 0.2-in. deflection with a 12-in. plate.

Groups A, B and C show reduction and recovery similar to that previously reported by Minnesota (Research Report 10-D) and Iowa (Bulletin 40). Groups D, E and F show severe reduction followed by rapid recovery. Group E shows these characteristics to a very high degree.

The low readings in Groups A and B for July 1951 were the result of heat-softened asphalt.

No further field work under this project is planned; however, the analysis and correlation of bearing, soil, moisture, frost, and weather data for 18 test points in Central Oregon and bearing, soil, moisture, and weather data for the 14 test points which have been followed in Western Oregon, will be completed.

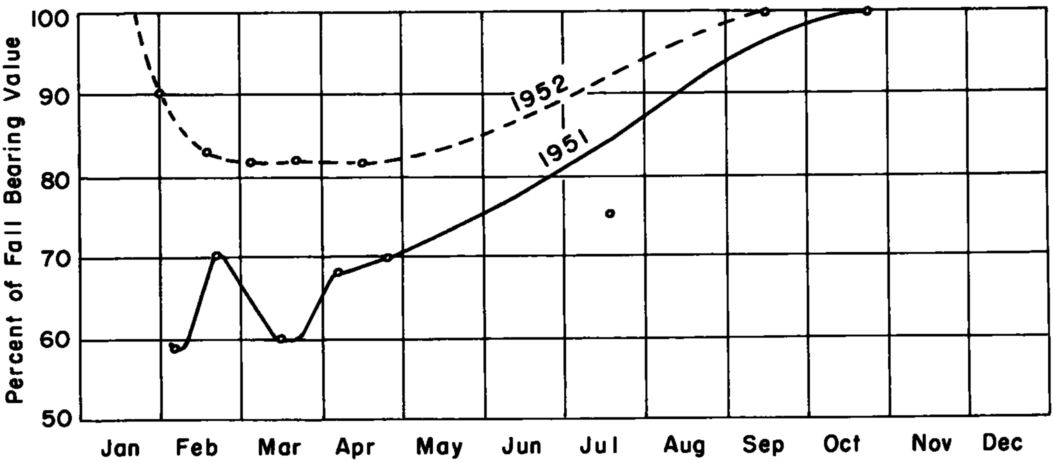


Figure 2. Group B Test Points 4 - 7.

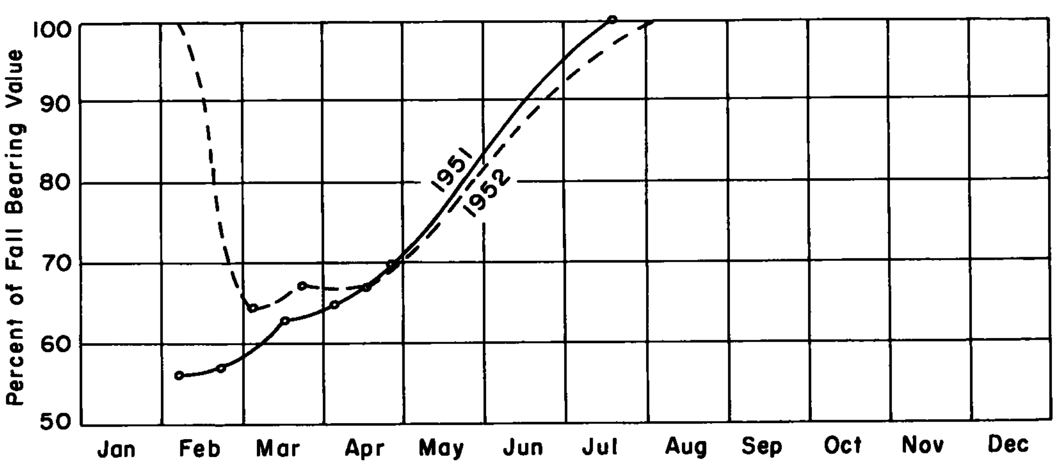


Figure 3. Group C Test Points 8 and 9.

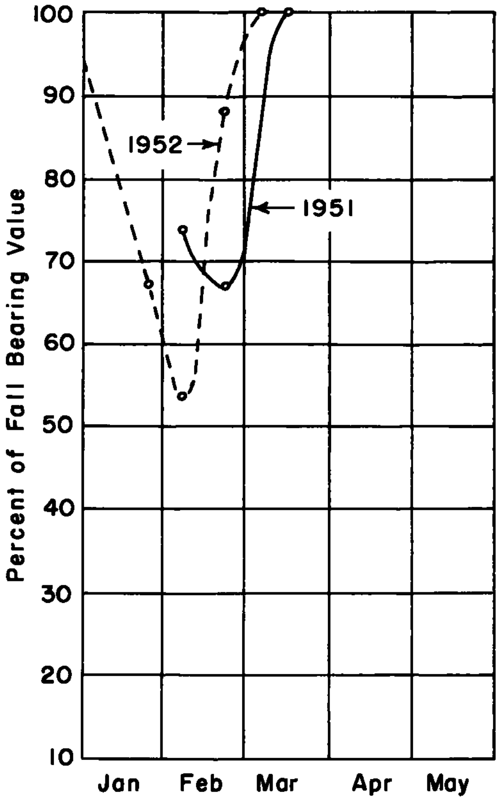


Figure 4. Group D Test Points 10 - 13.

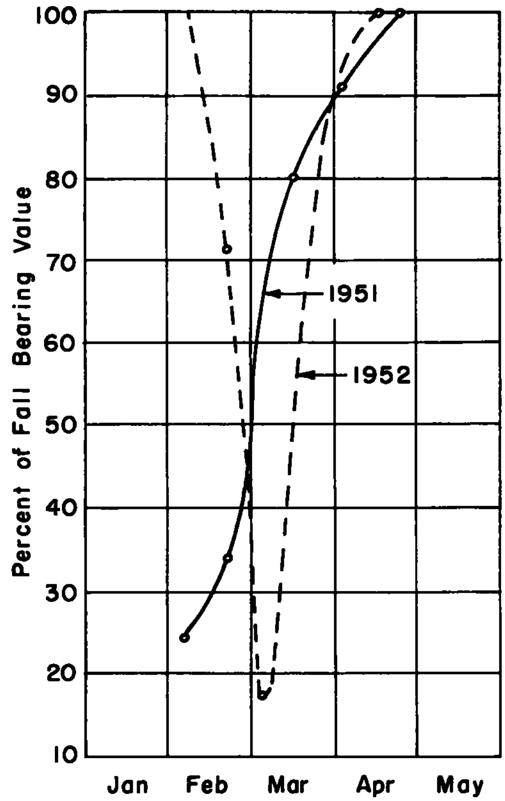


Figure 5. Group E Test Points 14 and 15.

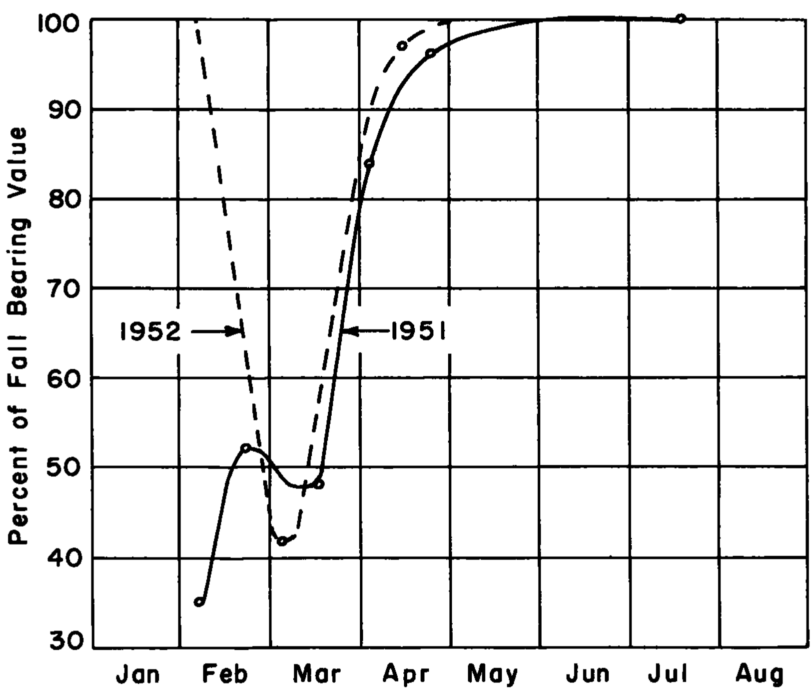


Figure 6. Group F test Points 16 - 18.

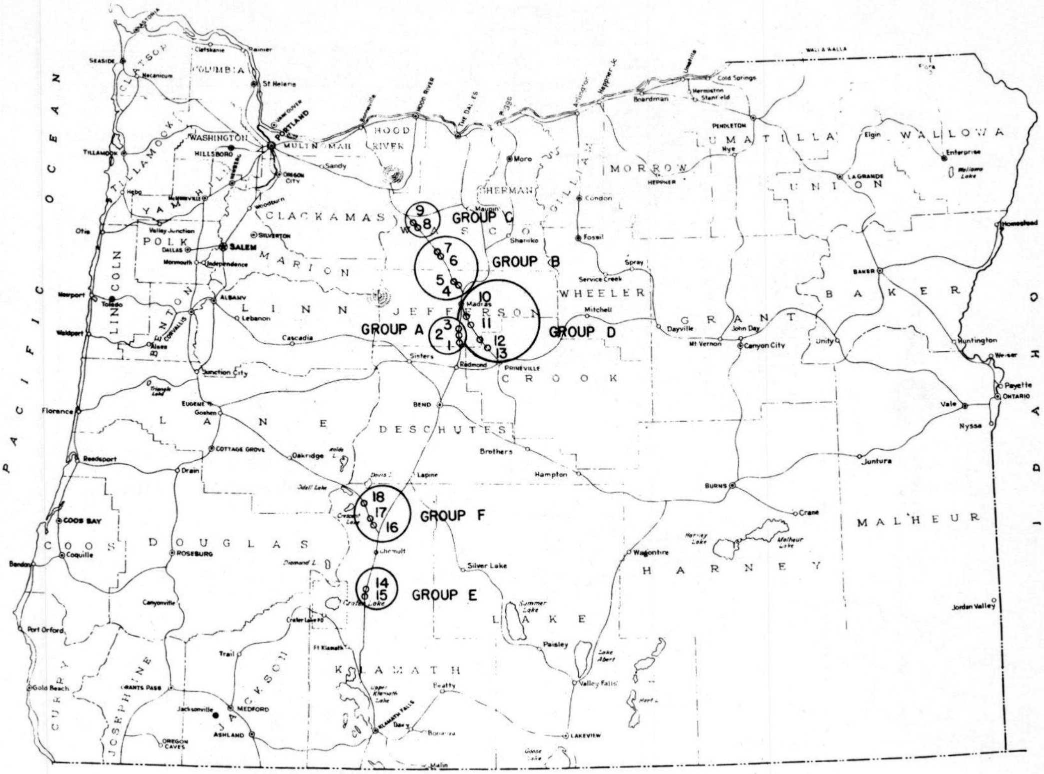


Figure 7. Test Point Locations.

Appendix B--Annual Report No. 8:1955

Final Report of State of Indiana
by Carl E. Vogelgesang, Chief Engineer, Indiana State Highway Department.

During the summer of 1953, the final selection of sites for determining the load-carrying capacity of flexible pavements as affected by frost action was decided upon. In principle, plate bearings would be made with a 12-in. plate during the early fall at a time when pavements and subgrades should be at their maximum strength. Plate bearings would be repeated at the same sites during the following spring at a time when pavements and subgrades should be weakest. A comparison of the two bearing values would then be used to indicate loss due to frost action.

A total of 33 sites was originally selected for this study. However, it was soon realized that this involved a very ambitious program. After careful consideration, two of the original sites (sites 12 and 14 in the northern circuit) were discarded, leaving a total of 31 locations for study. Locations were selected to cover a range of climatological influences, subgrade soils, and various types and thicknesses of flexible pavement construction throughout Indiana. These considerations resulted in eight of the final test sites being located in the southern half of the state and twenty-three in the northern half. Figure 1 shows the location of these sites. A description of each site is given at the end of this Appendix. The thicknesses listed in these descriptions, ranging from 6¾ in. to 13¾ in., were determined in September 1953. Later determinations showed variations in thicknesses at most locations (see Table 1).

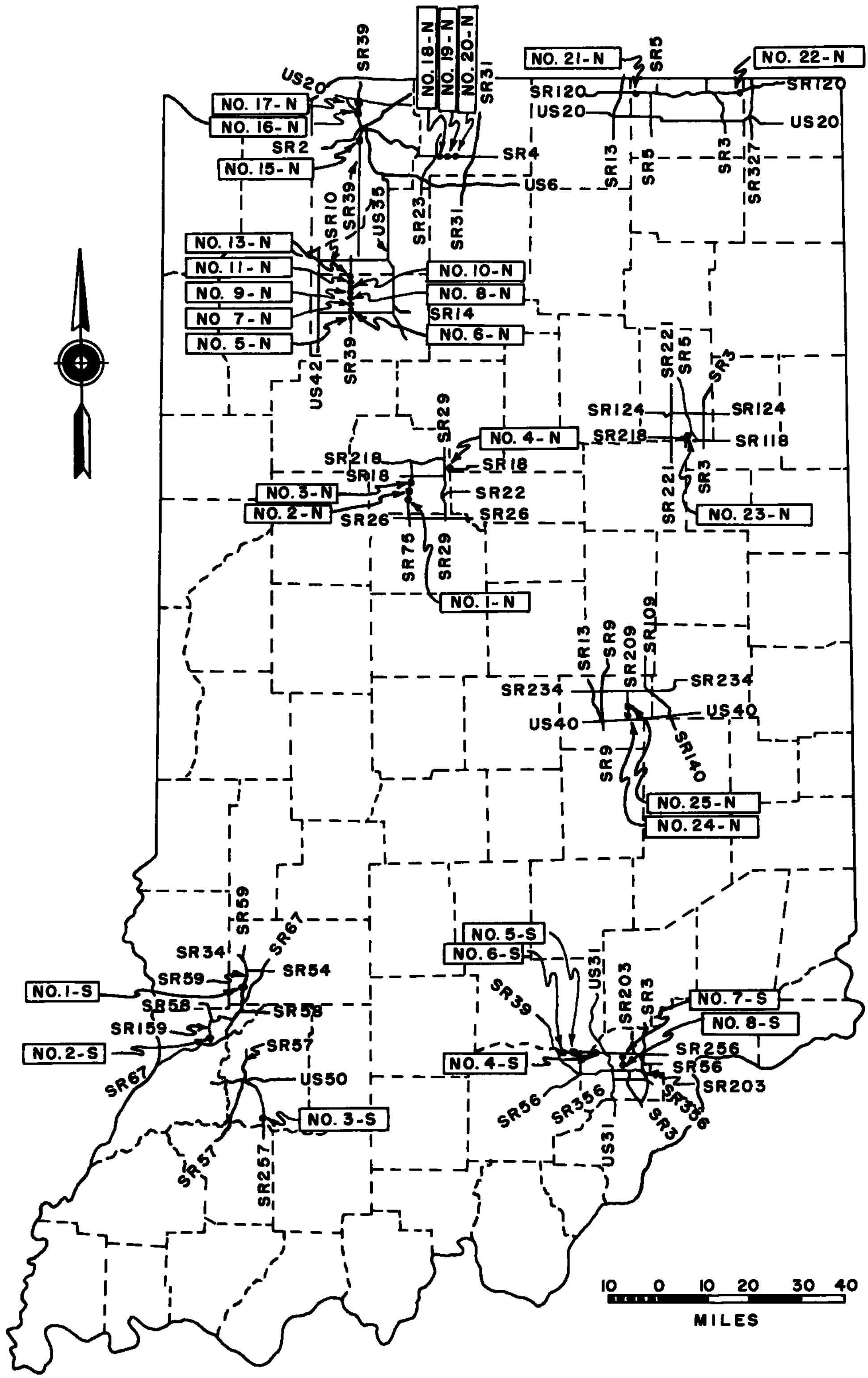


Figure 1. Location of Sites for Plate Bearing Tests.

The truck for the loading unit was completed in 1949, and was used numerous times on special projects. It was particularly well suited for in-place C. B. R. testing and was used extensively for this purpose during the construction of US 41 test road during 1949.

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

EQUIPMENT

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

Vehicle	Axle	Axle load (lb)
Truck	Front	5,200
	Front tandem	11,600
	Rear tandem	9,000
	Total	25,800
Trailer	Front	12,700
	Rear	12,300
	Total	25,000
Entire Unit		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 to 40,300 lb the maximum total load applied through the jack column. To produce this load requires a gauge reading of 8,000 psi. This maximum load applied to a 12-in. plate develops a unit load of 357 psi on the surface being tested.

The truck and trailer unit is shown in Figure 2. Figure 3 shows the equipment in operating position.

In addition to the work for this Committee, 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. On the test roads, a total of 83 plate loadings was made on subgrades, subbases, bases and finished surfaces. Some of these test data are included in this report.

TESTS

Procedures for making plate-bearing tests were in accordance with those recommended by the Committee.

The first cycle of tests was begun in September 1953. For the first part of this cycle, plate-bearing tests were made on the surface in the center of a traffic lane at all 31 sites. The first test at each location was made using the regular procedure; that is, each increment of load was released and the pavement allowed to recover before the next increment of load was applied. The "quickie" procedure was used for additional tests at 26 sites. In this method, the pavement is not allowed to recover until the last increment of load has been applied. Typical bearing-value curves obtained by each of these methods are given in Figure 4. A comparison of these data shows no significant difference in the results obtained by the two methods. Moisture samples of the subgrade were obtained and the pavement thicknesses determined at each site.

The first cycle was completed in the spring of 1954. At least two bearing tests were made on the surface at each site, using the regular procedure. Pavement thicknesses were measured and subgrade samples obtained for moisture content determination and laboratory analysis.

The wide differential in the loss of bearings during the early spring series of the first cycle confirmed the original belief that more detailed information was needed.

SUMMARY C
FOR 2 CO

Tests Made

Average Bea

Site No.	Type of Base	Subgrade Soil Type Fall 1953	Subgrade Soil Type Spring 1954	Subgrade Soil Type Fall 1954	Subgrade Soil Type Spring 1955	1st Cycle Fall 1953	1st Cycle Early Spring 1954	1st Cycle % Fa 19 Valu
5-S	Traffic bound stone	A-7-6(13) Cl	A-6(9) SiCl	A-6(11) SiCl	A-6(11) SiCL	86	70	8
6-S	Traffic bound stone	A-7-6(13) Cl	A-7-6(13) Cl	A-7-6(13) Cl	A-7-6(13) Cl	88	63	7
8-S	Traffic bound stone bit. stab. stone	A-6(12) Cl	A-6(10) Cl	A-4(8) Cl	A-4(8) Cl	106	82	7
4-S	Traffic bound stone	A-6(10) SiClL	A-6(9) SiClL	A-4(8) ClL	A-4(8) ClL	140	131	9
24-N	Traffic bound stone bit. stab. stone	A-6(11) ClL	A-4(5) ClL or L	A-4(7) ClL or L	A-4(7) ClL or L	144	108	7
3-S	Traffic bound stone bit. stab. stone	A-4(8) SiL	A-4(8) SiL	A-4(8) SiClL	A-4(8) SiClL	149	136	9
7-S	Traffic bound stone bit. stab. stone	A-6(10) ClL	A-6(8) ClL	A-4(6) ClL	A-4(6) ClL	157	105	6
1-S	Traffic bound stone	A-6(10) ClL	A-6(10) SiClL	A-6(9) Cl	A-6(9) Cl	160	126	7
2-S	Waterbound macadam	A-6(9) SiL	A-6(9) SiL	A-4(8) SiClL	A-4(8) SiClL	177	153	8
20-N	Traffic bound gravel	A-6(6) ClL	A-4(5) Cl	A-4(5) Cl	A-4(5) Cl	177	104	5
23-N	Traffic bound gravel	A-4(2) SL	A-4(2) SL	A-6(5) ClL	A-6(5) ClL	180	171	9
1-N	Traffic bound gravel	A-4(2) SL	A-4(5) ClL	A-4(5) ClL	A-4(5) ClL	185	122	6
25-N	Traffic bound stone bit. stab. stone	A-4(5) ClL	A-4(5) L	A-4(5) L or ClL	A-4(5) L or ClL	190	128	6
16-N	Traffic bound gravel	ClL	A-4(7) ClL	A-4(7) ClL	A-4(7) ClL	192	119	6
3-N	Traffic bound gravel	A-6(4) SL	A-6(6) ClL	A-6(6) ClL	A-6(6) ClL	206	107	5
4-N	Traffic bound stone	A-4(1) SL	A-4(1) SL	A-4(0) SL	A-4(1) SL	212	180	8
17-N	Traffic bound gravel	SL	A-2-4(0) SL	A-2-4(0) SL	A-2-4(0) SL	234	156	6
2-N	Traffic bound gravel	A-2-4(0) SL	A-2-4(2) SL	A-2-4(0) SL	A-2-4(0) SL	268	241	9
15-N	Traffic bound stone	SL	A-3(0) S	A-3(0) S	A-3(0) S	272	216	7
18-N	Traffic bound gravel	SL	A-2-4(0) SL	A-2-4(0) SL	A-2-4(0) SL	274	232	8
5-N	Traffic bound stone	SL	A-3(0) S	A-2-4(0) S	A-2-4(0) S	275	240	8
9-N	Traffic bound stone	S	A-3(0) S	A-3(0) S	A-3(0) S	282	258	9
19-N	Traffic bound gravel	L	A-4(4) L	A-4(4) L	A-4(4) L	292	156	5
10-N	Traffic bound stone	SL or S	A-2-4(0) SL or S	A-2-4(0) SL or S	A-2-4(0) SL or S	344	304	8
22-N	Traffic bound stone	A-2-4(0) S	A-1-b S	A-1-b S	A-1-b S	354	317	9
6-N	Traffic bound stone	S	A-2-4(0) S	A-3(0) S	A-3(0) S	359	341	9
7-N	Traffic bound stone	S	A-3(0) S	A-3(0) S	A-3(0) S	387	356	9
8-N	Traffic bound stone	S	A-3(0) S	A-2-4(0) S	A-2-4(0) S	396	352	8
21-N	Traffic bound gravel	A-2-4(0) S	A-3(0) S	A-3(0) S	A-3(0) S	408	336	8
11-N	Soil-Cement	S	A-3(0) S	A-3(0) S	A-3(0) S	[1]	[1]	
13-N	Soil-Cement	S	A-3(0) S	A-3(0) S	A-3(0) S	[1]	[1]	

[1]Exceeded capacity of equipment.

Accordingly, six sites were selected for complete testing of the surface, base, and subgrade. The sites selected were 4-S, 6-S, and 7-S in the southern circuit, and 2-N, 3-N, and 4-N in the northern circuit. This phase of testing, listed in Tables 1 and 3 as "Late Spring 1954", was begun during the third week of April and completed in May. Bearing tests were again run on the surface, the base, and the subgrade at each of the sites mentioned. Densities and moisture contents for base and subgrade were also determined. Samples of base and subgrade were obtained for laboratory analysis.

Since all loadings for the fall and early spring series of the first cycle were run in the center of the traffic lane, it seemed desirable at this stage to determine how

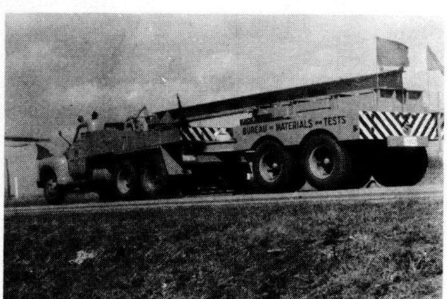


Figure 2. Truck and trailer unit used for plate bearing tests.

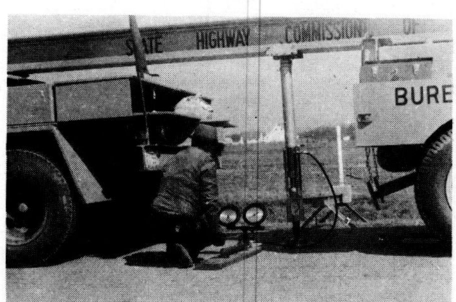


Figure 3. Equipment in operating position.

1

RING VALUES
TE CYCLES

ement Surface
lue at 0.2 in Defl. - psi

		2nd Cycle			Total Pavement Thickness - in.						Moisture Content of Subgrade percent				
						1st Cycle			2nd Cycle		1st Cycle			2nd Cycle	
te ing 54	% of Fall 1953 Value	Fall 1954	Spring 1955	% of Fall 1954 Value	Design	Fall 1953	Early Spring 1954	Late Spring 1954	Fall 1954	Spring 1955	Fall 1953	Early Spring 1954	Late Spring 1954	Fall 1954	Spring 1955
		74	62	84	6 ¾	6 ¾	8		8	8 ¼	20.2	24.1		24.4	22.9
0	80	80	40	50	6 ¾	6 ¾	7	7	9 ½	8	24.9	22.6	26.6	24.5	25.9
		117	63	54	6 ¾	7 ½	7		6 ½	5 ½	17.3	15.3		18.1	18.3
9	85	143	103	72	6 ¾	6 ¾	7 ½	7 ½	7	6	17.1	13.6	17.2	18.5	20.6
		153	116	76	6 ¾	13	13		12 ½	12	22.8	16.4		17.7	11.6
		142	50	35	6 ¾	7 ½	7		6 ½	6 ½	16.7	12.6		18.1	15.8
35	54	141	53	38	6 ¾	6 ½	8	5	4	6	10.4	14.0	13.3	14.0	14.3
		132	85	63	6	7	8 ½		8 ¾	8 ¾	12.7	17.7		16.4	19.4
		184	134	73	8 ¾	10 ½	10 ½		8 ½	9	18.3	18.4		21.1	19.3
		166	47	28	9	9 ¾	8 ½		9 ½	13	10.7	13.1		13.7	13.7
		166	123	74	9	11	12		12 ½	12 ½	14.4	18.5		19.8	20.2
33	72	217	151	60	9	11	11		12	11 ½	8.0	12.5		11.0	11.7
		158	123	78	6 ¾	10 ½	12		11	9 ½	17.5	15.0		21.3	12.4
		175	98	56	9	11	10		12	10	12.1	12.1		12.2	13.5
65	80	230	156	68	9	10	7	10	11	13	10.1	14.3	14.8	12.4	13.2
08	98	204	172	84	6	12	10 ½	11	12	13 ½	7.2	12.2	12.3	11.4	14.6
		230	191	83	9	10 ½	10		10	10 ½	10.4	6.5		6.3	6.1
47	92	264	199	75	9	9	9	10 ¼	10 ½	9 ¾	5.9	9.1	5.2	5.3	6.3
		248	244	98	8	13 ¾	13 ¾		14	15	8.7	10.5			12.5
		293	226	77	9	10 ¼	10 ½		11 ½	11	8.0	7.9		9.9	8.9
		284	246	87	8 ¾	8 ½	9		8	8 ½	10.0	12.4		8.0	10.2
		265	220	83	6 ¾	9	9		8 ½	9	12.1	7.2		4.8	8.9
		280	100	36	9	10 ½	10 ½		10 ½	10	7.7	10.0		9.5	11.4
		358	278	78	6 ¾	10	10		9 ½	10	6.6	8.5		7.5	7.1
		406	360	89	6	9	9		8 ½	9	7.6	6.6			5.0
		362	306	85	6 ¾	8 ¾	9		9	8 ½	4.5	5.8		4.8	6.7
		416	416	100	6 ¾	10	9 ½		9	10 ½	5.3	3.8		3.3	3.4
		392	364	93	6 ¾	9	9 ½		9	9	7.9	4.8		3.4	7.0
		427	412	97	9	9	8		10 ½	10 ½	5.1	4.1		3.8	5.7
		[1]	[1]		7	9 ½	8		9	9	5.0	4.4		4.2	3.7
		[1]	387		7	9	8		9	9	5.1	3.7		3.1	4.6

bearing values would vary when made near the pavement edge. Therefore, at sites 2-N, 3-N, and 4-N, tests were also made on the surface, base, and subgrade approximately 1.5 ft from the edge, which approximates the outer edge of the outside wheel track. Densities and moistures were also determined at these same locations.

The second cycle was begun in September 1954 and was completed before the fall rains. During this time, bearing tests were made on the surface at the same 31 test sites as used during the first cycle. Test holes were dug at each site to determine the pavement thickness and to obtain subgrade samples for moisture content determination. At sites where the subgrade soil varied from previous test samples, additional samples were obtained for laboratory analysis.

In addition to the plate-bearing tests on the surface, bearing tests were also made on the base and subgrade at sites 4-S, 8-S, 2-N, and 4-N. Densities and moisture contents for the base and subgrade were also determined at these locations. It will be noted in Table 3 that detailed tests made in the spring of 1954 at sites 6-S, 7-S, and 3-N were not repeated during the second cycle because of too much variation in thickness due to rutting of the subgrade at time of construction.

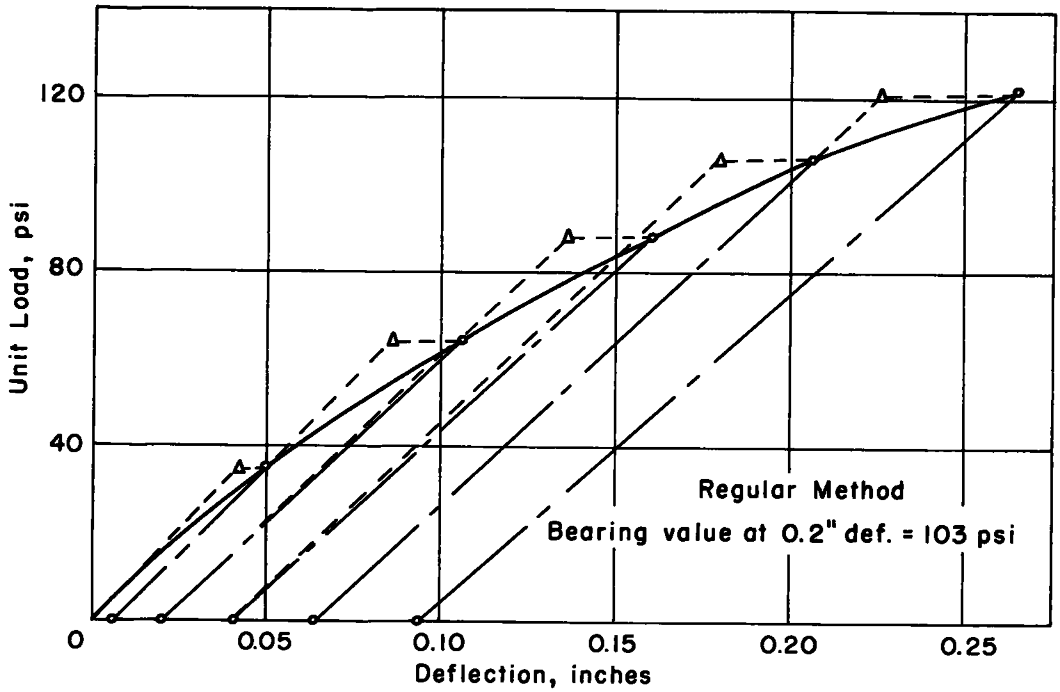
The final phase of the second cycle was begun in March 1955, after the frost was out of the ground. The procedure of testing and sampling was the same as used in the fall of 1954. Detailed tests were repeated at the same four sites.

During this second cycle, all bearing tests were made in the center of the traffic lanes.

TEST RESULTS

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 clay-loam subgrade, granular



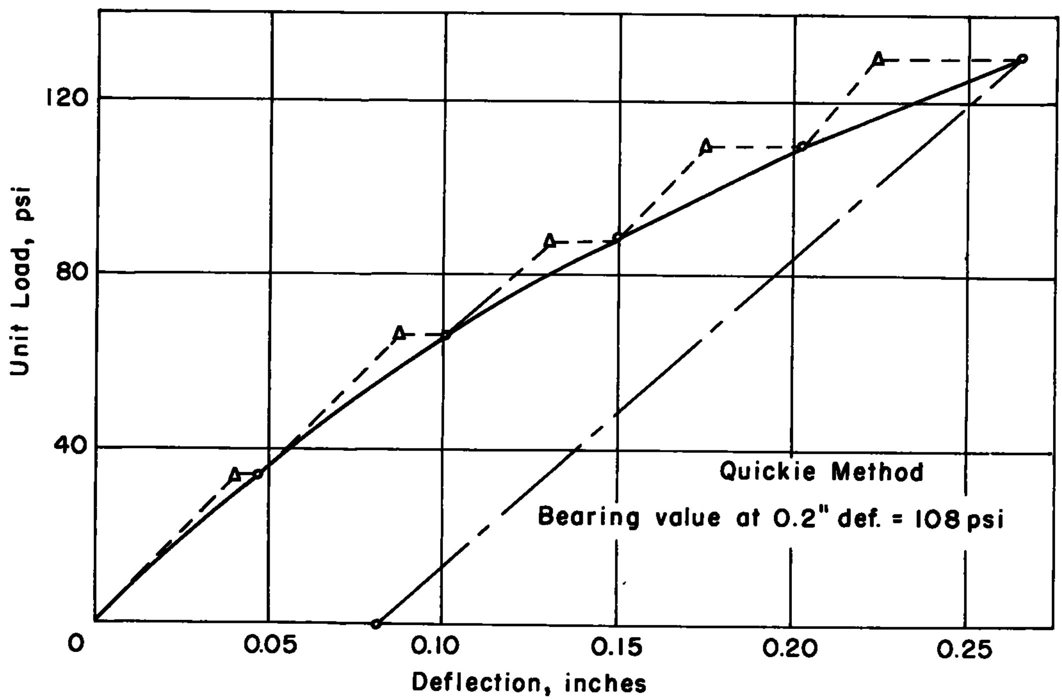


Figure 4. Typical Bearing Value Curves showing relation between regular and quickie methods. Tests run at Site 8-S. Construction was 1-3-in. course of No. 3 stone, traffic bound; 1-3-in. course of No. 3 stone bituminous stabilized, with seal; 1½-in. bituminous resurface, giving total thickness of 7½-in. Subgrade soil was clay and moisture content was 17.3 percent. 12-in. bearing plate was used.

subbase, base courses, binder, and surface, for a section of a test road constructed on US 31, during 1953. These test values are not included in the summary tables of bearing values, because this pavement, which is designed for heavy traffic and has a total thickness of 20 in., is not comparable with other pavements tested.

Table 1 is a summary for both cycles of all bearing tests made on the surface at the 31 sites. This table also shows type of base, subgrade soil type, percent of fall bearing-value, total pavement thickness, and moisture content of subgrade.

It was found, during the two cycles of testing, that the total pavement thickness at many of the sites varied considerably throughout the length of the sections tested. For this reason, which is in addition to some subgrade soil variation, direct comparison of spring bearing values to the previous fall values does not necessarily give a true or accurate value. In Table 1, the columns headed "% of Fall Value" do not consider the thickness or other variables. The spring bearing values for the first cycle appear to range from 52 to 95 percent of the previous fall values, or a loss of 5 to 48 percent. During the second cycle, the spring values appear to range from 28 to 100 percent of the previous fall values, or a loss of 0 to 72 percent. At most of the sites, the loss of bearing values was greater during the second cycle than during the first. During the second cycle, the loss was most severe at sites 3-S, 7-S, 19-N, and 20-N, being 65, 62, 64, and 72 percent, respectively. At these four sites the pavement showed definite signs of alligatoring and slight distortion; this weakening of the pavement structure could account for the high losses. It also should be noted that the subgrades at these locations are fine-grained soils. It is interesting to note that, during the second cycle at sites 7-N and 15-N, the losses were 0 and 2 percent, respectively. The reason that these sites did not show any loss is that the pavements were thicker at the locations tested in the spring than the locations tested the previous fall; and

TABLE 2

SPRING BEARING VALUES EXPRESSED AS PERCENT OF FALL VALUES AT SITES HAVING NO VARIATION IN TOTAL PAVEMENT THICKNESS

1st. Cycle				2nd. Cycle			
Site No.	Subgrade Soil	Total Pavement Thickness	Spring Bearing Value as % of Fall Value	Site No.	Subgrade Soil	Total Pavement Thickness	Spring Bearing Value as % of Fall Value
9-N	Sand	9	91	21-N	Sand	10 ½	97
22-N	Sand	9	90	8-N	Sand	9	93
2-N	Sandy loam	9	90	23-N	Clay loam	12 ½	74
10-N	Sandy loam or sand	10	88	1-S	Clay loam	8 ¾	63
2-S	Silty loam	10 ½	86	3-S	Silty clay loam	6 ½	35
15-N	Sand	13 ¾	79				
1-N	Clay loam	11	66				
19-N	Loam	10 ½	53				

TABLE 3

RANGE OF BEARING VALUES ON PAVEMENT SURFACE ACCORDING TO SUBGRADE SOIL TYPES

	1st. Cycle Bearing Value psi		% of Fall Value	2nd. Cycle Bearing Value psi		% of Fall Value
	Fall 1953	Spring 1954		Fall 1954	Spring 1955	
(a) Textural Classification						
Clay	86-106	63-104	72-77	80-166	40-85	28-63
Silty clay loam	140	126-131	94	142-184	50-134	35-73
Clay loam	144-192	105-128	62-75	141-230	53-156	38-78
Silty loam	149-177	136-153	86-91			
Sandy loam	180-344	156-304	67-95	204-358	172-278	75-84
Sand	282-408	216-356	82-95	248-427	220-416	83-100
(b) AASHO Classification						
A-7-6 and A-6	86-206	63-153	52-94	74-230	40-156	50-84
A-4	149-292	104-180	53-95	117-280	47-172	28-84
A-3	282-396	216-356	79-92	248-427	220-416	83-100
A-2	234-408	156-341	67-95	230-392	191-364	75-93

Note: Above data is for all types and thicknesses of pavement.

also, these sites have sand subgrades with low moisture contents and thick pavement. No bearing values are shown in Table 1 for sites 11-N and 13-N, which have soil-cement bases. The capacity of the equipment (20 tons) was exceeded at these two sites and it was not possible to determine the bearing value, even by extrapolation.

Table 2 was made to show the sites at which there was no variation in total pavement thickness at the locations tested during a complete cycle. This table shows the spring bearing values expressed as a percentage of the previous fall value. This summary probably illustrates more accurately the effect of frost action than does Table 1. Thus, during the first cycle at the nine sites having constant pavement thickness, the spring pavement bearing values range from 53 to 91 percent of the previous fall value. This is a loss of 9 to 47 percent. During the second cycle at the five sites shown, the spring values range from 35 to 97 percent of the previous fall values, or a loss of 3 to 65 percent. It further shows that the loss of bearing due to frost action for pavements having sand or sandy loam subgrades is not so severe. Pavements on subgrades that are not

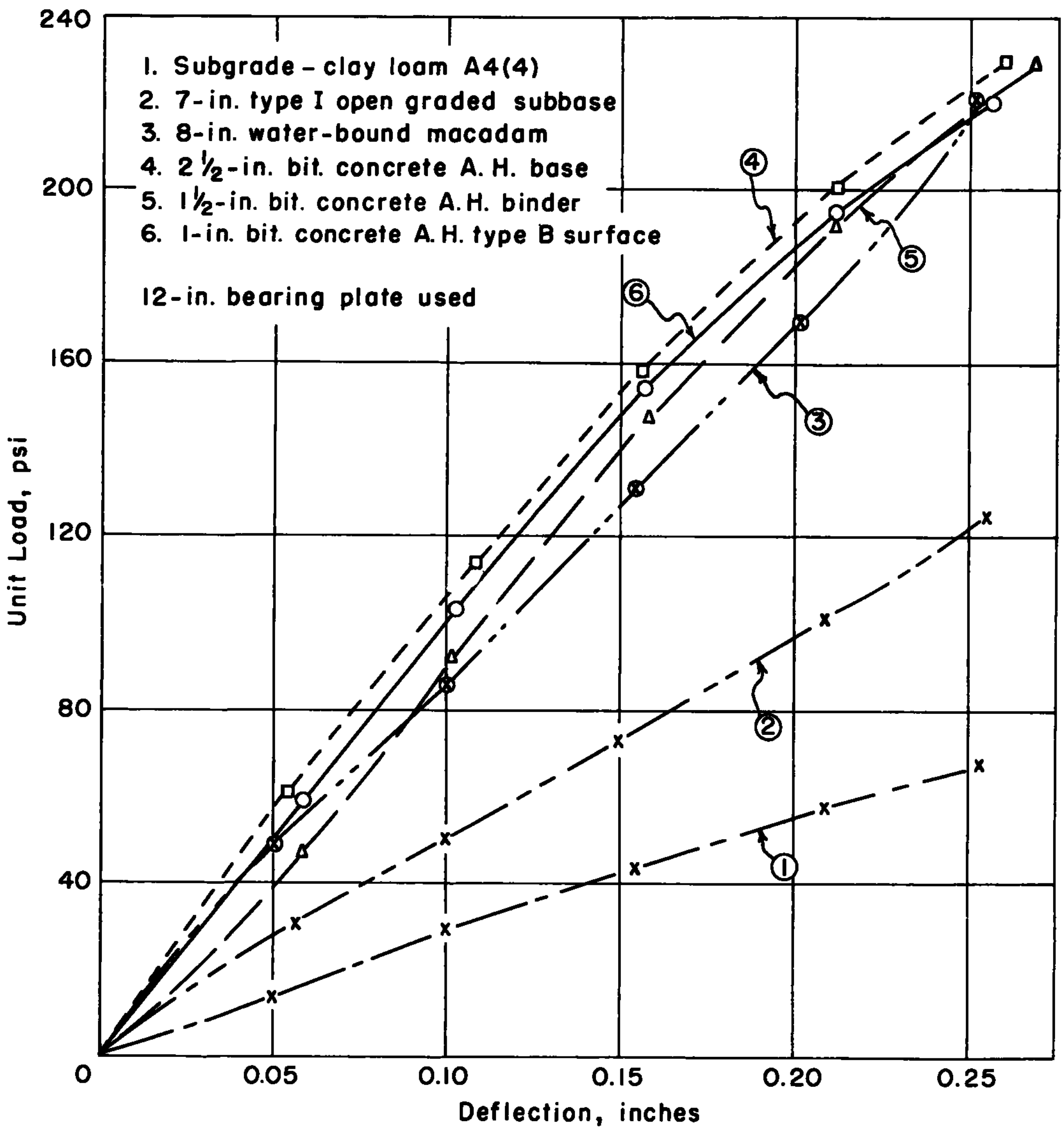


Figure 5. Typical Bearing Value Curves U.S. 31 Test Road.

granular show a loss of 14 to 47 percent for the first cycle and 26 to 65 percent for the second cycle. It should be noted that the greatest loss in bearing occurred during the second cycle on a thin pavement with a silty clay-loam subgrade.

Table 3 shows the range of bearing values for both cycles arranged according to subgrade soil types, disregarding the other variables. The data as shown are for all types and thicknesses of pavement, arranged by textural classification and by AASHO classification. It is quite evident from this table that pavements constructed on granular subgrade soils (sand or sandy loam, A-3 or A-2) have higher bearing and lower loss of bearing than those having finer-textured subgrades. This same information is shown graphically in Figures 6, 7, and 8.

The relation of bearing values to pavement thickness and subgrade soil is shown in Figures 9, 10, and 11 for clay, clay-loam, and sandy-loam subgrades, respectively; Figure 12 is for A-7-6 and A-6 subgrades, and Figure 13 is for A-4 subgrades. Pavements having clay or clay-loam (A-7-6, A-6, and A-4) subgrades show a general tendency for increased bearing values as the pavement thickness increases. In the case of sandy-loam subgrades this trend is not so evident. However, it should be pointed out that the pavements tested on sandy-loam subgrades were comparatively thick, ranging from 8½ to 13¾ in., which probably accounts for part of the deviation from the trend shown for fine-grained subgrades. The data for sandy (A-3 and A-2) subgrades are not shown because the points are quite scattered and do not show any apparent relation between bearing value and thickness. The remaining subgrade soil types are not shown

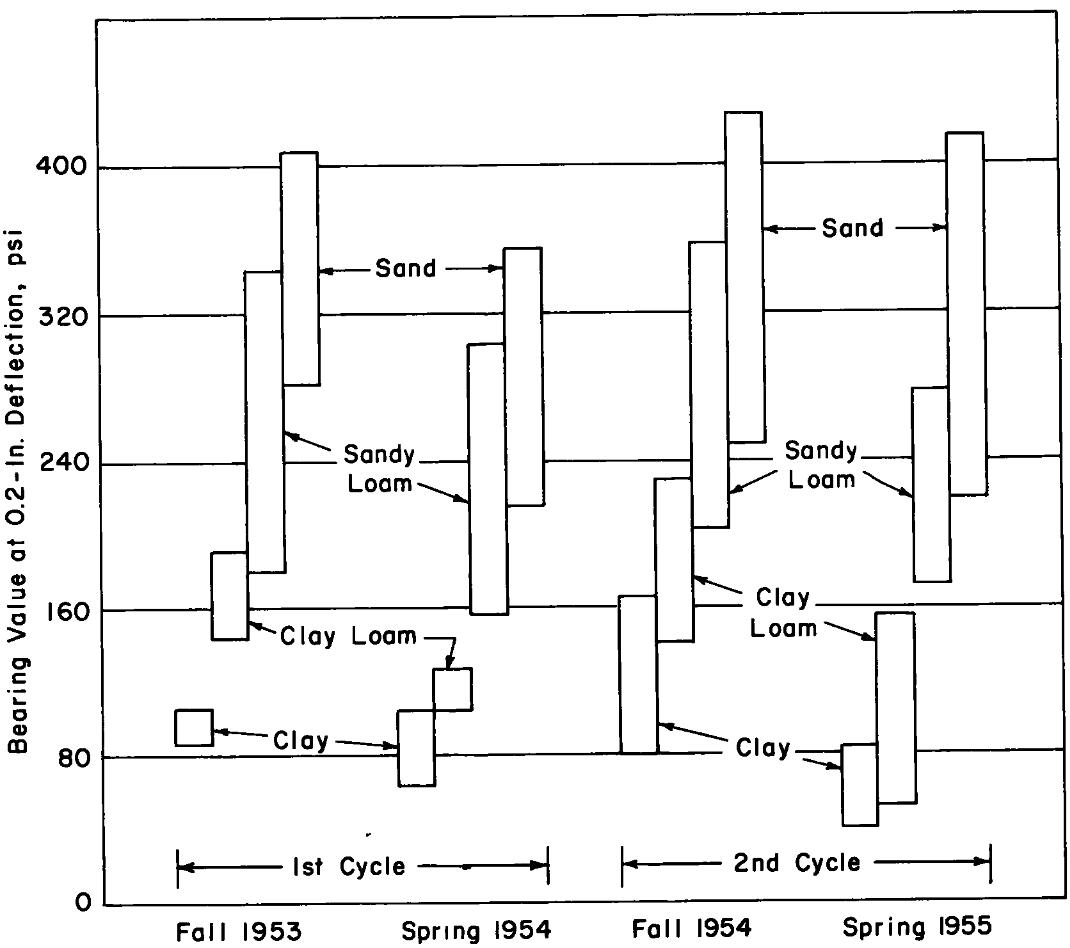


Figure 6. Variations of pavement bearing values for various subgrade soil types (Textural Classification). Data is for all types and thicknesses of pavements tested.

TABLE

SUMMARY OF ALL DETAILE

Tests Made on Surface,

Site No.	Location	Plate on	Bearing Value at 0.2 in Deflection psi, 1st Cycle, Fall 1953	1st Cycle, Early Spring 1954	1st Cycle, Late Spring 1954	2nd Cycle, Fall 1954	2nd Cycle, Spring 1953	Total Thickness Under Bearing Plate-Inches, 1st Cycle, Fall 1953	1st Cycle, Early Spring 1954	1st Cycle, Late Spring 1954	2nd Cycle, Fall 1954	2nd Cycle, Spring 1955
4-S	Center W. bound lane	Surface	140	131	119	143	103	6 ¾	7 ½	7 ½	7	6
		Stone base			85	105	43			4 ½	4 ½	2
		Subgrade			43	56	32					
6-S	Center W. bound lane	Surface	88	63	70	80	40	6 ¾	7	7	9 ½	8
		Stone base			60					6		
		Subgrade			24							
7-S	Center S. bound lane	Surface	157	105	85	141	53	6 ½	8	5	4	6
		Bit. stab. base			44					2 ½		
		Stone base			59					1 ¼		
		Subgrade			62							
8-S	Center S. bound lane	Surface	106	82		117	63	7 ½	7		6 ½	5 ½
		Bit. stabl. base				70	43				4	3 ½
		Subgrade				50	26					
2-N	Center N. bound lane	Surface	268	241	257	264	199	9	9	10 ¼	10 ½	9 ¾
		Gravel base			231	181	154			8	8	8 ½
		Subgrade			111	94	89					
	Outside track N. B. lane	Surface			149					12		
		Gravel base			122					9		
		Subgrade			88							
3-N	Center N. bound lane	Surface	206	107	165	230	156	10	7	10	11	13
		Gravel base			110					8		
		Subgrade			48							
	Inside track N. B. lane	Surface			266					11		
		Gravel base			143					9		
		Subgrade			53							
	Outside track N. B. lane	Surface			178					11		
		Gravel base			124					9		
		Gravel base			99					8		
4-N	Center E. bound lane	Surface	212	180	208	204	172	12	10 ½	11	12	13 ½
		Stone base			140	150	105			7	8	7 ½
		Gravel subbase					110					6 ½
		Subgrade			70	59	61					
	Outside track E. B. lane	Surface			144					11 ½		
		Stone base			109					7		
		Subgrade			66							

state is subdivided into three divisions (north, central, and southern) for these weather reports. Test sites in the southern circuit (1-S through 8-S) are in the southern division. Sites 24-N and 25-N are in the central division, the remainder being in the northern division. At the beginning of September 1953, when the first cycle was begun, the state had a deficiency of 2.22 in. of precipitation. During the next eight months, which covers the period to the completion

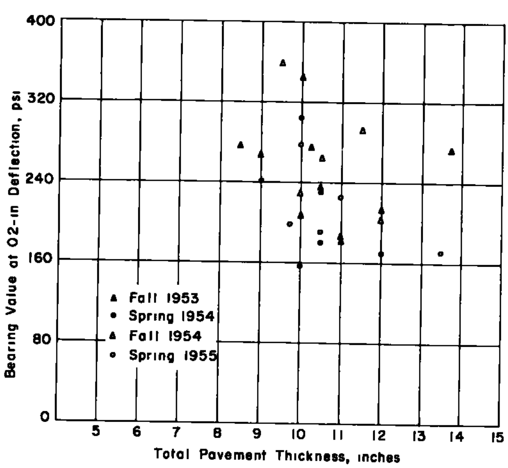


Figure 11. Relation of pavement bearing values to pavement thickness for sandy loam subgrade soils.

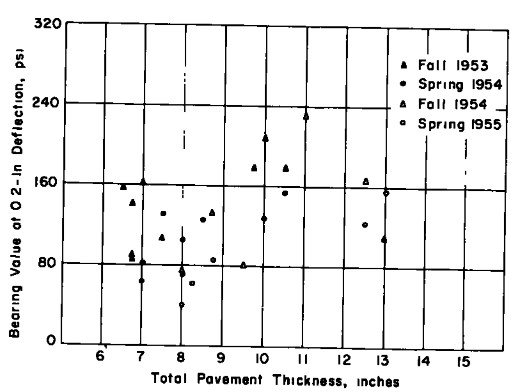


Figure 12. Relation of pavement bearing values to pavement thickness of A-7-6 and A-6 subgrade soils.

4

PLATE BEARING TESTS

Base, and Subgrade

Dry Density pcf			Max. Dry Density pcf			Moisture Content, percent			Opt. Moisture Content, percent			Remarks
Late Spring 1954	Fall 1954	Spring 1955	Late Spring 1954	Fall 1954	Spring 1955	Late Spring 1954	Fall 1954	Spring 1955	Late Spring 1954	Fall 1954	Spring 1955	
119.3	144.7	142.5	136.6	132.1	132.1	3.7	2.3	4.0	7.3	7.5	7.5	
115.9	112.5	115.4	110.0	113.8	113.8	17.2	18.5	14.8	15.4	14.1	14.1	
126.5			135.2			3.0			7.2			Base is quite variable at this site.
90.2			98.5			26.6			21.5			
												Base is quite variable at this site.
Not run												
113.1			116.7			13.3			12.9			
	112.5	108.7		109.2	109.2		18.1	21.3		16.5	16.5	
139.4	152.7	145.1	136.8	147.5	147.5	2.8	4.1	4.2	7.6	8.3	8.3	
118.0	130.6	134.7	132.5	136.1	136.1	5.2	5.3	6.3	8.4	7.5	7.5	
130.7			136.8			5.0			7.6			
124.6			131.9			5.3			8.0			
133.5			133.3			4.0			8.2			
115.5			110.1			14.8			17.0			
132.4			133.3			5.5			8.2			Subgrade is rutted here, the base being 11 in. in ruts.
111.9			110.1			16.0			17.0			
133.9			132.8			5.1			9.4			Subgrade is rutted here, the base being 11 to 16 in. in ruts, otherwise 7 to 9 in.
133.9			132.8			5.1			9.4			
132.9			137.0			4.3			7.9			
		151.8			137.7	3.6					7.5	
114.9	119.2	123.4	118.0	124.6	124.6	12.3	11.4	10.2	12.5	9.5	9.5	
135.5			137.0			3.8			7.9			
124.7			124.7			7.5			12.5			

of the spring 1954 tests, there was a deficiency of 6.88 in. of precipitation for the entire state. During the 12-month period from the end of the first cycle, the south and central divisions had a deficiency of rainfall, although the northern divisions had an excess. The months of December 1954, January 1955, and February 1955 were the coldest and appeared to be more severe than the winter months of the previous cycle. Actual frost penetration data are not available. However, the temperature records indicate that there was frost penetration into the subgrade at all test sites during each cycle.

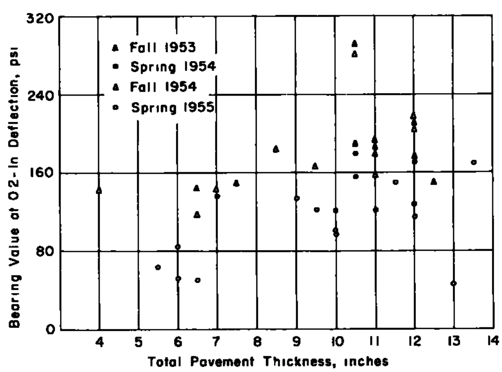


Figure 13. Relation of pavement bearing values to pavement thickness for A-4 subgrade soils.

SUMMARY

Both cycles were begun during the fall season under dry conditions. The winter of 1953-1954 was quite dry and mild. There was no spring breakup in 1954. In the fall of 1954 the bearing values of the surface had recovered to approximately the same as the previous fall. The winter of 1954-1955 was a little more severe than the previous winter. However, there was no general spring breakup in 1955, although at four sites there was evidence of pavement distress.

Bearing values for the types of pavements studied are primarily dependent on total pavement thickness, subgrade soil types, and moisture content of the subgrade soil. In general, increasing pavement thickness increases bearing value. For the range of thicknesses studied, pavements on granular subgrades have higher bearing values and lower losses than those on fine-grained soils. Increasing moisture content of the subgrade appears to decrease the bearing values. Disregarding these variables, the spring 1954 bearing values for all sites range from 52 to 95 percent of the fall 1953 values; the spring 1955 bearing values for all sites range from 28 to 100 percent of the fall 1954 values. Thus, the second cycle appeared to be more severe. This was especially true at sites 3-S, 7-S, 19-N, and 20-N, where there was evidence of alligatoring and distortion during the spring of 1955, when the losses were 65, 62, 64, and 72 percent, respectively. At these four sites the subgrade soils range from loam to clay. At sites having granular subgrade, the loss of bearing values was the least.

At the two sites having soil-cement bases it was not possible to determine bearing values; the capacity of equipment was exceeded.

Tests made at three sites in the spring of 1954 indicate that at a distance of 1.5 ft from the edge of pavement the surface bearing values are considerably less than in the center of the lane.

Density of base and subgrade within the ranges studied could not be correlated with bearing values. Other variables make it difficult to evaluate the actual effect of densities. It is felt that the results of these two cycles show the general trend for the loss

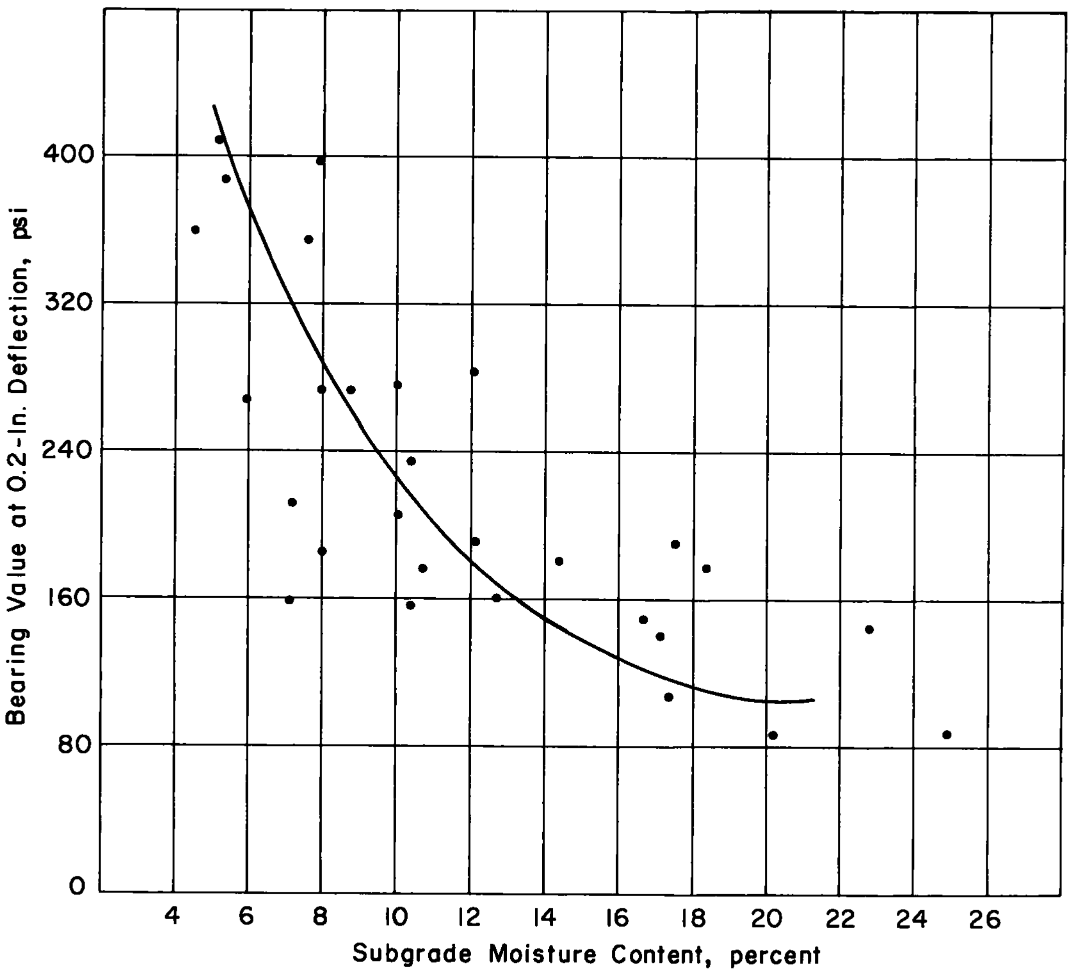


Figure 14. Relation of pavement bearing values to moisture content of subgrade (Fall 1953).

of bearing due to frost action for normal weather conditions in Indiana.

DESCRIPTION OF TEST SITES
(See Figure 3 for locations)

The thicknesses listed in the following descriptions were determined in September 1953. Later determinations showed variation in thickness at most locations due either to construction or resurface, or both. Variations are shown in Table 1.

Southern Circuit

Site No. 1-S: State Road 59, 6.2 miles north of the junction with State Road 67, in a long uniform fill. Original construction—6 in. crushed stone base and bituminous dust palliative. Thickness of surface—1 in., total thickness—7 in. Subgrade soil—clay loam, silty clay loam, and clay.

Site No. 2-S: State Road 159, 2.2 miles north of the junction with State Road 67, in a fill. Original construction—8 in. water-bound macadam base and ¾ in. surface and seal. Thickness of surface—2½ in., total thickness—10½ in. Subgrade soil—silty loam and silty clay loam.

Site No. 3-S: State Road 257, 8.3 miles south of the junction with US 150, in a low area at approximate ground elevation. Original construction—6 in. crushed stone base (upper 3 in. bituminous stabilized). Thickness of surface—1 in., total thickness—7 in.

TABLE 5

SUMMARY OF SOIL TESTS
SUBGRADE SOILS-SOUTHERN CIRCUIT

Site No.	Depth of Sample, ft	Ret. 1 in.	Pass. 1 in. Ret. ¾ in.	Pass. ¾ in. Ret. ½ in.	Pass. ½ in. Ret. No. 4	Pass. No. 4 Ret. No. 10	Pass. No. 10 Ret. No. 40	Pass. No. 40 Ret. No. 270	Silt	Clay and Colloids	Liquid Limit	Plasticity Index	Shrink. Limit	Vol. Change	Lineal Shrink.	Max. Dry Density	Optimum Moisture	Remarks
	0 to -0.5			0	2	5	6	15	45	27	35.0	15.2	15.3	22.0	6.4			A-6(10) ClL[1]
1-S	0 to -1.5			0	1	2	4	8	61	24	34.6	16.3	16.4	19.6	2.2			A-6(10) SiClL[2]
	0 to -1.5			0	1	2	7	11	48	31	33.2	13.0	14.6	19.6	5.8			A-6(9) ClL[3]
	0 to -0.5			0	2	3	2	4	70	19	34.8	13.2	17.5	21.0	6.1			A-6(9) Sil[1]
	0 to -1.5			0	2	3	2	3	75	15	33.8	13.0	19.2	12.2	1.7			A-6(9) Sil[2]
2-S	0 to -0.75			0	3	2	1	8	63	23	29.1	8.2	17.7	15.8	5.0			A-4(8) SiClL[3]
	-0.75 to -1.75					0	1	9	67	23	28.8	6.6	19.0	7.5	2.5			A-4(8) SiClL[3]
	-1.75 to -2.25						0	5	77	18	25.2	2.1	19.6	7.7	2.6			A-4(8) SiL[3]
	0 to -0.5			0	2	2	4	8	64	20	24.2	3.6	20.6	1.2	0.3			A-4(8) SiL or SiClL[1]
	0 to -1.5			0	3	3	5	8	64	17	28.3	9.6	18.0	12.0	1.6			A-4(8) SiL[2]
3-S	0 to -0.75		0	1	2	2	3	5	62	25	29.7	6.8	17.6	15.7	4.7			A-4(8) SiClL[3]
	-0.75 to -1.5					0	2	12	69	17	21.5	1.8	17.5	6.6	2.2			A-4(8) SiClL[3]
	-1.5 to -2.25					0	1	6	64	29	33.2	10.2	19.0	18.2	5.5			A-4(8) SiClL[3]
	0 to -0.5			0	1	1	1	13	58	26	32.6	14.8	15.1	20.1	6.0			A-6(10) SiClL[1]
4-S	0 to -1.0					0	1	17	55	27	28.5	11.5	14.8	1.8	0.9	110.0	15.4	A-6(9) SiClL[2]
	0 to -1.25					0	1	24	46	29	23.2	6.6	13.7	14.0	4.5	113.8	14.1	A-4(8) ClL[3]
	-1.25 to -3.0						0	22	52	26	20.6	4.2	16.3	4.7	1.6			A-4(8) SiClL[3]
	0 to -0.5		0	1	0	1	1	4	47	46	44.2	22.0	20.7	17.7	5.2			A-7-6(14) Cl[1]
	0 to -0.5				0	4	4	6	63	43	43.8	22.1	18.1	23.8	6.7			A-7-6(13) Cl[1]
5-S	0 to -1.5					0	2	7	52	39	36.8	12.7	15.6	20.5	6.1			A-6(9) SiCl[2]
	0 to -0.75					0	2	3	59	36	39.8	16.6	14.4	35.6	9.8			A-6(11) SiCl[3]
	-0.75 to -2.25					0	1	4	41	54	36.1	10.3	17.0	16.3	5.1			A-6(8) Cl[3]
	0 to -0.5					0	1	2	43	54	52.8	26.6	22.2	20.1	6.0			A-7-6(18) Cl[1]
6-S	0 to -0.5				0	1	1	3	41	54	50.7	26.0	21.3	23.2	6.7			A-7-6(16) Cl[1]
	0 to -1.5				0	1	1	9	44	45	43.5	20.1	17.7	22.9	6.7	98.5	21.5	A-7-6(13) Cl[2]
	0 to -0.5				0	1	4	19	47	29	31.4	14.1	14.8	15.1	4.5			A-6(10) ClL[1]
7-S	0 to -2.0			0	1	2	7	27	39	24	29.7	14.9	11.1	25.3	7.4	116.7	12.9	A-6(8) ClL[2]
	0 to -0.5			0	1	2	10	26	36	25	25.4	7.9	10.6	18.8	5.7			A-4(6) ClL[3]
	-0.5 to -1.25			0	1	1	6	16	48	28	26.7	8.0	15.5	14.6	4.4			A-4(8) ClL[3]
	0 to -0.5				0	1	4	19	37	49	37.3	18.6	14.5	25.2	7.3			A-6(12) Cl[1]
	0 to -2.0			0	1	2	4	14	40	39	32.4	14.6	14.3	19.6	6.0			A-6(10) Cl[2]
8-S	0 to -0.75			0	2	1	8	14	38	37	30.0	9.5	14.5	18.8	5.8	109.2	16.5	A-4(8) Cl[3]
	-0.75 to -1.5					0	3	15	57	25	26.4	3.5	18.3	10.4	3.4			A-4(8) SiClL[3]
	-1.5 to -2.5					0	2	7	56	35	36.5	13.7	17.4	19.3	5.7			A-6(10)SiCl[3]

[1] Samples taken in fall of 1953.
[2] Samples taken in spring of 1954.
[3] Samples taken in fall of 1954.

TABLE 6

SUMMARY OF SOIL TESTS
SUBGRADE SOILS-NORTHERN CIRCUIT

Site No.	Depth of Sample, ft	Ret. 1 in.	Pass. 1 in. Ret. ¾ in.	Pass. ¾ in. Ret. ½ in.	Pass. ½ in. Ret. No. 4	Pass. No. 4 Ret. No. 10	Pass. No. 10 Ret. No. 40	Pass. No. 40 Ret. No. 270	Silt	Clay and Colloids	Liquid Limit	Plasticity Index	Shrink. Limit	Vol. Change	Lineal Shrink.	Max. Dry Density	Optimum Moisture	Remarks
	0 to -0.5			0	10	12	13	24	26	15	21.5	6.9						A-4(2)SL[1]
1-N	0 to -0.8			1	2	4	9	27	34	23	23.6	8.7	12.0	12.5	4.0			A-4(5) ClL[2]
	0 to -1.25			0	3	3	11	25	31	27	23.3	7.4	12.3	17.3	5.3			A-4(5) ClL[3]
	0 to -0.25			0	10	13	18	28	20	11	21.1	5.9						A-2-4(0) Sl[1]
	0 to -0.25		2	1	7	8	12	29	23	18	18.1	4.7	11.2	8.4	2.9			A-4(2) SL[2]
2-N	-0.25 to -1.0		5	7	13	18	21	25	4	7	13.1	0.9	12.0	4.0	1.5			A-1-b S[2]
	0 to -0.5		0	3	10	12	14	28	21	12	15.1	3.3	9.8			131.9	8.0	A-4(0) SL[2]
	0 to -0.5		0	1	8	11	20	34	14	12	14.6	2.8	9.5	10.6	3.5	136.1	7.5	A-2-4(0) SL[3]
	0 to -0.5			0	3	8	12	27	31	19	26.1	10.7	13.7	17.9	5.2			A-6(4) SL[1]
3-N	0 to -1.0			0	2	3	9	28	29	29	27.8	10 6	12.4	20.3	6.1			A-6(6) ClL[2]
	0 to -0.4	0	3	1	5	8	11	25	33	14	20.7	6 9	12.5			121.2	12.0	A-4(3) SL[2]
	0 to -0.5			0	9	14	19	18	31	9	17.6	2.3						A-4(1) SL[1]
	0 to -0.75		0	3	12	10	14	22	29	10	21.7	3.4	14.0	7.7	3.5			A-4(1) SL[2]
4-N	-0.75 to -2.25		0	1	3	2	5	14	59	16	40.0	14.6	17.6	21.4	6 4			A-6(10) SiL[2]
	0 to -0.4	0	6	5	12	13	12	14	29	9	22 5	4.9	9.6			118.0	12.5	A-4(1) SL[2]
	0 to -0.75			0	16	10	15	23	26	10	23.1	3.8	14.2	11.4	3.8	124.6	9.5	A-4(0) SL[3]
	0 to -0.75				0	1	2	90	3	4	14.4	NP						A-3(0) S[2]
	-0.75 to -2.25		0	1	1	1	2	82	7	6	15.3	NP						A-2-4(0)[2]
5-N	0 to -0.75					0	2	89	4	5	16.8	NP						A-2-4(0) S[3]
	-0.75 to -1.5					0	4	83	7	6	15.4	NP						A-2-4(0) S[3]
	-1.5 to -2.5					0	5	74	9	12	17.5	NP						A-2-4(0) S or SL[3]
6-N	0 to -2.25					0	1	93	2	4	17.1	NP						A-2-4(0) S[2]
	0 to -2.25					0	2	93	1	4	18.9	NP						A-3(0) S[3]
	0 to -3.0					0	1	97	1	1	18.6	NP						A-3(0) S[2]
7-N	0 to -2.25					0	2	96	1	1	17.2	NP						A-3(0) S[3]
	0 to -2.25					0	2	94	1	3	15.7	NP						A-3(0) S[2]
8-N	0 to -2.25					0	2	94	2	2	16.8	NP						A-2-4(0) S[3]
	0 to -2.25			0	3	1	4	88	1	3	16.2	NP						A-3(0) S[2]
	-0.25 to -0.8			0	1	0	1	86	6	6	13.8	NP						A-2-4(0) S[2]
9-N	-0.8 to -1.5				0	1	1	88	4	6	15.2	NP						A-2-4(0) S[2]
	-1 5 to -2.5			0	1	1	2	71	13	12	19.0	NP						A-2-4(0) S[2]
10-N	0 to -1.5	0	1	0	3	5	13	57	11	10	12.8	NP						A-2-4(0) S or Sl[2]
	-1.5 to -3.0				0	1	3	93	1	2	15.1	NP						A-3(0) S[2]
	0 to -3.0					0	2	93	0	5	17.0	NP						A-3(0) S[2]
11-N	0 to -2.25					0	3	94	2	1	15.4	NP						A-3(0) S[3]
13-N	0 to -3.0					0	4	94	1	1	14.7	NP						A-3(0) S[2]
	0 to -2.25					0	3	96	1	0	14.9	NP						A-3(0)[3]
15-N	0 to -1.5			0	7	7	26	54	1	5	13.1	NP						A-3(0) S[2]
	-0.4 to -1.8		0	1	8	8	24	49	4	6	15.3	NP						A-2-4(0) S[3]
16-N	0 to -1.0			0	3	3	4	22	42	26	22.4	6.5	11.4	14.6	4.5			A-4(7) ClL[2]
	-1 0 to -2.0		0	1	2	2	5	15	45	30	21.2	5.4	14.2	9.0	3.0			A-4(8) ClL[2]
	0 to -0.5		0	4	16	10	9	39	10	12	15.1	3.8	9.3	9.3	5.5			A-2-4(0) SL[2]
15-N	-0.5 to -1.5	0	1	1	2	1	5	51	19	20	16.3	4.5	9.6	11.6	3 8			A-4(1) SL[2]
	-1.5 to -3.0					0	3	17	42	38	20.9	5.2	12.0	11.5	3 8			A-4(8) Cl[2]
	0 to -0.65			0	2	4	15	50	17	12	13.6	0.7	10.8	4.1	1.5			A-2-4(0) SL[2]
	-0.65 to -1.25			0	1	1	12	57	16	13	14.5	2.1	10.9	7.3	2.5			A-2-4(0) SL[2]
18-N	-1.25 to -1.75		0	4	10	7	17	43	10	9	13.5	NP	11.8	5.9	2.1			A-2-4(0) S[2]
	-1.75 to -2.0		0	4	11	9	18	42	9	7	12.0	NP	11.7	5.1	1.7			A-2-4(0) S[2]
19-N	0 to -2.0		0	1	8	6	6	29	40	10	19.3	5.7	12.2	12.8	4.1			A-4(4) L[2]
20-N	0 to -0.5			0	3	4	7	27	34	25	26.8	11.3	13.3	15.7	4.6			A-6(6) ClL[1]
	0 to -2.25			0	2	3	10	31	23	31	24.7	9.2	11.3	10.0	3.2			A-4(5) Cl[2]
21-N	0 to -0.5		0	4	13	9	23	42	5	4	NP	NP						A-2-4(0) S[1]
	0 to -1.0	0	2	6	14	7	19	45	3	4	13.9	NP						A-3(0) S[2]
22-N	0 to -0.5			0	13	9	23	44	7	4	NP	NP						A-2-4(0) S[1]
	0 to -1.0	3	4	4	9	9	24	39	7	3	13.5	NP						A-1-b S[2]
	0 to -0.5			0	4	13	15	24	30	14	27.4	9.6	14.6	21 0	6 1			A-4(2) SL[1]
	0 to -0.5			0	3	7	17	33	24	16	24.7	7.9	13.5	12.1	3.9			A-4(2) SL[2]
23-N	-0.5 to -1.5		0	1	5	7	18	28	26	15	23.1	5.7	14.1	10.2	3.2			A-4(2) SL[2]
	-1.5 to -2.0		0	3	10	14	20	16	22	15	29.9	12.8	12.4	21.9				A-6(2) SL[2]
	0 to -0.5			0	2	5	18	20	32	23	33.0	10.7	12.5	30.6	8.6			A-6(5) ClL[3]
	-0.5 to -1.25			0	5	7	18	23	27	20	25.7	7.6	12.5	15.5	4.9			A-4(3) SL[3]
	0 to -0.5			0	1	5	6	19	42	27	40.2	19.4	15.3	28.4	8.0			A-6(11) ClL[1]
	0 to -1.0			0	1	3	17	24	35	20	29.3	8.2	12.5	25.0	7.3			A-4(5) ClL or L[2]
24-N	-1.0 to -2.0			0	1	1	6	20	43	29	38.7	16.0	18.6	19.9	6.0			A-6(10) ClL[2]
	0 to -1.5			0	1	1	6	25	46	21	27.3	5.8	14.4	18.5	5.6			A-4(7) ClL or L[3]
	-1.5 to -2.5					0	4	17	38	41	38 3	18.4	12.7	29.7	8.3			A-6(9) Cl[3]
	0 to -0.5				0	4	13	24	36	23	27.5	9.8	14.7	22.9	6.6			A-4(5) ClL[1]
	-0.5 to -1.0			0	1	1	7	22	44	25	29.2	10.1	16.4	20.8	6.0			A-4(7) ClL[1]
25-N	0 to -0.6		0	1	1	1	11	28	39	19	22.3	3.3	14 7	10.9	3.6			A-4(5) L[2]
	-0.6 to -1.1				0	2	8	21	41	28	32.7	8.0	15.8	20.0	6.0			A-4(7) ClL[3]
	-1.1 to -2.1			0	1	4	4	16	40	35	44.7	24.3	10.1	50.6	12.7			A-7-6(15) Cl[2]

[1] Samples taken in Fall of 1953.
[2] Samples taken in Spring of 1954.
[3] Samples taken in Fall of 1954.

Subgrade soil-silty loam and silty clay loam.

Site No. 4-S: State Road 256, 4.1 miles west of the junction with US 31, in a flat upland area, in a very light fill. Original construction—6 in. crushed stone with bituminous seal. Thickness of surface—3/4 in., total thickness—6 3/4 in. Subgrade soil—silty clay loam and clay loam.

Site No. 5-S: State Road 256, 5.8 miles west of the junction with US 31, in a light fill, in lowland area. Original construction—6 in. crushed stone with bituminous seal. Thickness of surface—3/4 in., total thickness —6 3/4 in. Subgrade soil—clay, and silty clay.

Site No. 6-S: State Road 256, 7.2 miles west of the junction with US 31, in a light fill, in lowland area. Original construction—6 in. crushed stone with bituminous seal. Thickness of surface—3/4 in., total thickness—6 3/4 in. Subgrade soil—clay.

Site No. 7-S: State Road 203, 1.0 miles south of the junction with State Road 256, in a cut. Original construction—3 in. of traffic bound stone and 3 in. of bituminous stabilized stone with bituminous seal. Thickness of surface—2 in., total thickness—8 in. Subgrade soil—clay loam.

Site No. 8-S: State Road 203, 2.4 miles south of junction with State Road 256, on flat, high ground, grade at approximate ground line. Original construction—3 in. of traffic bound stone and 3 in. of bituminous stabilized stone with bituminous seal. Thickness of surface—1 1/2 in., total thickness—7 1/2 in. Subgrade soil—clay.

Northern Circuit

Site No. 1-N: State Road 75, 0.2 miles south of Cutler, in a deep cut. Original construction—9 in. of compacted aggregate (upper 3/4 in. bituminous stabilized and sealed).

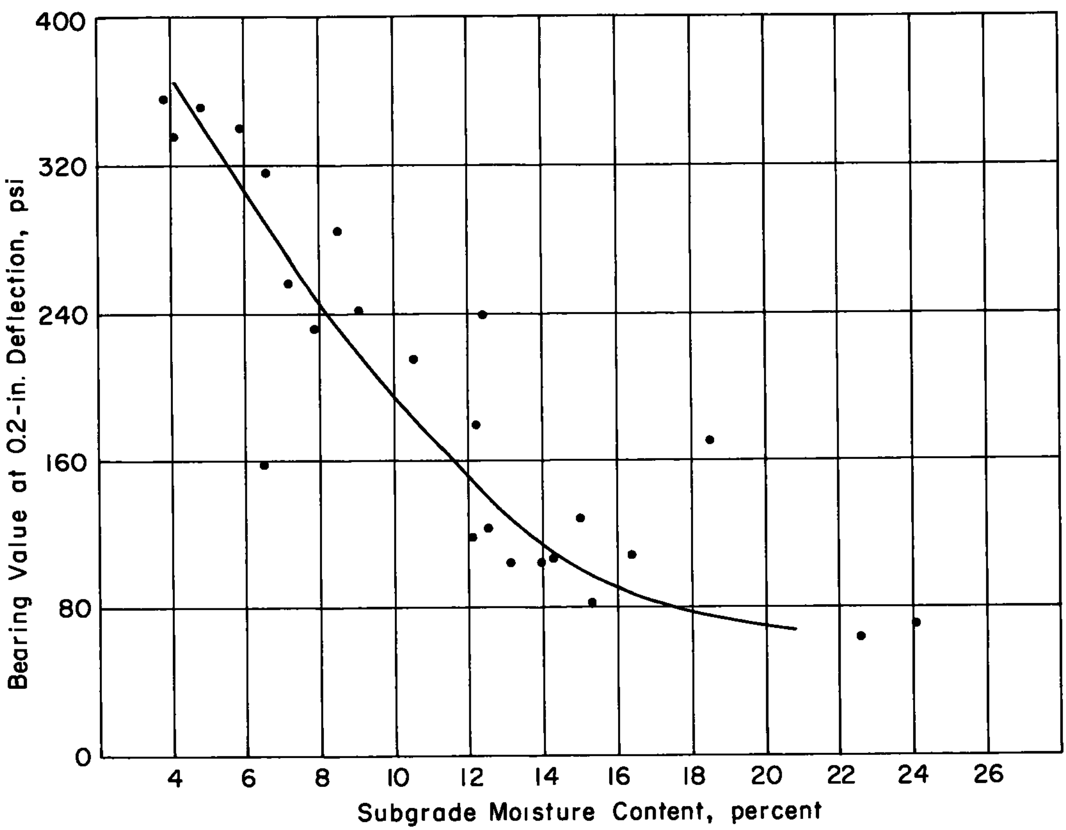


Figure 15. Relation of pavement bearing values to moisture content of subgrade (Spring 1954).

Thickness of surface—2 in., total thickness—11 in. Subgrade soil—sandy loam and clay loam.

Site No. 2-N: State Road 75, 0.2 miles north of Wildcat Creek, in fill. Original construction—9 in. of compacted aggregate with a bituminous dust palliative. Thickness of surface—1 in., total thickness—10 in. Subgrade soil—sandy loam.

Site No. 3-N: State Road 75, 1.0 miles north of Wildcat Creek, in a cut. Original construction—9 in. of compacted aggregate with a bituminous dust palliative. Thickness of surface—1 in., total thickness—10 in. Subgrade soil—sandy loam and clay loam.

Site No. 4-N: State Road 18, 0.2 miles east of the junction with State Road 29, in a very light fill. Original construction—6 in. of crushed stone. Thickness of surface—3 in., total thickness—9 in. Subgrade soil—sandy loam.

Site No. 5-N: State Road 39, 0.5 miles south of the junction with State Road 14, in a light fill. Original construction—8 in. of compacted aggregate with seal. Thickness of surface—1 in., total thickness—9 in. Subgrade soil—sandy loam and fine sand.

Site No. 6-N: State Road 39, 0.3 miles north of the junction with State Road 14, in a fill. Original construction—6 in. of crushed stone. Thickness of surface—3 in., total thickness—9 in. Subgrade soil—fine sand.

Site No. 7-N: State Road 39, 1.2 miles north of the junction with State Road 14, in a cut. Original construction—6 in. of crushed stone. Thickness of surface—3 in., total thickness—9 in. Subgrade soil—fine sand.

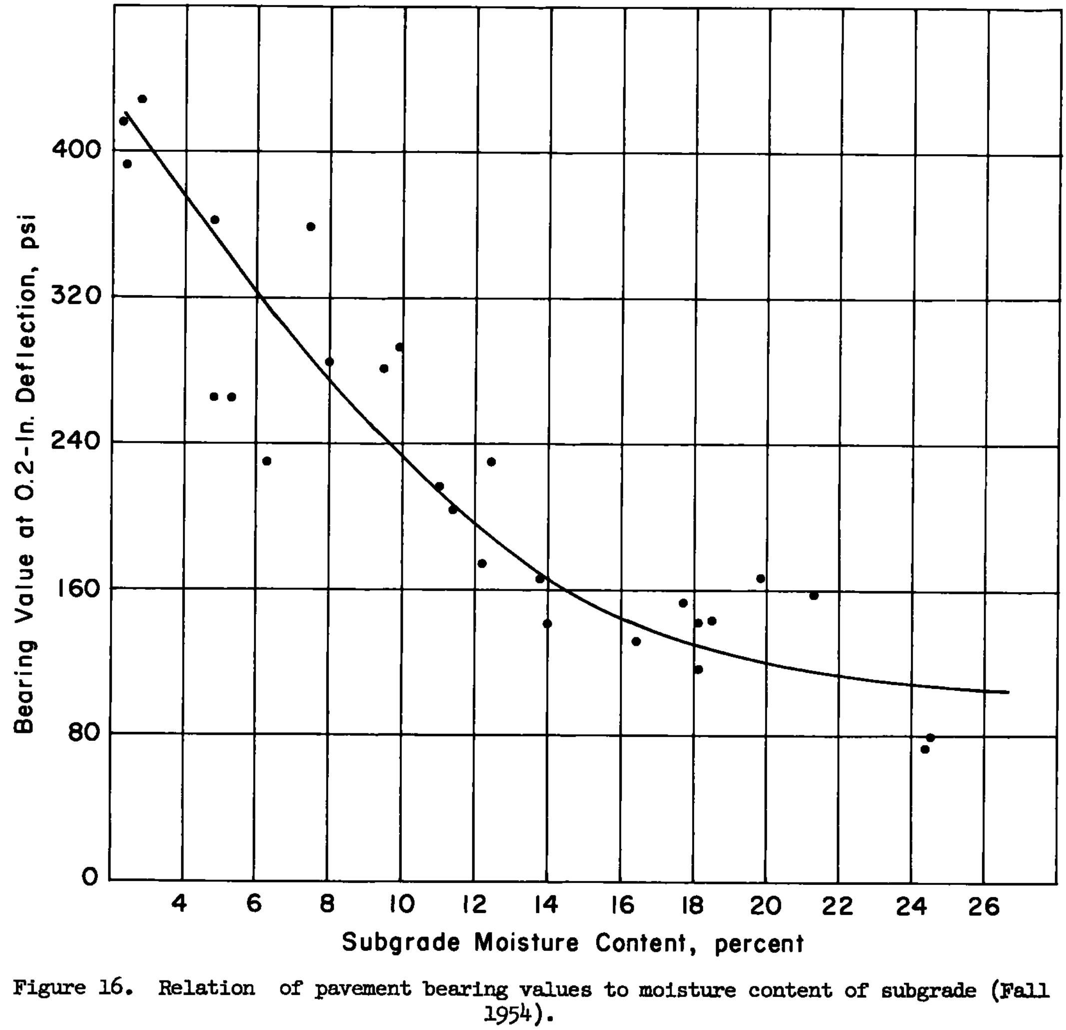


Figure 16. Relation of pavement bearing values to moisture content of subgrade (Fall 1954).

Site No. 8-N: State Road 39, 1.7 miles north of the junction with State Road 14, in a fill. Original construction—6 in. of crushed stone. Thickness of surface—3½ in., total thickness—9½ in. Subgrade soil—fine sand.

Site No. 9-N: State Road 39, 2.6 miles north of the junction with State Road 14, in a light fill. Original construction—6 in. of crushed stone. Thickness of surface—3½ in., total thickness—9½ in. Subgrade soil—fine sand or sandy loam.

Site No. 10-N: State Road 39, 5.6 miles north of the junction with State Road 14, in a fill. Original construction—6 in. of crushed stone. Thickness of surface—3½ in., total thickness—9½ in. Subgrade soil—fine sand or sandy loam.

Site No. 11-N: State Road 39, 6.4 miles north of the junction with State Road 14, in a fill. Original construction—6 in. of cement stabilized base ("windblown" sand) and approximately 1 in. bituminous surface. Thickness of surface—2 in., total thickness—8 in. Subgrade soil—fine sand.

Site No. 13-N: State Road 39, 7.7 miles north of the junction with State Road 14, in a cut. Original construction—6 in. of cement stabilized base ("windblown" sand) and approximately 1 in. bituminous surface. Thickness of surface—2 in., total thickness—8 in. Subgrade soil—fine sand.

Site No. 15-N: State Road 39, 0.2 miles south of the junction with State Road 2, in a cut. Original construction—8 in. of compacted aggregate with a bituminous dust palliative. Thickness of surface—5¾ in., total thickness—13¾ in. Subgrade soil—sandy loam and fine sand.

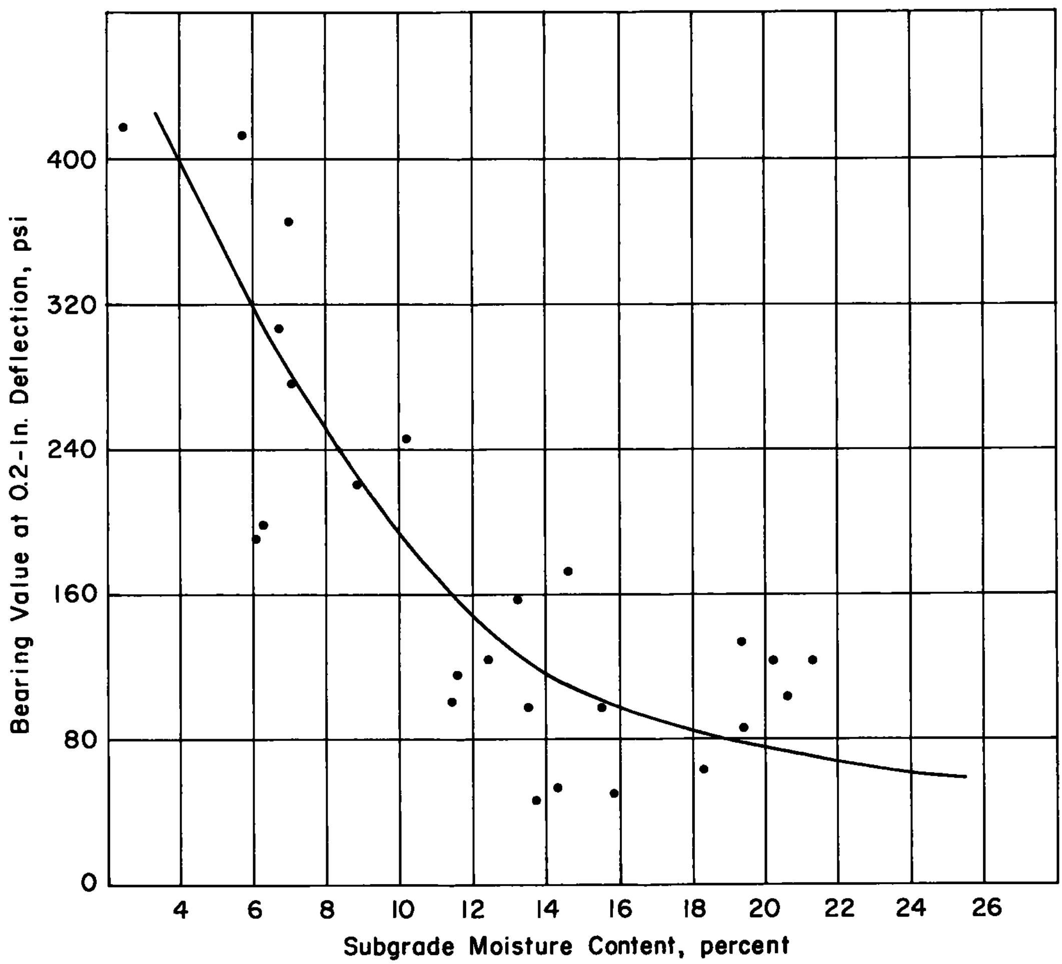


Figure 17. Relation of pavement bearing values to moisture content of subgrade (Spring 1955).

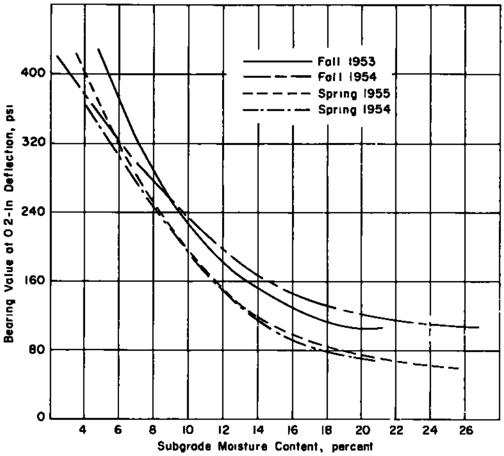


Figure 18. Relation of pavement bearing values to moisture content of subgrade (1953-1955).

Site No. 16-N: State Road 39, 1.2 miles south of the junction with US 20, in a cut. Original construction—9 in. of compacted aggregate (upper 1 in. bituminous stabilized). Thickness of surface—1¾ in., total thickness—10¾ in. Subgrade soil—clay loam.

Site No. 17-N: State Road 39, 0.3 miles south of the junction with US 20, in a cut. Original construction—9 in. of compacted aggregate (upper 1 in. bituminous stabilized). Thickness of surface—1 in., total thickness—10 in. Subgrade soil—sandy loam.

Site No. 18-N: State Road 4, 0.7 miles east of the junction with State Road 23, in a fill. Original construction—9 in. of compacted aggregate (upper 1 in. bituminous stabilized). Thickness of surface—1¼ in., total thickness—10¼ in. Subgrade soil—sandy loam.

Site No. 19-N: State Road 4, 2.4 miles

TABLE 7

CLIMATOLOGICAL DATA

From Report of U. S. Dept. of Commerce

Month	Division of State	Temperature Avg	Temperature Dep. from Normal	No. of Days Max. 32 or below	No. of Days Min. 32 or below	No. of Days Min. 0 or below	Precipitation Avg	Precipitation Dep. from Normal	Precipitation Accum.	Precipitation Accum. Dep.
									23.61[1]	-1.28[1]
									27.42[1]	-0.01[1]
									24.74[1]	-5.57[1]
									25.22[1]	-2.22[1]
Sept. 1953	North	65.7	0.0	0	0	0	1.74	-1.48	25.35	-2.76
	Central	67.1	0.1	0	1	0	1.11	-2.30	28.53	-2.31
	South	69.8	0.3	0	2	0	0.67	-2.55	25.41	-8.12
	State	67.4	0.1				1.20	-2.08	26.42	-4.30
Oct. 1953	North	57.3	3.8	0	0-7	0	1.31	-1.39	26.66	-4.15
	Central	57.8	2.7	0	0-9	0	1.21	-1.53	29.74	-3.84
	South	59.7	2.5				1.42	-1.46	26.83	-9.58
	State	58.2	3.0				1.31	-1.46	27.73	-5.76
Nov. 1953	North	43.2	3.0	0-4	7-20	0	1.34	-1.44	28.00	-5.59
	Central	43.6	1.5	0-4	10-26	0	1.53	-1.47	31.27	-5.31
	South	44.9	0.2	0	7-24	0	1.48	-1.83	28.31	-11.41
	State	43.9	1.7				1.45	-1.57	29.18	-7.33
Dec. 1953	North	32.2	3.0	3-9	21-28	0-5	1.44	-0.88	29.44	-6.47
	Central	33.1	1.7	3-7	21-28	0-3	2.23	-0.41	33.50	-5.72
	South	34.9	-0.1	2-6	19-29	0-3	2.36	-0.91	30.67	-12.32
	State	33.3	1.6				1.99	-0.73	31.17	-8.06
Jan. 1954	North	28.1	2.3	6-18	26-31	0-4	1.98	-0.37	1.98	-0.37
	Central	31.0	2.6	5-10	23-29	0-4	3.15	0.24	3.15	0.24
	South	34.0	1.7	3-8	20-29	0-1	3.38	-0.47	3.38	-0.47
	State	30.9	2.2				2.80	-0.20	2.80	-0.20
Feb. 1954	North	37.0	9.4	1-6	16-25	0-1	2.69	0.70	4.67	0.33
	Central	39.8	9.4	0-3	14-23	0	2.32	0.03	5.47	0.27
	South	43.1	8.9	0-2	7-23	0	2.34	-0.65	5.72	-1.12
	State	39.8	9.2				2.46	0.06	5.26	-0.14
Mar. 1954	North	35.2	-2.2	2-7	16-28	0	3.42	0.40	8.09	0.73
	Central	37.0	-2.6	1-4	18-26	0	2.59	-1.20	8.06	-0.93
	South	41.7	-2.4	0-3	12-24	0	1.90	-2.56	7.62	-3.68
	State	38.1	-2.4				2.67	-1.05	7.93	-1.19
Apr.	North	53.8	5.2	0-1	3-10	0	4.50	1.23	12.59	1.96
	Central	57.2	6.1	0	3-7	0	3.38	-0.25	11.44	-1.18
	South	60.0	5.7	0	1-9	0	3.25	-0.68	10.87	-4.36
	State	56.9	5.7				3.74	0.15	11.67	-1.04
Avg for 8 mo. Period	North						18.42	-3.23		
	Central						17.52	-6.89		
	South						16.80	-11.11		
	State						17.62	-6.88		

[1] As of Aug. 31, 1953

TABLE 8

CLIMATOLOGICAL DATA

From Report of U. S. Dept. of Commerce

Month	Division of State	Temperature Avg	Temperature Dep. from Normal	No. of Days Max. 32 or below	No. of Days Min. 32 or below	No. of Days Min. 0 or below	Precipitation Avg	Precipitation Dep. from Normal	Accum.	Accum. Dep.
	North	55.7	-4.2	0	1-14	0	2.73	-1.37	2.73	-1.37
May	Central	57.6	-4.4	0	0-7	0	2.73	-1.37	2.73	-1.37
1954	South	59.6	-4.7	0	0-8	0	2.79	-1.30	2.79	-1.30
	State	57.5	-4.5				2.75	-1.35	2.75	-1.35
	North	73.4	3.8	0	0	0	3.97	0.19	6.70	-1.18
June	Central	74.8	3.9	0	0	0	2.32	-1.72	5.05	-3.09
1954	South	76.1	2.8	0	0	0	2.30	-1.77	5.09	-3.07
	State	74.7	3.5				2.91	-1.05	5.66	-2.40
	North	74.5	0.1	0	0	0	4.96	1.73	11.66	0.55
July	Central	77.0	1.7	0	0	0	2.67	-0.67	7.72	-3.76
1954	South	79.6	2.2	0	0	0	1.87	-1.55	6.96	-4.62
	State	76.9	1.3				3.24	-0.09	8.90	-2.49
	North	71.3	-0.9	0	0	0	5.32	2.17	16.98	2.72
Aug.	Central	73.4	0.2	0	0	0	4.39	1.06	12.11	-2.70
1954	South	76.8	1.0	0	0	0	5 05	1.55	12.01	-3.07
	State	73.7	0.0				4.93	1.61	13.83	-0.88
	North	67.8	2.1	0	0-2	0	1.34	-1.88	18.32	0.84
Sept.	Central	69.5	2.5	0	0	0	0.98	-2.43	13.09	-5.13
1954	South	71.6	2.1	0	0	0	3.00	-0.22	15.01	-3.29
	State	69.5	2.2				1.74	-1.54	15.57	-2.42
	North	54.4	0.9	0	1-13	0	8.85	6.15	27.17	6.99
Oct.	Central	56.3	1.2	0	1-12	0	5.59	2.85	18.68	-2.28
1954	South	58.5	1.3	0	1-12	0	4.13	1.25	19.14	-2.04
	State	56.3	1.1				6.30	3.53	21.87	1.11
	North	41.0	0.8	0-1	10-27	0	1.69	-1.09	28.86	5.90
Nov.	Central	42.1	0.0	0-1	12-24	0	1.53	-1.47	20.21	-3.75
1954	South	44.6	-0.1	0-1	7-22	0	1.28	-2.03	20.42	-4.07
	State	42.5	0.3				1.51	-1.51	23.38	-0.40
	North	30.3	1.1	1-14	23-30	0-2	2.10	-0.22	30.96	5.68
Dec.	Central	32.4	1.0	2-11	24-29	0-1	2.49	-0.15	22.70	-3.90
1954	South	35.2	0.2	1-4	16-29	0	3.79	0.52	24.21	-3.55
	State	32.5	0.8				2.76	0.04	26.14	-0.36
	North	25.3	-0.5	8-19	24-30	2-7	1.86	-0.49	32.82	5.19
Jan.	Central	27.8	-0.6	7-17	24-29	2-6	2.38	-0.53	25.08	-4.43
1955	South	31.3	-1.0	3-10	22-30	0-6	2.02	-1.83	26.23	-5.38
	State	28.0	-0.7				2.08	-0.92	28.22	-1.28
	North	28.6	1.0	5-8	21-26	2-6	1.54	-0.45	34.36	4.74
Feb.	Central	31.7	1.3	3-7	21-26	2-4	2.52	0.23	27.60	-4.20
1955	South	35.3	1.1	2-6	15-25	0-3	5.77	2.78	32.00	-2.60
	State	31.7	1.1				3.19	0.79	31.41	-0.49
	North	37.9	0.5	2-7	16-26	0	3.17	0.15	37.53	4.89
Mar.	Central	41.1	0.6	0-4	13-24	0	3.38	-0.41	30-98	-4.61
1955	South	44.7	0.6	0-3	10-23	0	5.58	1.12	37.58	-1.48
	State	41.1	0.6				3.99	0.27	35.40	-0.22
	North	55.9	7.3	0	0-6	0	2.96	-0.31	40.49	4.58
Apr.	Central	57.6	6.5	0	0-6	0	3.68	0,05	34.66	-4.55
1955	South	59.8	5.5	0	0-5	0	4.70	0.77	42.28	-3.78
	State	57.7	6.5				3.74	0.15	39.14	-0.07

east of the junction with State Road 23, in a cut. Original construction—9 in. of compacted aggregate (upper 1 in. bituminous stabilized). Thickness of surface—1 in., total thickness—10 in. Subgrade soil—loam.

Site No. 20-N: State Road 4, 3.8 miles east of the junction with State Road 23, in a cut. Original construction—9 in. of compacted aggregate (upper 1 in. bituminous stabilized). Thickness of surface—¾ in., total thickness—9¾ in. Subgrade soil—clay loam and clay.

Site No. 21-N: State Road 120, 2.2 miles east of the junction with State Road 13, in a cut. Original construction—8 in. of compacted aggregate and a 1 in. bituminous surface. Thickness of surface—1 in., total thickness—9 in. Subgrade soil—sand and gravel.

Site No. 22-N: State Road 120, 6.5 miles east of the junction with State Road 3, in a cut. Original construction— 6 in. of stone. Thickness of surface—3 in., total thickness—9 in. Subgrade soil—sand and gravel.

Site No. 23-N: State Road 218, 1.8 miles west of the junction with State Road 5, in a light fill. Original construction—$7^1/_2$ in. of compacted aggregate and a $1^1/_2$ in. bituminous surface. Thickness of surface—$1^1/_2$ in., total thickness—9 in. Subgrade soil—sandy loam and clay loam.

Site No. 24-N: State Road 209, 0.2 miles north of the junction with US 40, grade at approximate ground line. Original construction—3 in. of stone and 3 in. of bituminous stabilized stone with a seal. Thickness of surface—$1^1/_4$ in., total thickness—$7^1/_4$ in. Subgrade soil—clay loam or loam.

Site No. 25-N: State Road 209, 0.7 miles north of the junction with US 40, in a light fill. Original construction—3 in. of stone and 3 in. of bituminous stabilized stone with a seal. Thickness of surface—$1^1/_4$ in., total thickness—$7^1/_4$ in. Subgrade soil—clay loam or loam.

HRB:OR-207

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