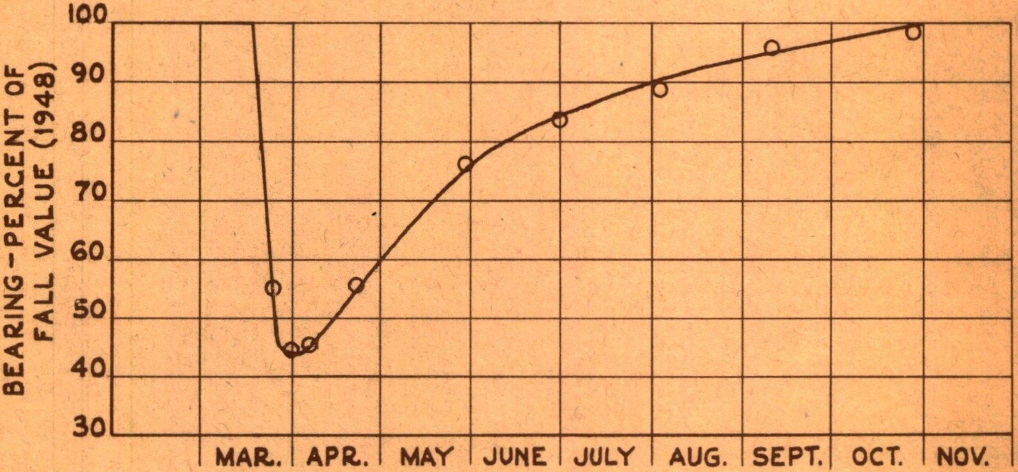
HIGHWAY RESEARCH BOARD

Research Report No. 10-D

COMMITTEE REPORT AND MANUAL
OF RECOMMENDED TESTING PROCEDURES
ON

Load Carrying Capacity of Roads as Affected by Frost Action



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ON

LOAD CARRYING CAPACITY OF ROADS AS AFFECTED BY FROST ACTION

COMMITTEE REPORT
PRESENTED AT THE TWENTY-NINTH ANNUAL MEETING
1949

HIGHWAY RESEARCH BOARD
DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH
NATIONAL RESEARCH COUNCIL

Washington 25, D. C. May 1950

DEPARTMENT OF MAINTENANCE

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Engineer of Maintenance, Iowa State Highway Commission

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[1]Since this report was printed, Mr Rex M. Whitton has succeeded Mr. Root as chairman of the Department of Maintenance.

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**Represents the Department of Soils Investigations.

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FOREWORD

The Committee on "Load Carrying Capacity of Roads as Affected by Frost Action" was organized to study and determine the weakening effect of freezing and thawing on the normal carrying capacity of highways. The first report was made at the annual meeting of the Highway Research Board in 1948 and indicated that the loss in carrying capacity might be as much as 60 percent. The following report covers the work of the Committee for 1949 and reviews the activities of the various states participating in the project and contributing research data.

In order that the field plate bearing tests conducted by the various states can be correlated and evaluated properly it is essential that all tests be performed in a uniform manner. It is for this purpose that the Committee has prepared a manual of procedure for conducting the field plate bearing tests. The manual is made a part of this publication.

REPORT OF COMMITTEE ON "LOAD CARRYING CAPACITY OF ROADS AS AFFECTED BY FROST ACTION"

C. L. Motl, Chairman
Maintenance Engineer Minnesota Department of Highways

SYNOPSIS

This report may be considered as a supplement to or a continuation of the report made in 1948[1] on research project No 7.

The project was established to determine the weakening effect of freezing and thawing on the normal carrying capacity of highways, and the first report made to the Highway Research Board indicated that the loss in carrying capacity might be as much as 60 percent.

This report covers the work of the Committee, and particularly the meeting held last June, 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 last June, 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 appears 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.

In recent years there has been growing concern over the rapid deterioration of some of the nation's highways. This deterioration has been attributed to various causes, over which there is considerable disagreement and growing controversy. Among the several causes cited, frost action is suggested as being serious and damaging. In regions subjected to freezing and thawing, it has been a generally accepted fact that during the springtime when the ground is thawing out, roadways cannot carry normal loads, and for many years a number of States have imposed load restrictions, by law, during such periods. With the advent of rigid or slab type pavements and with improved design in flexible base type pavements, it was hoped and expected that the weakening effect of frost action could largely be controlled within limits of reasonable highway costs. This hope has not materialized so far and, therefore, studies of frost effect on roads is now a subject of wide interst.

For several years scattered research has been directed toward the problem, but within the past two years an organized project has been under way under the general guidance of the Highway Research Board, and this is the second annual report on the project, now identified as Maintenance Department Project No. 7.

The objective of this research project is to determine the loss in carrying capacity of completed roads, road bases, sub-bases and subgrades during the spring of the year because of frost action. It is not the purpose of this project to investigate the design strength of roadway structures, but rather to explore their comparative strengths under springtime and normal conditions, and report on the percentage loss of carrying capacity.

The Committee has devoted considerable time to developing uniform testing procedures and methods for the guidance of the several States joining in the project. Tests are being made by means of full-scale bearing loads and by instrumentation, and correlation of the two methods is also being studied.

From the very beginning, full-scale bearing loads made with 6- and 12-in. diameter bearing plates soon confirmed the experience of previous researchers, that the carrying capacity of a road is not proportional to the loaded area, but

[1]PROCEEDINGS, Vol. 28, pp. 273-280 (1948), Highway Research Board.

rather to the perimeter of the loaded area. This is illustrated in Figures 1 and 2. Other interesting data was assembled and submitted in the first report.

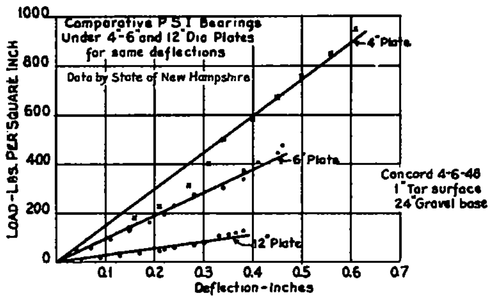

Figure 1.

Several States have now joined in the program of carrying on tests as a part of the project. Some States are carrying on full-scale plate bearing tests, some are carrying on instrumental tests only, while others are carrying on tests involving both field plate bearing and instrumental tests. The Highway Departments of the following States have joined in the research project up to the present time.

INDIANA

Indiana is taking an active interest in the project and has provided itself with good equipment for that purpose (Figure 3). While no data has been supplied by this State so far, it is expected that during the present cycle year of the coming winter and subsequent spring and summer season, Indiana will accumulate data that will be a valuable addition to the information being gathered by other States.

IOWA

Iowa has been conducting plate bearing tests during the past year, and the data being accumulated will be available as soon as a complete cycle of tests has been completed. In addition to plate bearing tests, correlating tests are being made with the North Dakota Cone instrument, and also with an instrument devised in Iowa, which is identified as a Subgrade Resistance Meter. The tests being made should be helpful in disclosing any correlations that may be possible between plate bearing tests and instrument tests. Iowa has also been very helpful in developing and suggest-

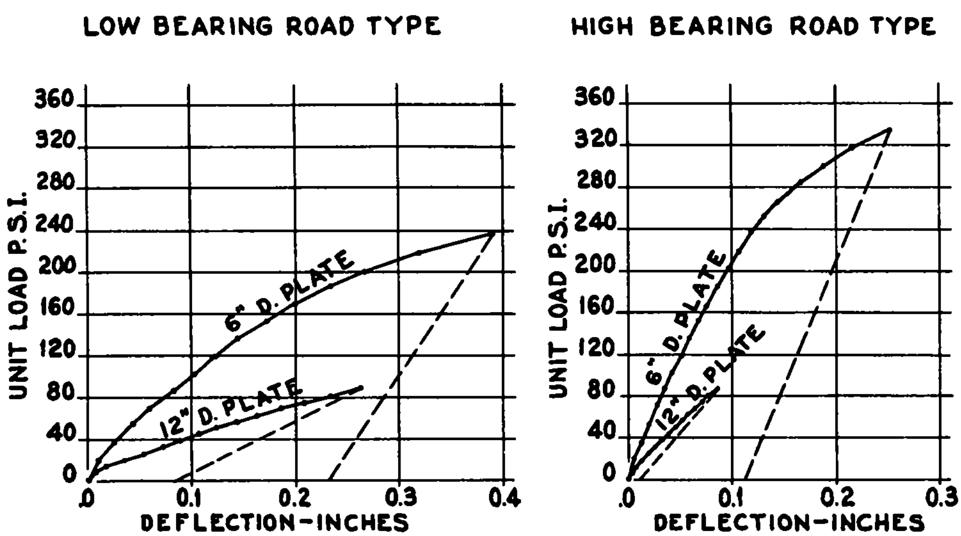

Figure 2. Load-Deflection Curves for Tests with 6 and 12 in. Plates - Tests on Top of Bituminous Surfaced Road - Test Points 3 ft. apart - State of Minnesota

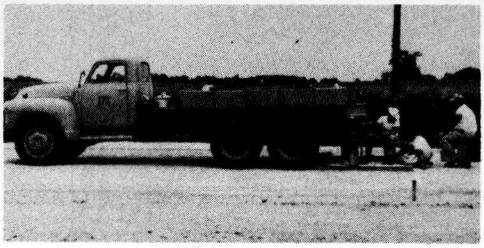

Figure 3. Testing Equipment - State of Indiana

ing procedures. Figure 4 shows the Iowa Subgrade Resistance Meter, which is inserted in a hole made in the subgrade and pressed against the walls of the surrounding soil by hydraulic force. The penetration of the plunger is recorded against the pressure reading on the dial and a time factor.

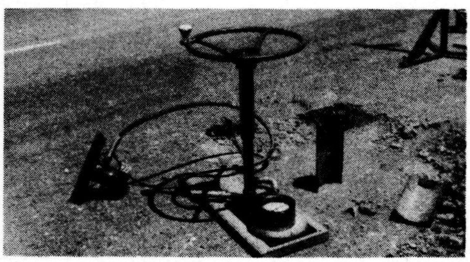

Figure 4. Subgrade Resistance Meter - State of Iowa

MICHIGAN

Michigan is confining its project contribution to the use of instrument tests, involving both the Housel Penetrometer instrument and the North Dakota Cone instrument. The studies are being conducted on bituminous surfaced roads involving tests as follows:

1. Housel Penetrometer test of the subgrade
2. North Dakota Cone test of the subgrade
3. Housel shear test on samples from the subgrade
4. Mechanical analysis of the gravel base course and of the subgrade
5. Moisture tests to 5-ft. depth
6. Descriptive log of soil texture to 5- or 6-ft. depth.

A group of five projects has been selected on which a series of tests and investigations are being conducted over a 12-month period. A considerable volume of technical data has already been accumulated and tabulated for the first half of the annual cycle. After the cycle has been completed, a report will be prepared for submittal to the Committee. Figure 5 shows the Housel Penetrometer instrument which was devised in Michigan. It tests the comparative supporting strength of soils by recording the successive penetrations into the soil of a small cylindrical cutting tool, being subjected to successive blows of uniform intensity.

Figure 5. Housel Penetrometer Instrument - State of Michigan

NEW HAMPSHIRE

New Hampshire furnished some interesting data on the results of its field plate bearing tests in last year's report, but during the past year this State experienced such a mild winter that it could not carry on its tests effectively. Therefore, no additional information is reported from that State at this time. The data submitted last year confirmed tests being made by other States, in that New

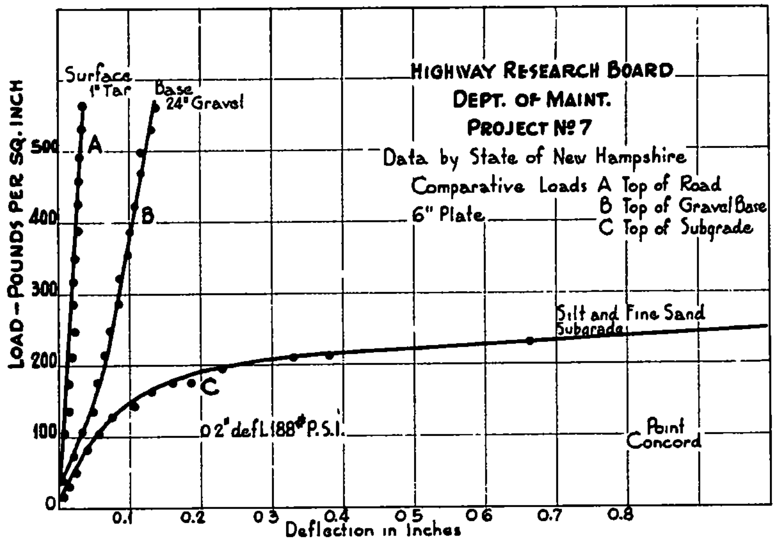

Figure 6. Comparative Loads - 6-in. Plate - State Of New Hampshire

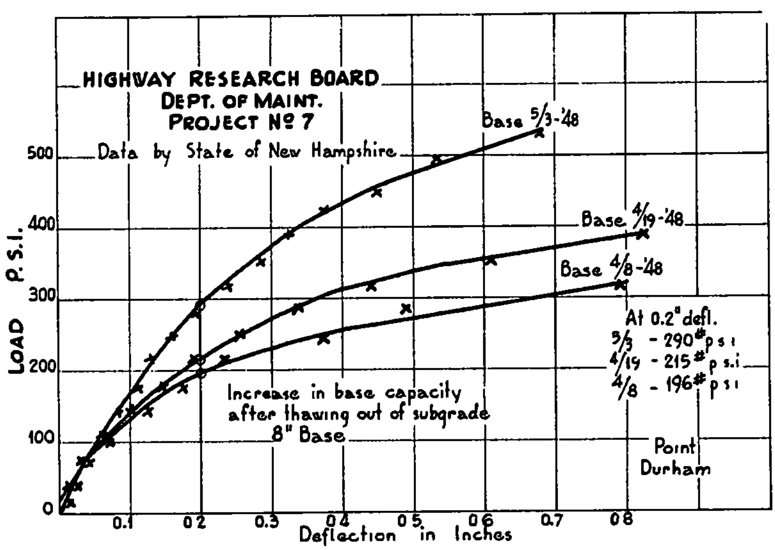

Figure 7. Increase in Base Capacity After Thawing out of Subgrade - 8-in. Base - State of New Hampshire

Hampshire also experienced a loss in road strength during the spring of the year after the frost left the ground. Figures 6 and 7 are representative of results obtained in New Hampshire last year.

NEW YORK

New York is conducting a series of field plate bearing tests at various points on its highways, as outlined in the following report submitted by that State:

"Since last fall, New York State has been attempting to measure the effects of frost action on the load carrying capacity of flexible pavements. This work was started on a moderate scale, using trucks and equipment borrowed from the maintenance forces. Three groups of tests have been made to date. The first two groups were made during the fall of 1948 and the spring of 1949 at the same locations, to measure the load carrying capacity for these periods in the year. The third group was made late in 1949 at new locations, and will be repeated during the spring of 1950.

"One of the difficulties in the performance of this work has been the assembling of the necessary testing equipment which would cover the required loads, be maneuverable, and yet not too expensive to use. During the fall of 1948, the loading equipment consisted of a 30-ton goose-neck trailer, shown in Figure 8. This, however, proved to

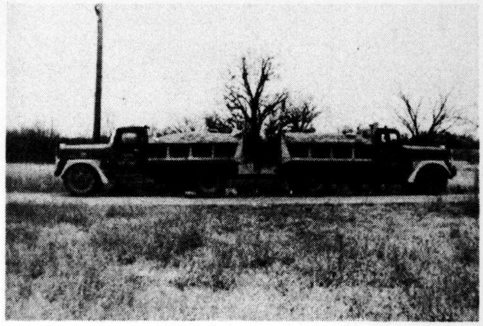

Figure 9. View of Loading Equipment Used During 1949 - Showing I-Beam Supported Beneath the Two Trucks - State of New York

Figure 8. View of Loading Equipment Used in Fall of 1948 - Showing Loaded 30-Ton Trailer - Jacking equipment set in rear of goose-neck behind wheels. State of New York

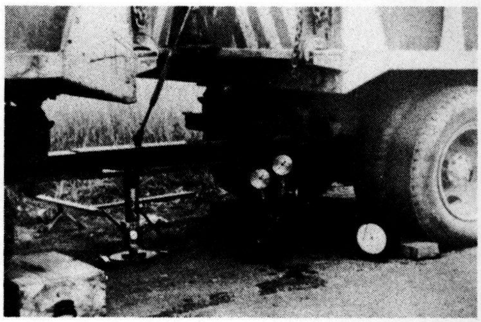

Figure 10. Close-up of Loading Equipment Used During 1949 - Showing Jack, Plate and Pump Arrangement - State of New York

be cumbersome, both in moving and in using. The loading arrangement for the tests made during the spring and fall of 1949 consisted of an I-beam supported beneath two 5-1/2 ton trucks, shown in Figure 9. These trucks, although loaded to capacity, did not have sufficient capacity to cover all tests. Figure 10 shows a close-up of the jack and plate arrangement.

"The fall and spring tests of 1948-1949 were performed at six locations. At each of these locations, the tests were made on the surface, on the base, and on the subgrade, using both 6-in. and 12-in. diameter plates. In order to permit the testing of a wider range of soil and pavement conditions, the tests this fall were made on the surface only, using both the 6-in. and the 12-in. diameter plates. This simplification permitted tests at 30 locations. These tests have been supplemented by the North Dakota Cone Test on the fine-grained soil subgrades. The locations of these tests were picked to represent different subgrade soil types.

"Typical results of plots of the load-deflection relationship obtained during the 1948-1949 series are shown in Figures 11, 12 and 13. The pavement section covered by these tests consisted of a 3-in. bituminous surface on an 8-in. granular base. The subgrade soil was a glacial outwash fine sand with some silt.

Figure 11 shows the relative values obtained on the surface, base, and subgrade, using the 6-in. diameter plate at one location in the spring.

Figure 12 shows the relative values

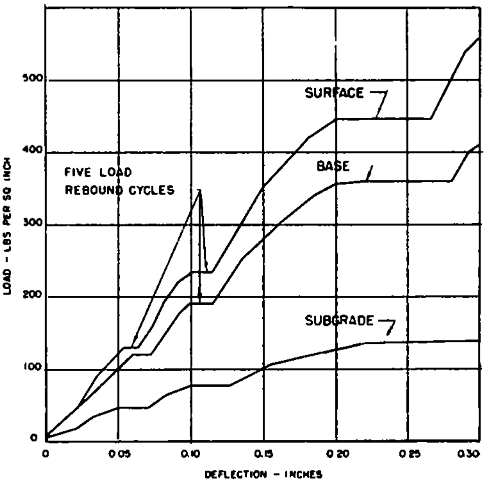

Figure 11. Load-Deflection Relationship of Curves for Surface, Base, and Subgrade - Using 6-in. Diameter Plate - March 29, 1949 - State of New York

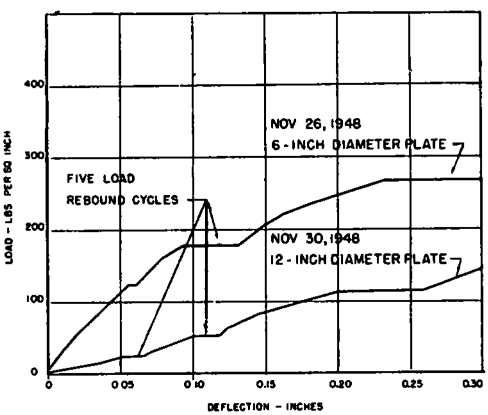

Figure 12. Load-Deflection Relationship of Curves for 6-in. and 12-in. Diameter Plates on Subgrade - State of New York

obtained using the 6-in. and 12-in. diameter plates on the subgrade.

Figure 13 shows a reduction in the load bearing capacity from fall to spring on the subgrade, using a 6-in. diameter plate.

"A comparison of the test results obtained during the 1948-1949 series has shown that the values representing the load carrying capacity in the spring averaged approximately 60 percent of the values in the fall. The individual values for all tests ranged from 35 percent to 85 percent of the fall values.

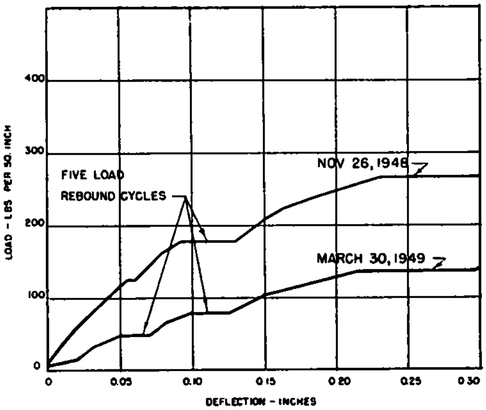

Figure 13. Load-Deflection Relationship of Curves for Fall and Spring, using 6-in. Diameter Plate on Subgrade - State of New York

"An attempt was made to correlate the reduction in bearing value from fall to spring with the respective changes in moisture content in the base and subgrade The values, however, were irregular, and no direct relationship was evident."

NORTH DAKOTA

North Dakota has made an excellent contribution toward the project, in conducting an extensive series of Cone Bearing tests. This State is not using plate bearing tests, but is confining its work entirely to the Cone Bearing method, which was originated in this State and with which the Highway Department is very familiar. The Cone Bearing tests were made at frequent intervals at ten selected test points and were taken, as recommended by the Committee, at levels of 3, 9, 15 and 24 inches below the surface of the subgrade. The subgrades selected for testing are surfaced as follows:

One point--Gravel surfacing

One point--Light bituminous surfacing on stabilized gravel base

One point--Asphaltic concrete surfacing on stabilized gravel base

Three points--Heavy bituminous

road mix surface on stabilized gravel base

Four points--Asphaltic concrete surfacing on stabilized gravel base over pit-run gravel lift base.

The Cone Bearing tests (averaged over the ten points tested) for the various depths below the subgrade, show surprising similarity in loss of base strength which seems to be about 45 percent as an overall average.

Figure 14 illustrates the average strength loss for the ten test points at the four levels selected.

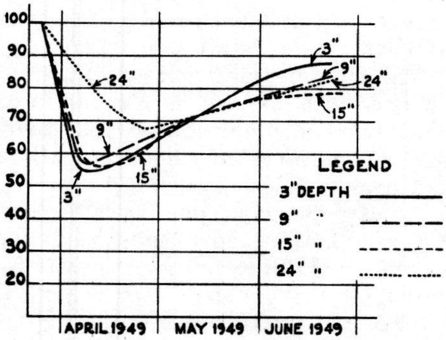

Figure 14. Loss of Strength at Depths of 3, 9, 15 and 24 in. below surface of Subgrade - Average of Ten Test Points - State of North Dakota

Figure 15 shows the grand average of all points and all levels. Please note the sharp drop during the thawing period and subsequent recovery period.

Figures 16 and 17 show the Cone Bearing instrument, a pointed tool which

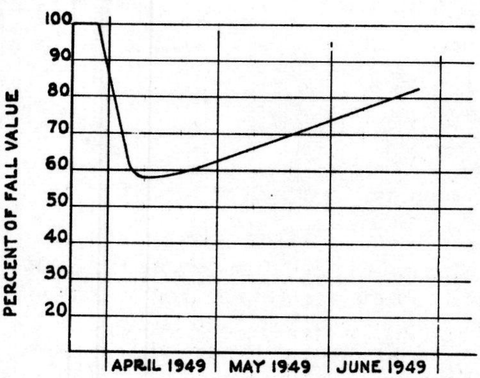

Figure 15. Average of All Tests at the Ten Test Points - State of North Dakota

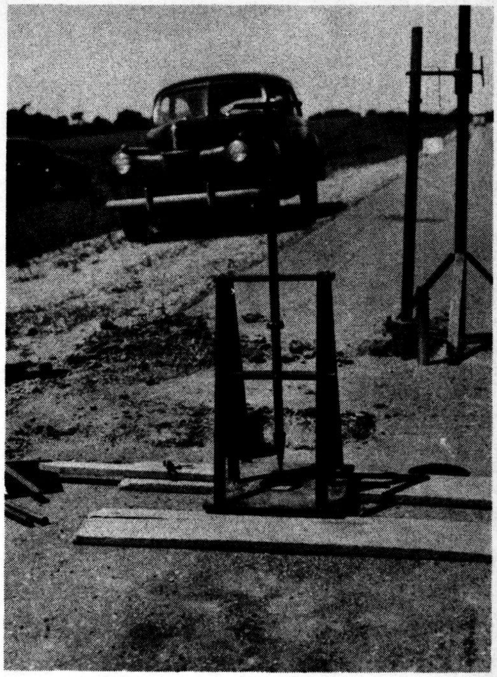

Figure 16. Cone Bearing Instrument - State of North Dakota

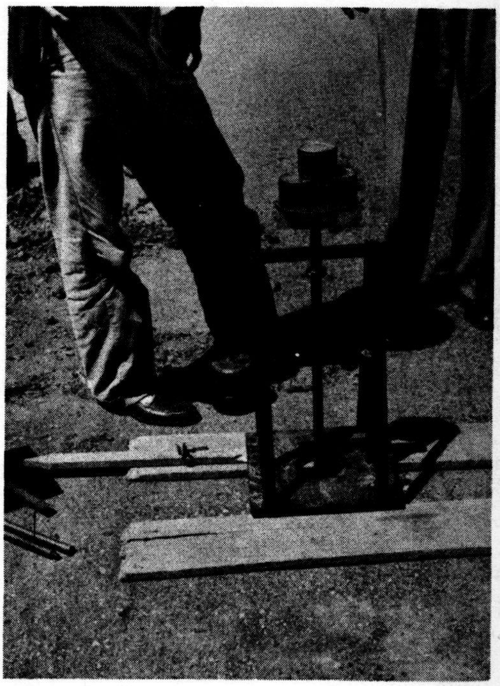

Figure 17. Cone Bearing Instrument - State of North Dakota

is forced into the soil by applying loads of 10, 20, 40 and 80 lb., and respective penetrations recorded. The applied load divided by area of penetration opening, is the bearing value.

OHIO

Ohio has provided itself with excellent equipment for taking field plate bearing tests. This State is taking a very active interest in the project, and it is expected that very helpful results will be secured from the work done by Ohio within the next year. Figures 18, 19 and 20 illustrate Ohio equipment.

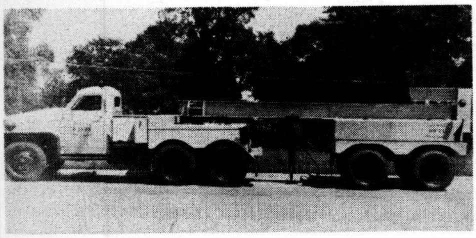

Figure 18. Testing Equipment - State of Ohio

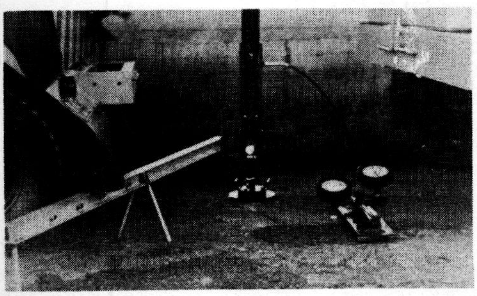

Figure 19. Testing Equipment - State of Ohio

MINNESOTA

Minnesota has carried on field plate bearing tests through three consecutive cycle years, and the data being secured show approximately the same results for each year.

In addition to plate bearing tests, some work has been done with the North Dakota Cone Bearing instrument, and the modified California Laboratory bearing test, with the view of correlating instrument test results with the plate

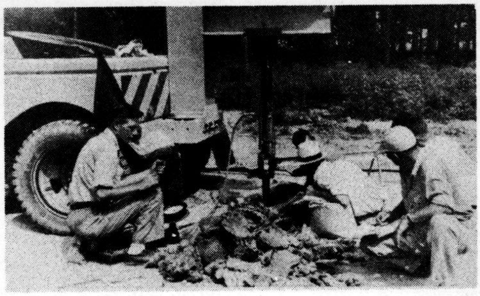

Figure 20. Testing Equipment - State of Ohio

bearing results. The Housel Penetrometer instrument has also been used lately in the correlation program.

The field bearing test equipment being used in Minnesota is similar to that being used in other States and, therefore, no pictures are shown of Minnesota equipment.

During the past cycle year the loss-of-strength data secured from field plate bearing tests followed the same pattern as that of the previous two years, and Figure 21 illustrates the average results from eight test locations. Note that maximum soil strength does not occur until late fall, after suffering a 55 percent loss in early April.

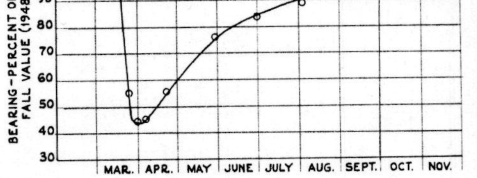

Figure 21.

It will be interesting to note the similarity of the results secured over three successive years of field testing. Figure 22 illustrates the grand average of all bearings taken during each of three years at many test locations.

In each year abrupt springtime

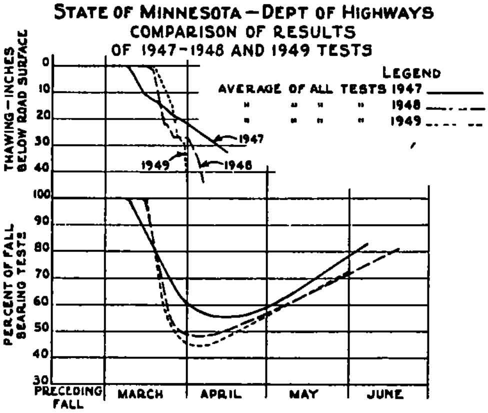

Figure 22.

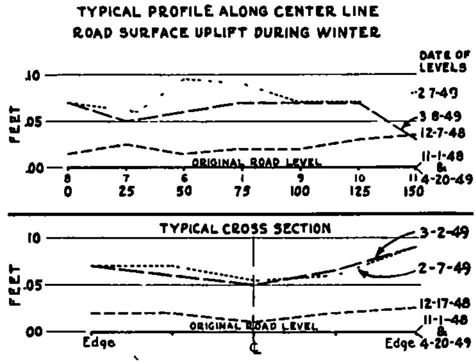

Figure 24.

strength loss of about 50 percent is followed by gradual recovery In the tests it has also been observed that there is close similarity of loss of strength values secured when loading (a) the top of the roadway, (b) the top of the stabilized gravel base, and (c) the top of the subgrade. Figure 23 illustrates average results at each level of all points tested.

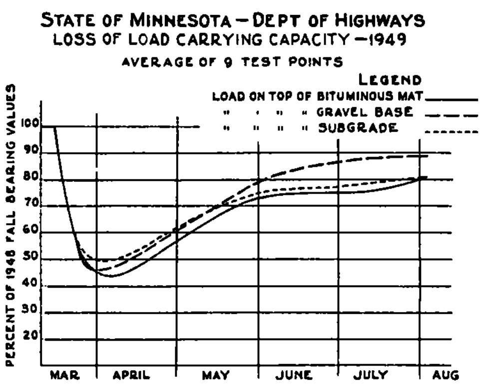

Figure 23.

Surface Heaving - Careful levels were taken over certain sections of roads before freezing started, and levels were repeated over these same roads during the winter and the following spring. The levels disclosed that there is some uplift of roads during a time when they are frozen, and that they resume their normal level again after the frost has left the ground. These are not so-called "frost heave" locations. Figure 24 illustrates these observations.

Moisture Tests - Along with the field plate-bearing tests, extensive moisture tests were made. The purpose of these tests was to determine if moisture variations might be the cause of bearing variations So far no conclusive results can be reported, but some interesting observations can be made. First of all, there seemed to be no startling changes in moisture content, although there were minor variations. Figures 25 and 26 show a comparison of moisture content at various times of the year, with that in the late fall when soil had highest bearing strength.

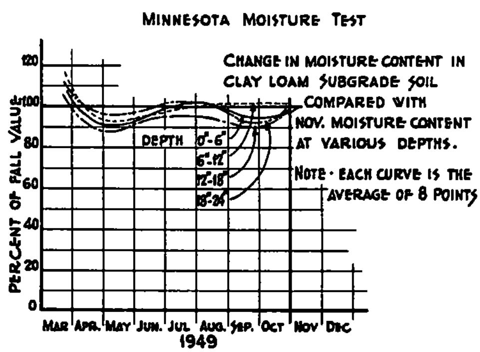

Figure 25.

While it is noted that the moisture content is highest just after the frost has left the ground, it does not appear that the small variations from the fall values are sufficient to account for all the loss of soil stability (an exception, however, should be recognized in those cases where the moisture content in clay loam soils may be close to the maximum). It is suspected that frost

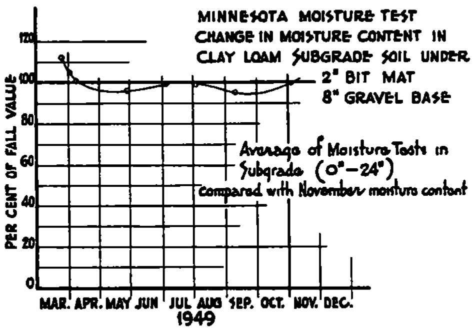

Figure 26.

action attacks the stability of a soil-mass by altering its structure without necessarily changing the moisture content.

So far no extensive nor conclusive results have been secured in trying to correlate field plate bearing tests with instrument testing. It has been observed, however, that field plate bearing tests are not as sensitive to minor soil and other variations as are the instrument tests. It appears, therefore, that instrument testing will require a greater degree of precision and experience for consistent results.

During the committee meeting held in St. Paul, Minnesota on June 27, 1949, it was decided that in addition to the complete and detailed tests that are expected to be made by the various States, a series of tests known as "quickie tests"[2] will also be carried on so that a greater number of loads can be tested at a greater number of locations, without requiring too much time for each test.

This type of test will involve principally the application of a load to the road surface only (and to the road base, optional) and the recording of pertinent data during the application of the load. Other pertinent information that States may desire can be accumulated at the same time, provided the load application procedure is not unduly delayed.

[2]For a description of the test procedure for the "quickie test" see page 11 of this publication.

MANUAL ON RECOMMENDED TESTING PROCEDURES

by the
Committee on Load Carrying Capacity of Roads as Affected by Frost Action,
C. L. Motl, Chairman

History of the Project - The Committee on "Load Carrying Capacity of Roads as Affected by Frost Action", Project Committee No. 7 of the Department of Maintenance, was established by the Highway Research Board in compliance with a request embodied in a resolution passed by the general assembly of the AASHO at its annual meeting in September 1947. The resolution was prompted by a committee report to the Maintenance Department which pointed out that frost damage to roads during the spring months of the year could be measured and that limited data showed this damage to be substantial. This fact has, of course, been known for years, but it appeared extremely desirable to determine the actual loss in carrying capacity by full scale field bearing tests. Since the authorization of this committee, a number of States have built full-scale equipment for field plate bearing tests and others are using or proposing to use other field tests which may yield valuable information of a complementary nature. Representatives of the Bureau of Public Roads, the Highway Research Board and a number of State Highway Departments are active on the Committee.

In view of the importance and magnitude of the problem, it was felt by the Committee that the testing procedures and equipment being used may be of interest to others concerned with the construction and maintenance of highways in the United States. This Manual covers therefore, a description of the procedures and equipment now being employed in a study of the problem, with the hope that others may desire to participate in the work. Additional participating agencies will be most welcome, and any desired information concerning the work of the Committee will be gladly furnished upon request.

Objectives - The objective of the Committee is the determination of the loss in load carrying capacity of completed roads, road bases, sub-bases and subgrades during the spring of the year because of frost action. In other words, it is the aim to discover, as far as possible, the percentage-loss in road strength of various types of completed roads, and not necessarily to determine proper unit strengths of soils, base materials, etc. to be used in road design. It is quite likely, however, that some data obtained by this study may be valuable to those engaged in research related to soils and materials used in road design. Some States will undoubtedly wish to carry the testing beyond the scope of this committee to obtain data useful to them in other fields.

Testing Procedures - The first work done under the cognizance of this committee involved detailed tests at a limited number of locations. The tests made at each location were rather extensive in nature and took into consideration all three elements of the road, the surface, the base (and sub-base), and the subgrade. The Committee is now concerned with the accumulation of a substantial amount of test data to confirm the premise that an appreciable loss in load carrying capacity occurs generally during the spring thawing period, which is not limited to any one particular type of pavement or type of subgrade. The Committee has devised a "Quickie" test, the recommended use of which will result in broader coverage of soil and pavement types. The procedures for conducting the "Quickie" test and the complete detailed test are described below.

THE "QUICKIE" TEST

1. Selection of Test Sites.

The sections to be tested shall be selected to cover the desired area adequately and to include the major subgrade soil types and designs of flexible pavements. The number of test locations will, of necessity, be limited by the equipment and personnel available to make the tests within the time during which the loss of load carrying capacity is the greatest.

On each section, a minimum of three test points shall be selected where the performance of the road has been satisfactory under the loads to which it has been subjected during the spring thawing period. Care should be taken to avoid any areas where differential frost heaving, high ground water or poor drainage conditions exist.

2. Periods of Testing.

As a basis of comparison in determining the loss of load-carrying capacity, it is necessary that late summer or fall field bearing values be obtained. Existing conditions will determine the exact period of the year when load carrying capacity is at the highest level. Results of tests obtained during the critical thawing period occurring the following spring and during the recovery period can then be compared with the fall values to determine the percentage loss in load-carrying capacity.

3. Field Plate Bearing Test Equipment.

(a) A truck or trailer or a combination of both, loaded to produce the desired reaction of the pavement surface under test (See Figure 1).

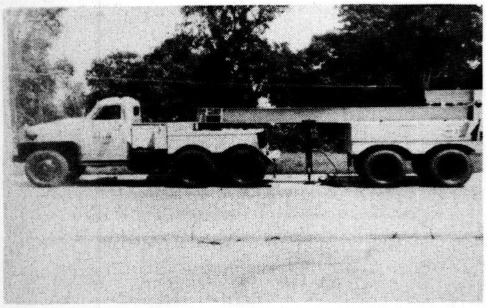

Figure 1. Truck-Trailer Unit Used for Plate Bearing Test Reaction - Ohio

(b) Hydraulic jack equipment to transfer the load from the truck to the bearing plate, and gauges for indicating the load increments and deflections of the pavement. (See Figure 2)

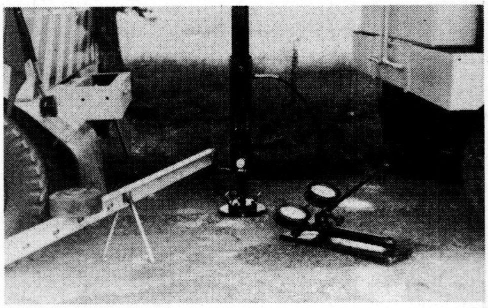

Figure 2. Plate Bearing Test Jack and Incidental Equipment - Ohio

(c) Circular steel bearing plates (6 in. or 12 in. in diameter) (See Figure 2).

A description of the equipment used by the Minnesota Department of Highways is included as an example. Several States used similar equipment.

The equipment was designed to provide a mobile, self-contained unit for making field plate bearing tests. The primary requisite for this equipment was that it should provide a minimum total reaction load of 28,000 lb. and, at the same time, not exceed an axle loading of 4 tons.

It was decided to design this equipment on a truck and trailer combination for two reasons. First to make use of the present truck mounted equipment and second, it was planned to make field plate bearing tests on subgrade where a total reaction load of 10,000 lb. would be sufficient to obtain the desired 0.2-in. deflection and where soft subgrade conditions would cause difficulty in moving equipment heavy enough to provide the larger reaction load.

<u>Equipment for Total Reaction Load of 10,000 Pounds</u> - A 6 x 4 Studebaker truck chassis was reinforced to carry the additional load required to produce the desired reaction. (Figure 3) In order to eliminate any effect of the rear truck tires on the area under stress, the frame of the truck was extended to the rear

so that the bearing plate would be at least 4-1/2 feet from the centers of the rear tires. (Figure 4) With this arrangement, it was necessary to mount 5 one-ton concrete blocks on the truck bed in

Figure 3. Truck Used Singly for 10,000-lb. Test Reaction - Minnesota

order to attain a total maximum load of 10,000 lb. Due to the low clearance under the truck, it was not feasible to place the bearing plate and jack under the truck although such an arrangement would have made it possible to reduce the required load. When loaded as described, the truck weighs a total of 19,200 lb., with 15,600 lb. distributed between the two rear axles and the remainder on the front axle. This is within the four ton maximum axle load permitted on certain roads during the spring months.

A hydraulic pump is used to apply the pressure to an 8-ton jack. A 10,000-lb. pressure gauge, with dial divisions of 100 lb., is used to measure this pressure. The jack and hydraulic pump were calibrated in a compression machine in the laboratory. (Figure 4)

The plunger on the 8-ton jack can be extended with interchangeable threaded sections of various lengths for taking bearings at various depths below the surface of the road. The base of the jack is connected through a ball joint to a 4- by 6-in. rectangular plate which fits into a slot under the extended truck frame. The jack assembly is thus suspended in

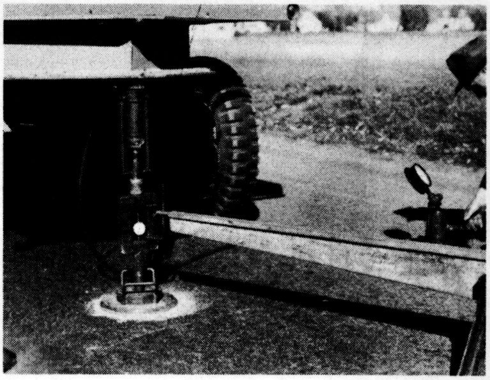

Figure 4. Plate Bearing Test Set-Up - Minnesota

an inverted position from the truck frame. Two springs retract the plunger as the load is released.

A steel block of hollow rectangular shape is used as one section of the plunger. This permits measurement of deflection with a single Ames dial set within the hollow and on the axis of the plunger and center of the bearing plate. The Ames dial is supported from a cantilever beam mounted on legs, the nearest of which are 4 ft. distant from the center of the bearing plate.

Equipment for Total Reaction Load of 28,000 Pounds - A Trailmobile Dual Tandem Trailer Model 662 similar to that shown in Figure 1 was employed to produce a combined total reaction load of 28,000 lb. when jacking against an I-beam connecting the truck and trailer. As loaded, the trailer and beam assembly weighs about 16,000 lb. For ease of connection, a standard fifth wheel assembly was secured to the truck frame and the beam connected to this through a steel pin. The manufacturer's specifications and actual load tests show that this type of connection will withstand the jacking load without failure.

In this assembly, a hydraulic pump is used to apply the pressure to a 20-ton jack. The jack assembly is mounted on the lower flange of the I-beam on rollers so that it can be moved freely.

The jack and hydraulic pump were calibrated in a compression machine in the laboratory.

As in the case of the 8-ton jack, the plunger on the 20-ton jack can be extended with interchangeable threaded sections of various lengths for taking bearings at various depths below the surface of the road.

A steel block of hollow rectangular shape is used as one section of the plunger. This permits measurement of deflection with a single Ames dial set within the hollow and on the axis of the plunger and center of the bearing plate. The Ames dial is supported from a beam mounted on legs, the nearest of which are 4 ft. distant from the center of the bearing plate.

4. Procedure for Making Field Plate Bearing Test.

(a) The bearing test shall be made on the surface of the pavement and in addition if desired it may be made on top of the base course.

(b) The bearing plate shall be centered under the jack assembly. Fine sand passing the No. 40 sieve and retained on the No. 200 sieve shall be used in the least amount necessary to provide uniform bearing under the plate.

(c) An initial load of about 2 psi. shall be applied to firmly seat the 12-in. diameter plate after which the initial or zero reading on the deflection gauge shall be recorded. Loads shall then be applied as rapidly and as uniformly as possible according to the following procedure. The first load increment shall be of such a magnitude as to produce a total deflection of approximately .05 in. after the rate of movement under the maintained load has slowed to less than .004 in. per min.[3] The load and deflection shall then be recorded. The second increment of load shall be sufficient to produce a total deflection of approximately 0.1 in. after the rate of movement has slowed to less than .004 in. per min. The same procedure shall be followed for deflections of .15, .20 and .25 in. The load and deflection shall be recorded in the case of each of the applied load increments. The deflection readings shall be plotted against load in pounds per square inch and a curve drawn through the plotted points. From the curve, the load required to produce a deflection of 0.2 in. shall be recorded as an indication or measure of the load-carrying capacity of the road (See Figure 5 for method of plotting data).

(d) The loss in load-carrying capacity shall be the difference between the bearing value obtained in the fall and that recorded in the spring expressed as a percentage of the fall bearing value.

(e) The depth of thawing at time of test should be determined by the use of a sounding rod or soil auger.

(f) Other data such as weather, temperatures, etc. may be recorded, if available.

(g) If field plate bearing test equipment is not available, other tests such as the North Dakota Cone, the Housel Penetrometer Test, or the Iowa Subgrade Resistance Test may be used at the same periods as outlined for the plate bearing test (See Figures 6, 7, 8 and 9). These test methods however are such that the tests have to be made on the subgrade. This would require more time to actually complete the tests and consequently would remove them from the "Quickie Test" category.

[3]It will be necessary to discontinue increasing the load increment before the deflection reaches 05 in. so as to allow for the additional deflection that will occur before desired rate of movement is attained. The same will apply to all subsequent load increments

THE DETAILED TEST

As stated previously, the initial work sponsored by the Committee was for the purpose of determining the loss in load-carrying capacity and the subsequent recovery of all elements of the road: the surface, the base (and subbase) and the subgrade. It is believed that studies of this nature will yield a more accurate and comprehensive picture of what is happening at a specific test location than the "quickie" tests, although of necessity fewer test sites can be covered.

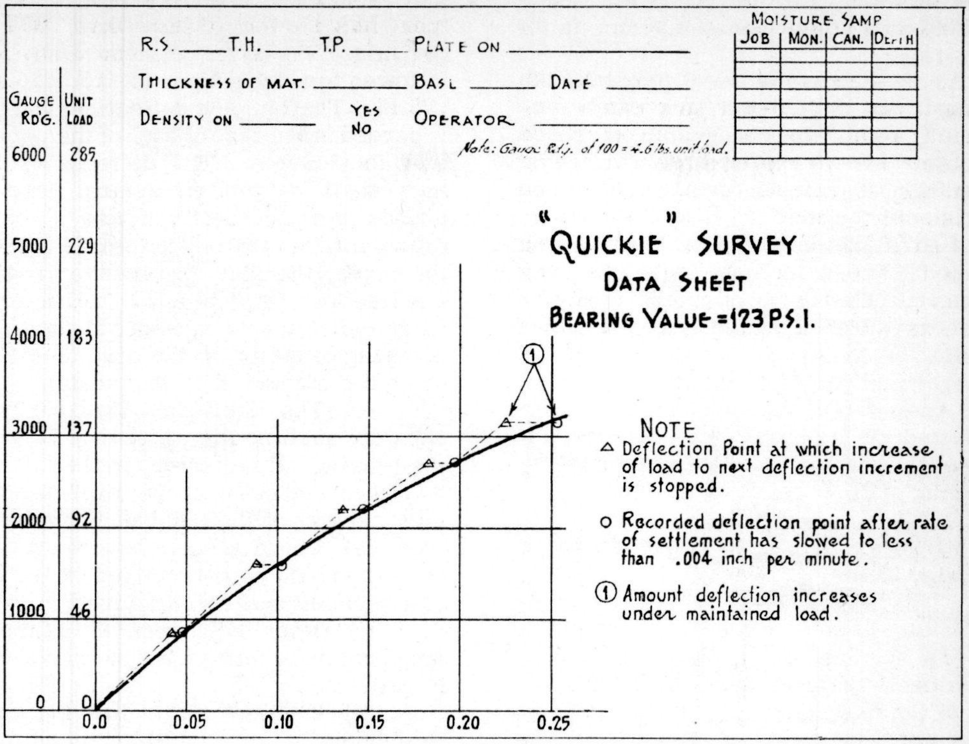

Figure 5.

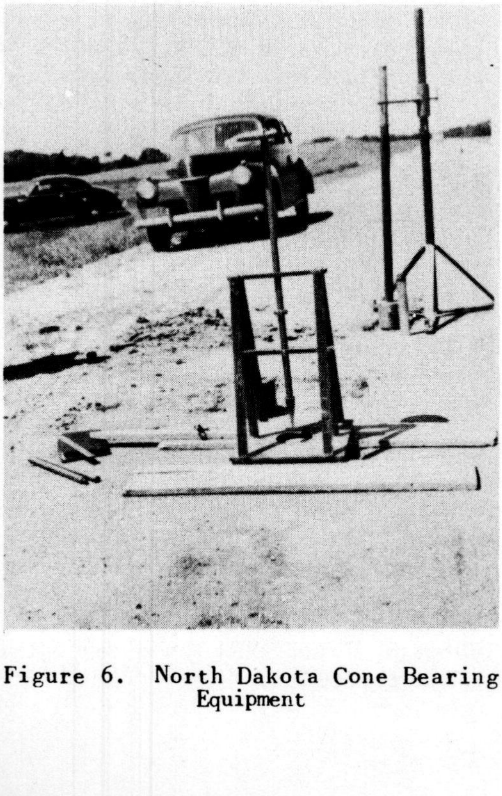

Figure 6. North Dakota Cone Bearing Equipment

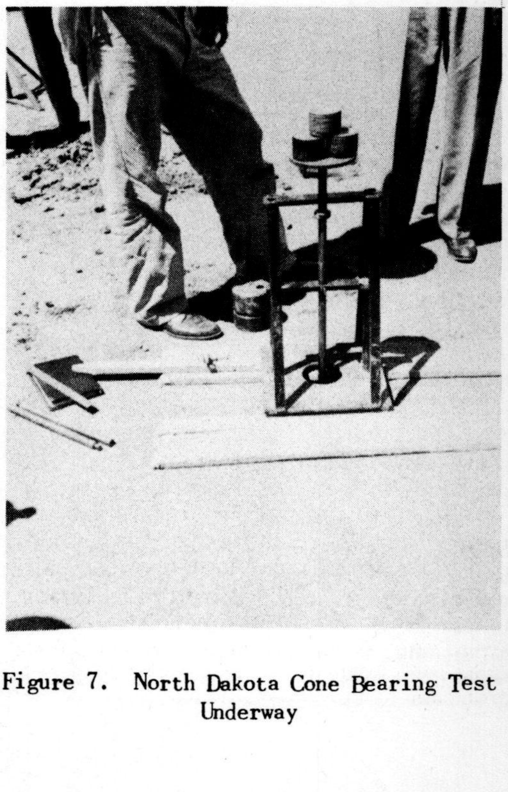

Figure 7. North Dakota Cone Bearing Test Underway

1. Selection of Test Sites.

Sections of highway constructed in accordance with current design and specifications shall be selected. These sections should represent average good conditions where performance has been satisfactory under the load restrictions applied if any during the spring thawing period. The selection should avoid any areas affected by abnormal conditions such as differential frost heaving, high ground water or poor drainage.

Figure 8. Housel Penetrometer Equipment

The general record of performance, traffic flow and load restrictions should be considered.

The number of test locations shall be such as to permit at least one repetition of the test at each point during the critical thawing period.

2. Periods of Testing.

These should be the same as described in Section 2 under The Quickie Surveys. In order to determine adequately the rate of recovery of bearing capacity, it is recommended that an additional series of tests be made between the critical spring and fall periods.

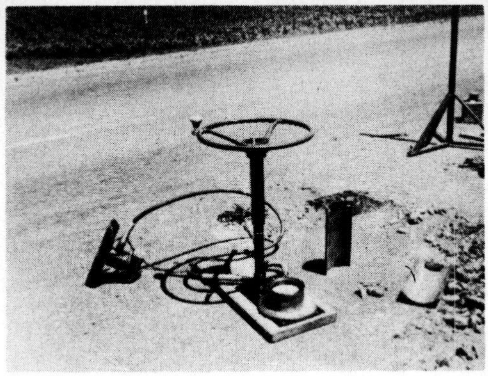

Figure 9. Iowa Subgrade Resistance Testing Equipment

3. Field Plate Bearing Test Equipment.

The equipment shall be the same as described under the Quickie Survey (See Figure 1).

4. Procedure for Making Field Plate Bearing Test.

(a) Tests shall be made on the surface of the bituminous mat, on the top of the base, and on the top of the subgrade. For tests on the base or subgrade, the material overlying the surface to be tested shall be carefully removed from an area approximately the size and shape of the bearing plate. The test on the base course shall be made at a point 3 ft. distant from that on the surface and the test on the subgrade 3 ft. distant from either of the previous tests. The test points shall be located transversely in the wheel tracks.

(b) The bearing plate shall be centered under the jack assembly. Fine sand passing the No. 40 sieve and retained on the No. 200 sieve shall be used in the least amount necessary to provide uniform bearing under the plate.

(c) An intital load of about 2 psi. shall be used to firmly seat the 12-in. diameter plate and the corresponding initial or zero reading on the deflection gauge recorded. Loads shall then be applied as rapidly and as uniformly as possible. The first load increment shall be of such a magnitude as to produce a total deflection of approximately .05 in. after the rate of movement under the maintained load has slowed to less than .004 in. per min.[4] The load and deflection shall then be recorded. The time required for the rate of movement to slow to less than .004 in. per min. shall also be recorded. The load shall then be released and the surface under test allowed to rebound for an interval of time equal to that previously recorded. The seating load of 2 psi. shall then be reapplied and the deflection reading recorded.

(d) The second increment of load shall be sufficient to produce a total deflection of 0.1 in. after the rate of movement has slowed to less than .004 in per min. The same procedure for release of load and recording of data shall be followed as in the case of the first load increment.

(e) The procedure as outlined in Paragraph (d) shall be followed for deflections of .15, .20 and .25 in.

5. Use of Load-Deflection Data.

Load deflection curves shall be plotted for each bearing test. The data shall be plotted on the Data Sheet (Figure 5) in the manner shown in Figure 10. From the curve bearing value in pounds per square inch at 0.2-in., deflection shall be determined as an indication of the load-carrying capacity of the surface under investigation.

Where the capacity of the equipment is not adequate to produce a deflection of 0.2 in., an approximation of the bearing value can be obtained by extrapolation of the stress-strain curve.

6. General Soils Data.

The following soil data is essential:

(a) Soils profile and pedological classification of the soil at each test point.

(b) Samples of the base material and subgrade soil for laboratory analysis and complementary laboratory tests

[4]See Footnote 3.

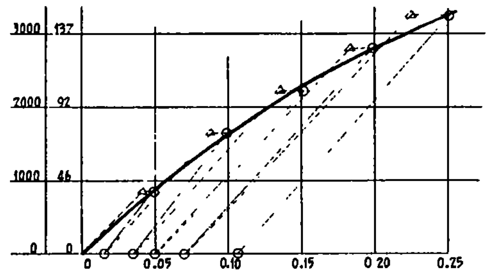

Figure 10. Detailed Procedure for Plating Field Plate Bearing Data

such as the CBR, triaxial or others.

7. Climatological Data.

A continuous record of air temperature and precipitation for the areas shall be obtained during the period of study.

8. Moisture and Density Tests.

Moisture and density tests of the base and subgrade shall be made frequently throughout the thawing period and thereafter until the maximum bearing value has been reestablished. Fluctuation of moisture content in the subgrade soils should be observed to a depth of at least 36 in.

9. Road Temperature Data.

The depth of frost thawing shall be determined by means of auger borings or other means at the time of making bearing tests.

Recording of temperatures at depth intervals sufficient to indicate fluctuations caused by sun and air temperatures shall be made if possible at several points. The use of thermocouple installations or other equipment to record temperatures, moisture conditions and freezing is highly desirable. Records should also be made of the degree of sunshine during the conduct of the tests.

Where possible precise levels should be taken at the selected sites to determine frost heaving.

10. Other Field Tests.

Complementary to the plate bearing test, other methods of field testing may be employed. The conduct of such tests might develop a correlation with the field plate bearing test and may ultimately serve as a means of measuring the load carrying capacity. The following are suggested:

(a) North Dakota Cone Bearing Test (Figure 6 and 7).

(b) Housel Penetrometer Test (Figure 8).

(c) Subgrade Resistance Test (Iowa State Highway Department) (Figure 9).

(d) Double Ring Cone Penetrometer Test (Waterways Experiment Station, U. S. Engineers, Vicksburg, Mississippi) (not illustrated).

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