ACFEL TR 6/8-10

FROST INVESTIGATION
1944-1945

REPORTS ON
CASPER AIRBASE, CASPER, WYOMING
FARGO MUNICIPAL AIRFIELD, FARGO, NORTH DAKOTA
AND
BISMARCK MUNICIPAL AIRFIELD, BISMARCK, NORTH DAKOTA

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CORPS OF ENGINEERS, U.S. ARMY
MISSOURI RIVER DIVISION
U.S. ENGINEER OFFICE, OMAHA, NEBRASKA
JUNE 1945

APPENDICES 8,9 AND 10
TO COMPREHENSIVE REPORT
DATED JUNE 1945

FROST INVESTIGATION

1944 - 1945

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REPORT ON

CASPER AIRBASE, CASPER, WYOMING

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FROST INVESTIGATION

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REPORT ON

CASPER AIRBASE, CASPER, WYOMING

1. Authorization.

The investigation of frost action beneath the airfield pavements was authorized by the letter dated 7 July 1944, from the Office, Chief of Engineers, to the Division Engineer, New England Division, subject: "Frost Investigation," and by the letter dated 28 August 1944, from the District Engineer, Boston District, to the Division Engineer, Missouri River Division, subject: "Frost Investigation".

2. Purpose.

The purpose of this investigation has been the determination of the development of frost action in pavement elements as affected by varying conditions of weather, soils, and ground water. The investigation at Casper Airbase was made to determine the effects of frost in an area and region having a fairly low annual precipitation, a generally low water table, and a naturally dry subsurface soil condition, these conditions existing simultaneously with subsurface soils having a borderline susceptibility to frost action under proper moisture conditions.

3. Scope.

The scope of this report covers an investigation of frost conditions existing under both flexible and concrete airfield pavements. The investigation under the flexible pavements includes the determination of moisture and density changes occurring in the various subsurface pavement elements during the period from early fall, 1944, through the spring thaw period of 1945, together with the measurement of heaving of the pavement caused by frost action, changes in California Bearing Ratio characteristics of the subgrade soils due to possible frost action, and the observation of ice lenses or other frost formations below the pavement surface by means of test pit excavations. The investigation of the concrete pavement areas includes the determination of surface heave by means of wire-line readings taken at various intervals throughout the fall, winter, and spring, and moisture, density and ice formation data obtained from pit excavations made at various periods during the investigation.

4. General Conditions.

a. Location, Terrain, and Drainage.

Casper Airbase is located approximately 8 miles northwest of the City of Casper in Natrona County, Wyoming. The general terrain of the airfield site is an elevated flat, breaking to the northeast and to the southeast into Six Mile Draw. Drainage is in general to the southeast. The surrounding terrain varies from draws and gullies to rolling country with the Casper Mountain Range rising approximately 10 miles south of the airfield. The elevation of the airfield is approximately 5325 feet above mean sea level. The drainage system on the airfield consists of a surface and a storm sewer system discharging into natural courses to the northeast and southeast of the airfield. No appreciable subsurface water conditions were encountered, neither during construction, nor in any tests subsequently performed for the frost investigation. The ground water elevation in the airfield region is indicated to be in excess of 90 feet below the surface of the airfield.

b. Types of Pavement.

All airfield pavements on this airfield are flexible type with the exception of approximately 277,000 square yards of Portland cement concrete apron pavement. The original design of flexible pavements for taxiways and the center runway areas on Casper Airfield called for the construction of a 5-inch asphaltic concrete surface and an 8-inch sand base constructed over a minimum of approximately 2 feet of suitable subgrade soil materials. The runway sections on this airfield were constructed with the center portions 150 feet wide, meeting the requirements heretofore stated, with an additional 75-foot width of paved shoulder constructed on each side of the center pavement. The runway shoulder pavements were designed for a 3-inch cold mix bituminous mat surface and a 6-inch sand base, constructed over a minimum of 2 feet of suitable subgrade soil material. The center portions of all taxiway pavements were designed to have a section similar to the center portion of the runways, this section consisting of a 5-inch asphaltic concrete surface, a 6-inch sand subbase and a minimum of 2 feet of suitable soil materials. Twelve and one-half foot shoulders were constructed on all taxiway sections. These pavements consisted of a 1½-inch asphaltic concrete wearing surface, a 6-inch sand base, and a minimum of 2 feet of suitable subgrade soil materials. The concrete apron pavement consists of a 7-inch concrete slab, with unsupported edges variously thickened from 9 inches to 10½ inches and construction joints varying from 7-inches to 9-inches in thickness. All concrete pavements were constructed on compacted existing subgrade soils. A major portion of the airfield pavements were constructed during the period. May 1942 to October 1942. The 12½-foot widths of taxiway shoulders were constructed in July 1943.

c. Traffic History.

Aircraft traffic began on this airfield in November 1942. Traffic during the period of operation of this airfield consisted principally of B-17 and B-24 type planes having gross weights of approximately 50,000 pounds. The average traffic during the period of operation through October 1944, is estimated to have been approximately 95 landings and take-offs per day.

d. Condition of Pavement.

The condition of the flexible airfield pavements varies from fair to good. Numerous small depressed areas exist on all flexible pavement surfaces due to differential settlement under traffic. These depressions are accentuated by the very small transverse grades employed in the construction of the various airfield surfaces and minor ponding of water on the pavement results during periods of precipitation. Minor cracking, existing on some surfaces is considered to be due largely to the action of traffic. The condition of all concrete pavement existing on the apron is considered to be good.

e. Frost Conditions.

The subsurface soils existing under the pavement surfaces on this airfield consist principally of ML, SF, SP, SC, SW, and CL type materials. All soils and also all base course materials in the airfield pavements are considered to be susceptible in varying degree to frost action, both in the form of heaving and in reduction of supporting power during the thaw period, provided these elements are subjected to the proper moisture condition. Some materials, such as materials of SF classification, are considered to be borderline materials relative to the occurrence of frost action, and particular attention has been given to the observation of frost actions in these and similar type materials. Pavement behavior data on this airfield since the date of construction, do not indicate serious heaving of the pavement nor pavement distress due to frost action. While the soil and base course materials, are considered to be variously susceptible to frost action, other conditions, such as the low rate of rainfall and very low water table, tend to reduce the occurrence of frost action in the airfield soils.

f. Climatic Conditions.

The general weather conditions in the Airfield region are moderate, and are considerably milder than would be generally indicated by the latitude of the region. The normal cumulative degree-days below freezing value, based on a five-year mean, wrong is 532. The 1943-44 season produced 720 cumulative degree-days below freezing. The normal accumulative precipitation for the period September, October, November, and December for the airfield region, is approximately 4.4 inches. The 1943 accumulative precipitation during the fall period totaled 3 inches, while the 1944 precipitation during a similar period totaled approximately 2.5 inches. The weather during the period of investigation of this airfield, therefore, was considered to be more severe than normal relative to the cumulative degree-days below freezing, while precipitation conditions are considered to have been less severe than normal.

5. Definitions.

The description of the tests and analyses of results involve a specialized use of certain terms and words. These words and terms are defined for use in this report as follows:

a. Test Area - The test area is the portion of the airfield selected for investigations and observations.

b. Pavement - The term pavement is defined as a covering of a prepared or manufactured product superimposed upon a subgrade or base to serve as an abrasion and weather resisting structural medium.

c. Base - The term base applies to the course of specially selected soils, mineral aggregates, or treated soils or aggregates placed and compacted on the natural or compacted subgrade.

d. Subbase - The term subbase refers to a course intermediate between the base and subgrade, and may consist of selected soils, mineral aggregates, treated materials or highly compacted existing soil.

e. Subgrade - The term subgrade applies to the natural soil in place or to fill material upon which a pavement, base or subbase is constructed.

f. Map Cracking - Map cracking is the development of a definite crack pattern in the pavement surface under the action of repeated loadings. Map cracking is distinguished by the formation by cracking of continuous connected polygonal pavement segments.

g. Consolidation - Consolidation is the increase in unit weight, or decrease in volume of a material due to the action of applied loadings. Consolidation is considered to be synonymous with compaction in this report.

h. Permanent or Vertical Deformation - Permanent or vertical deformation is the accumulative non-elastic part of the total vertical movement of the surface of the pavement which remains after the load is removed.

i. Capacity Operation - Capacity operation is defined as the maximum traffic that can possibly operate on an airfield for a period of approximately 20 years. The daily operation may be assumed as varying from 100 cycles of landings and take-offs for the very heavy planes to 1500 cycles for very light weight planes.

j. Frozen Soil - Frozen soil is referred to in this report as follows:

(1) Homogeneous Frozen Soil. A homogeneously frozen soil is a soil in which all the water in the soil is frozen within the natural voids existing in the soil, without observable segregation or accumulation of ice lenses or frost forms exceeding in volume such natural void spaces.

(2) Stratified Frozen Soil. A stratified frozen soil is a soil in which a part of the water in the soil is frozen in the form of observable ice lenses, occupying space in excess of the original soil voids.

(3) Hard Frozen Soil. Hard frozen soil is soil at or below a temperature of 32^oF, which has been hardened due to the solidification, by freezing, of water films between soil particles.

k. Frost Growths - Any observable crystalline or solid frozen forms of water in soils formed by freezing temperatures.

l. Ice Lenses - Ice lenses are the observable frozen free water bodies existing in stratified frozen soil.

m. Ice Crystals - Ice crystals are the observable ice particles existing in the void spaces and pores of homogeneous frozen soil.

n. Frost Zone - Frost zone refers to the vertical limits of frozen soil.

o. Frost Penetration - Frost penetration is the maximum depth from the surface to the bottom of the frozen soil.

p. Depth of Freezing Temperature Penetration - The depth of freezing temperature penetration is the maximum depth below the surface of freezing temperature.

q. Degree-Days Below Freezing - Degree-days below freezing is the cumulative difference between the average of the daily maximum and minimum temperature and 32° Fahrenheit.

r. Terminal Frozen Plane - The terminal frozen plane is the final thawing plane in the frozen soil.

6. Test Area A.

a. Location and Pavement Description.

Test Area A is located on the concrete apron pavement, station 1+95 to station 3+45, beginning 110 feet southeast of the northwest edge of the apron, and extending 300 feet in a southeasterly direction. The pavement consists of a 7-inch Portland cement concrete pavement, the construction joints of which are thickened to 9 inches and the unsupported expansion joints and edges are thickened to $10\frac{1}{2}$ inches. The concrete pavement is laid directly on compacted existing sand and sandy-clay subgrade soils. The location of the test area is shown on Plate 2.

b. Test Explorations.

Test explorations in Test Area A, the location of which are shown on Plate 2, consist of the following groups:

(1) Preliminary Soil Explorations.

Preliminary soil explorations consisting of borings made in the apron pavement within the test area to determine the subgrade soil conditions existing in the proposed site were made in August 1944. The preliminary test boring holes are numbered on Plate 2.

(2) Fall Explorations.

Two Test Pits, numbered TP 1A and TP 1B, were excavated in October 1944, to determine density and moisture. In addition to the pit excavations, excavations and borings were made adjacent to several contraction and expansion joints in the concrete pavement to obtain data relative to the subsurface moisture conditions existing under such joints, as affected by the infiltration of surface water through such joints.

(3) Winter Explorations.

Winter explorations consisted of two Test Pits numbered TP 2A and TP 2B, excavated in January 1945. Subsurface soil, water and frost conditions were determined from these excavations.

(4) Spring Explorations.

Two Test Pits, numbered TP 3A and TP 3B, were excavated in March 1945 for the purpose of determining the condition of the subsurface pavement elements relative to water content, density and bearing ratio.

c. Equipment Installations.

The following installations were made in the pavement area:

(1) Bench Marks.

Six bench marks for use with two transverse wire-lines, were placed in Test Area A for the purpose of obtaining readings used for determination of heave in the pavement section. The bench marks consisted of rods driven into the soil below the frost level and protected through the frost zone by a pipe covering, the rod being surrounded with a soft asphalt mixture to permit free movement of the frozen ground. The location of the bench marks in Test Area A are shown on Plate 2. Details of bench mark equipment are shown on Plate 3.

(2) Temperature Measuring Equipment and Water Observation Wells.

Temperature measuring equipment was not installed on this airfield. Water observation wells were not used due to the indicated extreme depth of the natural water table.

d. Observations and Measurements.

The following observations and measurements were made in Test Area A:

(1) Wire-line Readings.

Wire-line readings were determined in October 1944, and during January, February and March 1945. The data so obtained have been used to determine heave of the pavement area. These data have been plotted as heave contours on Plate 4.

(2) Frost Penetration.

The depth of frost penetration was determined in test pits excavated during January 1945. In the absence of temperature data in the test area, the depth of frost penetration is considered to be that depth at which frozen ground was noted or frost crystals or lenses found. The depth of frost penetration in the excavated pits was determined by the depth of frozen ground, since no ice crystals or lenses were observable in the base or subgrade materials in these pit excavations. In Test Pit TP 2A, the subgrade materials, from a depth of 0.77 feet to 0.89 feet below the surface of the pavement, were frozen hard. The material between 0.89 feet and 1.24 feet below the surface was soft and loose, while the material between 1.24 feet and 2.45 feet was frozen hard. In Test Pit TP 2B, sand-gravel-clay material, existing from 0.73 feet to 1.0 feet was not frozen, although a clay-sand material existing from 1.0 feet to 2.5 feet was frozen hard. No ice lenses or frost crystals were visible in either pit excavation.

(3) Ice Lens Survey.

As noted in the preceding sub-paragraph (2), "Frost Penetration," no ice lenses or crystals were observed during excavation of the test pits in January 1945.

(4) Water Filtration Investigations.

Borings through the pavement were made in October 1944, to determine the conditions of moisture existing in subsurface materials under several types of pavement joints in Test Area A. The borings consisted of one hole bored through the pavement directly above the joint and a series of bored holes spaced one-foot apart on a line normal to the joint. The holes were bored through the pavement and auger samples of soil were taken to a total depth varying from 3 to 6 feet. Water contents of the materials were taken at depth intervals of approximately 6 inches, beginning at the bottom of the pavement. The vertical borings were made in a line normal to one side of the joint only. Data were obtained from one transverse contraction, one expansion, and two construction joints. The data so obtained are shown on Plate 4.

e. Field Tests.

(1) Subsurface Moisture Tests.

Subsurface moisture tests were obtained at all pit excavations made in the fall, winter, and spring test periods. The moisture determinations in the test pits were obtained directly under the concrete pavement and at intervals of approximately 6 inches to a depth of 5 feet, and at one-foot intervals thereafter to a total depth of 15 feet. The samples below a

5 feet depth were obtained by means of soil augers. The moisture data obtained from the various test pit excavations are shown on Plate 5.

(2) Subsurface Density Tests.

Subsurface density tests were obtained from all materials in the test pit excavations in the fall and spring test periods. The density tests were obtained at one-foot intervals beginning at the top of the subgrade, for a total depth of approximately 5 feet below the pavement surface. The results of these tests are shown on Plate 5.

f. Laboratory Tests.

The following laboratory tests were performed:

(1) Classification Tests.

Mechanical analysis and Atterberg tests were made for classification of all soils and aggregate materials. All materials were classified in accordance with the Casagrande method and by the methods and procedures given in Appendix 14 of the Frost Investigation Report. Classification and analysis data for all materials are given in Table 2.

g. Conclusions, Test Area A.

(1) Heaving.

The heave measured in Test Area A was indicated to be relatively minor, the maximum heave not exceeding 0.03 feet, with an average heave of approximately 0.01 feet. The absence of sufficient frost action to produce heave is indicated by the general absence of ice lenses or other frost formations in the subgrade during the test pit excavations in the winter test period. Although an appreciable water content is indicated as existing in the subsurface materials by the data shown on Plate 5, the quantity of water present within and directly below the frost zone is indicated as being insufficient to produce appreciable ice formations, which under the conditions of test, effectively retarded the development of appreciable heave.

(2) Frost and Freezing Temperature Penetration.

The depth of freezing temperature penetration was not determined in this test area, since subsurface temperature measurements were not made. The depth of frost penetration was determined by the observation of the depth of frozen ground in the test pit excavations made 15 and 16 January 1945. No ice lenses or frost forms were visible in either test pit excavations; however, the depth of frost penetration is concluded to have extended at least to a depth of 2.45 feet in Test Pit TP 2A, and at least to a depth of 2.5 feet in Test Pit TP 2B, based on the existence of hard frozen soil to these depths.

(3) Ice Lens Surveys.

No ice lenses or frost formations were observed during either of the winter test pit excavations. The absence of observable ice lenses and frost formations is considered to have been due to the presence of moisture content in the soil of insufficient magnitude to cause the formation of such ice or frost forms to a degree permitting observation, although temperatures in these materials were at or below freezing temperatures.

(4) Subsurface Moisture Changes.

The results of the moisture data obtained in the series of pits excavated in October 1944, and in January and March 1945, indicate that the changes in moisture content of the subsurface materials occurring through the investigational period were relatively small, with the exception of the increases in observed water content during the winter, of the materials lying at depths of from 5 to 7 feet in the B series of test pits. The variations in moisture content indicated as occurring in the various subsurface materials between depths of 3 feet and 5 feet are considered as being due in large part to the possible effects of frost action and the persistence of a freezing plane in this area during a large portion of the winter period. The moisture changes are indicated as being relatively small however, and the small amount of change is considered to be due to the generally low moisture content present in the subsurface materials to depths exceeding 15 feet, the effect of such low moisture content being the retardation of any action tending to increase appreciably the water content of the materials lying in or immediately adjacent to the frozen zone in the upper portion of the pavement structure.

(5) Subsurface Density Changes.

The results of the density tests made in the upper portion of the subgrade in October 1944, and in March 1945, indicate that, in general, the changes in density occurring in the subsurface materials were relatively small. A very minor increase in density was noted as occurring in the upper portion of the A series of pits, while similar soils in the upper portion of the B series of pits indicated a very slight decrease. The remainder of the tests, taken at lower depths, indicate a trend toward obtaining higher densities in these materials in the spring than was obtained in the fall. Changes in density, whether toward increasing or decreasing, are considered to have been relatively minor and not indicative of the occurrence of frost action of any appreciable magnitude.

(6) Water Infiltration Tests.

The results of the water infiltration tests in the construction, contraction, and expansion joints in Test Area A indicate that, in general, the moisture contents of the subsurface materials directly under and adjacent to these joints have been influenced only to a negligible degree by water infiltration.

7. Test Area B.

a. Location and Pavement Description.

Test Area B consists of a flexible pavement taxiing area located

Profile says sand & gravel

on Taxiway T-2, Station 30+75 to Station 33+75. The pavement in this area consists of 5 inches of asphaltic concrete surface, and a 6-inch sand base, constructed over sandy-clay subgrade. The soil materials in the upper portion of this subgrade consist, in general, of a CL-SF classification material, a light brown, sandy-clay soil, while material underlying the upper portion of the subgrade are principally CL, SC or CL-SF materials. The $12\frac{1}{2}$-foot widths of taxiway shoulders consist of a $1\frac{1}{2}$-inch thickness of asphaltic concrete surfacing constructed over a 6-inch sand and gravel base, classified as a GW ? SW material, these elements being constructed over compacted sandy-clay material. Pavement details relative to the cross sections and profiles of the test area are shown on Plate 2.

b. Test Explorations.

A chronological summary of test explorations is given in Table 1. The test explorations in Area B, the locations of which are shown on Plate 2, consisted of the following groups:

(1) Preliminary Explorations.

Preliminary soils explorations for the purpose of determining subsurface condition under proposed test areas were made in August 1944. Test borings were made throughout the investigated area at 100-foot longitudinal intervals.

(2) Fall Explorations.

The fall explorations consisted of the excavation in October 1944, of two Test Pits numbered TP 1A and TP 1B. Density, moisture, and "in-place" California Bearing Ratio data from undisturbed samples were secured in these excavations.

(3) Winter Explorations.

The winter explorations made in January 1945, consisted of the excavation of Test Pits TP 2A and TP 2B. Moisture determinations and observations of frost conditions were made in these test pits.

(4) Spring Explorations.

Two Test Pits numbered TP 3A and TP 3B were excavated in March 1945. These test pits were excavated for the purpose of determining density, moisture, and "in-place" bearing ratio data for comparison with data obtained during the fall and winter periods.

c. Equipment Installations.

(1) Bench Marks.

Bench marks, consisting of steel rods driven into soil below frost level and protected by a pipe covering through the frost zone, were placed in the pavement at six points with three bench marks to each transverse line of measurement. The locations of the bench marks are shown on Plate 2. The details of the bench mark equipment are shown on Plate 3.

(2) Temperature Measuring Equipment.

No subsurface temperature measuring equipment was installed in the airfield pavements for this investigation.

(3) Water Observation Wells.

Due to the indicated depth of water table elevations in the test area, water observation wells were not installed.

d. Observations and Measurements.

The following observations and measurements were made in Test Area B:

(1) Wire-line Readings.

Wire-line readings were obtained in October 1944, and in January, February, and March, 1945. The readings cover the periods prior to, and during freeze-up, and after thaw. The data obtained from wire-line readings have been used to determine the period of maximum heave.

(2) Frost Penetrations.

The depth of frost penetration was determined by observations made in the pits excavated during January 1945. The depth of frost penetration was difficult to determine in the test pit excavations due to the lack of sufficient water content in the soil to produce hard frozen ground or prominent frost forms.

(3) Ice Lens Survey.

Observations of ice lenses and frost formations were made during the excavation of Test Pits TP 2A and TP 2B in the period 13 January to 18 January 1945. The cumulative degree-day value during the period of excavation was approximately 320. The excavations were made during a period of above-freezing air temperatures, the cumulative degree-day value decreasing, from 10 January to 18 January, by approximately 40 degree-days. The following conditions were observed in Test Pit TP 2A: The base course and subgrade were frozen to a total depth of 1.5 feet from the surface. Although this material was frozen hard, no ice lenses or frost crystals were visible, either in the base course, or the subgrade. In Test Pit TP 2B, the base course materials were frozen to a depth of 1.05 feet. The subgrade, in this case, was not frozen. No ice lenses or frost crystals were observed.

e. Field Tests.

(1) Subsurface Moisture Tests.

Moisture data were obtained in the pit excavations during the fall, winter and spring periods to a total depth of 15 feet below the surface. The moisture contents were determined at intervals of (4) four inches through the base course and to a depth of 3 feet, and at intervals of 6 inches between 3 feet and 6 feet, the moisture tests then being taken at intervals of one-foot, to a total depth of 15 feet. Moisture data are shown on Plate 5 and are organized in Table 2.

(2) Subsurface Density Tests.

Subsurface density test samples were taken in the fall and spring test excavations. Densities were obtained in the base course, top of subgrade, top of subbase, and at one-foot intervals thereafter to a total depth of approximately 7 feet, the densities being obtained through the normal range of expected frost penetration. The density tests obtained during the spring period in Test Pits TP 3A and TP 3B were taken to a total depth of approximately 2½ feet, this depth being indicated as the approximate depth of frost penetration. Density data are shown on Plate 5 and Table 2.

(3) California Bearing Ratio Tests.

"In-place" California bearing ratio tests were made on the surface of the base course, the surface of the subgrade, and at various depths below the top of the subgrade during the pit excavations in October 1944 and in March 1945. The "in-place" bearing ratio data are given in Table 2.

f. Laboratory Tests.

The following laboratory tests were performed:

(1) Classification Tests.

Mechanical analysis and Atterberg Tests were made for the classification of all soils and aggregate materials. All materials were classified in accordance with the Casagrande Method and by the methods and procedures given in Appendix 14 of this Frost Investigation Report. Classification and analysis data for all materials are given in Table 2.

(2) California Bearing Ratio Tests.

Laboratory California bearing ratio tests were made on undisturbed samples obtained from the surface of the subgrade and at various elevations beneath the surface to a depth of approximately 3 feet. The undisturbed specimens of soil were saturated in the laboratory and were tested for bearing ratios under surcharges approximating a dead load imposed on the material in place in the pavement. In addition to laboratory bearing ratio tests on undisturbed saturated specimens, compaction-bearing ratio studies were made on all typical subgrade soils and on a typical base course aggregate. The compaction-bearing ratio studies were made in accordance with procedures established by the Office, Chief of Engineers, and transmitted to the Division Engineer, Missouri River Division, in a letter dated 12 May 1944, subject: "California Bearing Ratio Procedures." The compaction-bearing ratio studies were made by compacting the representative materials in California bearing ratio molds, using varying hammer blows of 10, 25 and 55 blows per layer in each series of tests, each series being repeated for various moisture contents. The compacted materials, after density determinations, were saturated and tested for bearing ratios. Laboratory bearing ratio data on undisturbed specimens are given in Table 2. Data relative to the compaction-bearing ratio studies are shown on Plate 6.

g. Conclusions, Test Area B.

(1) Heaving of Pavement.

Pavement movements in Test Area B during the investigation period consisted of both increases and decreases in elevation, subsidence of the pavement surface occurring over a considerable portion of the test area. The maximum pavement movement is indicated as having occurred about 5 February 1945. An increase in elevation, or heave, of 0.03 feet was noted on only one test reading, whereas, subsidence to the extent of 0.01 feet was noted over an area extending completely through the test area. The wire-line data, upon which the pavement surface movement has been based, indicate that no apprecable differential movement of the shoulder pavements took place relative to the movement of the center portion of the taxiway pavement. This reaction is in contrast to taxiway pavements on other fields in which a noticeable heaving of flexible pavements occurred adjacent to shoulders which was considered to be due to infiltration of surface water into the lower portion of the shoulder pavements. The absence of heave is considered to be due principally to the type of soils present in the subgrade and to the absence of appreciable surface water infiltration and to the low water content existing in the upper portion of the pavement subsurface materials.

(2) Frost and Freezing Temperature Penetration.

Freezing temperature penetrations were not determined since temperature measuring equipment was not installed in this area. The depth of frost penetration has been based on the observation of frost and ice formations and the existence of frozen ground in the test pits excavated on 15 and 16 January 1945. The cumulative degree-day value at the time of excavation was approximately 325, as compared to a seasonal total of 745. Based on the observations made at Pierre and Watertown Airfields, the increase in degree-days after excavation is not considered as changing, to any major extent, the conclusions noted herein. The results of the winter test pit excavation observations indicate that the soil in Test Pit TP 2A, excavated on 17 January 1945, was frozen to a depth of 1.5 feet. No visible ice lenses were present. Test Pit TP 2B, also excavated on 17 January 1945, was frozen to a depth of 1.05 feet. Only the base course materials in the latter pit were frozen.

(3) Ice Lens Survey.

The ice lens survey, consisting of observations made in the pit excavations in the taxiway pavement, Test Area B, on 17 January 1945, indicate that ice lens formations and frost formations were not present at the time of test, in either the base course or subgrade materials. Although hard frozen ground existed to depths of 1.5 and 1.05 feet, respectively, in the two test pits. It is considered that the lack of development of ice formations is due principally to an existing low moisture content in the materials in the frozen zone and in the soils underlying the frozen zone, and to the prevalence of subgrade materials having relatively low capillary action.

(4) Subsurface Moisture Conditions.

No major changes in the moisture content of any of the materials existing at depths of less than five feet under Test Area B are indicated to have occurred during the period of investigation. All materials above a depth of approximately five feet below the surface, are indicated to have appreciably lower moisture content than the underlying materials. The variations in moisture content, indicated on Plate 5 as occurring between the winter and spring periods at depths between 5 feet and 16 feet, may be due in part, to the stratification of previous and impervious soils at these depths rather than to the direct effect of the existence of freezing temperatures at higher elevations.

(5) Subsurface Density Test.

The results of the field density tests made in October 1944, and March 1945, indicate that density changes in the materials underlying the Test Area B pavements during the period of investigation were negligible.

(6) California Bearing Ratio Tests.

Data obtained from the "in-place" California bearing ratio tests made in October 1944 and during the spring period, in March 1945 indicate that some decreases of the bearing ratio of the base course and the top portion of the subgrade may have occurred during the winter period. The fall "in-place" bearing ratio values obtained from the top of the base course were 66 and 52 in the A and B series of test pits, respectively, whereas the spring values for the same materials were 26 and 32 respectively. The "in-place" bearing ratio values obtained from the surface of the subgrade likewise indicated decreases of bearing ratio values. The fall bearing ratio tests gave values of 34 and 21 in the A and B series of tests pits respectively, whereas the spring values were reduced to 24 and 18 respectively, in the same series of pit excavations. Bearing ratio values obtained from surfaces approximately one-foot below the top of the subgrade indicated only minor variations between fall and spring testing periods. It is indicated that the variations in bearing ratio of the "in-place" tests may have been due, to an appreciable extent, to slightly greater moisture content existing in these materials during the spring test period, although the moisture increases occurring in the upper portion of the subgrade are indicated by the test data obtained in in the fall and spring test period to have been small. The indicated changes in bearing ratio values of the base course and the top of the subgrade may therefore have been due, in part, to structural changes in the soils induced by frost action in these materials. Bearing ratio data obtained from laboratory saturated undisturbed specimens indicate that the bearing ratio values obtained from the saturated undisturbed specimens tend to be appreciably less than the bearing ratio values obtained from either the fall, or the spring "in-place" bearing ratio tests. Bearing ratio data are summarized in Table 2.

8. General Conclusions.

The results of the frost investigation at Casper Airbase indicate that the frost action occurring under both the concrete and the flexible pavements on this airfield, under the conditions existing during the period of investigation, has been negligible, the existence of frost-susceptible materials nothwithstanding. The absence of other than very minor frost action under the airfield pavements is indicated by the very small heave noted in Test Area A, the concrete apron pavement, and in the minor heave and subsidence of the flexible pavement in Test Area B. The absence of frost action is further indicated in the absence of observable ice lenses, or frost formations in the frozen soil encountered in the test pits excavated in the two test areas. The lack of pronounced moisture changes in or immediately adjacent to the frozen zone is considered to be further evidence of negligible frost action. The results obtained from the California bearing ratio studies are inconclusive and do not indicate that the changes in bearing ratio characteristics are with certainty, due to possible action of frost. The absence of development of major frost action is considered to be due largely to the low water content existing in the subsurface pavement elements as affected, in turn, by regional climatic and subsurface water table conditions, these factors tending to maintain the low moisture content in the subsurface pavement elements on this field. The absence of heave on the shoulders of the taxiway pavement is at variance with the results noted on other airfields. The other fields, in general, showed a tendency toward shoulder pavement heaving due to the infiltration of surface water into the subsurface pavement materials under the edge of the pavement. The infiltration of surface water under the pavement shoulders on this airfield is indicated as having been relatively minor during the period of investigation. The generally low rates of precipitation, high rates of surface evaporation, satisfactory pavement drainage, and the absence of a definite water table near the surface of the pavements are all considered as contributing to the retardation of the development of major frost action in this area under the conditions existing during the investigation at this airfield. These conclusions are based on normal conditions existing in the airfield pavements and are considered to be valid only under conditions of satisfactory maintenance of the airfield pavement and adjoining surfaces, preventing the infiltration of appreciable quantities of surface water into the pavement. The results of the investigation indicate that the migration of water from materials at appreciable depths below the surface, upwards into the frost active zone is generally negligible, due to low subsurface moisture contents, and to the retardation of water migration by layers of materials having a low capillarity, these materials apparently having sufficiently low capillarity and sufficient thickness to prevent appreciable transfer of moisture through these strata into materials having higher capillary action.

TABLE 1

CHRONOLOGICAL SUMMARY OF EXPLORATIONS
CASPER AIRBASE, CASPER, WYOMING

1. Fall Period

    a. 5-15 August 1944
        (1) Preliminary Soil Explorations, Test Area B.

    b. 5 October 1944
        (1) Preliminary Soil Explorations, Test Area A.

    c. 3-15 October 1944
        (1) Installation of Bench Marks, Test Areas A and B.
        (2) Excavation of Test Pits TP 1A and TP 1B, Test Area A; and Test Pits TP 1A and TP 1B, Test Area B.
        (3) Concrete Pavement Water Infiltration Tests.
        (4) Wire-line Readings, Test Areas A and B.
        (5) "In-place" California Bearing Ratio Tests.

2. Winter Period

    a. 13-18 January 1945
        (1) Excavation of Test Pits TP 2A and TP 2B, Test Area A; and Test Pits TP 2A and TP 2B, Test Area B.
        (2) Wire-line Readings, Test Areas A and B.

    b. 5 February 1945
        (1) Wire-line Readings, Test Areas A and B.

3. Spring Period

    a. 19-22 March 1945
        (1) Excavation of Test Pits TP 3A and TP 3B, Test Area A; and Test Pits TP 3A and TP 3B, Test Area B.
        (2) Wire-line Readings, Test Areas A and B.
        (3) "In-place" California Bearing Ratio Tests.

FROST INVESTIGATION

1944 - 1945

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REPORT ON

FARGO MUNICIPAL AIRFIELD, FARGO, NORTH DAKOTA

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FROST INVESTIGATION

1944 - 1945

- - APPENDIX 9 - -

REPORT ON

FARGO MUNICIPAL AIRFIELD, FARGO, NORTH DAKOTA

1. Authorization.

The investigation of frost action beneath the airfield pavements was authorized by the letter dated 7 July 1944, from the Office, Chief of Engineers, to the Division Engineer, New England Division, subject: "Frost Investigation," and by the letter dated 28 August 1944, from the District Engineer, Boston District, to the Division Engineer, Missouri River Division, subject: "Frost Investigation".

2. Purpose.

The purpose of this investigation has been the determination of the development of frost action in pavement elements as affected by varying conditions of weather, soils, and ground water. The investigation at Fargo Municipal Airfield was made to determine the effects of frost in a region having a fairly high rate of precipitation, a high water table, generally wet subsurface soil conditions, together with the existence of soils considered to be susceptible to frost action, in a region indicated as having generally very severe winter weather conditions. The conditions existing under the pavement on this airfield are considered to be favorable for the development of severe frost action conditions.

3. Scope.

The scope of this report covers the investigation of frost conditions existing under an asphalt surfaced taxiway pavement, considered to be typical of the pavements on this airfield. The investigation includes the determination of moisture and density changes occurring in the various subsurface pavement elements during the winter period, together with changes in California bearing ratio characteristics, the measurement of heaving, observations of frost formations and ice lenses, and other data pertinent to frost conditions in the airfield region.

4. General Conditions.

a. Location, Terrain, and Drainage.

Fargo Municipal Airfield is located approximately one-half mile northwest of the northwest city limits of the City of Fargo, Cass County, North Dakota. The airfield site is located on a generally smooth, flat plain, originally the bed of an ancient glacial lake, Lake Agassiz. The immediate surrounding area ia very flat and runoff from precipitation in the airfield region tends to be slow. Airfield drainage is, in general, to the northeast into the Red River which, in turn, flows north into Lake Winnipeg and Hudson Bay. The elevation of the airffeld is approximately 897 feet above mean sea level. The airfield drainage system consists of surface drainage and a system of underground drains constructed adjacent to a majority of all pavement shoulders. The underground drains consist of ditches back-filled with coarse aggregate, the drains thus carrying both surface and subsurface drainage. The airfield is protected against overflow of surface water from other areas by an open drainage ditch on the west and north boundaries of the airfield, the surface and subsurface drainage on the airfield discharging into this ditch. During periods of precipitation, considerable water is temporarily ponded in the general airfield region due to the exceedingly flat terrain, and to the lack of natural water courses in the area. Although subsurface soils in the region generally tend to be impermeable, a natural water table is indicated as existing approximately 5 feet below the surface of the airfield.

b. Types of Pavement.

All airfield pavements on this field are of flexible type construction with the exception of two minor areas of concrete apron pavement. The flexible pavements on all runways and taxiways consist of a soil-cement base, comprised of a bank-run sandy-gravelly material mixed with Portland cement, variously surfaced with an asphaltic concrete or a cold mix bituminous mat. The soil-cement base course was constructed on a subbase composed of a bank-run clay-gravel material. All pavement structures, including the base and subbase, were built upon the existing ground or old runways surfaces in order to obtain more satisfactory drainage of the pavements.

c. Traffic History.

Aircraft operations on this airfield began in 1941. Traffic during the period of operations has consisted largely of small and medium sized commercial planes, small type and C-47 military planes, with occasional use by B-17 and B-24 type planes. Traffic during the period of operation has consisted of approximately 30 landings and take-offs per day.

d. Condition of Pavement.

The condition of all flexible type airfield pavements during the investigational period was generally good. Transverse cracking and minor pavement deformations due to the expansion of the soil-cement base exist in a number of areas on the runway pavements and to a lesser extent on the taxiway pavements. These cracks and spalled areas, evidently caused by contraction and expansion of the soil-cement base, were sealed and in good condition prior to the frost investigation. The condition of approximately 9,500 square yards of concrete apron pavements on the airfield was good.

e. Frost Conditions.

The select soil materials directly underlying the soil-cement base course consist principally of materials classified by the Casagrande method as CL-SF or SF types. The soils underlying the select materials are generally classified as OH-CH and CH materials. All of these materials are considered to be susceptible to frost action, under proper moisture and temperature conditions, based on the indicated high capillarity of these materials. The indicated presence of a water table, approximately 5 feet below the surface, is considered as being conducive to the formation of appreciable frost action in the various subgrade and subbase materials.

f. Climatic Conditions.

The climatic conditions existing in the Fargo Municipal Airfield region are considered to be very severe, exceeding in severity, the conditions existing on other fields investigated during the 1944-1945 Frost Investigation Program in the Missouri River Division. The normal cumulative degree-day below freezing value for the Fargo region is in excess of 2600. The normal precipitation for the Fargo Area for the 3 month period prior to winter freeze-up is indicated to be approximately 3 3/4 inches. The cumulative degree-day value for the 1943-1944 season was approximately 1800, while the cumulative degree-day value for the 1944-1945 season, covering the period of frost investigation, was approximately 1820 degree-days. The precipitation in the 3 months prior to freeze-up in the fall of 1944, was approximately 3½ inches. The weather conditions during the period of investigation for frost conditions during the 1944-1945 season were, therefore, appreciably milder than normal, both as respect to cumulative degree-days below freezing and to the precipitation occurring in the 3 months prior to freeze-up.

5. Definitions.

The description of the tests and analyses of results involve a specialized use of certain terms and words. These words and terms are defined for use in this report as follows:

a. Test Area - The test area is the portion of the airfield selected for investigations and observations.

b. Pavement - The term pavement is defined as a covering of a prepared or manufactured product superimposed upon a subgrade or base to serve as an abrasion and weather resisting structural medium.

c. Base - The term base applies to the course of specially selected soils, mineral aggregates, or treated soils or aggregates placed and compacted on the natural or compacted subgrade.

d. Subbase - The term subbase refers to a course intermediate between the base and subgrade, and may consist of selected soils, mineral aggregates, treated materials or highly compacted existing soil.

e. Subgrade - The term subgrade applies to the natural soil in place or to fill material upon which a pavement, base or subbase is constructed.

f. Map Cracking - Map cracking is the development of a definite crack pattern in the pavement surface under the action of repeated loadings. Map cracking is distinguished by the formation by cracking of continuous connected polygonal pavement segments.

g. Consolidation - Consolidation is the increase in unit weight, or decrease in volume of a material due to the action of applied loadings. Consolidation is considered to be synonymous with compaction in this report.

h. Permanent or Vertical Deformation - Permanent or vertical deformation is the accumulative non-elastic part of the total vertical movement of the surface of the pavement which remains after the load is removed.

i. Capacity Operation - Capacity operation is defined as the maximum traffic that can possibly operate on an airfield for a period of approximately 20 years. The daily operation may be assumed as varying from 100 cycles of landings and take-offs for the very heavy planes to 1500 cycles for very light weight planes.

j. Frozen Soil - Frozen soil is referred to in this report as follows:

(1) Homogeneous Frozen Soil. A homogeneously frozen soil is a

soil in which all the water in the soil is frozen within the natural voids existing in the soil, without observable segregation or accumulation of ice lenses or frost forms exceeding in volume such natural void spaces.

(2) Stratified Frozen Soil. A stratified frozen soil is a soil in which a part of the water in the soil is frozen in the form of observable ice lenses, occupying space in excess of the original soil voids.

(3) Hard Frozen Soil. Hard frozen soil is soil at or below a temperature of 32°F, which has been hardened due to the solidification, by freezing, of water films between soil particles.

k. Frost Growths - Any observable crystalline or solid frozen forms of water in soils formed by freezing temperatures.

l. Ice Lenses - Ice lenses are the observable frozen free water bodies existing in stratified frozen soil.

m. Ice Crystals - Ice crystals are the observable ice particles existing in the void spaces and pores of homogeneous frozen soil.

n. Frost Zone - Frost zone refers to the vertical limits of frozen soil.

o. Frost Penetration - Frost penetration is the maximum depth from the surface to the bottom of the frozen soil.

p. Depth of Freezing Temperature Penetration - The depth of freezing temperature penetration is the maximum depth below the surface of freezing temperature.

q. Degree-Days Below Freezing - Degree-days below freezing is the cumulative difference between the average of the daily maximum and minimum temperature and 32° Fahrenheit.

r. Terminal Frozen Plane - The terminal frozen plane is the final thawing plane in the frozen soil.

6. Test Area A.

a. Location and Pavement Description.

Test Area A of the Fargo Municipal Airfield was located on Taxiway No. 2B, beginning at Station 3/50 and extending to Station 8/00. The test area is 50 feet wide and 450 feet in length. The taxiway pavement in Test Area A consists of 1.5 inches of asphaltic concrete surface constructed over a soil cement base course having a thickness of approximately 6.5 inches, a subbase composed of a CL-SF material approximately 15 inches in thickness overlying about 8 inches of OH-CH soil, and more than 3 feet of a CH material. The water table elevation in the test area on 17 October 1944, was 5.2 feet below the surface of the pavement, while the water table elevation on 10 February 1945 was approximately 6.8 feet below the surface. The subbase material in the test area pavement was constructed directly upon the compacted existing ground surface.

b. Test Explorations.

Test explorations in Test Area A, the locations of which are shown on Plate 2, consist of the following groups:

(1) Preliminary Soil Explorations.

Preliminary soil explorations, consisting of borings made in the taxiway pavement in the general test area, were made in September 1944, to determine the subgrade soils conditions existing in the proposed site.

(2) Fall Explorations.

Fall explorations consisted of the excavations of two Test Pits numbered TP 1A and TP 1B, respectively, in October 1944.

(3) Winter Explorations.

Two Test Pits numbered TP 2A and TP 2B were excavated in February 1945, to determine subsurface moisture and frost conditions.

(4) Spring Explorations.

Two Test Pits numbered TP 3A and TP 3B were excavated in

April 1945, to determine changes occurring in subsurface pavement elements relative to water content, density and bearing ratio after completion of thaw.

c. Equipment Installations.

The following installations were made in Test Area A:

(1) Bench Marks.

Six bench marks were placed on the shoulders of the taxiway in Test Area A giving 3 transverse wire-lines for measurement of heave in the test area pavement. The bench marks consisted of rods driven into the soil below the frost level and projected through the frost zone by a pipe covering, the pipe being filled with a mixture of soft cutback asphalt and distillate to permit heaving of frozen ground without disturbance of the bench mark rod. The location of the bench marks in Test Area A is shown on Plate 2. Details of bench mark equipment are shown on Plate 3.

(2) Temperature Measuring Equipment.

Subsurface temperatures were measured in the test area by means of thermometer wells installed to depths of 2, 4, 6, and 8 feet at Station 5/00 on the center-line of the pavement. The thermometer wells consisted of lengths of Saran synthetic plastic tubing, fitted with a standard metal pipe cap on the lower end and a similar removable cap mounted flush with the surface of the pavement at the upper end. An armored glass bulb thermometer was placed in each well, the thermometers resting in contact with the metal cap at the bottom of the wells. The details of the thermometer well equipment are shown on Plate 3.

(3) Water Wells.

A water table observation well consisting of an iron pipe approximately 1$\frac{1}{4}$ inches in diameter, fitted with a "Well Point," was driven into water bearing soil on the west shoulder of the taxiway pavement adjacent to Test Area A, at Station 5/00. Measurements of water table elevations were made by uncapping the pipe and inserting a measuring stick in the opening in the top of the pipe. Water table elevations were made at weekly intervals throughout the winter, and a portion of these data are shown on Plate 5.

d. Observations and Measurements.

The following observations and measurements were made in Test Area A:

(1) Wire-line Readings.

Initial wire-line readings were obtained in October 1944, and further data was obtained in January, February, and April 1945. The data so obtained have been used to determine heave of the pavement areas, and these data have been plotted as heave contours on Plate 6.

(2) Frost Penetration.

The depth of frost penetration was determined by an observation of frozen materials existing in the pits excavated during February 1945. The depth of frost penetration was based on the depth of frozen ground or depths to which frost crystals or ice lenses were observed. Observations in the two test pit excavations in February 1945, indicated that ice formations existed neither in the soil-cement base course nor in the selected subbase materials, the latter varying in depth from 0.55 to 1.57 feet in Test Pit TP 2A and from 0.6 to 1.5 feet in Test Pit TP 2B. However, ice formations were observed in both pits from the bottom of the select subbase materials to a depth of approximately 3.8 feet below the surface, which is assumed to have been the depth of frost penetration at that date.

(3) Freezing Temperature Penetration.

Freezing temperature penetration was determined by thermometer readings obtained from the thermometers inserted in the plastic tubing wells installed in the test area pavement. The depth of freezing temperature penetration is based on the maximum depth of penetration of a 32-degree

Fahrenheit temperature. The maximum depth of freezing temperature penetration is indicated to have occurred during the period of 3 March to 12 March 1945 when a maximum depth of freezing temperature penetration of 4.8 feet was reached. The cumulative degree-day value at the time of the maximum freezing temperature penetration was approximately 1806. Temperature data have been shown on Plate 4.

(4) Ice Lens Survey.

An ice lens survey was made concurrently with the determination of frost penetration in the pit excavations made in February 1945. As previously noted in the description under frost penetration, ice lenses were not observed in the soil-cement base nor in the SF material comprising the subbase underlying the base course construction. Frost lens formations were observed in all subgrade materials from the bottom of the subbase to a maximum depth of 3.8 feet, with the maximum lens formation occurring in a black CH soil at elevations of from 2.4 to 3.1 feet. The ice lens formations were generally irregular in shape, and were formed with their axes both horizontal and vertical. The ice lenses were approximately 1/16 of an inch thick and were from 3/8 tl 1/2 inches apart. The ice patterns tended to form polygonal shapes in the subgrade soil.

(5) Water Well Observations.

Water well observations to determine changes in the elevation of the indicated water table in the test area were made weekly during the period 2 December 1944 to 2 June 1945, and elevations were also obtained during test pit excavations. The results of the water table readings obtained during pit excavations are shown on Plate 5, and weekly data are shown on Plate 4.

e. Field Tests.

(1) Subsurface Moisture Tests.

Moisture data were obtained in the pit excavations made during the fall, winter, and spring periods, these data being taken to a total depth of approximately 7 feet below the surface. Moisture contents were determined at approximately one-foot intervals through the base course and to a depth of 7 feet. Test borings in the test pits were terminated at a depth of 7 feet. Moisture data are shown on Plate 5, and are summarized in Table 2.

(2) Subsurface Density Tests.

Subsurface density tests of the various pavement elements were made during the fall and spring test pit excavations. Densities were taken to a depth of approximately 5 feet during the fall test period, and to a depth of approximately 4.8 feet during the spring test period. Density data are shown on Plate 5 and are further summarized in Table 2.

(3) "In-place" California Bearing Ratio Tests.

"in-place" California Bearing Ratio Tests were made on the surfaces of the soil-cement base course, the subbase and the subgrade, and at approximately one-foot intervals of depths to a total of 5 feet in the test pits excavated in October 1944. "In-place" California bearing ratio data were also obtained during the spring test pit excavations in April 1945, with data being obtained at elevations similar to those used in the fall test pit excavations. These data are summarized in Table 2.

f. Laboratory Tests.

The following laboratory tests were performed:

(1) Classification Tests.

Mechanical analysis and Atterberg tests were made for the classification of all soils and aggregate materials. All materials were classified in accordance with the Casagrande method, using the methods and procedure given in Appendix 14 of the Frost Investigation Report. Classification and analysis data for all soil and aggregate materials are given in

Table 2.

(2) California Bearing Ratio Tests.

Laboratory California Bearing Ratio Tests were made on the subbase and on the various subgrade materials obtained as undisturbed specimens. The specimens were saturated prior to testing and were tested under surcharges approximately equivalent to the dead loads existing at the elevation of the undisturbed sample in the airfield pavement. The saturated undisturbed specimen bearing ratio data are given in Table 2. In addition to the undisturbed sample tests, compaction-bearing ratio studies were also made on all representative pavement subsurface materials. These tests were performed in accordance with the procedure established by the Office, Chief of Engineers, in the letter to the Division Engineer, Missouri River Division, dated 12 May 1944, subject: "California Bearing Ratio Procedure." The compaction-bearing ratio studies were made by compacting the various materials in standard molds in a series of tests, using varying hammer blows of 10, 25 and 55 blows per layer, each series of compactions being repeated for various moisture contents. The compacted materials, after density determinations, were saturated and tested for bearing ratio. The data obtained from the laboratory compaction-bearing ratio studies are shown on Plate 5.

g. Conclusions, Test Area A.

(1) Heaving.

The period of maximum heaving, as determined from wire-line readings made at intervals throughout the fall, winter, and spring periods, occurred on approximately 13 February 1945. Heaving data, as shown on Plate 6, indicate that appreciable heaving took place throughout the test area with a maximum heave of 0.12 feet occurring at the northwest corner of the test area while the average heave over the test area was approximately 0.07 feet. Differential heaving in the test area was indicated to be generally small, except in the area of maximum heave in the northwest corner of the test area. The degree of heaving occurring in the test area indicates that appreciable frost action took place under the airfield pavements. The cause of the heaving noted in the area is indicated by the presence of the ice lenses observed in the test pits excavated in the area during the period of heave.

(2) Frost and Freezing Temperature Penetration.

Based on the results of observations made in the test pit excavations in February 1945, the depth of frost penetration in the airfield regions at that time was approximately 3.8 feet; whereas, the depth of freezing temperature, as determined from thermometer readings made in an adjacent area at the same time was approximately 4.4 feet. Although the cumulative degree-day value at the time of the indicated maximum freezing temperature penetration in March was approximately 1806, the degree-day value at the time of the pit excavations on 12 February was approximately 1400. The difference between the depth of frost penetration as determined by the presence of frost formations, and the depth of freezing temperatures as measured by thermometers may be due to the possible existence of a zone of appreciable thickness having a temperature of 32-degrees Fahrenheit, the upper portion containing frozen water at 32-degrees, with the lower portion in an unfrozen condition pending further heat loss equal to the latent heat required to freeze the soil water. An appreciable distance may thus separate the maximum depth of freezing temperature penetration and the maximum depth of the frozen zone. This condition is probably accentuated on this airfield by the relatively large quantity of water present in the subgrade soils requiring the transfer of large quantities of heat to produce actual freezing of the soil water.

(3) Sub-surface Temperatures.

The temperature data obtained on this airfield indicate that the maximum penetration of freezing temperatures occurred approximately during the period of maximum cumulative degree-days below freezing. This behavior is considered to be due, to a large degree, to the existence of appreciable quantities of moisture in the subgrade soils. The data obtained from subsurface temperature readings, as shown on Plate 4, indicate that heat transfer from the interior of the earth producing thawing of ice in the frozen zone, was relatively minor on this airfield as compared with other airfields, notably the Pierre Airfield at Pierre, South Dakota. The subsurface temperature data indicate rather slow changes in temperature occurring at depths greater than approximately 3 feet below the surface, whereas, materials lying above this depth are indicated to be much more responsivle to changes of air temperatures, particularly changes occurring during short periods of time.

(4) Ice Lens Survey.

The pronounced ice lens formations noted in the subgrade materials between the bottom of the subbase and a depth of approximately 3.8 feet are indicated to be the result of frost action in subgrade soils having high capillarity with a water source in the water table, fluctuating between 5 and 7 feet below the surface of the pavement during the frost investigation period. The distribution of ice lenses throughout an appreciable range of depths of the subgrade soils indicates a slow penetration of freezing temperatures. The absence of thick ice lenses indicate, in general, a slow rate of capillary flow of moisture into the freezing zone. The observed ice lenses indicate the probably cause of the pavement heaving noted in the test area.

(5) Subsurface Moisture Conditions.

Moisture changes at elevations above a depth of 2½ feet are indicated to have been relatively minor during the investigational period. However, appreciable changes in moisture contents occurred at depths below 2½ feet, extending to a 5-foot depth in the A series, and to a 7-foot depth in the B series of test pits. The variations in moisture contents, beginning at a depth of 2½ feet and extending downward, are indicated as probably being due to the action of frost, since such action generally tends to accumulate water and ice in the upper part of this region. The variations in water content correspond approximately to the depth of the frozen zone which extended to a depth of approximately 3.8 feet, and to the depth of freezing temperature penetration, which extended to approximately 4.8 feet in the test area. The effect of the thawing of the ice lenses and ice formations in the frozen zone is indicated in the pronounced increase in moisture content occurring at a depth of approximately 4½ feet in each test pit in the excavations made on 11 and 12 April 1945. The high moisture contents of approximately 38 percent, existing in the two test pits are considered as being due to the melting of ice formations at and above this elevation in the original frozen zone, followed by slow drainage of this excess moisture into the area below the frozen zone. The effect of frost action, occurring in the frozen zone in the upper portion of the subgrade, on the elevation of the water table in the area, may be noted in the water table elevations shown on Plate 5. The changes in water table elevations are indicated as due, in part, to the migration and accumulation of water in the frozen zone, and in part to the freezing of the upper portion of the ground, preventing absorption of surface water, which in turn, would likewise tend to reduce the elevation of ground water.

(6) Subsurface Density Tests.

Density tests obtained in the test pit excavations during the fall and spring period indicate that an increase in density may have occurred in the subbase, and in the upper portion of the subgrade to a depth of approximately 4 feet. The reasons for the apparent increase in density of these materials are not known. Attention is invited to the fact that the areas indicating density increase lie within the observed frozen zone and depth of freezing temperature penetration.

(7) California Bearing Ratio Tests.

A comparison of "in-place" bearing ratio data obtained during the fall and spring period indicates that, in general, the "in-place" bearing ratio value obtained on the surface of a given material in the spring was appreciably less than the original fall bearing ratio for the same material. The reasons for the decreases in bearing ratio values in the spring tests are not apparent since both lower moisture contents and higher densities are indicated as existing during the spring period as contrasted to the fall period. A comparison of saturated bearing ratio data with the "in-place" bearing ratio data obtained in the spring of 1945, indicates, in general, that the bearing ratios obtained from the "in-place" test during the spring were less than the saturated undisturbed sample bearing ratios obtained in the fall, although the moisture contents of the saturated samples, in general, exceeded the moisture contents of the "in-place" materials tested in the spring. The differences in bearing ratio characteristics noted in the various materials may possibly have been due to structural changes induced in the materials by the action of frost during the winter period. The action of frost in producing changes in soil structure have been noted by observations of soils immediately after the thawing of the frost, the frost lenses and other formations tending to produce a separation of the soil into small blocks and segments, resulting in a heterogeneous soil structure in place of the homogeneous structure existing prior to freezing. The heterogeneous structure, although possibly having greater density, apparently does not have the strength characteristics of the homogeneous condition.

7. General Conclusions.

The frost investigations at Fargo Airfield indicate that relatively severe frost action occurred in the subsurface pavement elements during the investigational period. The occurrence of severe frost action is indicated in the appreciable heave obtained in the test area and by the extensive frost lens formations observed in the excavated test pits. A lowered pavement carrying capacity due to frost action is indicated in the decreased California bearing ratio values obtained in the spring as compared to the higher values obtained in the original fall tests. The effect of frost action in producing moisture and density changes is also indicated in the moisture and density data obtained in these investigations. The further effect of frost action towards reducing the elevation of the ground water table has been noted in the lowering of the water table under the airfield to the extent of approximately 2 feet during the winter period. The development of frost action under the airfield pavement is considered to have been somewhat retarded by the existence of a subbase having a low degree of frost action susceptibility since frost formations were not observed in these materials during the frost period. The disruptive effects of frost action on the airfield pavements also tended to be minimized by the fairly uniform heave conditions occurring throughout the pavement area, the lack of differential heaving tending to decrease pavement stresses during the vertical movement of the pavement.

TABLE 1

CHRONOLOGICAL SUMMARY OF EXPLORATIONS
FARGO MUNICIPAL AIRFIELD, FARGO, NORTH DAKOTA

1. Fall Period
    - a. 4-7 September 1944
        - (1) Preliminary Soil Explorations.
    - b. 11-17 October 1944
        - (1) Installation of Bench Marks.
        - (2) Installation of Well Point.
        - (3) Excavation of Test Pits TP 1A and TP 1B.
        - (4) Wire-line Readings.
        - (5) "In-place" California Bearing Ratio Tests.
    - c. 30 November 1944
        - (1) Installation of Thermometer Wells.
2. Winter Period
    - a. 2 December 1944 - 1 March 1945
        - (1) Weekly Thermometer Readings.
        - (2) Monthly Ground Water Level Readings.
    - b. 12-27 January 1945
        - (1) Wire-line Readings.
        - (2) Thermometer Readings.
        - (3) Ground Water Level Readings.
    - c. 10-13 February 1945
        - (1) Excavation of Test Pits TP 2A and TP 2B.
        - (2) Wire-line Readings.
3. Spring Period
    - a. 1 March - 2 June 1945
        - (1) Weekly Thermometer Readings.
        - (2) Monthly Ground Water Level Readings.
    - b. 10-13 April 1945
        - (1) Excavation of Test Pits TP 3A and TP 3B.
        - (2) Wire-line Readings.
        - (3) "In-place" California Bearing Ratio Tests.

FROST INVESTIGATION

1944 - 1945

- - APPENDIX 10 - -

REPORT ON

BISMARCK MUNICIPAL AIRFIELD, BISMARCK, NORTH DAKOTA

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FROST INVESTIGATION

1944 - 1945

- - APPENDIX 10 - -

REPORT ON

BISMARCK MUNICIPAL AIRFIELD, BISMARCK, NORTH DAKOTA

1. Authorization.

The investigation of frost action beneath certain airfield pavements was authorized by the letter dated 7 July 1944, from the Office, Chief of Engineers, to the Division Engineer, New England Division, subject: "Frost Investigation," and by the letter dated 28 August 1944, from the District Engineer, Boston District, to the Division Engineer, Missouri River Division, subject: "Frost Investigation".

2. Purpose.

The purpose of this investigation has been the determination of the development of frost action in pavement elements as affected by varying conditions of weather, soils and ground water. The investigation at Bismarck Municipal Airfield was made to determine the effects of frost in a region having a fairly low annual precipitation but with severe winter weather conditions, and on an airfield having subsurface materials, including subgrade soils, which may generally be considered as susceptible to frost action, the possibility of frost action in these materials being increased by the presence of a perched water table at a depth of approximately twelve feet below the surface.

3. Scope.

The scope of this report covers an investigation of frost conditions existing under a flexible runway pavement. The investigation includes the determination of moisture and density changes occurring in the various subsurface pavement elements, together with changes in the California bearing ratio characteristics of the materials in the base course and upper portion of the subgrade. The period of testing extended from 30 August 1944 to 16 April 1945. The observation of frost and ice lens formations in the subsurface materials during the winter period has been included in this investigation.

4. General Conditions.

a. Location, Terrain, and Drainage.

Bismarck Municipal Airfield is located immediately south of the southeast limits of the City of Bismarck in Burleigh County, North Dakota. Fort Lincoln, a military reservation, adjoins the airfield on the west and south. The airfield site is located on a relatively flat, elevated bench above and approximately 2 miles east of the Missouri River. The terrain to the east and north of the airfield consists of a series of ascending elevated benches of the Missouri River Valley, while the terrain to the west and south of the airfield descends into river bottom lands. Drainage in the region of the airfield is considered to be generally good due to the elevation of the site and the character of the surrounding terrain. The normal elevation of natural ground water on the airfield site is indicated to be approximately 40 feet below the surface; however, a perched water table was found to exist under some portions of the airfield pavements, including the frost investigation site, at a depth of approximately 12 feet below the surface. The elevation of the airfield is approximately 1650 feet above mean sea level. The drainage system on the airfield consists principally of surface drainage with a portion of the field drained by a storm sewer system, discharging into natural water courses to the south of the airfield site. The perched water table is indicated to be due to the presence of an impervious clay pan, underlying sandy and gravelly materials, producing a subsurface ponding condition during a large portion of the year.

b. Types of Pavements.

The pavements on this airfield consist of four bituminous paved runways, one bituminous paved taxiway, a bituminous paved apron, and three small Portland cement concrete aprons, the latter averaging approximately 100 by 120 feet each in size, with a combined area of approximately 2,560 square yards. The bituminous paved surfaces consist of cold mix bituminous mat wearing surfaces, having thicknesses varying from 2 inches to approximately 4½ inches, laid in turn on gravel base courses having thicknesses varying from 6 to 6½ inches. The base courses are constructed on compacted subgrade materials classified as SF-ML and ML type soils. A major portion of the airfield runway pavements were constructed during 1942. One of the concrete apron pavements was constructed during 1935 and 1939, while the two remaining concrete paved aprons were constructed in 1942 and 1943. All pavements were constructed by the City of Bismarck and the Works Progress Administration.

c. Traffic History.

Aircraft traffic prior to 15 September 1943, consisted principally of 6 landings and take-offs per day of commercial airline aircraft. Military operations beginning 15 September 1943, and continuing thereafter through the date of this report, have consisted of an average of approximately 20 landings and take-offs per day, consisting principally of P-39 and P-38 type aircraft, and also including P-47, B-17 and B-24 type craft in addition to the normal civilian commercial airline service. The traffic distribution on the runway pavements during the period of operation is estimated to have been as follows: NW-SE, 60%; NE-SW, 25%; N-S, 10%; E-W, 5%.

d. Condition of Pavement.

The condition of all airfield pavements is considered to be fair, with checking and minor cracking existing in nearly all flexible pavement surfaces. The checking and cracking existing in the flexible pavement surfaces is indicated to be due, in part, to a somewhat brittle condition of the cold mix bituminous mat, the cracking of the mat possibly being accelerated by pavement flexure occurring in the subsurface pavement courses under traffic. The prevalence of cracking may also be due, in part, to the occurrence of contractive forces during the winter period as a result of low temperatures, producing the equivalent of shrinkage cracks in the pavement surface. Minor depressions exist on various portions of the surfaces of the airfield pavements, and this condition, together with the noted cracking, is indicated as possibly inducing the infiltration of some surface water into the base and subsurface courses. The surfaces of the airfield pavements have not been recently sealed.

e. Frost Conditions.

The soils underlying the airfield pavements consist principally of materials of SF and ML classifications, and combinations of these materials, principally SF-ML and CL-ML groups, together with some materials of SP classification. The gravel base courses existing under the bituminous surfaces are generally classified as SC materials, and are considered to be susceptible to frost action due to the quantity of silt material incorporated into the base. The subgrade soil materials and the existence of a perched water table at a distance of 12 feet below surface, create conditions which are considered to be favorable toward the occurrence of frost action in the subsurface pavement elements. Prior to the period of the frost investigation, no indications of frost heaving or other major pavement changes due to frost action had been noted.

f. Climatic Conditions.

The winter weather conditions at this airfield are considered to be relatively severe, with a normal freezing index of approximately 2,550 cumulative degree-days below freezing. Normal precipitation for the 3 months preceding freeze-up in the fall is indicated to be approximately 2.6 inches. Rainfall during the 1944 season was approximately 3 inches. The winters of 1943-1944 and 1944-1945 were generally less severe than normal, the cumulative degree-days for these periods being, respectively, 1710 and 1740. The weather conditions during the period of investigation on this airfield, therefore, have been considered to have been appreciably less severe than normal, relative to the duration of minimum temperatures, while precipitation during a 3-month period prior to freeze-up is indicated to have been slightly more severe than normal.

5. Definitions.

The description of the tests and analyses of results involve a specialized use of certain terms and words. These words and terms are defined for use in this report as follows:

a. Test Area - The test area is the portion of the airfield selected for investigations and observations.

b. Pavement - The term pavement is defined as a covering of a prepared or manufactured product superimposed upon a subgrade or base to serve as an abrasion and weather resisting structural medium.

c. Base - The term base applies to the course of specially selected soils, mineral aggregates, or treated soils or aggregates placed and compacted on the natural or compacted subgrade.

d. Subbase - The term subbase refers to a course intermediate between the base and subgrade, and may consist of selected soils, mineral aggregates, treated materials or highly compacted existing soil.

e. Subgrade - The term subgrade applies to the natural soil in place or to fill material upon which a pavement, base or subbase is constructed.

f. Map Cracking - Map cracking is the development of a definite crack pattern in the pavement surface under the action of repeated loadings.

Map cracking is distinguished by the formation by cracking of continuous connected polygonal pavement segments.

g. Consolidation - Consolidation is the increase in unit weight, or decrease in volume of a material due to the action of applied loadings. Consolidation is considered to be synonymous with compaction in this report.

h. Permanent or Vertical Deformation - Permanent or vertical deformation is the accumulative non-elastic part of the total vertical movement of the surface of the pavement which remains after the load is removed.

i. Capacity Operation - Capacity operation is defined as the maximum traffic that can possibly operate on an airfield for a period of approximately 20 years. The daily operation may be assumed as varying from 100 cycles of landings and take-offs for the very heavy planes to 1500 cycles for very light weight planes.

j. Frozen Soil - Frozen soil is referred to in this report as follows:

(1) Homogeneous Frozen Soil. A homogeneously frozen soil is a soil in which all the water in the soil is frozen within the natural voids existing in the soil, without observable segregation or accumulation of ice lenses or frost forms exceeding in volume such natural void spaces.

(2) Stratified Frozen Soil. A stratified frozen soil is a soil in which a part of the water in the soil is frozen in the form of observable ice lenses, occupying space in excess of the original soil voids.

(3) Hard Frozen Soil. Hard frozen soil is soil at or below a temperature of 32°F, which has been hardened due to the solidification, by freezing, of water films between soil particles.

k. Frost Growths - Any observable crystalline or solid frozen forms of water in soils formed by freezing temperatures.

l. Ice Lenses - Ice lenses are the observable frozen free water bodies existing in stratified frozen soil.

m. Ice Crystals - Ice crystals are the observable ice particles existing in the void spaces and pores of homogeneous frozen soil.

n. Frost Zone - Frost zone refers to the vertical limits of frozen soil.

o. Frost Penetration - Frost penetration is the maximum depth from the surface to the bottom of the frozen soil.

p. Depth of Freezing Temperature Penetration - The depth of freezing temperature penetration is the maximum depth below the surface of freezing temperature.

q. Degree-Days Below Freezing - Degree-days below freezing is the cumulative difference between the average of the daily maximum and minimum temperature and 32° Fahrenheit.

r. Terminal Frozen Plane - The terminal frozen plane is the final thawing plane in the frozen soil.

s. Flexing - Flexing is the visible springing or vertical elastic movement of the pavement under a moving wheel load.

6. Test Area A.

a. Location and Pavement Description.

Test Area A is located on the E-W Runway, Station 8+25 to Station 11+25. The runway pavement in the test area is 150 feet wide. The runway shoulders are turf. The pavement in Test Area A consists of a 4½ inch thickness of a cold mix bituminous mat surface course, constructed with sand-gravel aggregate and a medium curing cutback asphalt, a gravel base course approximately 6½ inches in thickness and approximately 3 feet of CL-ML type subgrade soils. The CL-ML type subgrade soils are underlain by strata of ML, SP and SF materials. Sandy and gravelly materials exist below the upper subgrade soils to a depth of approximately 12 feet, at which point a clay hard pan is encountered of such character and elevation that water is entrapped in the permeable materials overlying the hardpan, resulting in the formation of a perched water table.

b. Test Explorations.

Test explorations in Test Area A, the location of which are shown on Plate 2, consist of the following:

(1) Preliminary Soil Explorations.

Preliminary soil explorations were made in August and September 1944, for the purpose of determining the uniformity of soil conditions under the proposed test area.

(2) Fall Explorations.

The fall explorations consisted of the excavation of two Test Pits, numbered TP 1A and TP 1B, during October 1944. The explorations included the determination of moisture, density, and "in-place" bearing ratio characteristics of the subsurface elements.

(3) Winter Explorations.

Two Test Pits, numbered TP 2A and TP 2B, were excavated in February 1945. Observations of frost formations in the subsurface pavement elements and moisture tests were made in these excavations.

(4) Spring Explorations.

Test Pits numbered TP 3A and TP 3B were excavated in April 1945. Moisture, density, and "in-place" bearing ratio data were obtained in this series of tests.

c. Equipment Installations.

The following installations were made in Test Area A;

(1) Bench Marks.

Six bench marks were installed in the test area giving two transverse wire-lines for the measurement of heave in the pavement surface.

The bench marks consisted of steel rods driven into the soil below the frost level and protected through the frost zone by a pipe covering, the pipes, in turn, being filled with a mixture of soft asphalt, and distillate to prevent disturbance of the rod during pavement heaving. The location of the bench marks in the test area are shown on Plate 2. Details of bench mark equipment are shown on Plate 3.

(2) Water Wells.

A water well, for the purpose of observing changes in elevation of the perched water table during the investigational period, was installed at the edge of the runway pavement adjacent to Test Area A, at Station 9+75. The water well consisted of a length of iron pipe, one and one-quarter inches in diameter, equipped with a perforated well point, the point being driven to approximately 16 feet below the surface of the pavement.

(3) Temperature Measuring Equipment.

Temperature measuring equipment was not installed in the test area on this airfield.

d. Observations and Measurements.

The following observations and measurements were made in Test Area A:

(1) Wire-line Readings.

Wire-line readings for the determination of pavement heave were made in October 1944, and in January, February and April 1945. The data obtained from wire-line readings have been used to determine heave contours as shown on Plate 5.

(2) Frost Penetration.

The depth of frost penetration was determined in the pits excavated in February 1945. The depth of frost penetration is considered to be the depth at which observable ice forms or hard frozen ground was encountered in the test pit excavations. The depth of freezing temperature penetration was not determined on this airfield since subsurface temperature measuring equipment was not installed at this airfield. The observations of frost penetration, as determined by the depth of frozen ground, indicated that the depth of frost penetration was 3.7 feet below the surface of the pavement in Test Pit TP 2A, while in Test Pit TP 2B, the frost penetration reached a depth of 3.8 feet. The observations indicated that the material was frozen continuously from the bottom of the bituminous surface to the maximum depth of frost penetration noted.

(3) Ice Lens Survey.

In the test pits excavated on 8 February 1945, no ice crystals or frost formations were noted in the gravel base course, although this course was hard frozen. In the subgrade, however, continuous hairline lenses in layers from 1/16 to 1/8 of an inch apart, existed in large numbers in the upper 0.23 feet of the subgrade in Test Pit TP 2A and similar ice lenses existed in the upper 0.3 feet of subgrade in Test Pit TP 2B. No ice formations were observed below these depths, although frozen ground existed to an appreciably greater depth.

e. Field Tests.

(1) California Bearing Ratio Tests.

Field "in-place" California bearing ratio data were obtained in the test area during both the fall and the spring test pit excavations. The bearing ratio tests were made on the surfaces of the base course and subgrade, and on several elements at varying depths below the top of the subgrade. The data obtained from the "in-place" bearing ratio tests are given in Table 2.

(2) Subsurface Moisture Tests.

Moisture data were obtained at various depths and in the various elements of the pavement during the fall, winter, and spring test pit excavations. The water contents of the various elements were taken to a total depth of approximately 12 feet, at which elevation the perched water table was encountered. The fall moisture tests were made in October 1944, the winter tests in February 1945, and the spring tests in April 1945. The moisture data obtained from these tests are shown on Plate 4.

(3) Subsurface Density Tests.

Density data were obtained to a depth of approximately 4.5 feet during the fall and spring test periods. These data are given in Table 2, and are shown in graphic form on Plate 4.

f. Laboratory Tests.

The following laboratory tests were performed:

(1) Classification Tests.

Mechanical analysis and Atterberg tests were made for the classification of all soil and aggregate materials. All materials were classified in accordance with the Casagrande method, using the methods and procedures given in Appendix 14 of the Frost Investigation Report. Classification and analysis data for all soil and aggregate materials are given in Table 2.

(2) California Bearing Ratio Tests.

Laboratory determinations of California bearing ratios were made on all base courses, and on typical subgrade materials existing within the depth of pit excavations. Laboratory tests were made on undisturbed specimens of subgrade soils which were obtained in steel cylinders and saturated in the laboratory prior to testing. All subgrade materials were tested in the laboratory under appropriate surcharges, using surcharge loadings equivalent to the dead load imposed on the same material in the airfield pavement. Laboratory tests were made on samples obtained during the fall test period in October 1944. The results of the saturated bearing ratio tests on the undisturbed specimens are given in Table 2. In addition to the field and undisturbed laboratory specimen tests, a compaction-bearing ratio study was made in the laboratory on disturbed specimens of soil and base course materials recompacted to various densities at different moisture contents and under varied conditions of compaction, using methods established by the Chief of Engineers. These methods are described in Appendix 14 of the Frost Investigation Report. Bearing ratio data were obtained from the saturated recompacted specimen. The data from the compaction-bearing ratio study are shown on Plate 6.

g. Conclusions, Test Area A.

(1) Heaving of Pavement.

Pavement heave is indicated as having reached a maximum on about 13 January 1945. A maximum heave of 0.10 foot was noted at one corner of the test area, and the average heave was approximately 0.04 feet on that date. Heaving was fairly uniform in the test area, except that the average heaving of the south half of the test area was approximately 0.02 feet, while the average heave of the north half of the pavement was about 0.05 feet. Although temperature, soil, water table elevation and the water contents in the subgrade soils were favorable for the development of severe frost action, the observed results indicate only relatively minor heaving. The effect of this heaving on the reduction of carrying capacity of the pavement was not determined.

(2) Frost Penetration.

The depth of frost penetration, indicated to be approximately 3.8 feet as determined from the depth of hard frozen ground in the test pits excavated on 7 and 8 February 1945, corresponded to a cumulative degree-day below freezing value of approximately 1280. The depth of frost penetration determined from the test pit excavations is indicated as having been at or near the maximum depth of frost penetration in the test area during the investigational period.

(3) Ice Lens Survey.

Observations in the test pit excavations indicated that ice lens formations tended to be concentrated in the upper portion of the subgrade, thin lenses and crystals existing from the top of the subgrade to distances of 0.23 feet and 0.3 feet below the top of the subgrade in Test Pits TP 2A and TP 2B, respectively. Ice formations were not present, neither in the base course, nor at elevations lower than the first 0.23 feet of subgrade in Test Pit TP 2A or the first 0.3 feet of subgrade in Test Pit TP 2B, although frozen ground was noted as extending to a depth of approximately 3.8 feet below the pavement surface in each test pit. An examination of moisture data obtained in the two test pit excavations indicate that high moisture contents were present in the soils exhibiting the frost formations. It is further indicated that the soils directly underlying the upper portion of the subgrade had water contents appreciably less than the soil above. It is considered possible that some dehydration of the lower soils may have occurred, this water migrating into the upper portion of the subgrade to form the observed frost formations.

(4) Subsurface Moisture Changes.

The subsurface moisture changes, occurring in Test Area A during the frost investigational period, are indicated to have been relatively minor. In the A series of tests, small increases of moisture content occurred from the top of the subgrade to a depth of approximately 3.5 feet. The total change in moisture content between the fall and the spring readings was approximately 5 percent, the spring period indicating the higher moisture content. The moisture increases occurring in the B series of pits were less than those occurring in the A series. The B series of pits indicated moisture content increases of approximately 3 to 4 percent between the top of the subgrade and a depth of approximately 5 feet. The moisture changes are indicated as having occurred principally in the CL-ML soils existing in the upper portion of the subgrade. The CL-ML soils overlaid material of SF-ML, SP, and SF type soils, the latter soils extending to the perched water table elevation. It is possible that the SF-ML, SF and SP soils may have possessed sufficiently low capillarities to have retarded the migration of water from the perched water table into the frost active zone of CL-ML materials. The result of such action would be a retardation of water accumulation and frost action in the materials lying above the low capillarity soils.

(5) Subsurface Density Test.

The subsurface density data obtained during the fall and spring test pit excavations indicate almost negligible variations in density in the subsurface materials during the winter test period. It is considered that the frost action occurring at these levels in the test pit was insufficient to produce any major change in density of the subsurface materials within the frost active zone.

(6) California Bearing Ratio Tests.

California bearing ratio data obtained from the tests made in October 1944 and in April 1945, indicate that the changes in "in-place" bearing ratios of the various subgrade elements below the surface course during the winter period were very small. Field bearing ratio data were somewhat erratic, the field "in-place" bearing ratio of the base course being indicated as having decreased from a fall bearing ratio value of 32 to a value of 26 in the spring A series of test pits, while in the B series of test pits, a base course "in-place" bearing ratio of 15 was obtained during the fall, and a ratio of 23 was obtained during the spring. Small decreases of subgrade bearing ratio values were noted in the spring "in-place" data as compared to the fall test data. The bearing ratios of materials below the top of the subgrade are indicated as having undergone only negligible or extremely small changes. The results of the following spring "in-place" bearing ratio tests do not indicate major changes as having occurred in the bearing ratio characteristics of the pavement subsurface materials during the winter period, due to frost action.

7. General Conclusions.

Frost action occurring under the flexible airfield pavement test area on the Bismarck Airfield during the 1944-1945 winter season is indicated to have been relatively minor despite weather, soil, and moisture conditions which might be considered as conducive to the development of severe frost action. The absence of severe frost action is indicated in the minor heaving observed in the test area and in the absence of pronounced development of ice or frost formations in the subsurface pavement elements during the winter. The changes in moisture contents of the upper portion of the subgrade soils lying within the frozen zone and density variations of the same materials, both indicate only very minor effects due to frost action. The result of California bearing ratio data obtained from the field "in-place" tests likewise indicate only relatively minor changes as occurring during the winter period as a result of frost action. The absence of more pronounced frost action is considered to have been due possibly to the existence of low capillarity soil types of SF, SP and GP classification, lying between the high capillarity upper subgrade soils and the perched water table. The low capillarity is indicated to have retarded the migration of water from the water source into the frost active zone, thus diminishing heave and retarding the formation of ice lenses and other frost action phenomena which might otherwise have been expected under the temperature and weather conditions existing on this airfield.

TABLE 1

CHRONOLOGICAL SUMMARY OF EXPLORATIONS
BISMARCK MUNICIPAL AIRFIELD, BISMARCK, NORTH DAKOTA

1. Fall Period

    a. 30 August - 2 September 1944
        (1) Preliminary Soil Explorations.

    b. 19-24 October 1944
        (1) Excavation of Test Pits TP 1A and TP 1B.
        (2) Installation of Bench Marks.
        (3) Installation of Well Point.
        (4) Wire-line Readings.
        (5) "In-place" California Bearing Ratio Tests.

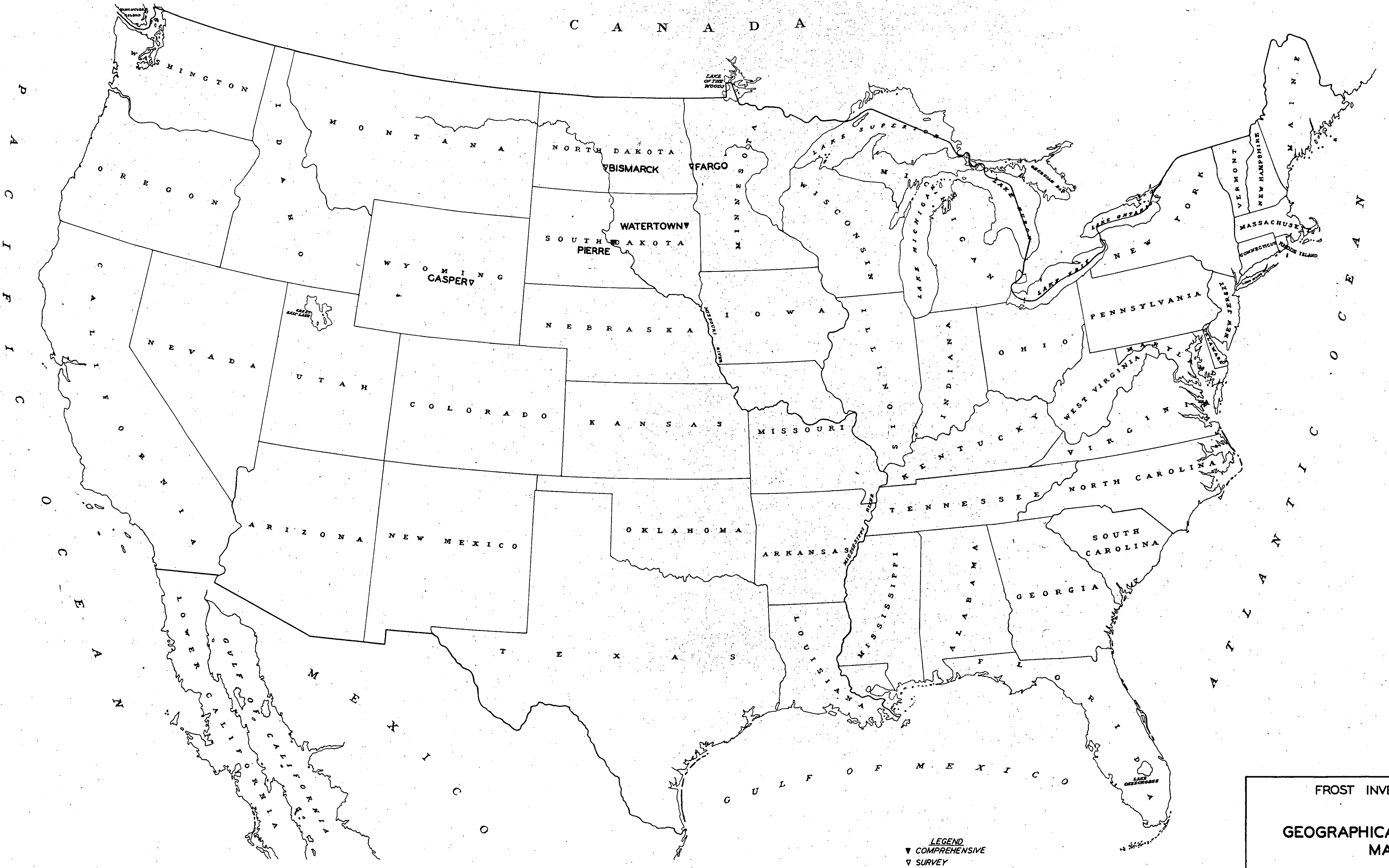
2. Winter Period

    a. 15-30 January 1945
        (1) Wire-line Readings.

    b. 6-9 February 1945
        (1) Excavation of Test Pits TP 2A and TP 2B.
        (2) Wire-line Readings.

3. Spring Period

    a. 13-16 April 1945
        (1) Excavation of Test Pits TP 3A and TP 3B.
        (2) Wire-line Readings.
        (3) Ground Water Level Readings.
        (4) "In-place" California Bearing Ratio Tests.



FROST INVESTIGATION

GEOGRAPHICAL LOCATION MAP

100 50 25 0 50 100 200 300
SCALE IN MILES

MISSOURI RIVER DIV., OMAHA, NEBR.

JUNE, 1945

FROST INVESTIGATION
SUMMARY OF SOIL AND PAVEMENT TEST DATA
CASPER AIR BASE, CASPER, WYOMING
TEST AREA A

TEST PIT	DATE	TYPE	DEPTH IN FEET	SOIL DATA														SUBGRADE DATA					PAVEMENT DATA	
				SOIL CLASS.	GRAIN SIZE % Finer than indicated grain size								ATTERBERG LIMITS			NATURAL DENSITY		FIELD TESTS		MODULI TESTS			CONCRETE FLEXURAL STRENGTH	
					0.005 mm	0.02 mm	0.05 mm	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	LIQUID LIMIT	PLASTIC INDEX	SPECIFIC GRAVITY	WATER CONTENT % Dry Wt.	UNIT WEIGHT p.c.f.	WATER CONTENT % Dry Wt.	DENSITY p.c.f.	K_u	P_s/P	K	ACTUAL VALUE	28-DAY VALUE
1A	10-'44	Surface	0.0 - 0.8	Conc.																				
		Subgr.	0.8 - 1.5	SF-CL	6	13	20	31	60	99	100	—	26	11	2.66	10.6(2)	119 (2)	10.6 (2)	119 (2)					
			1.5 - 3.0	SF-CL	17	26	39	50	70	99	100	—	25	9	2.69	9.8(2)	114 (2)	9.8 (2)	114 (2)					
			3.0 - 3.9	SF-CL	20	28	44	53	73	99	100	—	25	10	2.70	15.2(2)	100 (2)	15.2 (2)	100 (2)					
			3.9 - 5.0	SF	3	5	9	16	32	74	88	97	20	5	2.70	4.4(2)	127 (2)	4.4 (2)	127 (2)					
			5.0 - 8.5	SP	1	3	5	14	40	91	96	100	17	2	—			~~5.3 (3)~~	—					
			8.5 -10.5	SF-CL	12	19	37	50	72	99	99.5	100	24	8	—			~~12.5 (2)~~	—					
			10.5 -13.0	SF	9	12	22	34	56	94	98	100	21	5	—			~~12.0 (3)~~	—					
			13.0 -15.0	CL-SF	13	15	21	32	60	98	100	—	24	9	—			~~9.4 (2)~~	—					
1B	10-'44	Surface	0.0 - 0.8	Conc.																				
		Subgr.	0.8 - 1.8	SF-CL	9	19	25	35	58	93	97	100	29	9	2.70	10.0(2)	122 (2)	10.0 (2)	122 (2)					
			1.8 - 2.8	SF-CL	10	14	18	26	49	100	—	—	17	3	2.64	9.1(2)	113 (2)	9.1 (2)	113 (2)					
			2.8 - 3.8	SP	5	7	10	20	47	99	100	—	15	0	2.66	7.4(2)	110 (2)	7.4 (2)	110 (2)					
			3.8 - 4.8	SP	"	"	"	"	"	"	"	—	"	"	"	3.5(2)	110 (2)	3.5 (2)	110 (2)					
			4.8 - 5.8	SP	"	"	"	"	"	"	"	—	"	"	"	4.8(2)	107 (2)	4.8 (2)	107 (2)					
			5.8 - 7.5	SP	"	"	"	"	"	"	"	—	"	"	"	5.6(2)	116 (2)	5.6 (2)	116 (2)					
			7.5 - 8.0	CL	36	49	56	66	77	94	98	100	47	30	—			~~13.5~~	—					
			8.0 - 9.0	SF-~~CL~~	4	7	10	14	24	55	80	100	25	11	—			~~3.6~~	—					
			9.0 -10.0	SF-~~CL~~	"	"	"	"	"	"	"	"	"	"	—			~~8.1~~	—					
			10.0 -11.0	SF	9	13	21	31	54	93	96	98	20	3	—			~~5.7~~	—					
			11.0 -12.6	SF	5	6	12	25	53	97	100	—	18	3	—			~~3.9~~	—					
			12.6 - 15.0	SF	9	13	17	25	48	97	98	100	20	5	—			~~8.4~~	—					
2A	1-'45	Surface	0.0 - 0.8	Conc.																				
		Subgr.	0.8 - 1.8	*SF														11.2 (4)	SF					
			1.8 - 3.5	*SF														~~6.7 (6)~~		F				
			3.5 - 4.5	*ML-SF														~~8.2 (2)~~						
			4.5 - 5.5	*GP														~~8.4 (2)~~						
			5.5 - 8.0	*GF														~~7.4 (3)~~						
			8.0 - 9.0	*GP														~~13.5~~						
			9.0 -12.0	*ML-CL														~~7.3 (3)~~						
			12.0 -13.0	*GF														~~8.6~~						
			13.0 -15.0	*SF														~~8.9 (2)~~						

* Field Classification

FROST INVESTIGATION
SUMMARY OF SOIL AND PAVEMENT TEST DATA
CASPER AIR BASE, CASPER, WYOMING
TEST AREA A

TEST PIT	DATE	TYPE	DEPTH IN FEET	SOIL DATA														SUBGRADE DATA					PAVEMENT DATA	
				SOIL CLASS.	GRAIN SIZE % Finer than indicated grain size								ATTERBERG LIMITS			NATURAL DENSITY		FIELD TESTS		MODULI TESTS			CONCRETE FLEXURAL STRENGTH	
					0.005 mm	0.02 mm	0.05 mm	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	LIQUID LIMIT	PLASTIC INDEX	SPECIFIC GRAVITY	WATER CONTENT %Dry Wt.	UNIT WEIGHT p.c.f.	WATER CONTENT %Dry Wt.	DENSITY p.c.f.	K_u	P_s/p	K	ACTUAL VALUE	28-DAY VALUE
2B	1-'45	Surface	0.0 - 0.7	Conc.	A																			
		Subgr.	0.7 - 1.0	*GF														9.1						
			1.0 - 2.5	*SF														11.5 (6)	SF	F				
			2.5 - 4.5	*ML-SF	—													~~4.8 (5)~~						
			4.5 - 6.0	*ML-CL	—													~~13.5 (3)~~						
			6.0 - 7.5	*CL														~~19.2~~						
			7.5 - 9.5	*GP														~~2.9 (2)~~						
			9.5 -10.5	*GF														~~7.2~~						
			10.5 -11.0	*ML-SF														~~6.3~~						
			11.0 -13.0	*GF														~~8.0 (2)~~						
			13.0 -15.0	*SF														~~8.4 (2)~~						
3A	3-'45	Surface	0.0 - 0.7	Conc.	A																			
		Subgr.	0.7 - 1.6	*SF-CL												11.5(2)	122(2)	11.5 (2)	122 (2)	SF-CL SF	M			
			1.6 - 2.5	*SF												10.8(2)	117(2)	10.8 (2)	117 (2)					
			2.5 - 4.0	*SF												14.5(2)	107(2)	~~14.5 (2)~~	~~107 (2)~~					
			4.0 - 4.5	*CL-SF	—													~~9.6~~	~~—~~					
			4.5 - 7.0	*SP														~~6.9 (4)~~	~~—~~					
			7.0 - 9.0	*CL-SF	—													~~9.9 (2)~~	~~—~~					69.0 7 7/78.1 11.1
			9.0 -10.0	*SF														~~3.0~~	~~—~~					
			10.0 -11.5	*SP														~~5.8~~	~~—~~					
			11.5 -13.0	*CL-SF														~~13.4~~	~~—~~					
			13.0 -14.0	*CL-SF														~~6.6~~	~~—~~					
			14.0 -15.0	*SF														~~4.4~~	~~—~~					
3B	3-'45	Surface	0.0 - 0.8	Conc.	A																			
		Subgr.	0.8 - 1.7	*SF-CL												10.3(2)	119(2)	10.3 (2)	119 (2)	SF-CL				
			1.7 - 2.7	*SF												6.9(2)	116(2)	6.9 (2)	116 (2)	SFM				
			2.7 - 5.0	*SF												5.7(2)	114(2)	~~5.7 (2)~~	~~114 (2)~~					
			5.0 - 7.0	*CL														~~15.3 (3)~~	~~—~~					
			7.0 - 8.0	*CL														~~5.9~~	~~—~~					
			8.0 - 9.0	*GF														~~3.9~~	~~—~~					
			9.0 -10.0	*GF														~~7.7~~	~~—~~					
			10.0 -11.0	*SF-CL														~~5.9~~	~~—~~					
			11.0 -12.0	*SF														~~3.5~~	~~—~~					
			12.0 -13.0	*SF														~~8.3~~	~~—~~					
			13.0 -15.0	*CL														~~8.8 (2)~~	~~—~~					

* Field Classification

FROST INVESTIGATION
SUMMARY OF SOIL AND PAVEMENT TEST DATA
CASPER AIR BASE, CASPER, WYOMING
TEST AREA B

TEST PIT	DATE	TYPE	DEPTH IN FEET	SOIL DATA														C.B.R. DATA										
				SOIL CLASS.	GRAIN SIZE %Finer than indicated grain size								ATTERBERG LIMITS			NATURAL DENSITY		FIELD IN-PLACE TESTS			UNDISTURBED CYL. TESTS			REMOLDED TESTS-100% DENSITY				
					0.005 mm	0.02 mm	0.05 mm	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	LIQUID LIMIT	PLASTIC INDEX	SPECIFIC GRAVITY	WATER CONTENT %DryWt	UNIT WEIGHT p.c.f.	WATER CONTENT %DryWt.	DENSITY p.c.f.	C.B.R. 0.1" Pen.	WATER CONTENT %DryWt.	DENSITY p.c.f.	C.B.R. 0.1" Pen.	WATER CONTENT BEFORE SOAKING	WATER CONTENT AFTER SOAKING	% SWELL	DENSITY p.c.f.	C.B.R. 0.1" Pen.
																					--S O A K E D--							
1A	10-'44	Surface	0.0-0.6	Asph.																								
		Base	0.6-1.3	GW	2	4	6	12	25	43	54	81	18	3	2.66	4.5(2)	133 (2)	4.5 (2)	133 (2)	66 (3)								
		Subgr.	1.3-2.3	SP	5	6	12	26	54	100	-	-	18	0	2.63	5.4(4)	113 (4)	5.4(4)	113 (4)	34 (2)	14.6(2)	112 (2)	18 (2)	N				
			2.3-2.9	SP	3	5	8	18	50	99	100	-	17	0	-	3.9(2)	105 (2)	3.9 (2)	105 (2)	3.7(3)	17.1(2)	106 (2)	6.5(2)					
			2.9-3.3	SP	"	"	"	"	"	"	"	-	"	"	-	4.3(2)	103 (2)	4.3 (2)	103 (2)	-								
			3.3-4.3	SP	"	"	"	"	"	"	"	-	"	"	-	4.1(2)	108 (2)	4.1 (2)	108 (2)	5.1(2)								
			4.3-5.3	SF CL	12	18	21	32	60	99	100	-	20	6	-	3.7(2)	122 (2)	3.7 (2)	122 (2)	3.8(4)								
			5.3-6.0	SF CL	"	"	"	"	"	"	"	-	"	"	-	8.8(2)	120 (2)	8.8 (2)	120 (2)	22 (3)								
			6.0-7.0	SF CL	"	"	"	"	"	"	"	-	"	"	-			~~13.2~~	-	13 (4)								
			7.0-9.7	CL	32	47	56	66	82	100	-	-	44	26	-			13.6 (2)	-									
			9.7-11.0	SW	3	6	10	18	38	76	85	99	16	1	-			5.2	-									
			11.0-12.5	CH	58	72	82	85	91	98	100	-	49	30	-			~~14.5~~ (2)	-									
			12.5-15.0	CH	41	49	54	60	69	98	100	-	53	33	-			~~15.5~~ (3)	-									
1B	10-'44	Surface	0.0-0.6	Asph.																								
		Base	0.6-1.1	SW	3	5	7	8	19	54	75	99	18	3	2.66	3.1(2)	129 (2)	3.1(2)	129 (2)	52 (3)								
		Subgr.	1.1-1.9	SF-CL	11	15	20	32	61	99	100	-	26	11	2.67	6.4(4)	121 (4)	6.4 (4)	121 (4)	-	10.5 (2)	122 (2)	8.0(2)					
			1.9-3.0	SP	4	6	7	18	50	99	100	-	17	2	2.65	2.6(4)	108 (4)	2.6 (4)	108 (4)	21 (4)	14.6 (2)	111 (2)	4.9(2)	N				
			3.0-4.0	SP	"	"	"	"	"	"	"	-	"	"	"	2.3(2)	108 (2)	2.3 (2)	108 (2)	5.3(4)								
			4.0-5.0	SP	"	"	"	"	"	"	"	-	"	"	"	2.5(2)	108 (2)	2.5 (2)	108 (2)	6.5(5)								
			5.0-5.5	SP	"	"	"	"	"	"	"	-	"	"	"	2.3(2)	112 (2)	2.3 (2)	112 (2)	12 (3)								
			5.5-6.0	SF-CL	17	23	28	40	66	100	-	-	20	5	-	5.9(2)	110 (2)	5.9 (2)	110 (2)	21 (2)								
			6.0-10.5	" "	"	"	"	"	"	"	-	-	"	"	-			~~9.9~~										
			10.5 11.5	CL	39	52	57	66	75	89	95	100	47	30	-			~~12.9~~ (4)	-									
			11.5-13.0	CH	68	83	88	91	94	99	100	-	57	33	-			~~15.0~~ (2)	-									
			13.0-15.0	CH	68	73	76	81	87	99	100	-	61	40	-			~~14.5~~ (2)	-									
2A	1-'45	Surface	0.0-0.7	Asph.															GW									
		Base	0.7-1.3															4.8	SF									
		Subgr.	1.3-1.8	*SF														6.6 (2)										
			1.8-7.3	*SF														~~3.8 (13)~~			F							
			7.3-9.5	*CL														~~13.6 (2)~~										
			9.5-11.0	*GF														~~7.2~~										
			11.0-13.0	*CH-CL														~~15.6 (2)~~										
			13.0-14.0	*CL														~~10.6~~										
			14.0-15.0	*CL														~~14.5 (2)~~										

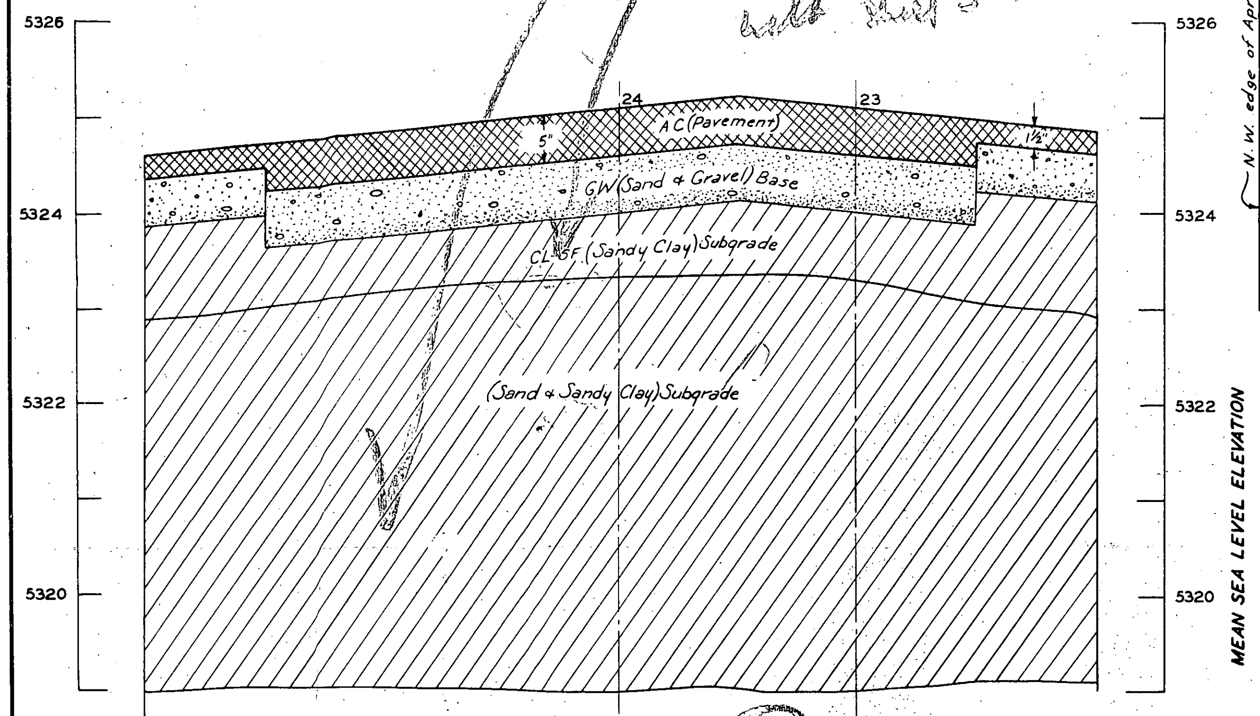
* Field Classification

FROST INVESTIGATION
SUMMARY OF SOIL AND PAVEMENT TEST DATA
CASPER AIR BASE, CASPER, WYOMING
TEST AREA B

TEST PIT	DATE	TYPE	DEPTH IN FEET	SOIL DATA														C.B.R. DATA										
				SOIL CLASS.	GRAIN SIZE %Finer than indicated grain size								ATTERBERG LIMITS			NATURAL DENSITY		FIELD IN-PLACE TESTS			UNDISTURBED CYL. TESTS			REMOLDED TESTS-100% DENSITY				
					0.005 mm	0.02 mm	0.05 mm	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	LIQUID LIMIT	PLASTIC INDEX	SPECIFIC GRAVITY	WATER CONTENT %DryWt	UNIT WEIGHT p.c.f.	WATER CONTENT %DryWt.	DENSITY p.c.f.	C.B.R. 0.1" Pen.	WATER CONTENT %DryWt.	DENSITY p.c.f.	C.B.R. 0.1" Pen.	WATER CONTENT BEFORE SOAKING	WATER CONTENT AFTER SOAKING	% SWELL	DENSITY p.c.f.	C.B.R. 0.1" Pen.
2B B	1-'45	Surface	0.0-0.7	Asph.																								
		Base	0.7-1.1															3.4	-GW									
		Subgr.	1.1-1.5	*SF														8.0$^{(2)}$	SF	F								
			1.5-1.8	*SF														5.6										
			1.8-5.0	*SF														2.7$^{(9)}$										
			5.0-6.0	*SF														5.2$^{(2)}$										
			6.0-9.0	*SF														3.4$^{(3)}$										
			9.0-10.0	*SF														5.1										
			10.0-12.0	*SF														8.7										
			12.0-13.0	*SF														13.7										
			13.0-14.0	*CL														15.4										
			14.0-15.0	*CH-CL														14.0										
3A B	3-'45	Surface	0.0-0.6	Asph.																								
		Base	0.6-1.1	*GW												4.3$^{(2)}$	138$^{(2)}$	4.3$^{(2)}$	138$^{(2)}$	26$^{(3)}$	GW							
		Subgr	1.1-2.1	*SP												5.7$^{(2)}$	121$^{(2)}$	5.7$^{(2)}$	121$^{(2)}$	24$^{(2)}$	SF							
			2.1-4.5	*SP												3.6$^{(2)}$	106$^{(2)}$	3.6$^{(2)}$	106$^{(2)}$	8.3$^{(2)}$		M						
			4.5-6.3	*SF														2.9$^{(3)}$	-									
			6.3-11.0	*CL														15.3$^{(5)}$	-									
			11.0-12.5	*SW-SF														16.5$^{(2)}$	-									
			12.5-15.0	*CH														13.1$^{(2)}$	-									
3B B	3-'45	Surface	0.0-0.6	Asph.																								
		Base	0.6-1.1	*SW												3.0$^{(2)}$	131$^{(2)}$	3.0$^{(2)}$	131$^{(2)}$	32$^{(3)}$	GW							
		Subgr.	1.1-1.7	*SF-CL												7.6$^{(2)}$	122$^{(2)}$	7.6$^{(2)}$	122$^{(2)}$	18$^{(2)}$	SF-CL							
			1.7-6.0	*SP												2.5$^{(2)}$	113$^{(2)}$	2.5$^{(2)}$	113$^{(2)}$	3.5$^{(3)}$		M						
			6.0-8.0	*SF														5.0$^{(2)}$	-									
			8.0-9.0	*SF														14.9	-									
			9.0-10.5	*CL														16.2	-									
			10.5-11.5	*SP														4.3	-									
			11.5-14.0	*CH														16.7$^{(3)}$	-									
			14.0-15.0	*CH														20.3	-									

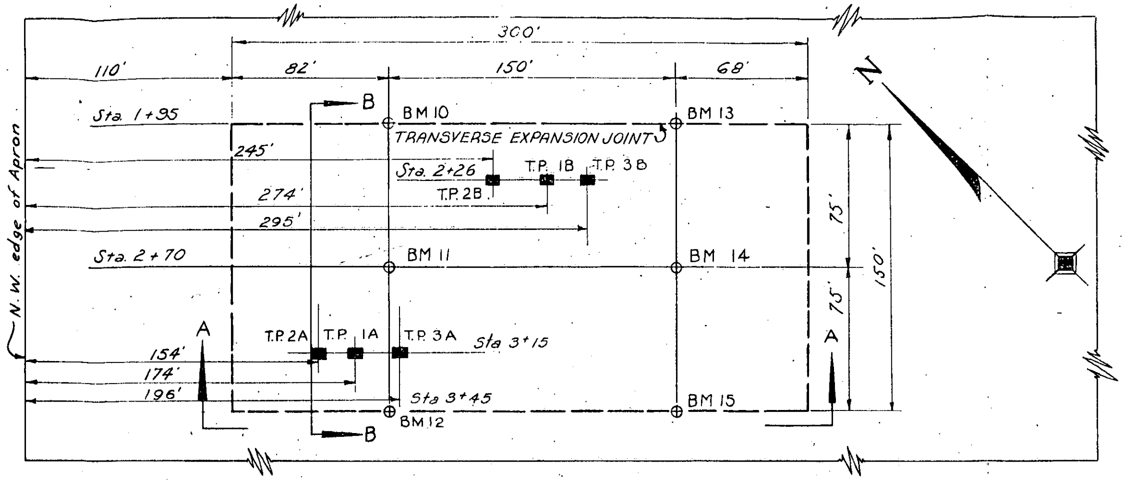
* Field Classification

Does not agree with sheet 3 Table 2



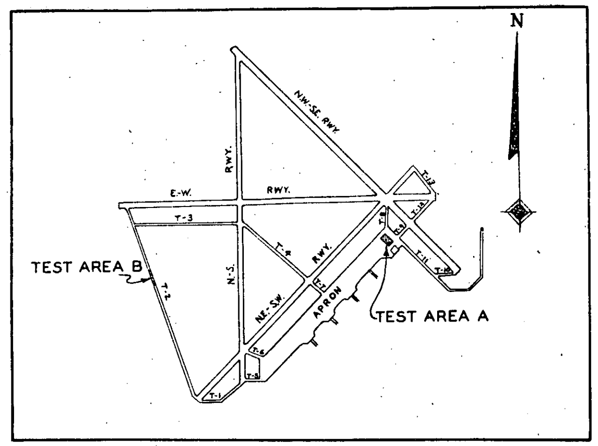
SECTION C C - TEST AREA B

Scale in feet



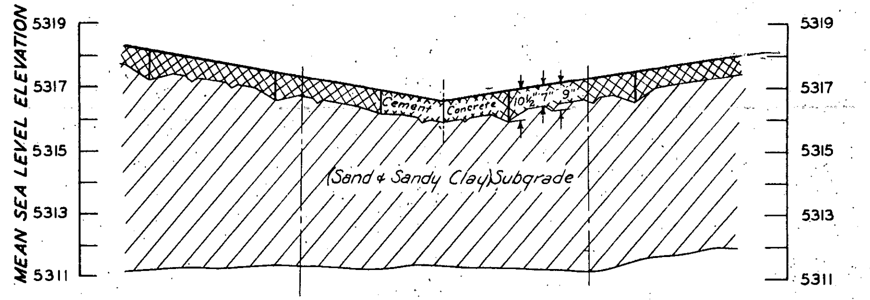
PLAN - TEST AREA A

Scale in feet

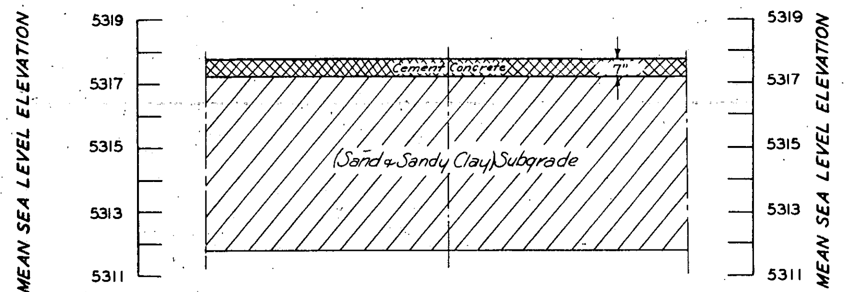


SITE MAP

Scale in feet



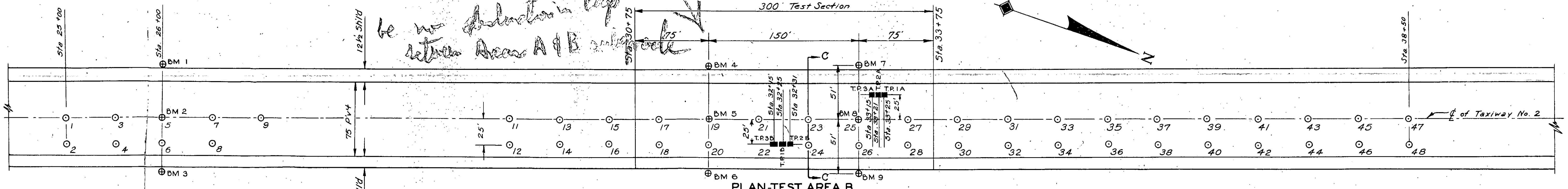
SECTION A A - TEST AREA A



SECTION B B - TEST AREA A

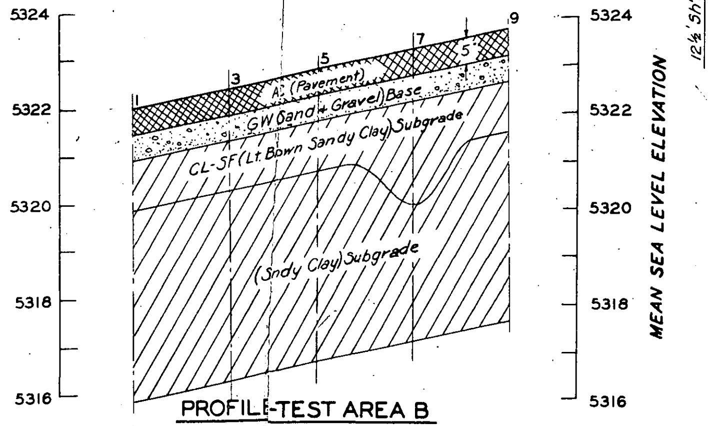
Scale in feet

appears to be no distinction in logs between Areas A & B subgrade



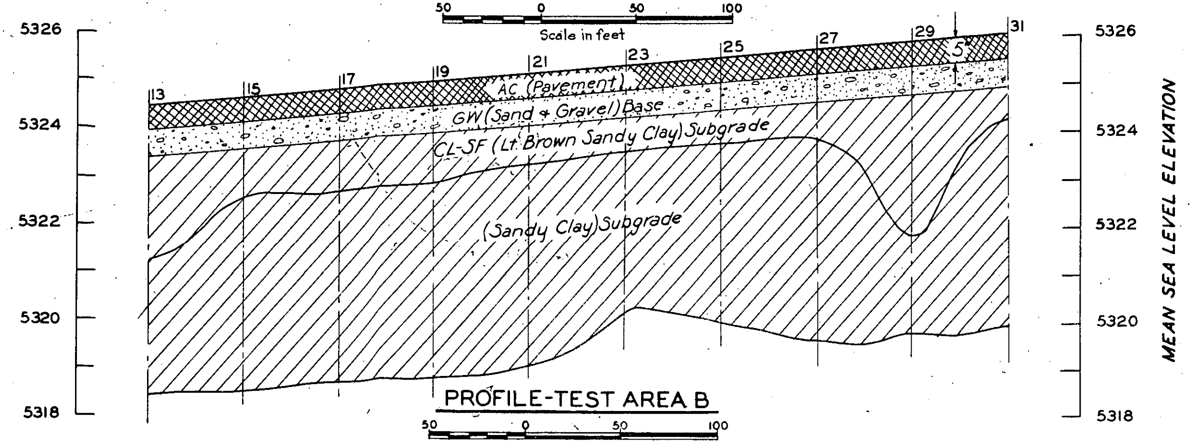
PLAN - TEST AREA B

Scale in feet



PROFILE - TEST AREA B

Scale in feet



PROFILE - TEST AREA B

Scale in feet

LEGEND

AUGER BORING ⊙
TEST PIT ■
BENCH MARK ⊕

Note:
Pavement thicknesses shown are design thicknesses.

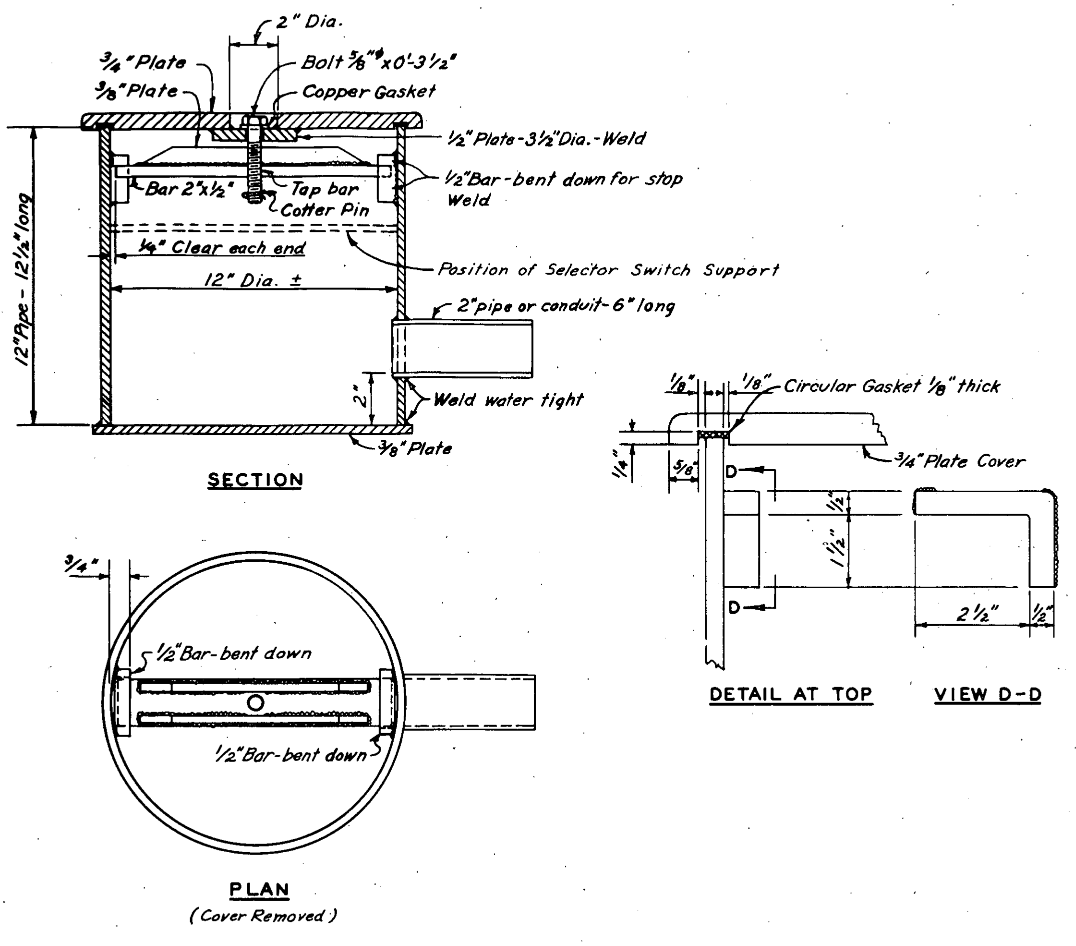
FROST INVESTIGATION
CASPER AIRBASE, CASPER WYO.

PLANS AND PROFILES TEST AREAS A & B

SCALE: AS SHOWN
298
MISSOURI RIVER DIV., OMAHA, NEBR. JUNE, 1945

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



SECTION

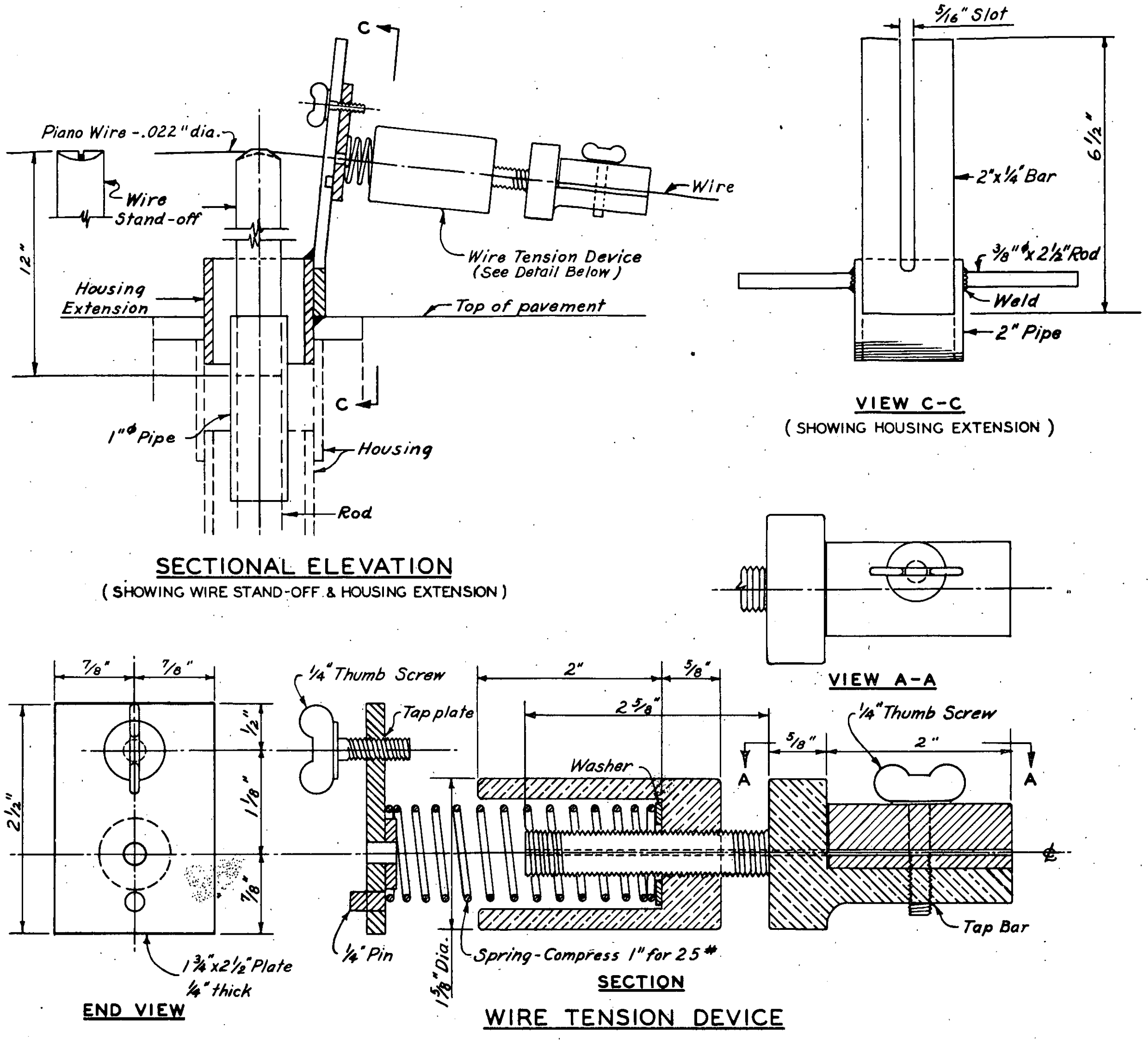
PLAN

(Cover Removed)

DETAIL AT TOP

VIEW D-D

THERMOCOUPLE TERMINAL BOX



SECTIONAL ELEVATION

(SHOWING WIRE STAND-OFF & HOUSING EXTENSION)

VIEW C-C

(SHOWING HOUSING EXTENSION)

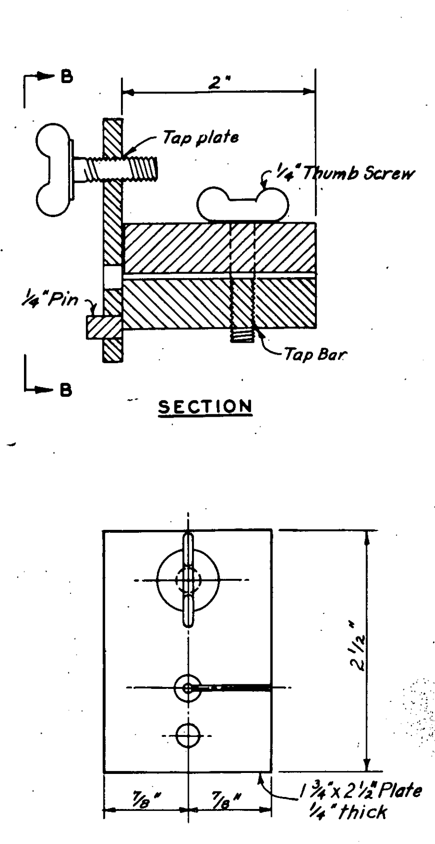
VIEW A-A

END VIEW

SECTION

WIRE TENSION DEVICE

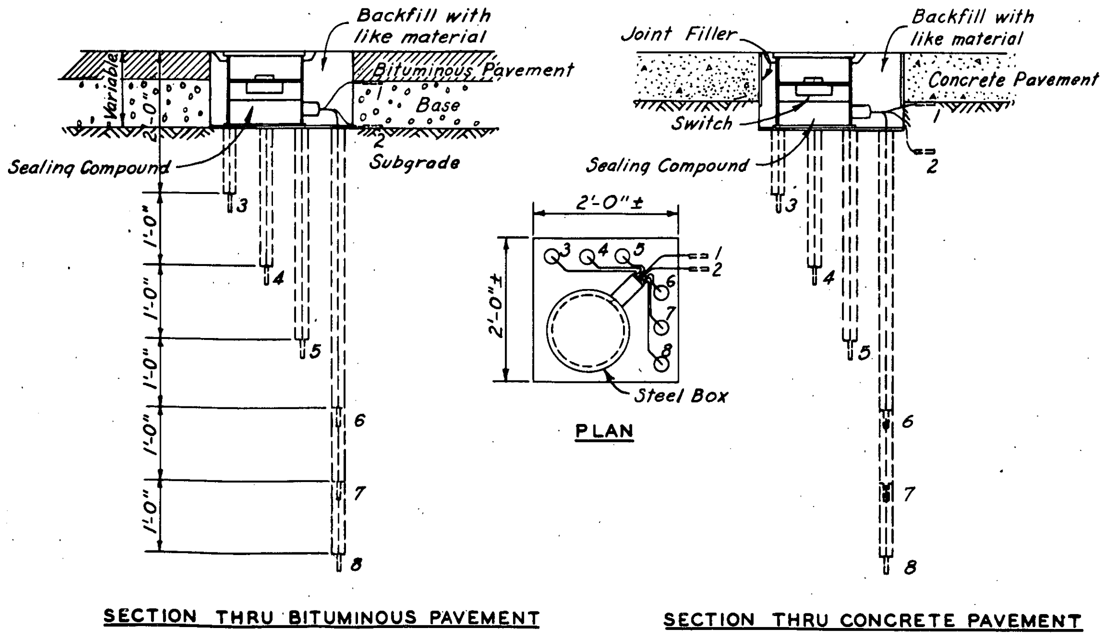
WIRE LINE APPARATUS



SECTION

VIEW B-B

WIRE HOLDER

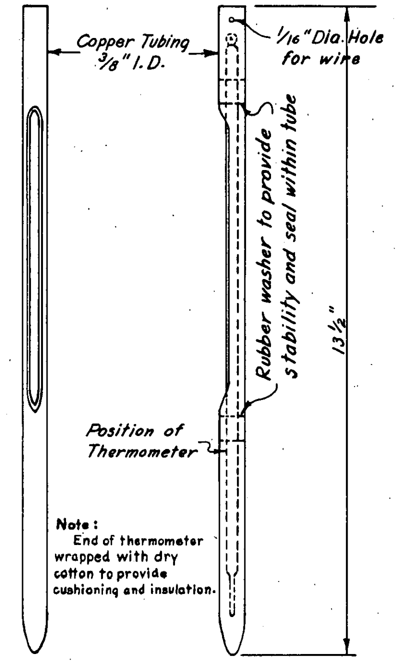


SECTION THRU BITUMINOUS PAVEMENT

PLAN

SECTION THRU CONCRETE PAVEMENT

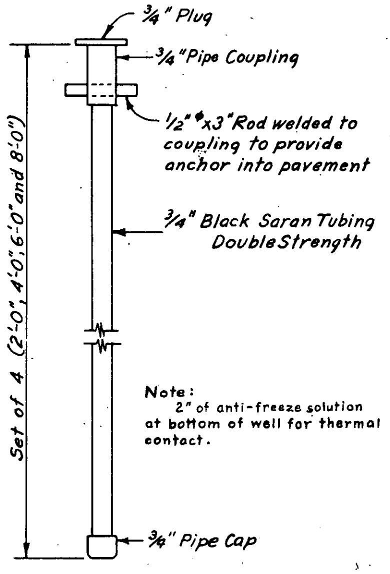
THERMOCOUPLE INSTALLATIONS



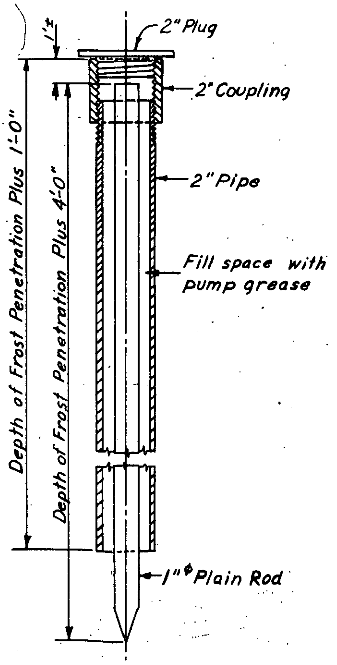
FRONT VIEW

SIDE VIEW

THERMOMETER HOLDER



THERMOMETER WELL



BENCH MARK

FROST INVESTIGATION

EQUIPMENT DETAILS

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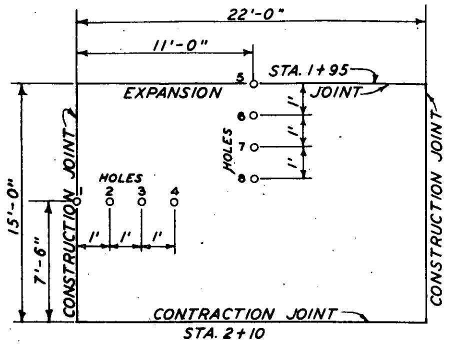
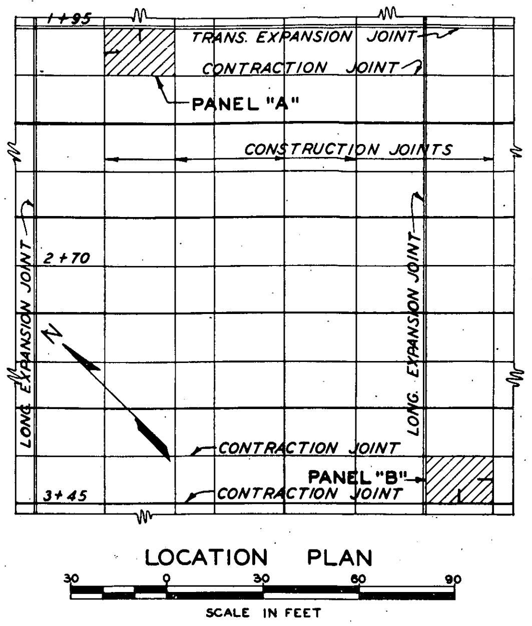
MISSOURI RIVER DIV., OMAHA, NEBR. JUNE, 1945

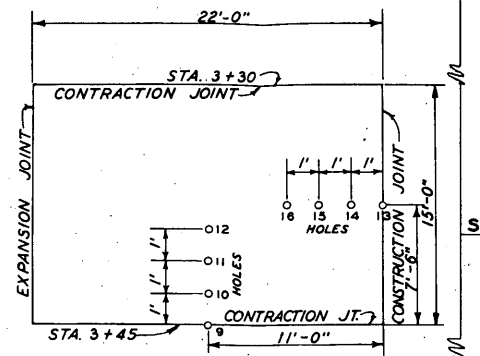
PLATE 3



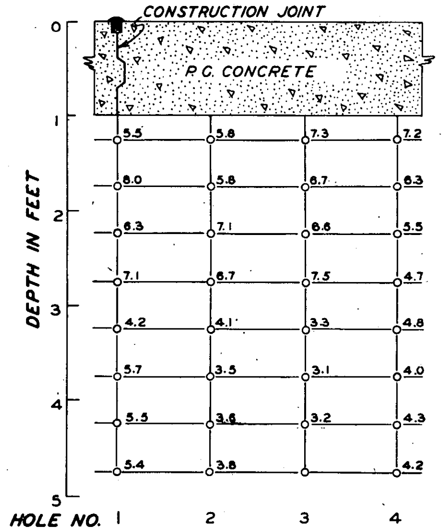
PLAN - PANEL "A"



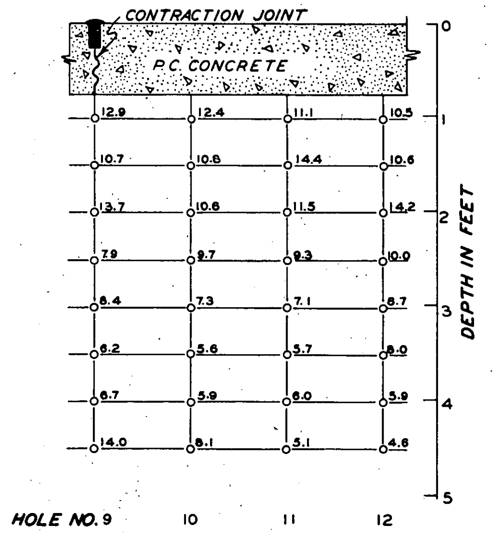
LOCATION PLAN



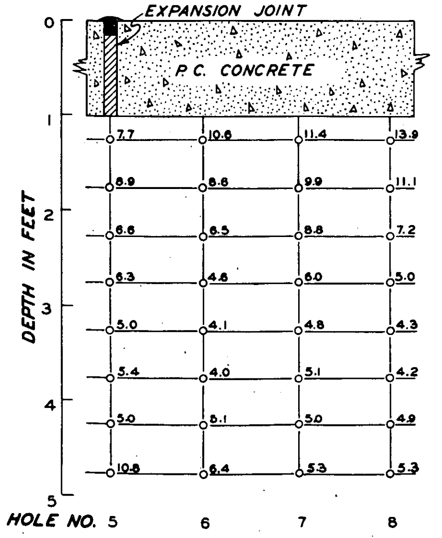
PLAN - PANEL "B"



DATE 10-11-44
SECTION

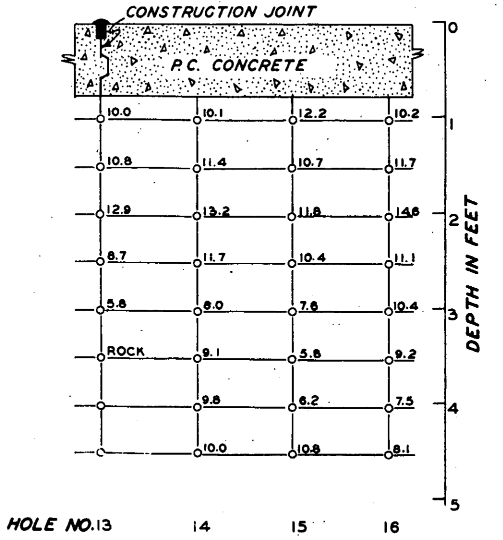


DATE 10-11-44
SECTION



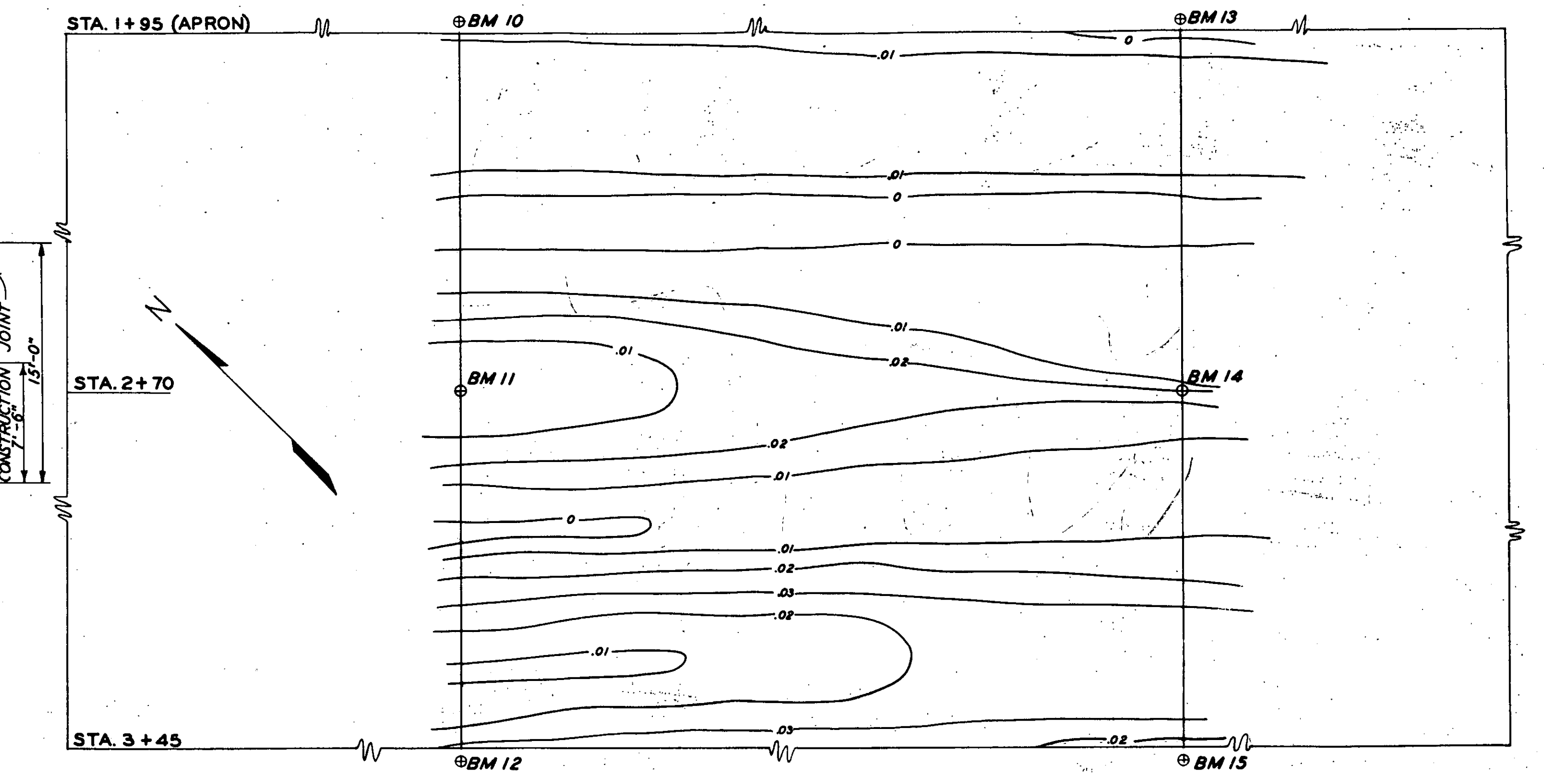
DATE 10-11-44
SECTION

PANEL "A"



DATE 10-11-44
SECTION

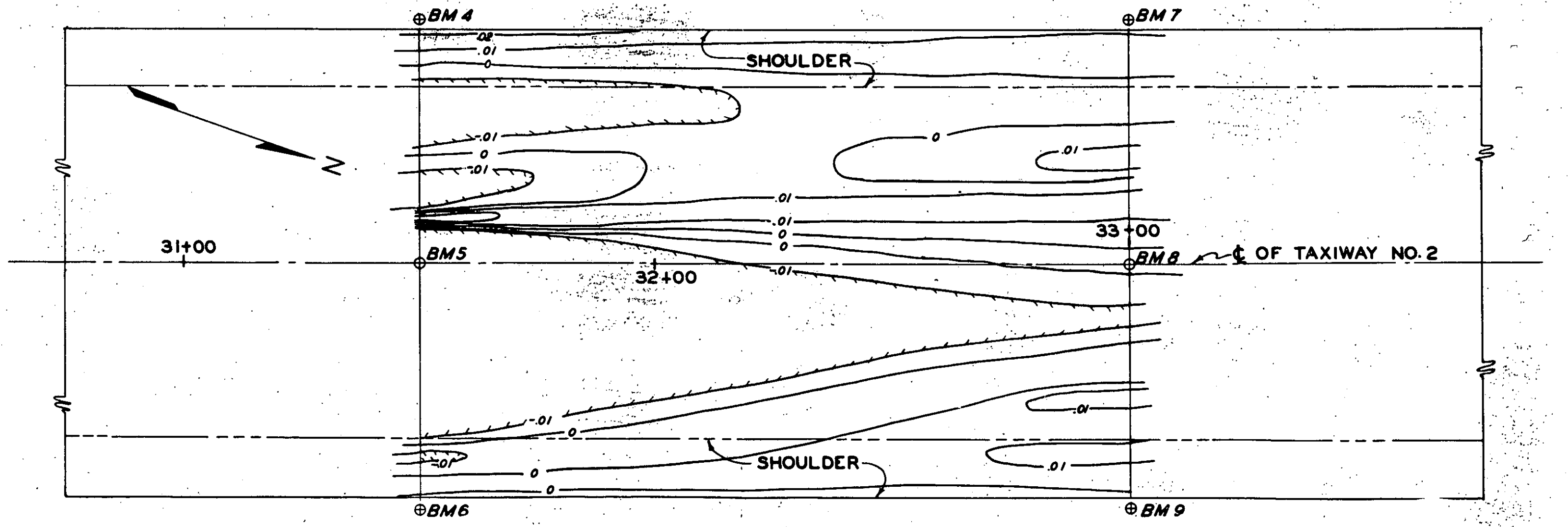
PANEL "B"



SURVEY 5 OCT. 1944 TO 5 FEB. 1945
FOR TEST AREAS A AND B.

TEST AREA A

CONTOUR INTERVAL = ONE HUNDREDTH OF A FOOT



TEST AREA B

FROST INVESTIGATION
CASPER AIRBASE, CASPER, WYO.

FROST HEAVE CONTOURS
WATER INFILTRATION DATA
TEST AREAS A AND B

SCALE: AS SHOWN

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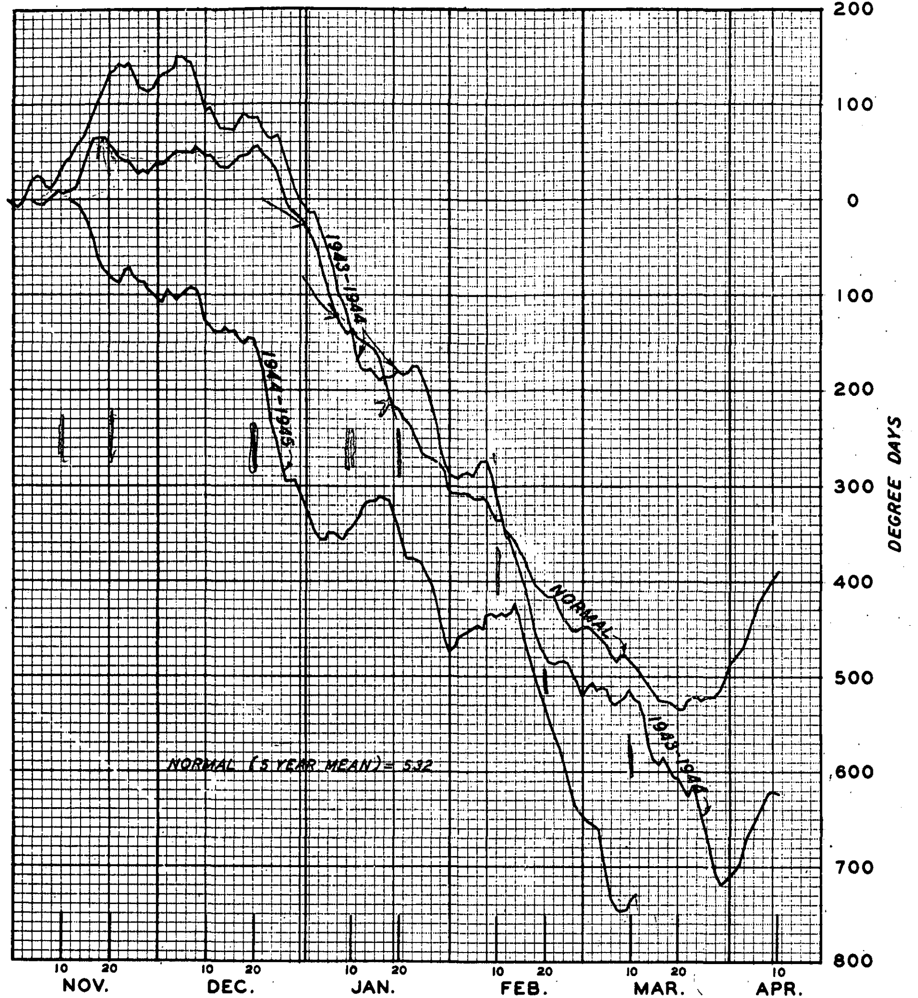
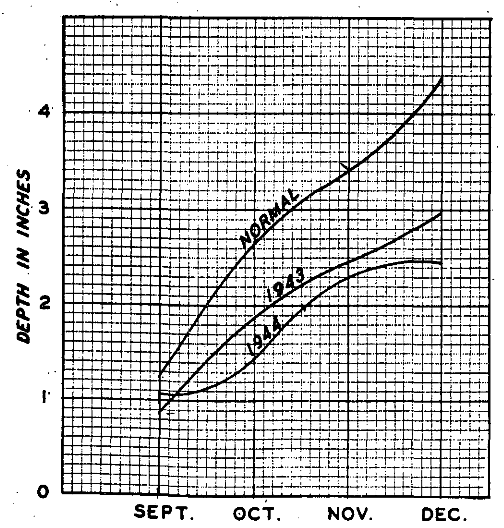
MISSOURI RIVER DIV., OMAHA, NEBR. JUNE, 1945

Normal FI 5774



TOTAL CUMULATIVE DEGREE DAYS BELOW 32°F

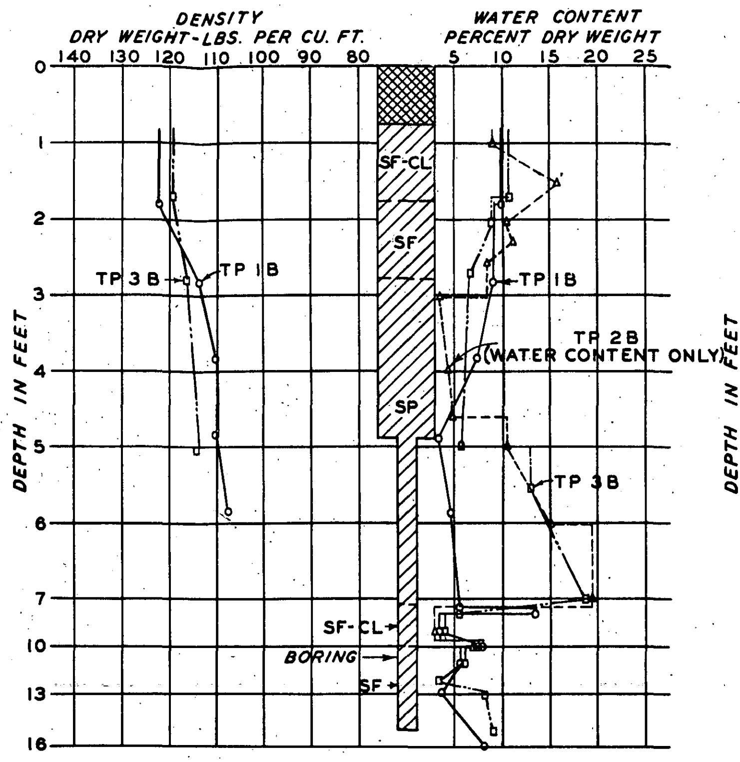


CUMULATIVE PRECIPITATION (MONTHLY)

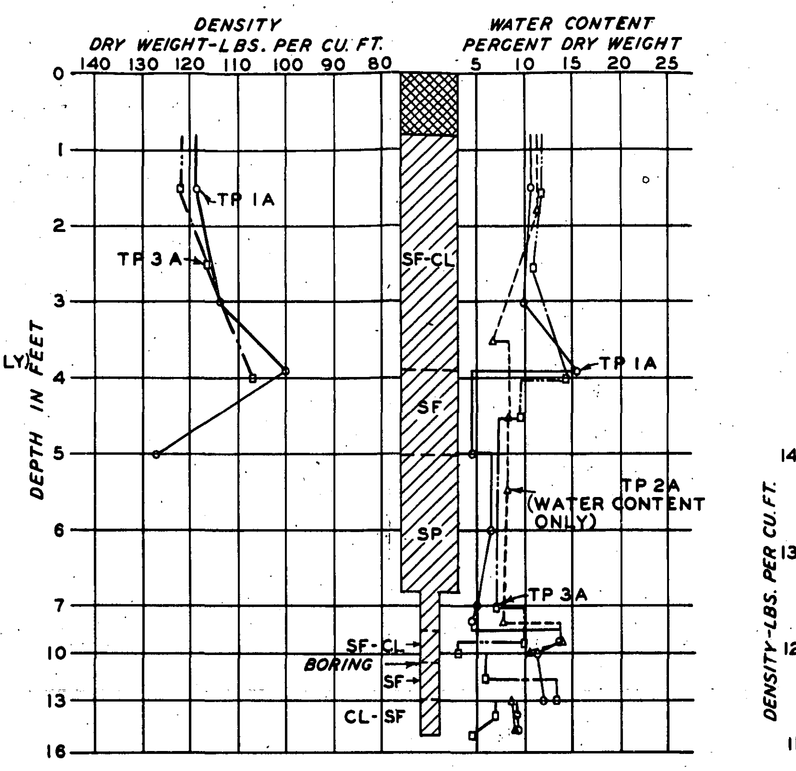
SNOWFALL 1944-1945			
MONTH	PRECIP-ITATION INCHES	DEPARTURE FROM NORMAL INCHES	UNMELTED SNOW INCHES
OCT.	0.35	-0.94	3.1
NOV.	0.88	+0.09	8.3
DEC.	0.55	0.0	7.3
JAN.	0.25	- 0.35	4.4
FEB.	0.49	- 0.27	8.2
MAR.	0.88	- 0.30	10.2

41.5

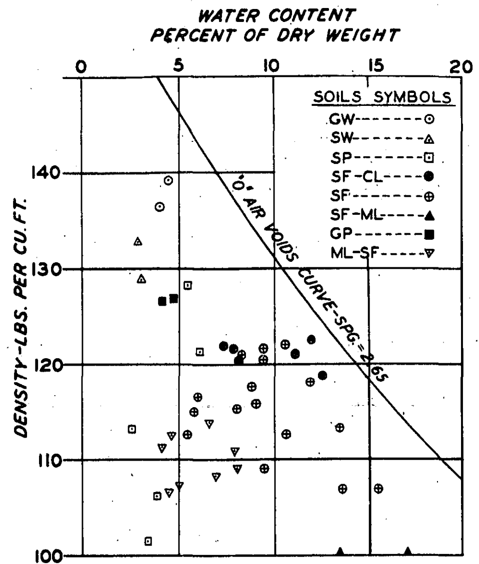
.35
.88
1.23



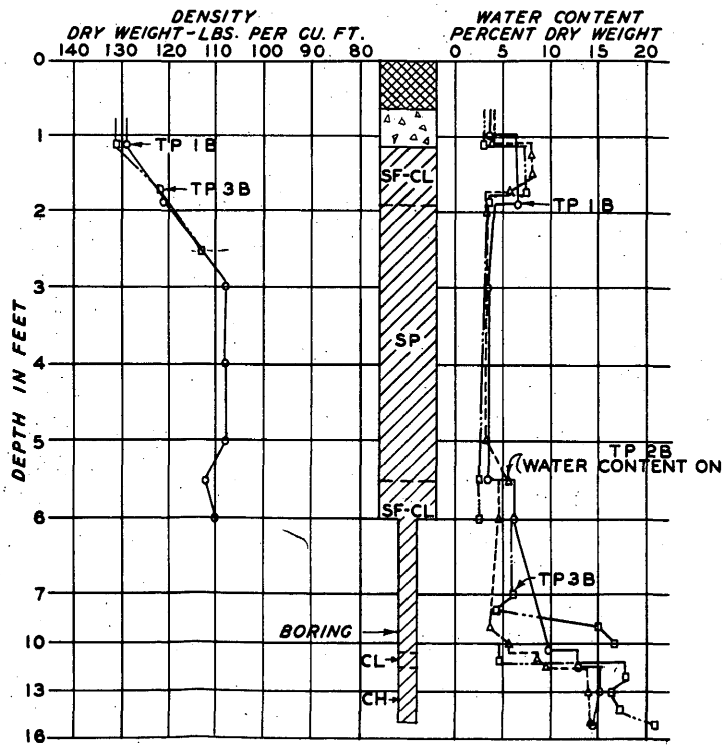
TEST AREA	TEST PIT	STATION	DATE	SYMBOL
A	TP 1B	2+26	10 OCT.1944	○
A	TP 2B	2+26	16 JAN.1945	△
A	TP 3B	2+26	21 MAR.1945	□



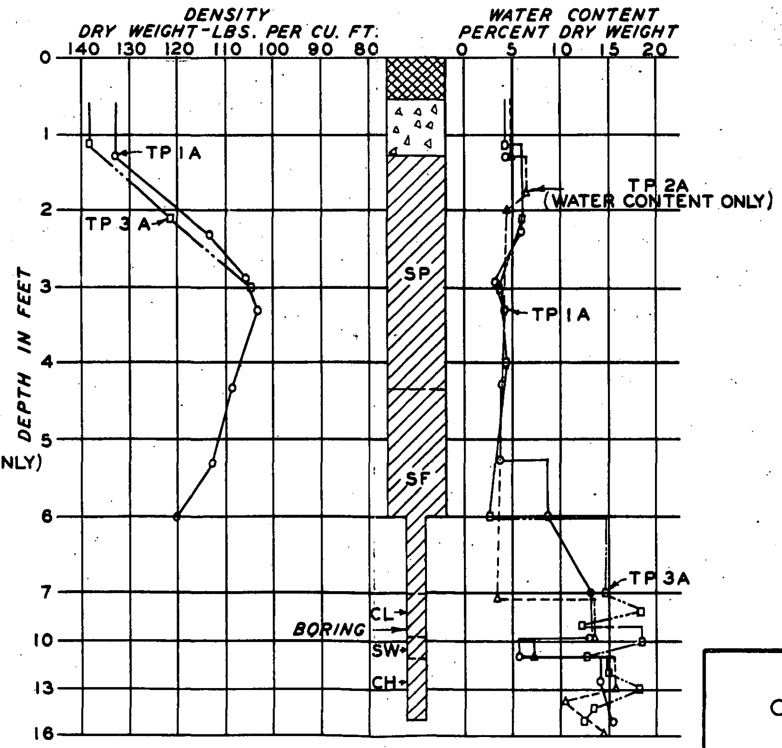
TEST AREA	TEST PIT	STATION	DATE	SYMBOL
A	TP 1A	3+15	9 OCT.1944	○
A	TP 2A	3+15	15 JAN.1945	△
A	TP 3A	3+15	21 MAR.1945	□



NATURAL DENSITY VS. NATURAL WATER CONTENT



TEST AREA	TEST PIT	STATION	DATE	SYMBOL
B	TP 1B	32+25	14 OCT.1944	○
B	TP 2B	32+31	17 JAN.1945	△
B	TP 3B	32+15	20 MAR.1945	□



TEST AREA	TEST PIT	STATION	DATE	SYMBOL
B	TP 1A	33+25	15 OCT.1944	○
B	TP 2A	33+31	17 JAN.1945	△
B	TP 3A	33+15	20 MAR.1945	□

LEGEND

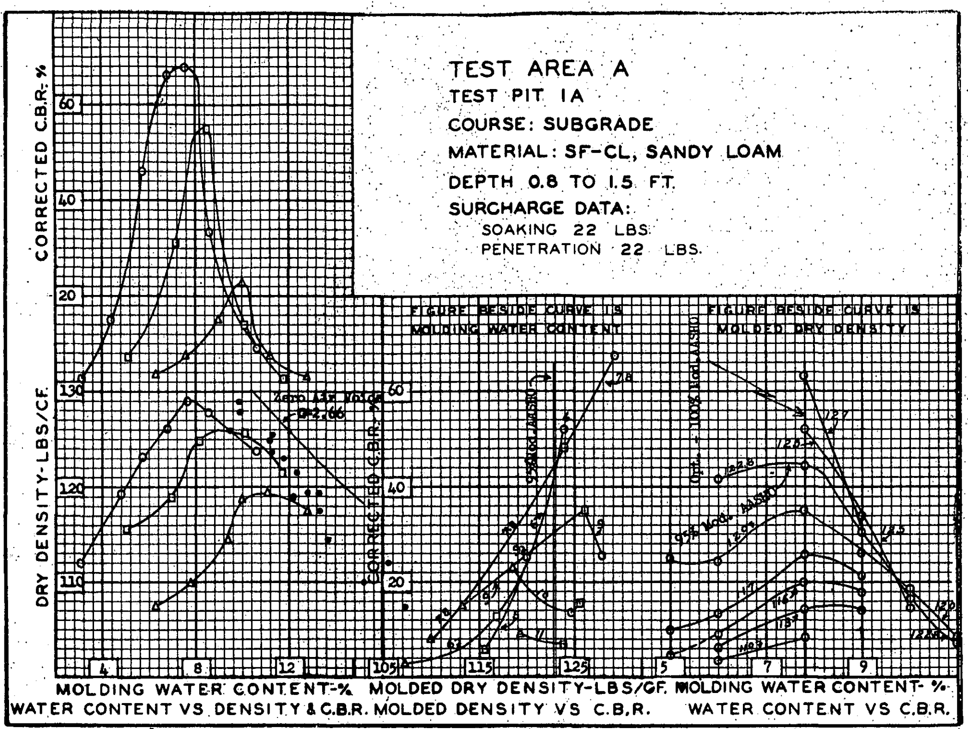
▩	*PAVEMENT*
△	*BASE*
▨	*SUBGRADE*

FROST INVESTIGATION
CASPER AIRBASE, CASPER, WYO.

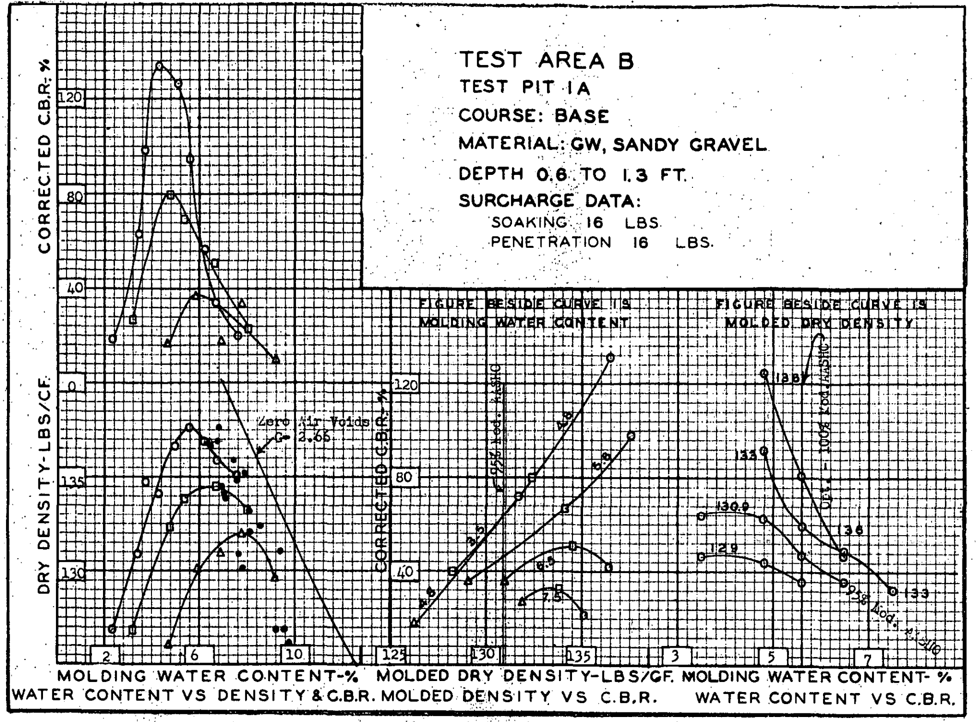
WEATHER, WATER CONTENT AND DENSITY DATA

SCALE: AS SHOWN

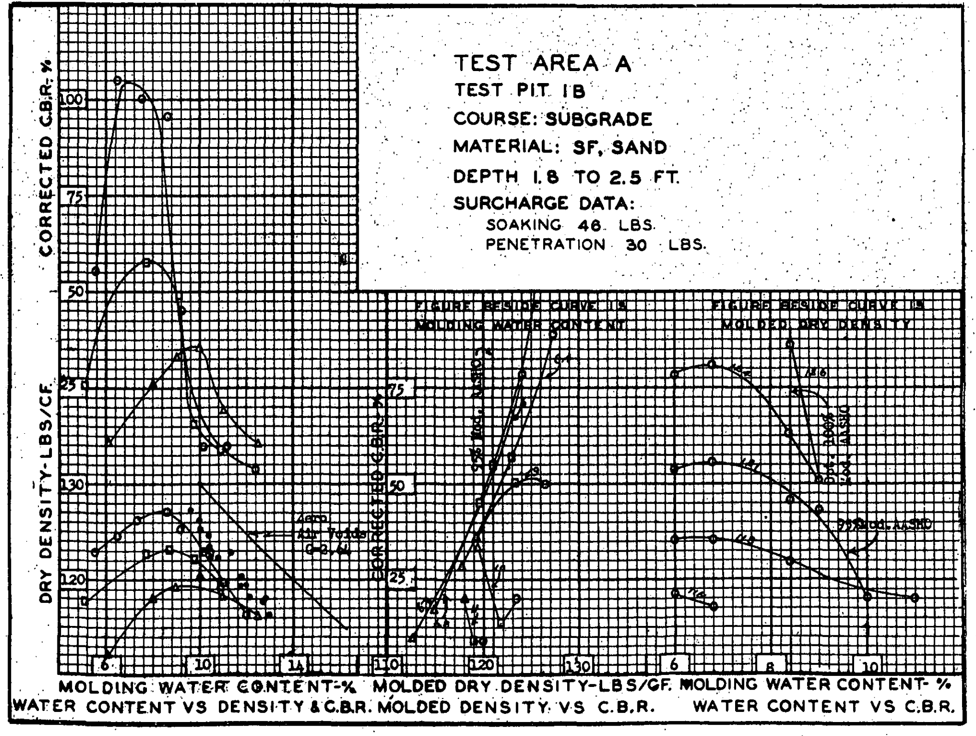
MISSOURI RIVER DIV., OMAHA, NEBR.
JUNE, 1945



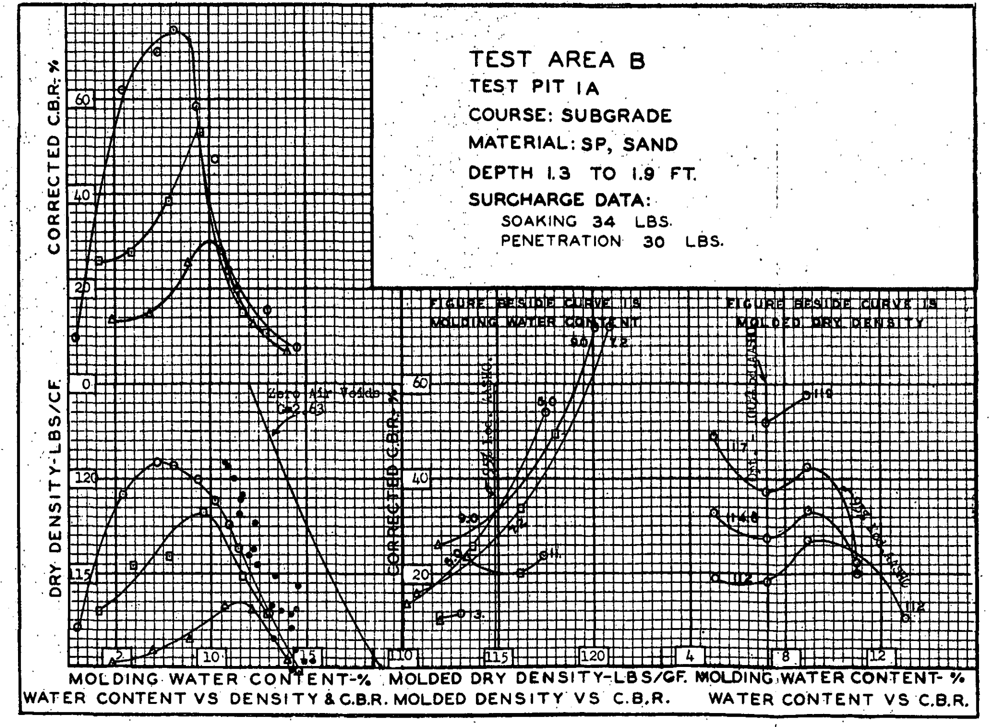
TEST AREA A
TEST PIT 1A
COURSE: SUBGRADE
MATERIAL: SF-CL, SANDY LOAM
DEPTH 0.8 TO 1.5 FT.
SURCHARGE DATA:
SOAKING 22 LBS.
PENETRATION 22 LBS.



TEST AREA B
TEST PIT 1A
COURSE: BASE
MATERIAL: GW, SANDY GRAVEL
DEPTH 0.6 TO 1.3 FT.
SURCHARGE DATA:
SOAKING 16 LBS.
PENETRATION 16 LBS.



TEST AREA A
TEST PIT 1B
COURSE: SUBGRADE
MATERIAL: SF, SAND
DEPTH 1.8 TO 2.5 FT.
SURCHARGE DATA:
SOAKING 46 LBS.
PENETRATION 30 LBS.



TEST AREA B
TEST PIT 1A
COURSE: SUBGRADE
MATERIAL: SP, SAND
DEPTH 1.3 TO 1.9 FT.
SURCHARGE DATA:
SOAKING 34 LBS.
PENETRATION 30 LBS.

LEGEND

- ○ 55 BLOWS PER LAYER
- □ 25 BLOWS PER LAYER
- △ 10 BLOWS PER LAYER
- ● WATER CONTENT, TOP INCH

GENERAL NOTES:
ALL SPECIMENS SOAKED TOP AND BOTTOM FOR 4 DAYS.
ALL SPECIMENS COMPACTED IN 5 LAYERS, 10 LB. HAMMER, 18" DROP, IN CBR MOLD.

FROST INVESTIGATION
CASPER AIR BASE, CASPER, WYOMING

CALIFORNIA BEARING RATIO STUDIES

SCALE: AS SHOWN 302

MISSOURI RIVER DIVISION, OMAHA, NEBR. JUNE, 1945

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FROST INVESTIGATION
SUMMARY OF SOIL AND PAVEMENT TEST DATA
FARGO MUNICIPAL AIRFIELD, FARGO, NORTH DAKOTA
TEST AREA A

TEST PIT	DATE	TYPE	DEPTH IN FEET	SOIL DATA														C.B.R. DATA										
				SOIL CLASS.	GRAIN SIZE %Finer than indicated grain size								ATTERBERG LIMITS			NATURAL DENSITY		FIELD IN-PLACE TESTS			UNDISTURBED CYL. TESTS			REMOLDED TESTS-100% DENSITY				
					0.005 mm	0.02 mm	0.05 mm	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	LIQUID LIMIT	PLASTIC INDEX	SPECIFIC GRAVITY	WATER CONTENT %DryWt	UNIT WEIGHT p.c.f.	WATER CONTENT %DryWt.	DENSITY p.c.f.	C.B.R. 0.1" Pen.	WATER CONTENT %DryWt.	DENSITY p.c.f.	C.B.R. "0.1" Pen.	WATER CONTENT BEFORE SOAKING	WATER CONTENT AFTER SOAKING	% SWELL	DENSITY p.c.f.	C.B.R. 0.1" Pen.
																					— — S O A K E D — —							
1A	10-'44	Surface	0.0 - 0.1	Asph.																								
		Base	0.1 - 0.6	Soil-Cement												10.0(2)	122(2)	10.0(2)	122(2)	—								
		Subgr.	0.6 - 1.5	CL-SF	9	16	21	30	50	91	96	97	30	12	2.70	9.8(4)	127(4)	9.8(4)	127(4)	19(4)	10.5(2)	126(2)	27(2)					
			1.5 - 2.5	OH-CH	22	45	57	65	75	91	98	100	64	29	2.57	22.7(2)	90(2)	22.7(2)	90(2)	8.3(2)	27.2(2)	88(2)	9.0(2)					
			2.5 - 3.2	CH	57	87	94	96	97	99	100	--	73	40	2.64	31.7(2)	88(2)	31.7(2)	88(2)	4.3(3)	32.2(2)	88(2)	6.8(2)					
			3.2 - 4.3	CH	63	91	97	99	99	100	--	--	76	47	2.70	28.6(2)	90(2)	28.6(2)	90(2)	3.1(3)	28.1(2)	91(2)	4.0(2)					
			4.3 - 5.0	CH												30.1(2)	92(2)	30.1(2)	92(2)	3.3(2)								
			5.0 - 6.0	CH														~~32.8~~	—	—								
1B	10-'44	Surface	0.0 - 0.1	Asph.																								
		Base	0.1 - 0.7	Soil-Cement												12.2(2)	122(2)	12.2(2)	122(2)									
		Subgr.	0.7 - 1.5	CL-SF	7	11	16	22	42	92	100	--	31	12	2.67	11.3(4)	124(4)	11.3(4)	124(4)	7.2(2)	11.9(2)	124(2)	11(2)					
			1.5 - 2.4	OH-CH	32	56	68	75	84	97	100	--	62	31	2.52	30.7(2)	88(2)	30.7(2)	88(2)	6.0(2)	24.8(2)	93(2)	10(2)					
			2.4 - 3.2	CH	43	75	88	92	97	99	100	--	75	47	2.66	33.1(2)	86(2)	33.1(2)	86(2)	4.9(2)	32.2(2)	88(2)	5.3(2)					
			3.2 - 4.2	CH	64	92	98	99	99	99	100	--	80	56	2.69	31.3(2)	86(2)	31.3(2)	86(2)	3.7(2)	32.2(2)	86(2)	4.0(2)					
			4.2 - 5.0	CH												31.9(2)	90(2)	31.9(2)	90(2)	4.4(2)								
			5.0 - 6.0	*CH														~~30.7~~										
			6.0 - 7.0	*CH														~~30.9~~		19.								
2A	2-'45	Surface	0.0 - 0.1	Asph.																								
		Base	0.1 - 0.6	Soil-Cement														10.5(2)										
		Subgr.	0.6 - 1.6	*SF														9.8(4)										
			1.6 - 2.5	*OH-CH														24.7(4)		6.5								
			2.5 - 3.5	*CH														33.4(4)										
			3.5 - 6.0	*CH														~~29.1(4)~~	FP									
			6.0 - 7.0	*CH														34.1										
2B	2-'45	Surface	0.0 - 0.1	Asph.																								
		Base	0.1 - 0.6	Soil-Cement														13.9(2)										
		Subgr.	0.6 - 1.5	*SF														11.1(3)										
			1.5 - 2.4	*OH-CH														30.1(4)										
			2.4 - 4.0	*CH														~~37.5(5)~~	FP									
			4.0 - 7.0	*CH														34.0(4)										

OCT 11-17

3 19 4
76
.14
6|9.0
15

96.3
32.1

87.3
3|262

83
6.0
14
7.0

65.7
34.3

Sub-Base CBR = 76 (19×4)
14.4 (7.2×2)
6|90.4
15

Subgrade CBR = 8.3
6.0
2|14.3
7.1

*Field Classification

SHEET 1 OF 2 TABLE 2

FROST INVESTIGATION
SUMMARY OF SOIL AND PAVEMENT TEST DATA
FARGO MUNICIPAL AIRFIELD, FARGO, NORTH DAKOTA
TEST AREA A

TEST PIT	DATE	TYPE	DEPTH IN FEET	SOIL DATA														C.B.R. DATA										
				SOIL CLASS.	GRAIN SIZE %Finer than indicated grain size								ATTERBERG LIMITS			NATURAL DENSITY		FIELD IN-PLACE TESTS			UNDISTURBED CYL. TESTS			REMOLDED TESTS-100% DENSITY				
					0.005 mm	0.02 mm	0.05 mm	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	LIQUID LIMIT	PLASTIC INDEX	SPECIFIC GRAVITY	WATER CONTENT %DryWt	UNIT WEIGHT p.c.f.	WATER CONTENT %DryWt.	DENSITY p.c.f.	C.B.R. 0.1" Pen.	WATER CONTENT %Dry Wt.	DENSITY p.c.f.	C.B.R. 0.1" Pen.	WATER CONTENT BEFORE SOAKING	WATER CONTENT AFTER SOAKING	% SWELL	DENSITY p.c.f.	C.B.R. 0.1" Pen.
3A	4-'45	Surface	0.0 - 0.1	Asph.																								
		Base	0.1 - 0.6	Soil-Cement												9.7(3)	120(3)	9.7(3)	120(3)									
		Subgr.	0.6 - 1.6	*CL-SF												10.7(2)	133(2)	10.7(2)	133(2)	12(2)								
			1.6 - 2.4	*OH-CH												24.3(2)	97(2)	24.3(2)	97(2)	5.4(2)								
	April 10-13th		2.4 - 3.7	*CH												29.0(2)	97(2)	29.0(2)	97(2)	4.9(2)								
			3.7 - 4.3	*CH												36.6(2)	84(2)	36.6(2)	84(2)	4.2(2)								
			4.3 - 5.0	*CH												~~29.1(2)~~	~~91(2)~~	~~29.1(2)~~	~~91(2)~~	~~2.1(2)~~								
			5.0 - 6.0	*CH														~~30.9(2)~~	~~—~~									
			6.0 - 7.0	*CH														37.9										
3B	4-'45	Surface	0.0 - 0.1	Asph.																								
		Base	0.1 - 0.7	Soil-Cement												12.6(3)	120(3)	12.6(3)	120(3)									
		Subgr.	0.7 - 1.5	*CL-SF												11.3(2)	128(2)	11.3(2)	128(2)	5.9(3)								
			1.5 - 2.5	*CH-OH												29.6(2)	95(2)	29.6(2)	95(2)	3.8(2)								
			2.5 - 3.4	*CH												33.0(2)	91(2)	33.0(2)	91(2)	2.5(2)								
			3.4 - 4.4	*CH												37.7(2)	81(2)	37.7(2)	81(2)	5.8(3)								
			4.4 - 6.0	*CH														~~31.0(4)~~	~~—~~	~~2.5(2)~~								
			6.0 - 7.0	*CH														~~29.5~~	—									
			7.0 - 8.0	*CH														35.3	—									

NO FROST

CBR - Subbase = 24.0 (12×2)
17.7 (5.9×3)
5 | 41.7
8.3

CBR - Subgrade = 5.4
4.9
4.2
3.8
2.5
5.8
6 | 26.6
4.45
use 5

3.8
5.4
2 | 9.2
4.5

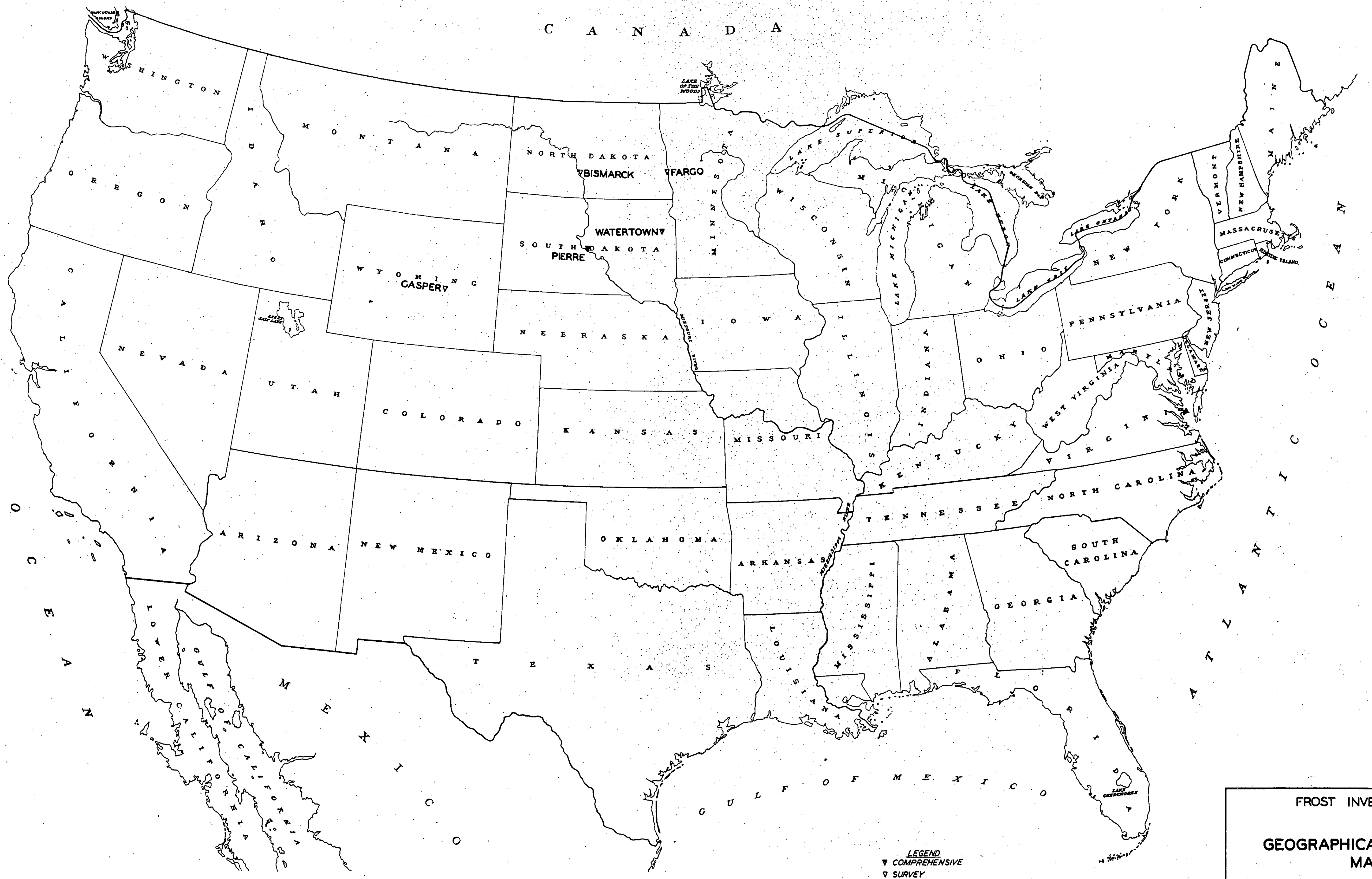
5.9
3
17.7

* Field Classification

SHEET 2 OF 2 TABLE 2

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



FROST INVESTIGATION

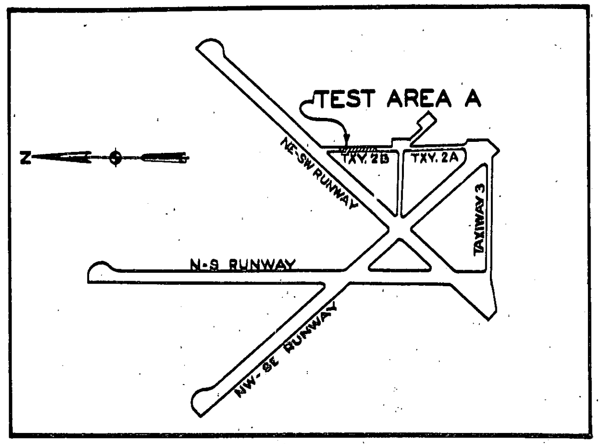
GEOGRAPHICAL LOCATION MAP

100 50 25 0 50 100 200 300
SCALE IN MILES

MISSOURI RIVER DIV., OMAHA, NEBR.

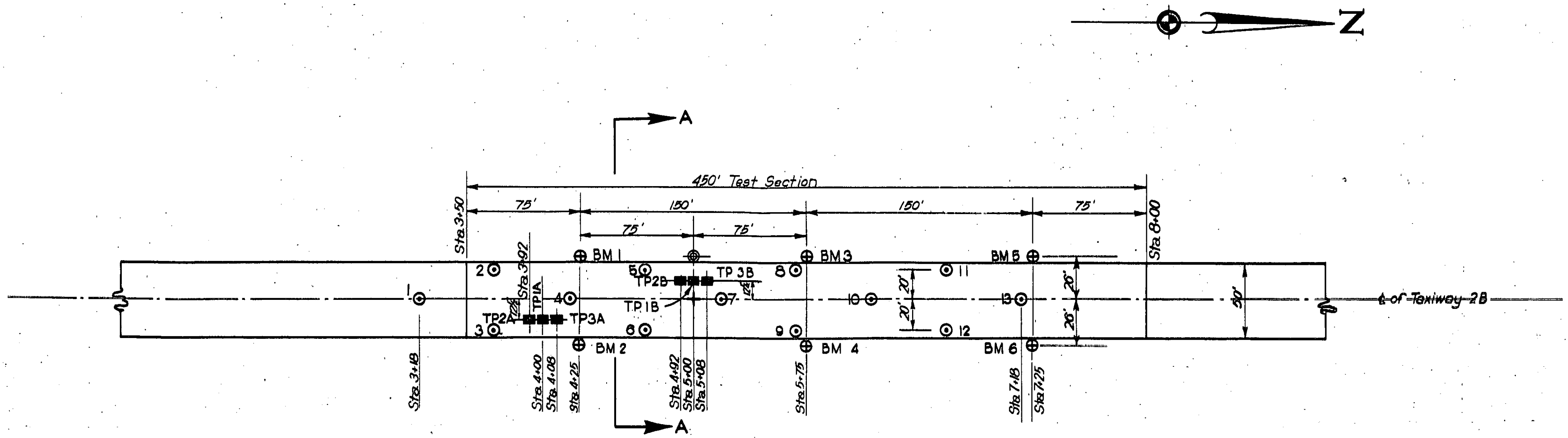
JUNE, 1945

PLATE I



SITE MAP

400 0 400 800
SCALE IN FEET



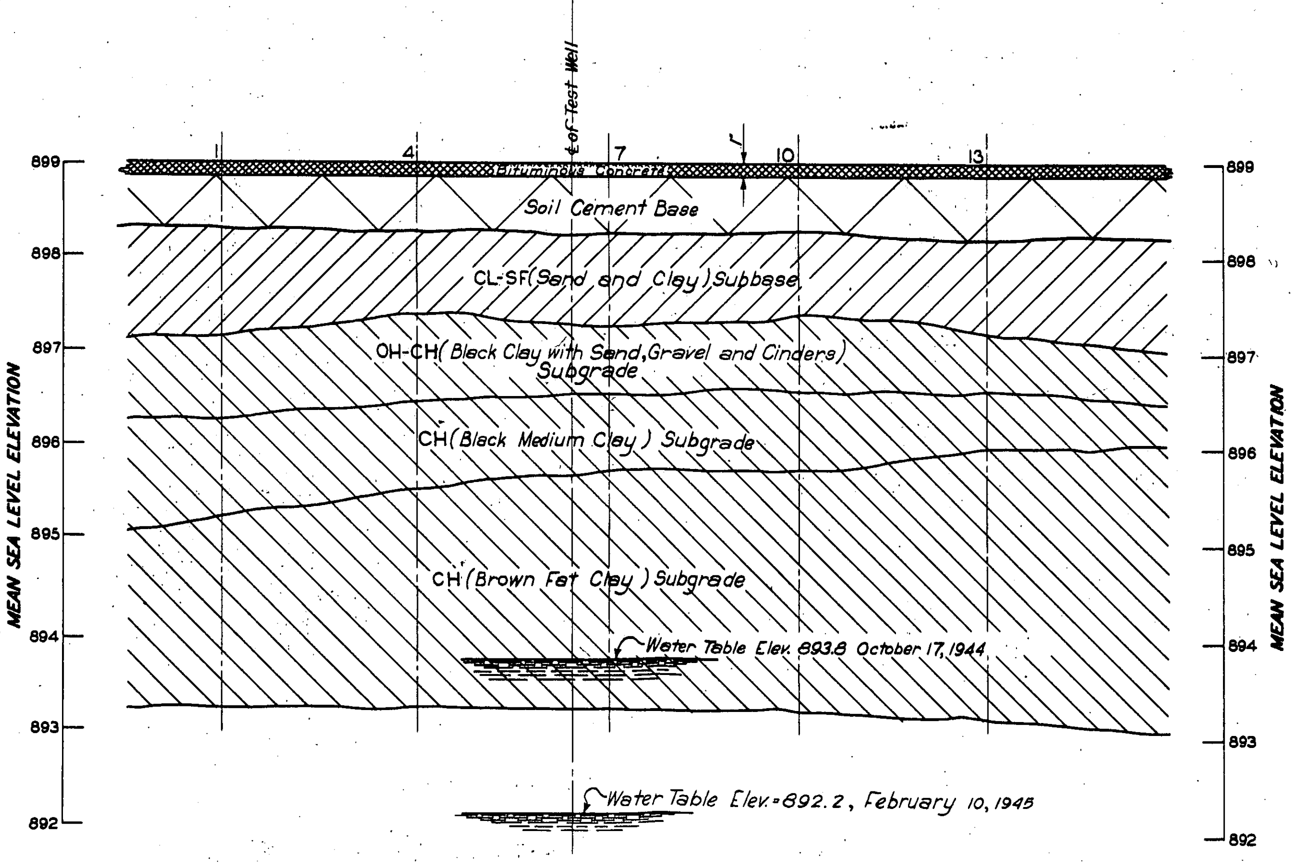
PLAN
TEST AREA A

50 0 50 100
SCALE IN FEET

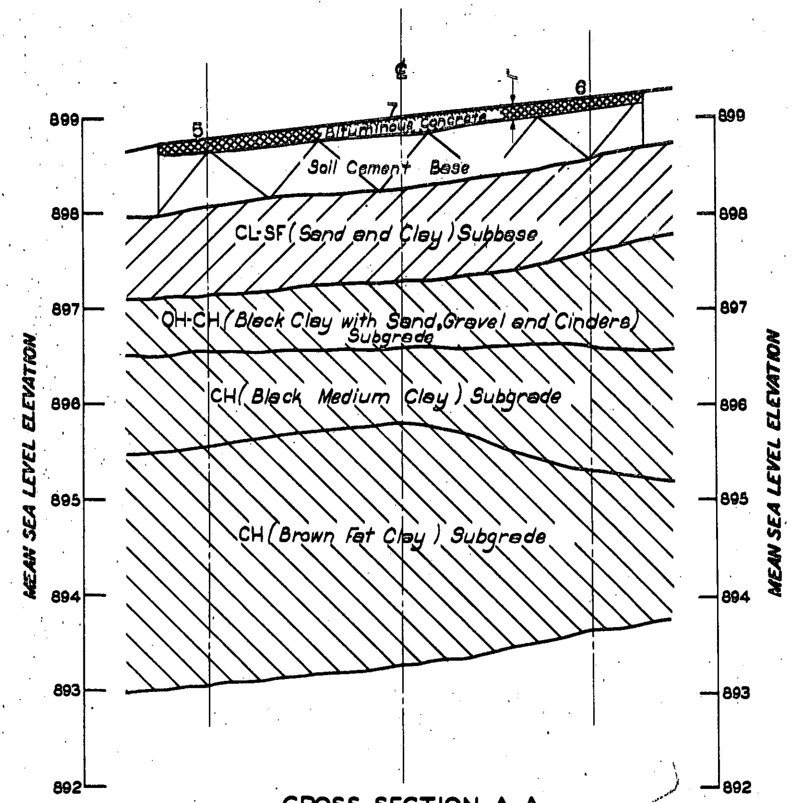
LEGEND

- AUGER BORING ⊙
- TEST PIT ■
- BENCH MARK ⊕
- OBSERVATION WELL ○
- THERMOMETER +

Note:
Pavement thicknesses shown are design thicknesses.



PROFILE ALONG CENTERLINE
TEST AREA A



CROSS SECTION A-A

20 0 20 40
SCALE IN FEET

FROST INVESTIGATION
FARGO MUNICIPAL AIRFIELD
FARGO, NORTH DAKOTA

PLAN AND PROFILE
TEST AREA A

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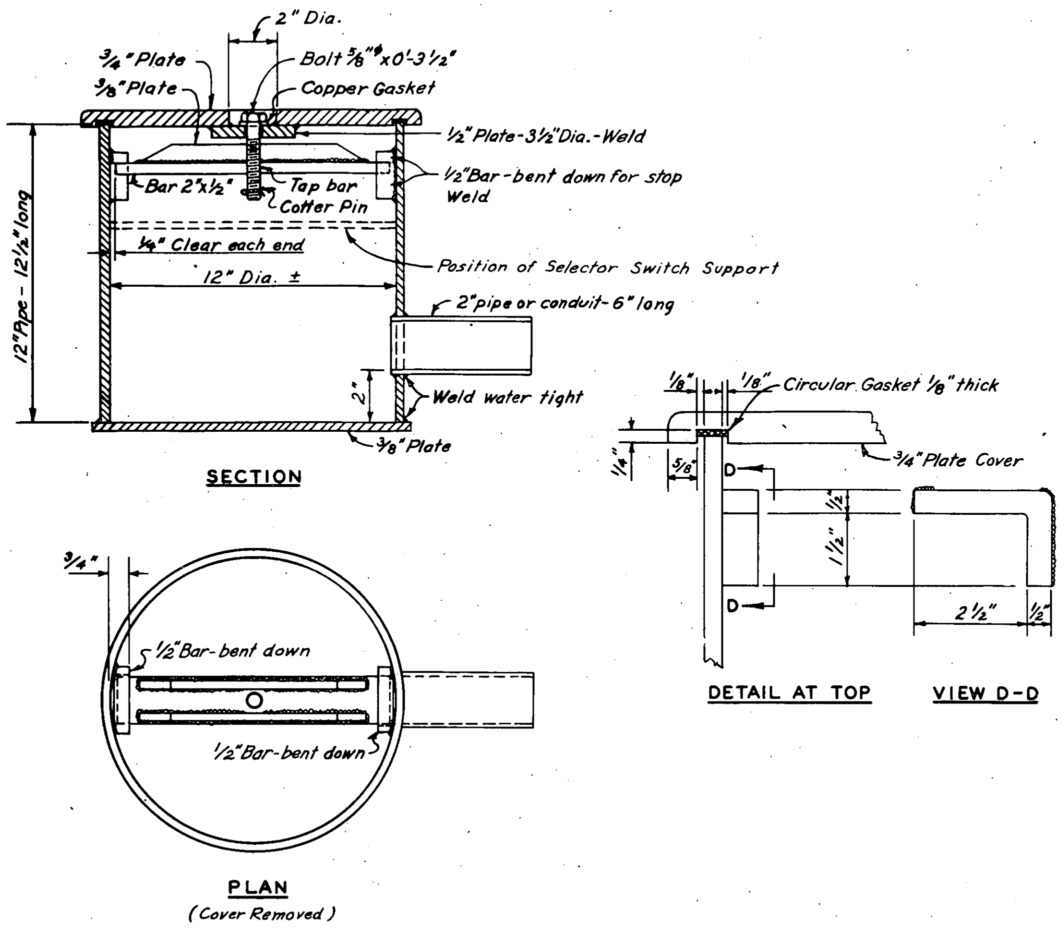
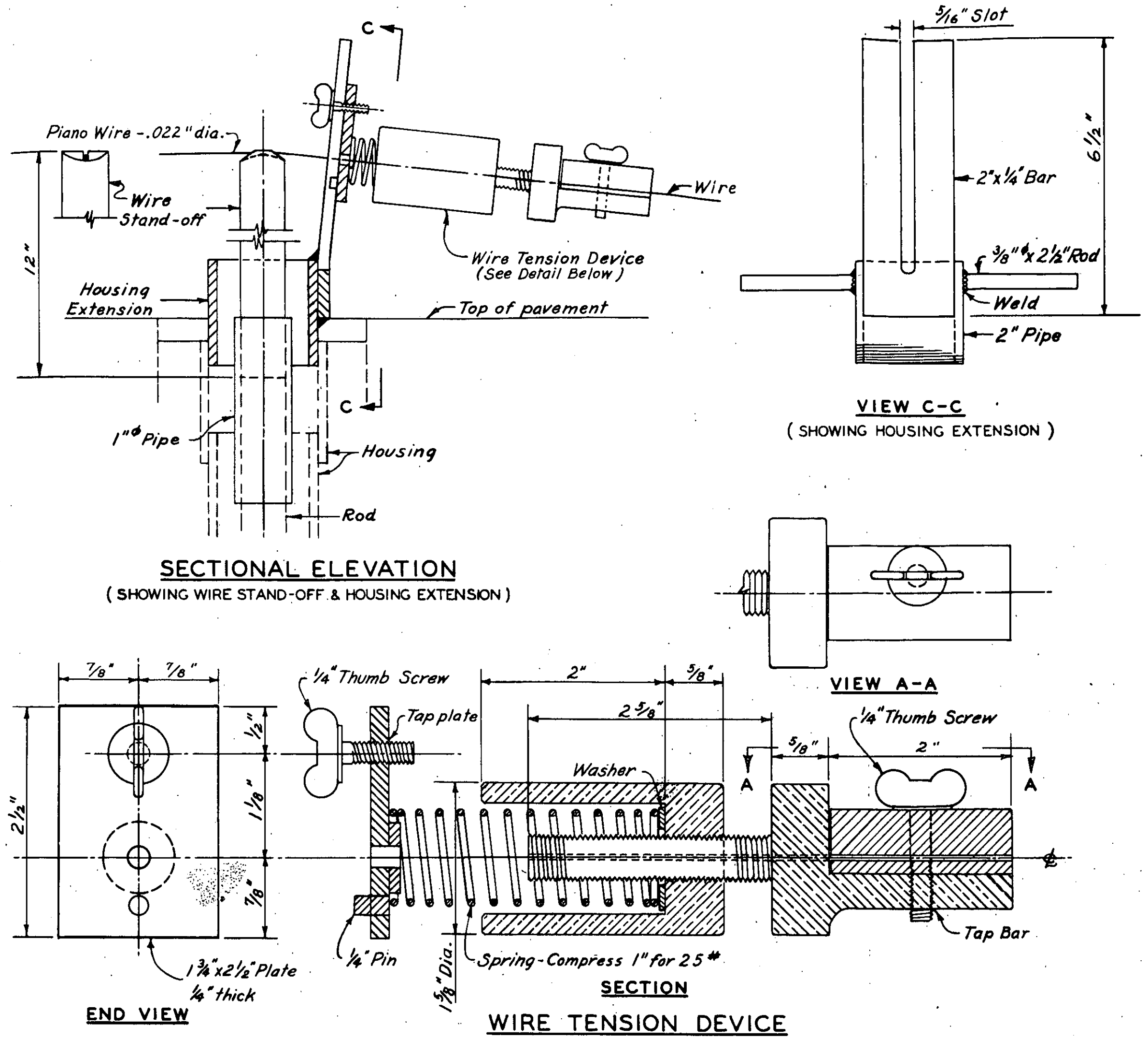
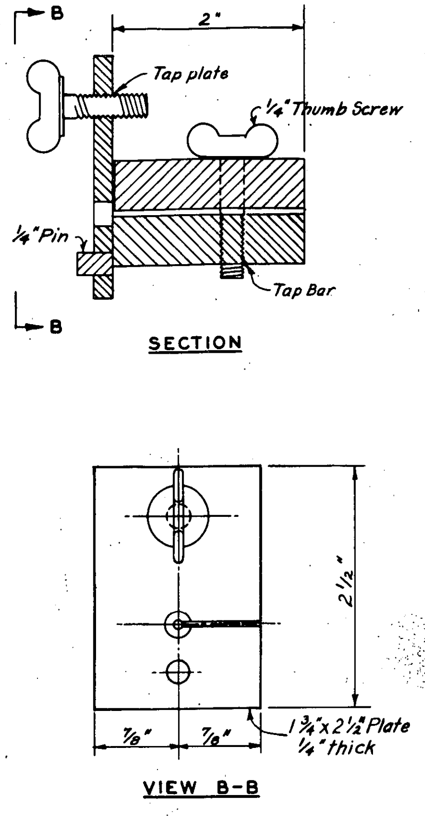
SCALE: AS SHOWN
MISSOURI RIVER DIV., OMAHA, NEBR. JUNE, 1945



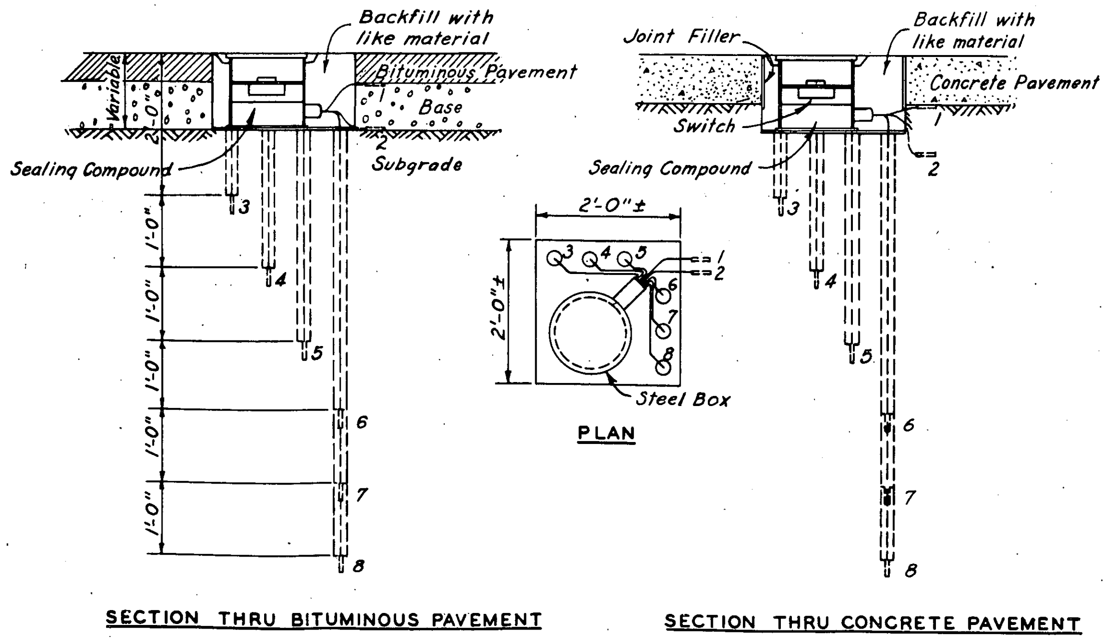
THERMOCOUPLE TERMINAL BOX



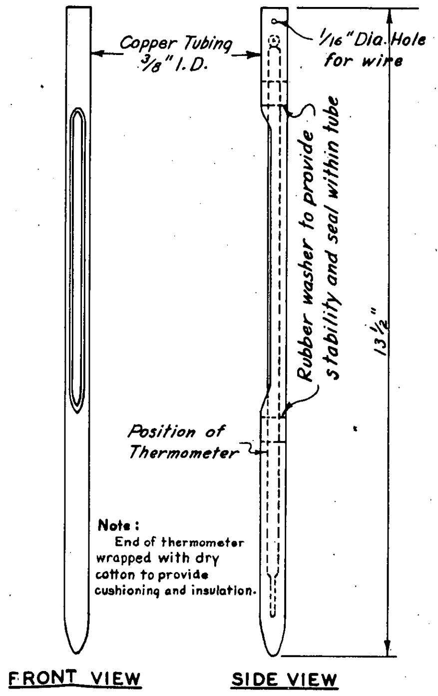
WIRE LINE APPARATUS



WIRE HOLDER

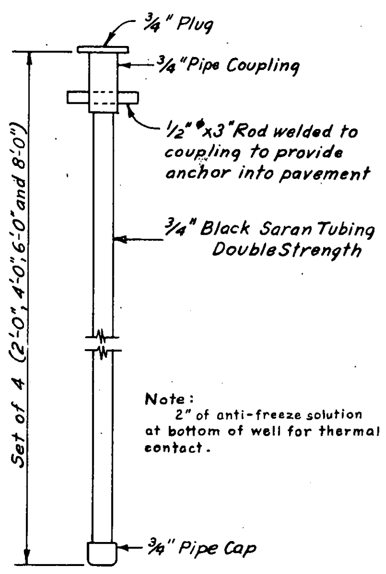


THERMOCOUPLE INSTALLATIONS



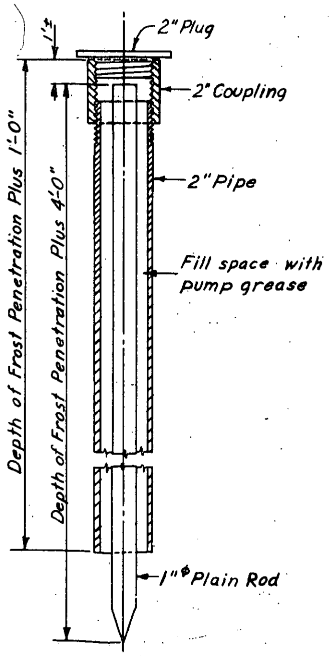
Note: End of thermometer wrapped with dry cotton to provide cushioning and insulation.

THERMOMETER HOLDER



Note: 2" of anti-freeze solution at bottom of well for thermal contact.

THERMOMETER WELL



BENCH MARK

FROST INVESTIGATION

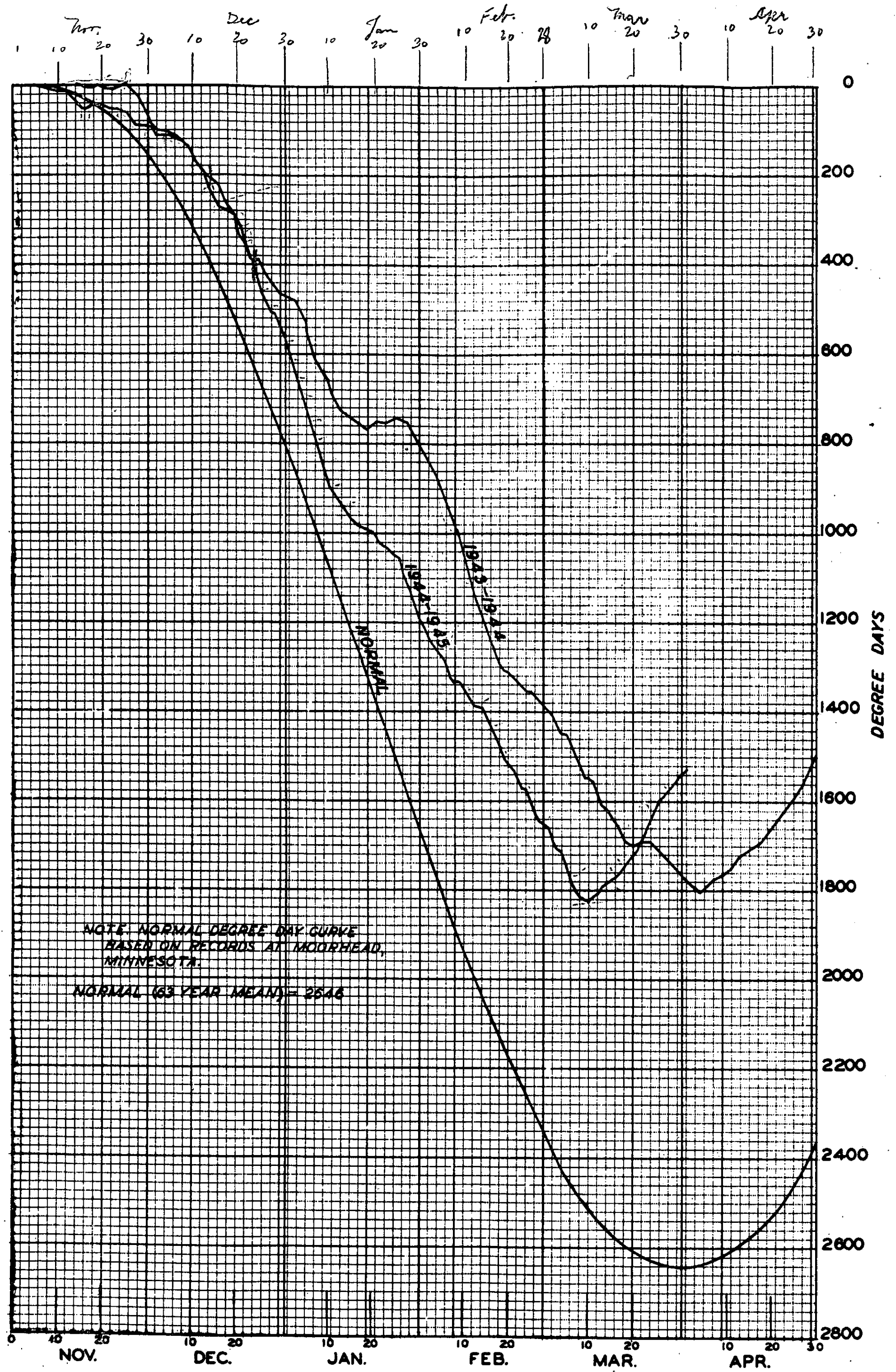
EQUIPMENT DETAILS

MISSOURI RIVER DIV., OMAHA, NEBR. JUNE, 1945

PLATE 3

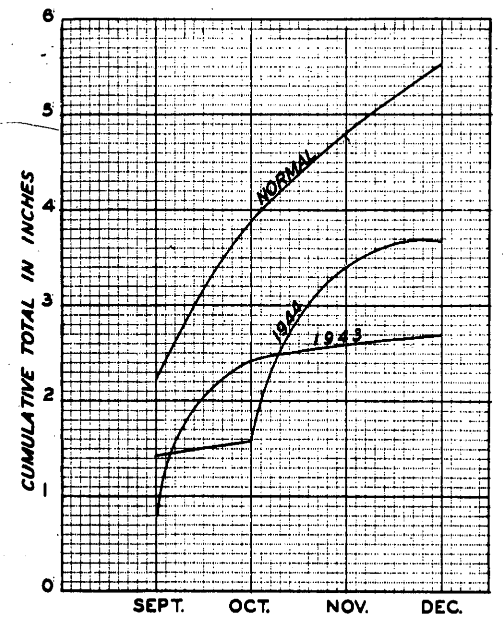
WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

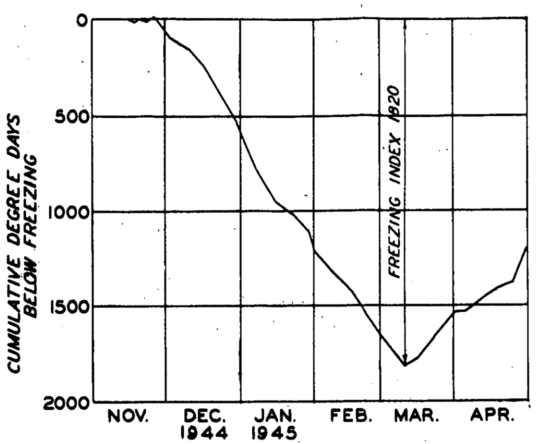


TOTAL CUMULATIVE DEGREE DAYS
BELOW 32°F

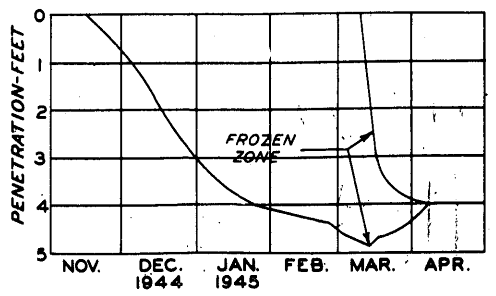
SNOWFALL 1944 - 1945			
MONTH	PRECIP- ITATION INCHES	DEPARTURE FROM NORMAL INCHES	UNMELTED SNOW INCHES
OCT.	0.17	-1.52	0
NOV	1.85	+0.95	5.3
DEC.	0.19	-0.53	3.0
JAN.	0.33	-0.34	4.3
FEB.	0.87	+0.18	8.4
MAR.	1.20	+0.19	1.0



CUMULATIVE PRECIPITATION
(MONTHLY)

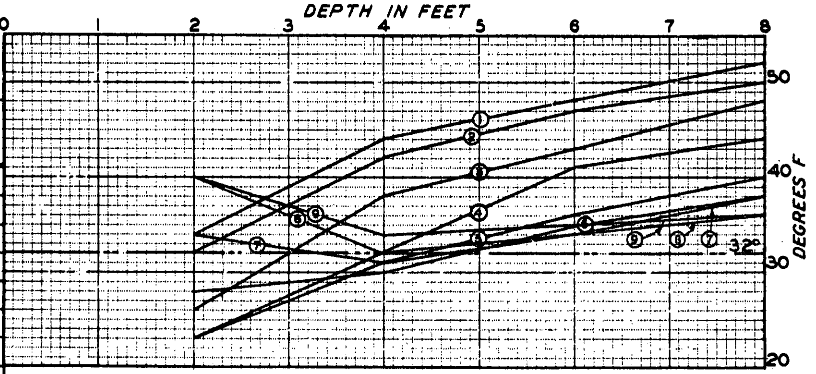


TEMPERATURE VS. TIME

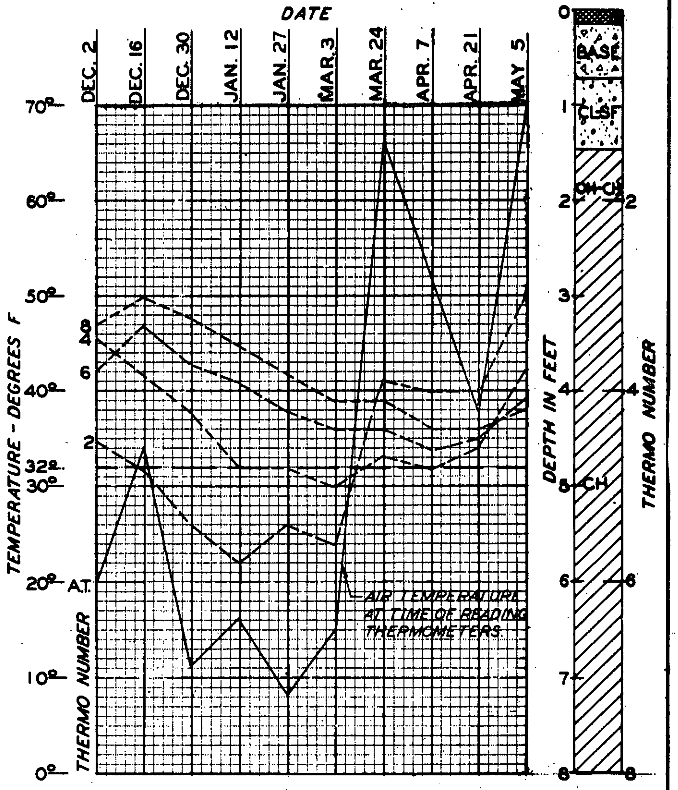


FREEZING TEMPERATURE PENETRATION

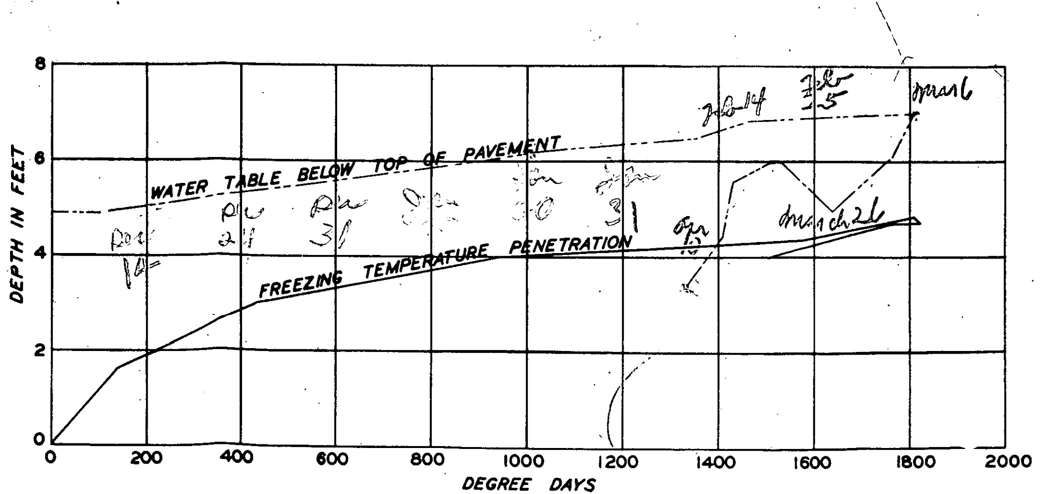
CURVE NO.	DATE	DEGREE DAYS	AIR TEMPER- ATURE
1	12-9-44	138	26
2	12-16-44	224	34
3	12-30-44	531	11
4	1-13-45	939	21
5	2-24-45	1574	32
6	3-12-45	1806	46
7	3-17-45	1761	49
8	4-7-45	1502	52
9	4-21-45	1406	38



TEST AREA A
SUBSURFACE TEMPERATURES



TEST AREA A - STA. 5+00
TEMPERATURE SUMMARY



FREEZING TEMPERATURE PENETRATION AND WATER TABLE DATA

FROST INVESTIGATION
FARGO MUNICIPAL AIRFIELD
FARGO, NORTH DAKOTA

WEATHER AND SUBSURFACE TEMPERATURE DATA

SCALE: AS SHOWN

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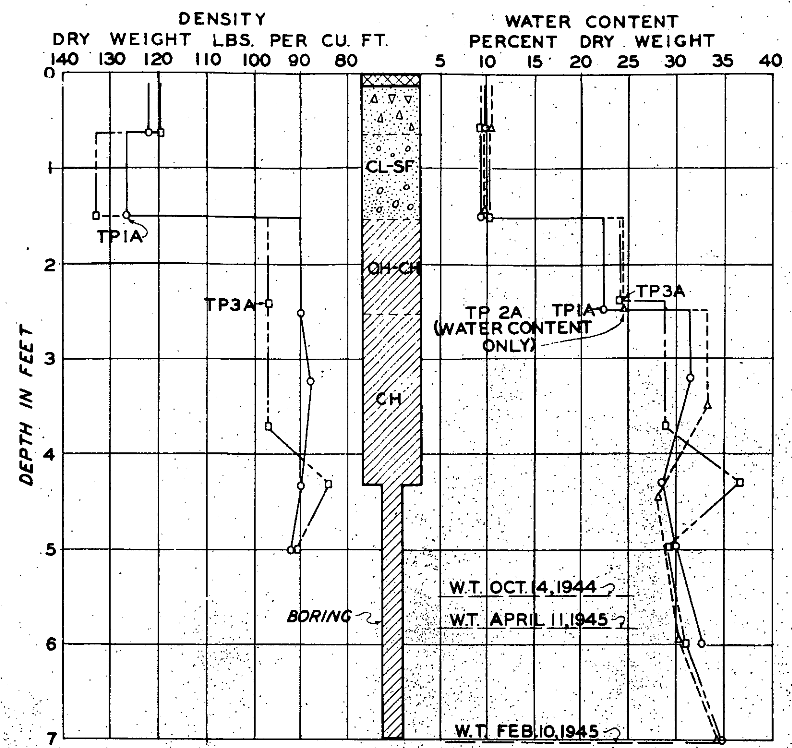
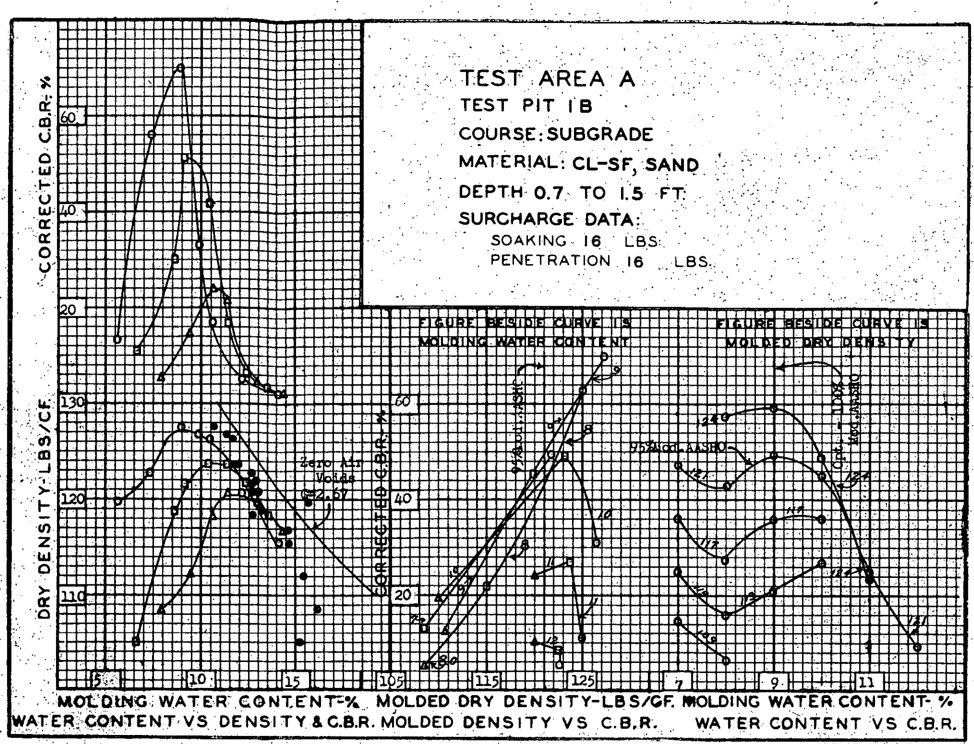
MISSOURI RIVER DIV., OMAHA, NEBR.

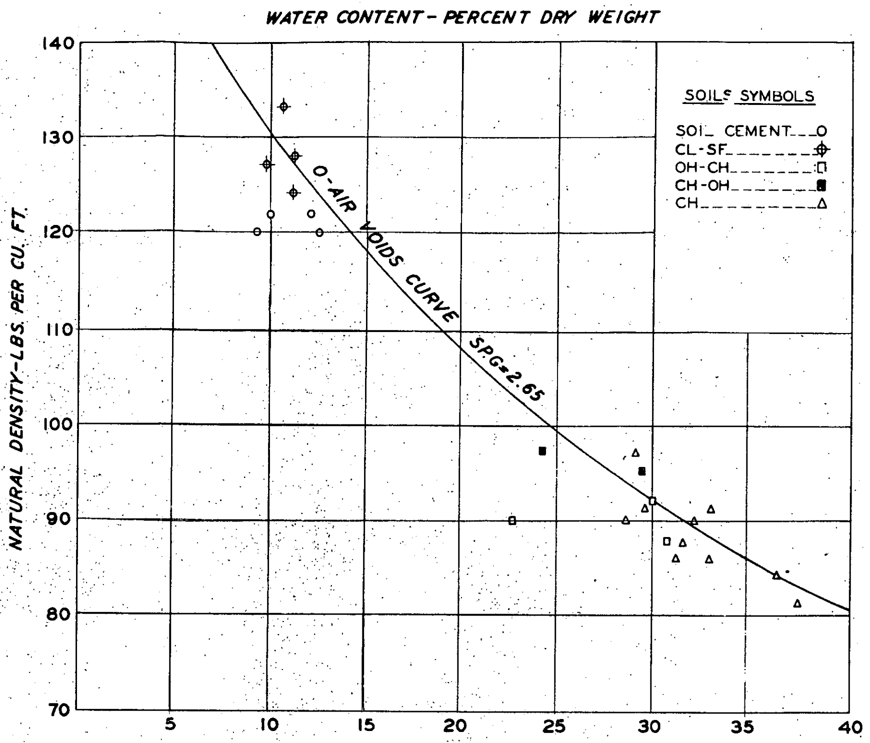
JUNE, 1945

PLATE 4

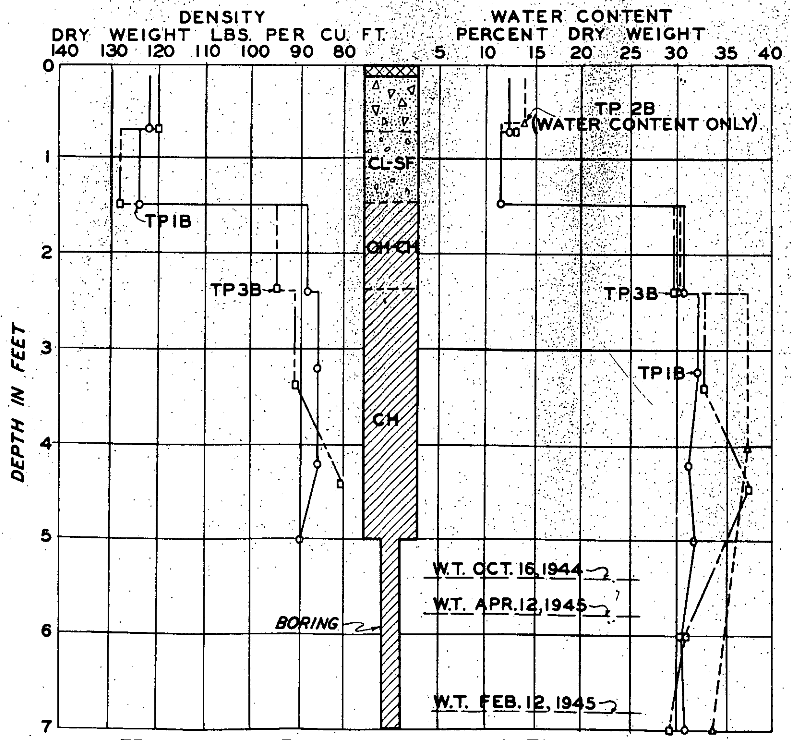


TEST AREA	TEST PIT	STATION	DATE	SYMBOL
A	TP1A	4+00 12½'RT.	10-13-44	○
A	TP2A	3+92 12½'RT.	2-10-45	△
A	TP3A	4+08 12½'RT.	4-12-45	□

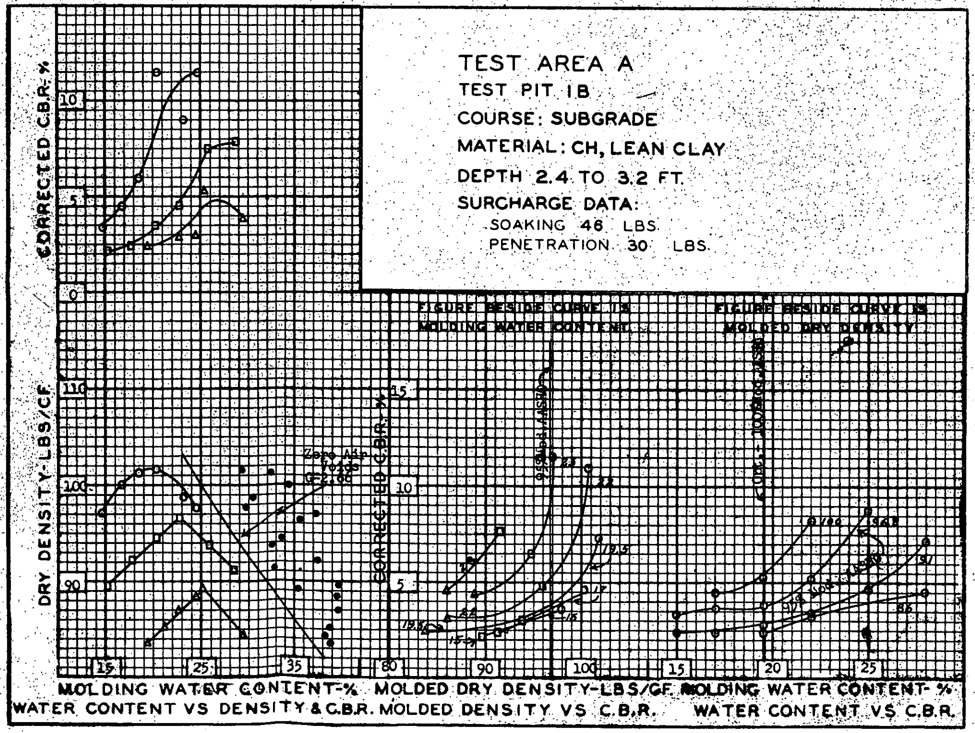




WATER CONTENT VERSUS NATURAL DENSITY



TEST AREA	TEST PIT	STATION	DATE	SYMBOL
A	TP1B	5+00 12½'LT.	10-16-44	○
A	TP2B	4+92 12½'LT.	2-12-45	△
A	TP3B	5+08 12½'LT.	4-11-45	□



LEGEND

DENSITY - WATER CONTENT

- ▩ *PAVEMENT*
- ▦ *SOIL CEMENT BASE*
- ▒ *SUBBASE*
- ▨ *SUBGRADE*

CALIFORNIA BEARING RATIO

- ○ 55 BLOWS PER LAYER
- □ 25 BLOWS PER LAYER
- △ 10 BLOWS PER LAYER
- ● WATER CONTENT, TOP INCH

GENERAL NOTES:

ALL SPECIMENS SOAKED TOP AND BOTTOM FOR 4 DAYS.

ALL SPECIMENS COMPACTED IN 5 LAYERS, 10 LB. HAMMER, 18" DROP, IN CBR MOLD.

FROST INVESTIGATION
FARGO MUNICIPAL AIRFIELD,
FARGO, NORTH DAKOTA

DENSITY, WATER CONTENT DATA CALIFORNIA BEARING RATIO STUDIES

SCALE: AS SHOWN

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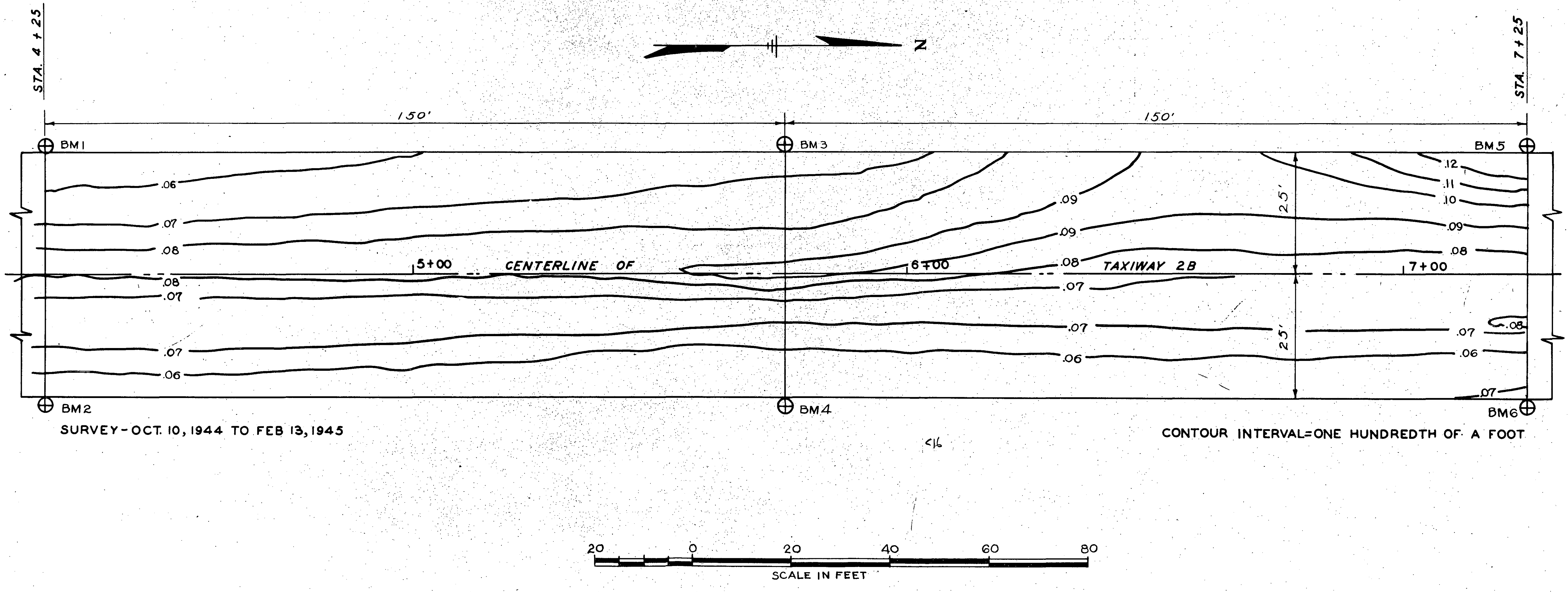
MISSOURI RIVER DIVISION, OMAHA, NEBR. JULY, 1945

WAR DEPARTMENT

CORPS OF ENGINEERS. U.S. ARMY



SURVEY - OCT. 10, 1944 TO FEB 13, 1945

CONTOUR INTERVAL=ONE HUNDREDTH OF A FOOT

<16

FROST INVESTIGATION
FARGO MUNICIPAL AIRFIELD
FARGO, NORTH DAKOTA

FROST HEAVE CONTOURS
TEST AREA A

SCALE: AS SHOWN 271

MISSOURI RIVER DIV., OMAHA, NEBR. JUNE, 1945

PLATE 6

FROST INVESTIGATION
SUMMARY OF SOIL AND PAVEMENT TEST DATA
BISMARCK MUNICIPAL AIRFIELD, BISMARCK, NORTH DAKOTA
TEST AREA A

TEST PIT	DATE	TYPE	DEPTH IN FEET	SOIL DATA														C.B.R. DATA										
				SOIL CLASS.	GRAIN SIZE %Finer than indicated grain size								ATTERBERG LIMITS			NATURAL DENSITY		FIELD IN-PLACE TESTS			UNDISTURBED CYL. TESTS			REMOLDED TESTS-100% DENSITY				
					0.005 mm	0.02 mm	0.05 mm	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	LIQUID LIMIT	PLASTIC INDEX	SPECIFIC GRAVITY	WATER CONTENT %Dry Wt.	UNIT WEIGHT p.c.f.	WATER CONTENT %Dry Wt.	DENSITY p.c.f.	C.B.R. 0.1" Pen.	WATER CONTENT %Dry Wt.	DENSITY p.c.f.	C.B.R. 0.1" Pen.	WATER CONTENT BEFORE SOAKING	WATER CONTENT AFTER SOAKING	% SWELL	DENSITY p.c.f.	C.B.R. 0.1" Pen.
																					--	SOAKED	--					
1A	10-'44	Surface	0.0 - 0.3	Asph.																								
		Base	0.3 - 0.6	SC	4	7	9	10	28	55	59	85	19	4	2.68	4.7(2)	135(2)	4.7(2)	135(2)	32(4)								
		Subgr.	0.6 - 1.5	CL-ML	9	31	55	67	88	99	100	--	29	7	2.64	16.6(2)	102(2)	16.6(2)	102(2)	21(3)	20.4(2)	102(2)	21(2)					
			1.5 - 2.6	CL-ML	8	34	61	71	91	99	100	--	33	10	2.61	16.8(2)	84(2)	16.8(2)	84(2)	5.5(3)	34.0(2)	83(2)	3.0(2)					
			2.6 - 3.6	CL-ML	"	"	"	"	"	"	"	--	"	"	"	17.4(2)	77(2)	17.4(2)	77(2)	3.2(4)	--	--	--					
			3.6 - 4.3	SF-ML	10	28	47	57	91	99	100	--	24	7	2.65	15.0(2)	88(2)	15.0(2)	88(2)	5.6(5)	31.3(2)	88(2)	1.1(2)					
			4.3 - 6.5	SP	6	11	17	21	60	83	91	100	15	0	--	8.1(2)	99(2)	8.1(2)	99(2)	3.5(5)								
			6.5 -11.0	SP	1	3	5	8	9	63	85	100	19	0	--			2.8(3)	--	--								
			11.0 -14.0	SP	1	2	3	4	7	71	82	95	20	0	--													
1B	10-'44	Surface	0.0 - 0.2	Asph.																								
		Base	0.2 - 0.6	SC	5	9	11	14	34	57	69	97	18	1	2.65	4.7(2)	124(2)	4.7(2)	124(2)	15(2)								
		Subgr	0.6 - 1.5	CL-ML	9	33	60	65	88	99	100	--	30	8	2.64	17.9(2)	98(2)	17.9(2)	98(2)	22(2)	23.0(2)	98(2)	18(2)					
			1.5 - 2.5	CL-ML	4	24	55	68	89	99	100	--	30	9	2.63	17.2(2)	83(2)	17.2(2)	83(2)	7.4(3)	31.5(2)	85(2)	3.7(2)					
			2.5 - 3.5	CL-ML	"	"	"	"	"	"	"	--	"	"	"	15.7(2)	80(2)	15.7(2)	80(2)	6.5(3)								
			3.5 - 4.5	CL-ML	"	"	"	"	"	"	"	--	"	"	"	15.9(2)	84(2)	15.9(2)	84(2)	2.4(2)								
			4.5 - 5.3	SF-ML	11	27	45	54	90	99	100	--	25	7	2.68	14.6(2)	92(2)	14.6(2)	92(2)	4.1(5)	26.8(2)	94(2)	2.1(2)					
			5.3 - 8.2	SF	8	11	20	30	91	99	100	--	20	0	--			7.9(3)	--	--								
			8.2 -11.5	GP	1	4	6	7	12	51	71	98	19	0	--			3.9(2)	--	--								
			11.5 -13.7	SP	3	5	7	7	10	85	94	100	26	2	--													
2A	2-'45	Surface	0.0 - 0.3	Asph.																								
		Base	0.3 - 0.6	*SC														4.7										
		Subgr	0.6 - 1.5	*CL-ML														17.5(4)										
			1.5 - 3.1	*CL-ML														19.0(7)										
			3.7 - 4.7	*ML														~~11.0(2)~~										
			4.7 - 6.4	*SF														~~5.9(2)~~										
			6.4 - 7.0	*SP														~~4.8~~										
			7.0 -10.0	*SP														~~3.4(3)~~										
			10.0 -11.5	*SP																								
2B	2-'45	Surface	0.0 - 0.3	Asph.																								
		Base	0.3 - 0.6	*SC														4.7										
		Subgr	0.6 - 4.8	*CL-ML														18.1(13)										
			4.8 - 5.8	*SF-ML														~~14.7~~										
			5.8 - 6.8	*SF														~~7.0~~										
			6.8 - 7.8	*SF														~~4.9~~										
			7.8 - 9.9	*GP														~~3.2(2)~~										
			9.9 -11.5	*SP														~~3.8~~										

* Field Classification

SHEET 1 OF 2 TABLE 2

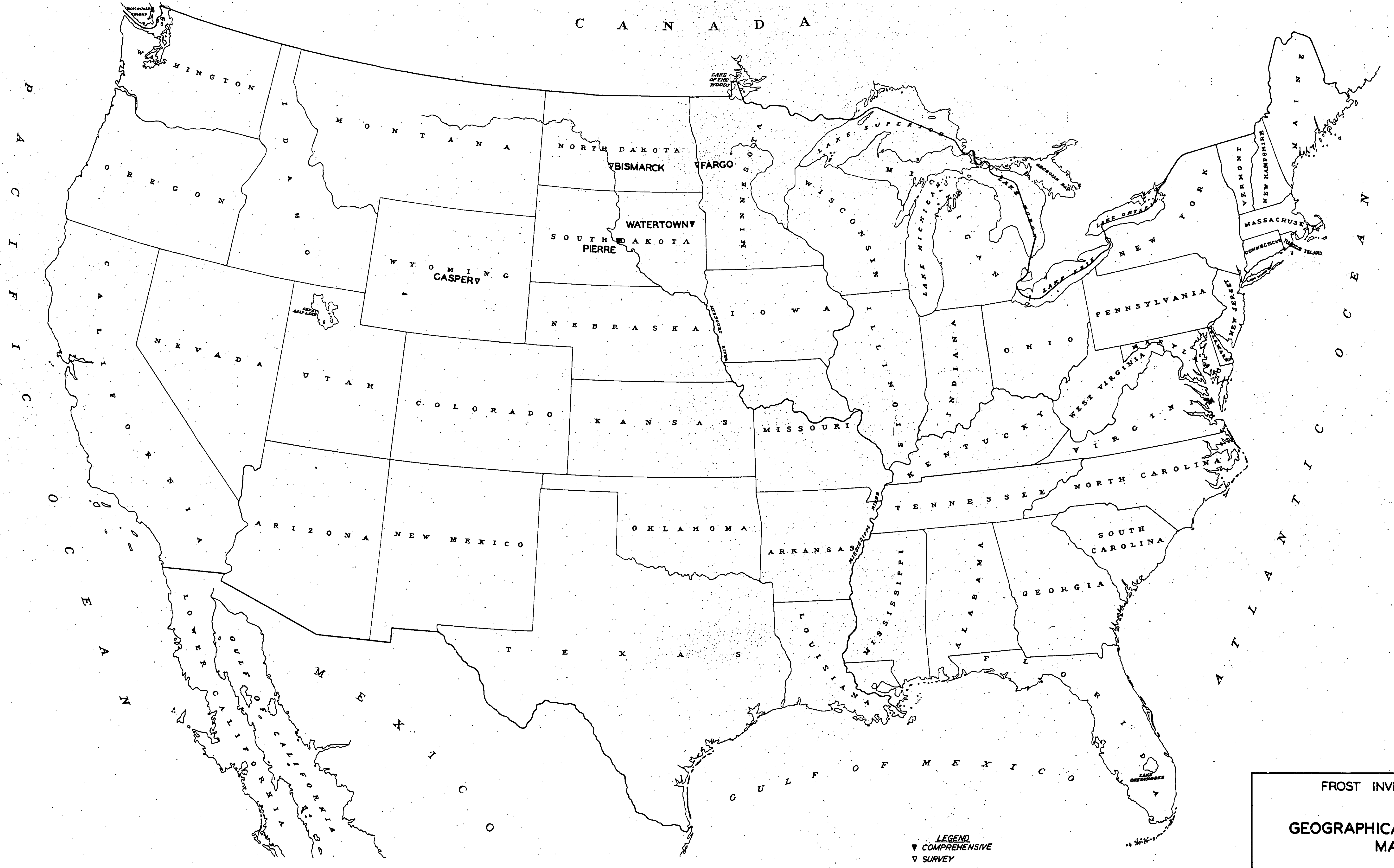
FROST INVESTIGATION
SUMMARY OF SOIL AND PAVEMENT TEST DATA
BISMARCK MUNICIPAL AIRFIELD, BISMARCK, NORTH DAKOTA
TEST AREA A

TEST PIT	DATE	TYPE	DEPTH IN FEET	SOIL DATA															C.B.R. DATA													
				SOIL CLASS.	GRAIN SIZE %Finer than indicated grain size								ATTERBERG LIMITS			NATURAL DENSITY		FIELD IN-PLACE TESTS			UNDISTURBED CYL. TESTS			REMOLDED TESTS-100% DENSITY				
					0.005 mm	0.02 mm	0.05 mm	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	LIQUID LIMIT	PLASTIC INDEX	SPECIFIC GRAVITY	WATER CONTENT %DryWt	UNIT WEIGHT p.c.f.	WATER CONTENT %DryWt.	DENSITY p.c.f.	C.B.R. 0.1" Pen.	WATER CONTENT %DryWt.	DENSITY p.c.f.	C.B.R. 0.1" Pen.	WATER CONTENT BEFORE SOAKING	WATER CONTENT AFTER SOAKING	% SWELL	DENSITY p.c.f.	C.B.R. 0.1" Pen.
3A	4-'45	Surface	0.0 - 0.4	Asph.																								
		Base	0.4 - 0.7	*SC												4.4(2)	133(2)	4.4(2)	133(2)	26(3)								
		Subgr	0.7 - 1.7	*OL-ML												21.4(2)	99(2)	21.4(2)	99(2)	18(2)		M						
			1.7 - 2.9	*OL-ML												21.7(2)	81(2)	21.7(2)	81(2)	4.2(3)								
			2.9 - 4.0	*OL-ML												22.1(2)	83(2)	22.1(2)	83(2)	3.3(2)								
			4.0 - 5.0	*SF-ML												~~13.7(2)~~	~~91(2)~~	~~13.7(2)~~	~~91(2)~~	~~3.3(3)~~								
			5.0 - 6.5	*SP														~~7.2(3)~~	--									
			6.5 - 9.0	*SP														~~3.5(3)~~	~~--~~									
3B	4-'45	Surface	0.0 - 0.3	Asph.																								
		Base	0.3 - 0.6	*SC												5.3(2)	131(2)	5.3(2)	131(2)	23(3)								
		Subgr	0.6 - 1.7	*OL-ML												21.4(2)	100(2)	21.4(2)	100(2)	14(3)								
			1.7 - 2.8	*OL-ML												19.3(2)	86(2)	19.3(2)	86(2)	7.1(2)		M						
			2.8 - 4.0	*OL-ML												20.0(2)	81(2)	20.0(2)	81(2)	4.0(2)								
			4.0 - 5.0	*OL-ML												~~19.5(2)~~	~~86(2)~~	~~19.5(2)~~	~~86(2)~~	~~2.9(3)~~								
			5.0 - 5.5	*SF-ML														~~13.9~~	~~--~~									
			5.5 - 7.0	*SF-ML														~~8.6(2)~~	~~--~~									
			7.0 - 8.0	*SP														~~2.5~~	--									
			8.0 - 9.0	*GP														~~3.0~~	~~--~~									

*Field Classification

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



FROST INVESTIGATION

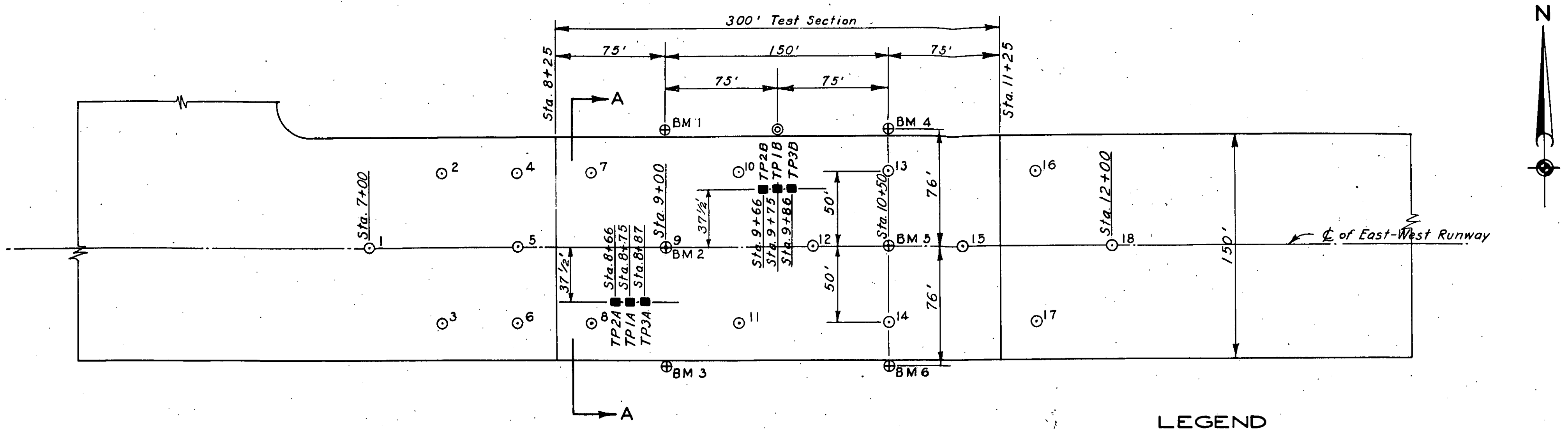
GEOGRAPHICAL LOCATION MAP

100 50 25 0 50 100 200 300
SCALE IN MILES

MISSOURI RIVER DIV., OMAHA, NEBR.

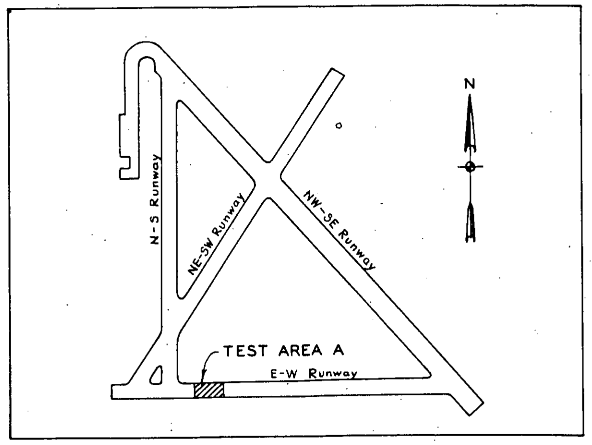
JUNE, 1945

PLATE 1



PLAN-TEST AREA A

50 0 50 100
SCALE IN FEET



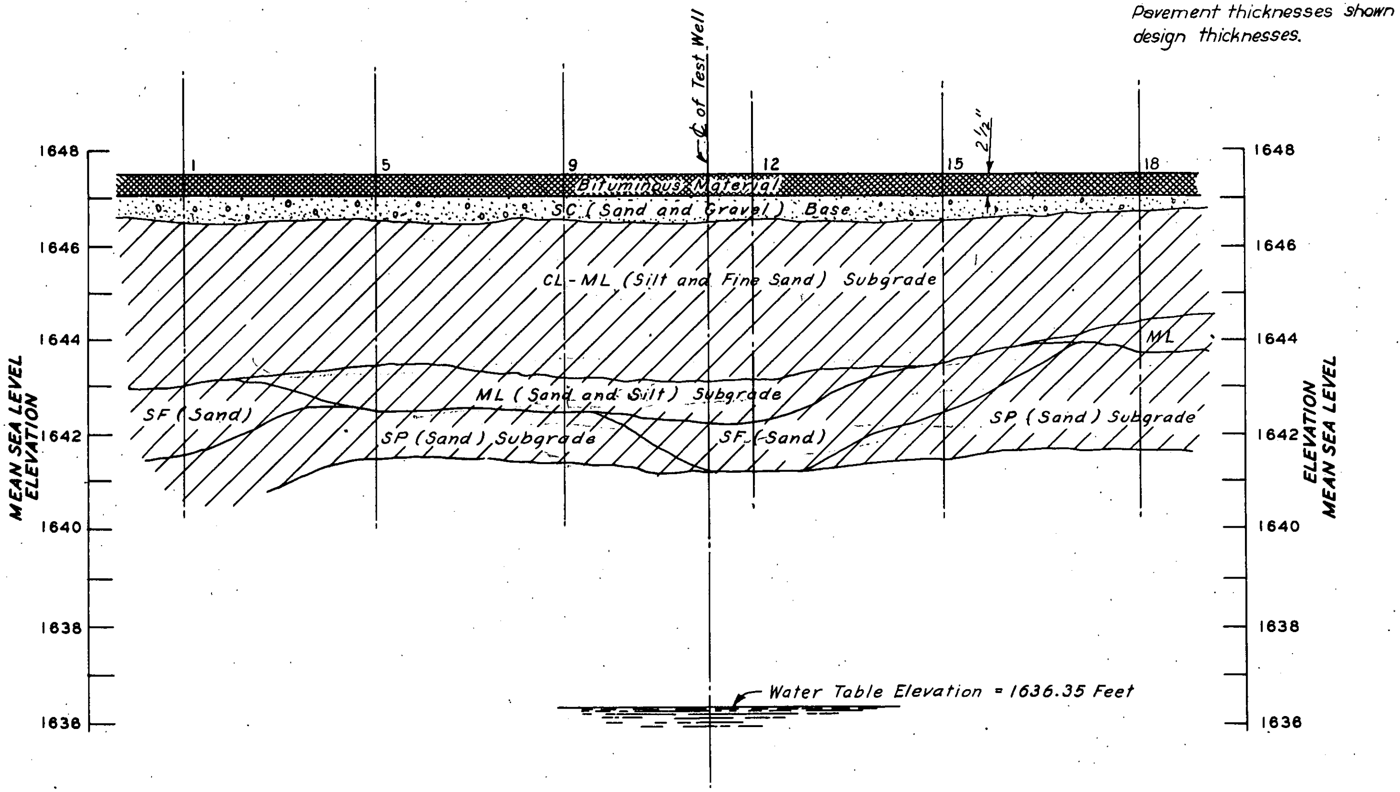
SITE MAP

400 0 400 800
SCALE IN FEET

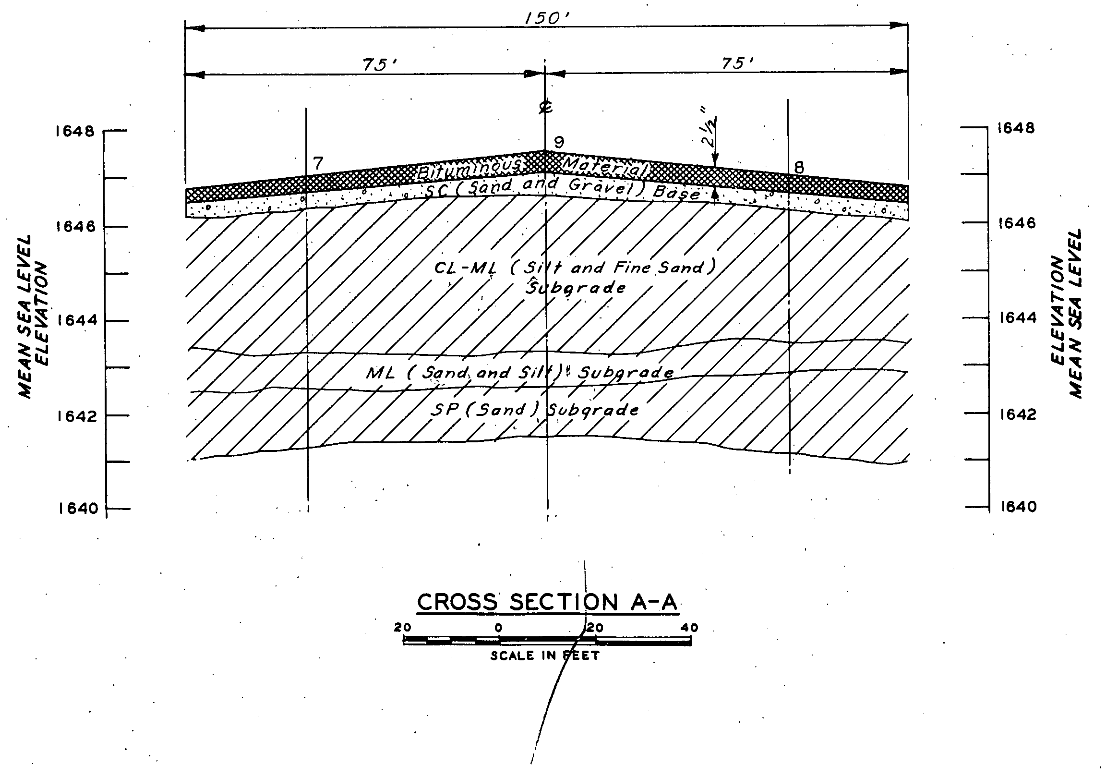
LEGEND

AUGER BORING	⊙
TEST PIT	■
BENCH MARK	⊕
OBSERVATION WELL	◎

Note:
Pavement thicknesses shown are design thicknesses.



CENTER LINE PROFILE
TEST AREA A



CROSS SECTION A-A

20 0 20 40
SCALE IN FEET

FROST INVESTIGATION
BISMARCK MUNICIPAL AIRFIELD
BISMARCK, NORTH DAKOTA

PLAN AND PROFILE
TEST AREA A

SCALE: AS SHOWN

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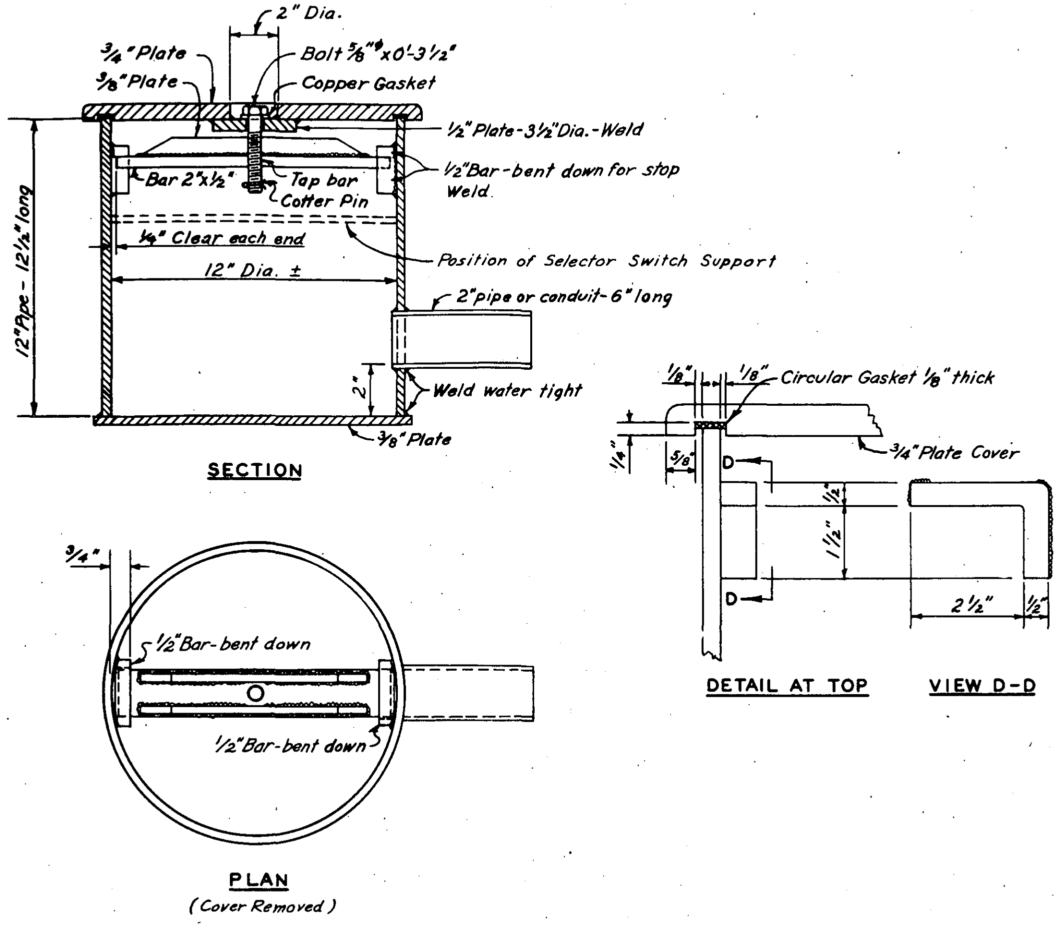
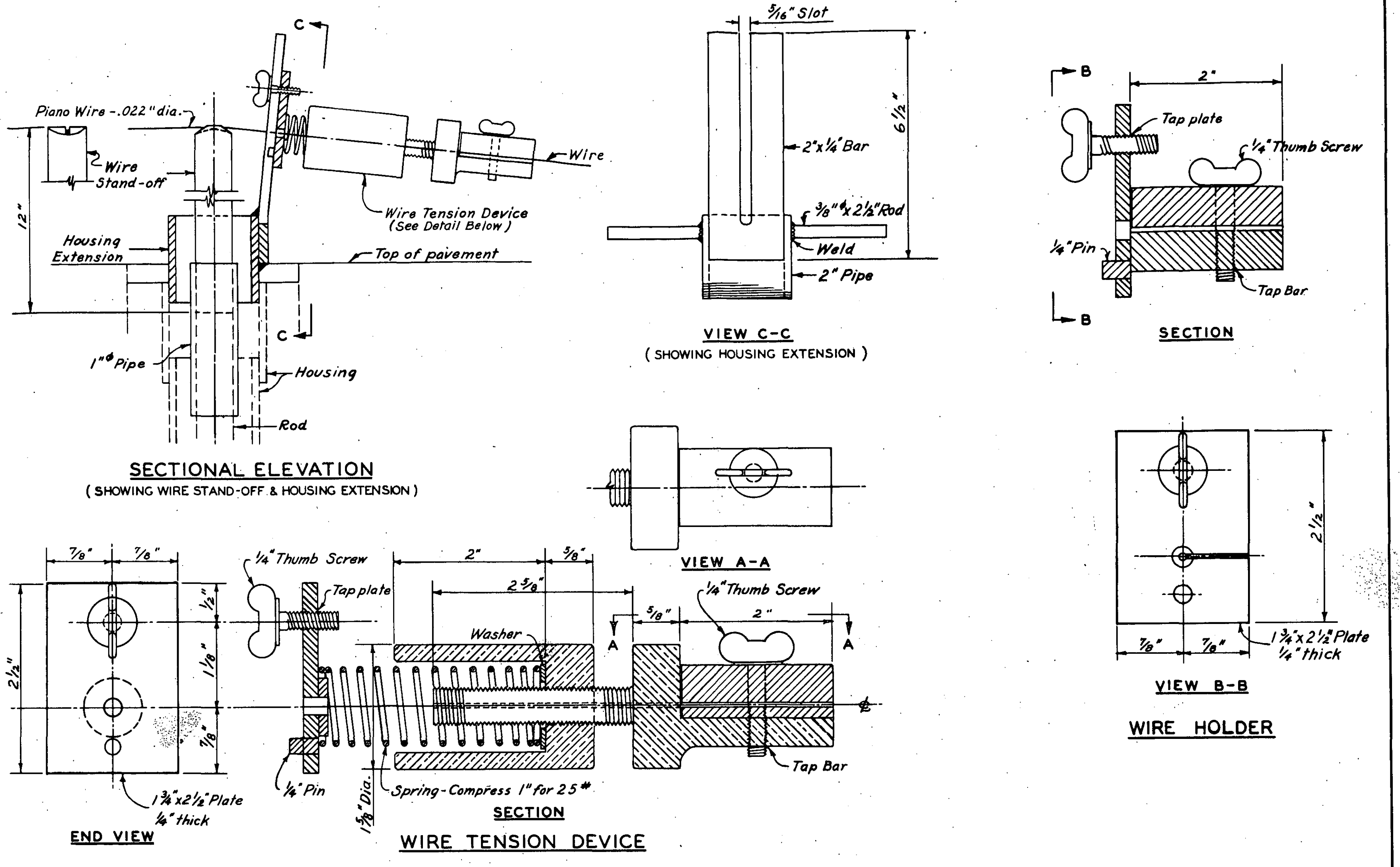
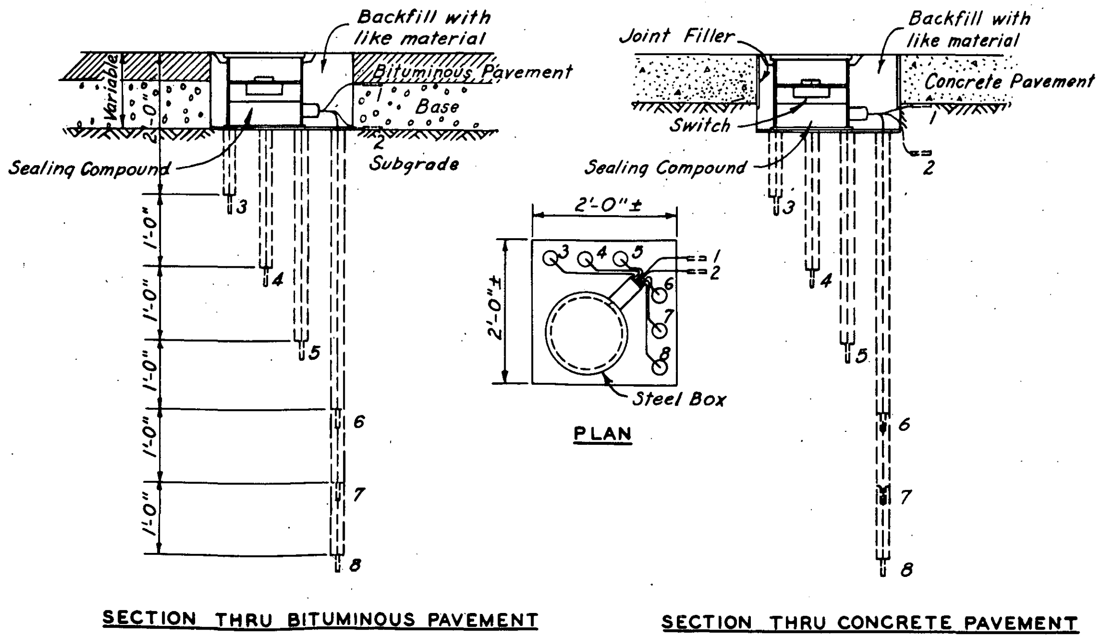
MISSOURI RIVER DIV., OMAHA, NEBR. JUNE, 1945



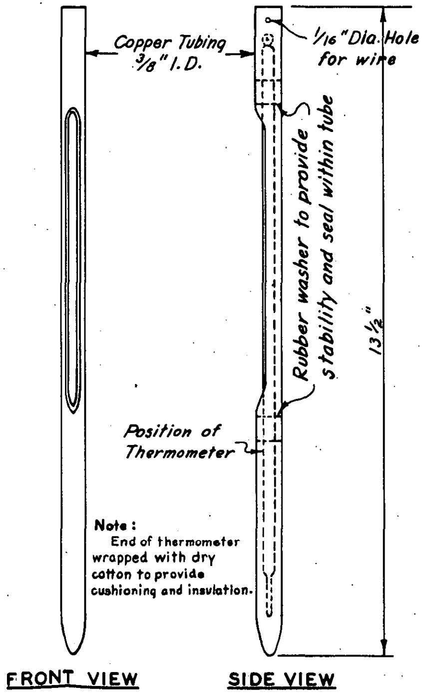
THERMOCOUPLE TERMINAL BOX



WIRE LINE APPARATUS

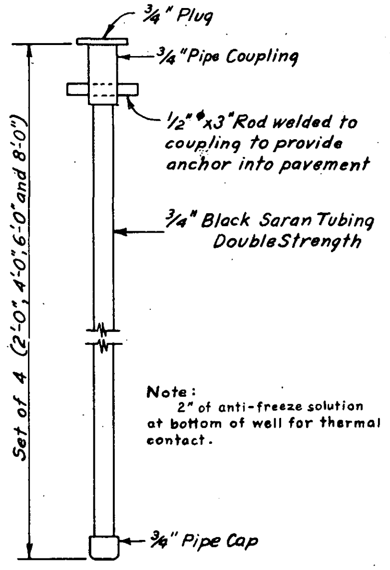


THERMOCOUPLE INSTALLATIONS



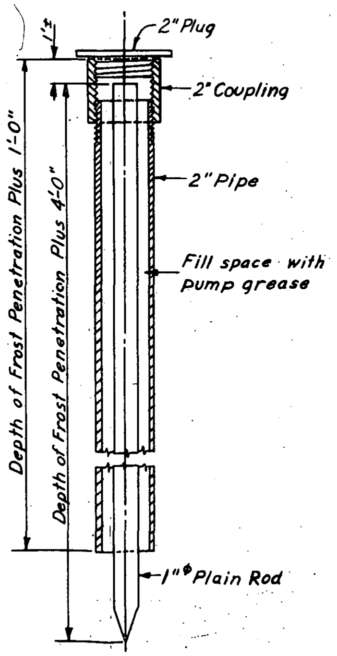
Note:
End of thermometer wrapped with dry cotton to provide cushioning and insulation.

THERMOMETER HOLDER



Note:
2" of anti-freeze solution at bottom of well for thermal contact.

THERMOMETER WELL

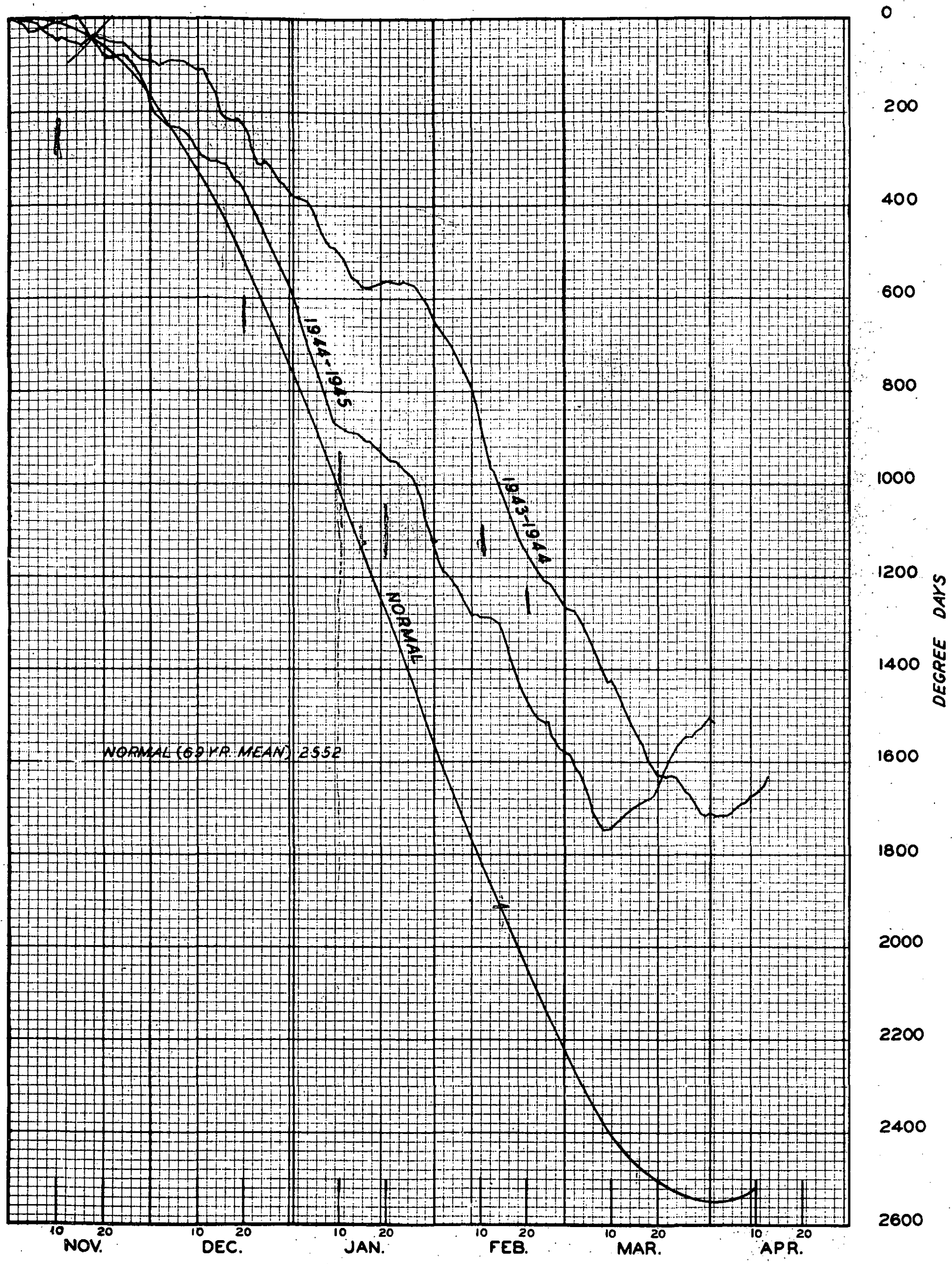


BENCH MARK

FROST INVESTIGATION

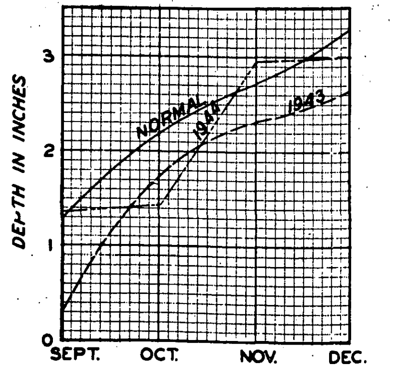
EQUIPMENT DETAILS

MISSOURI RIVER DIV., OMAHA, NEBR. JUNE, 1945



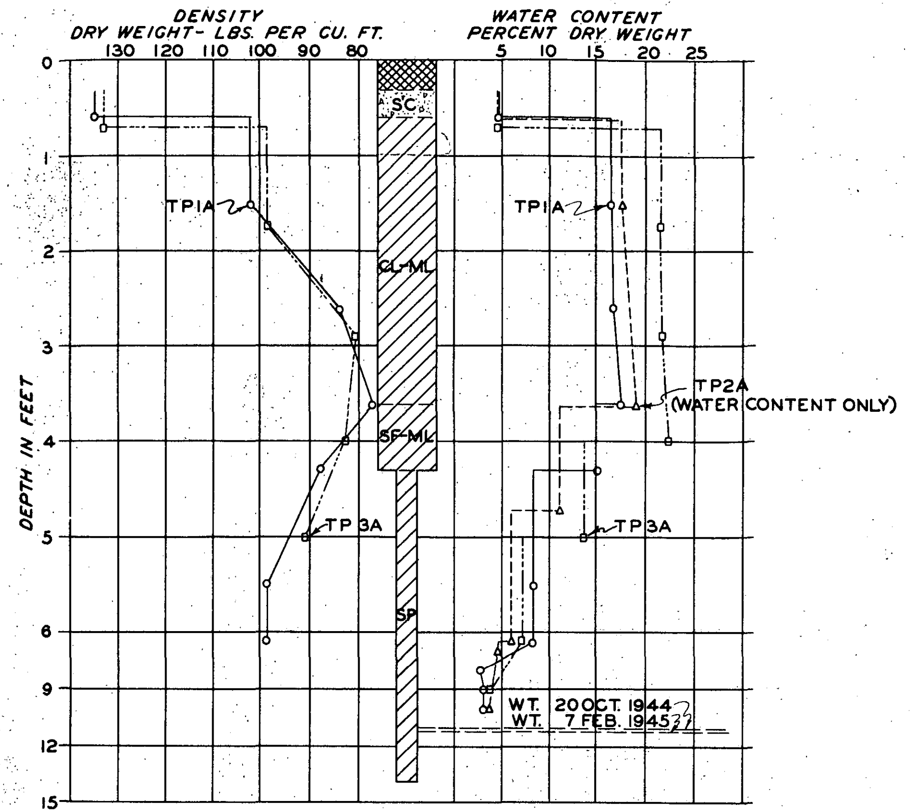
TOTAL CUMULATIVE DEGREE DAYS
BELOW 32° F

7.7
4.9
12.6

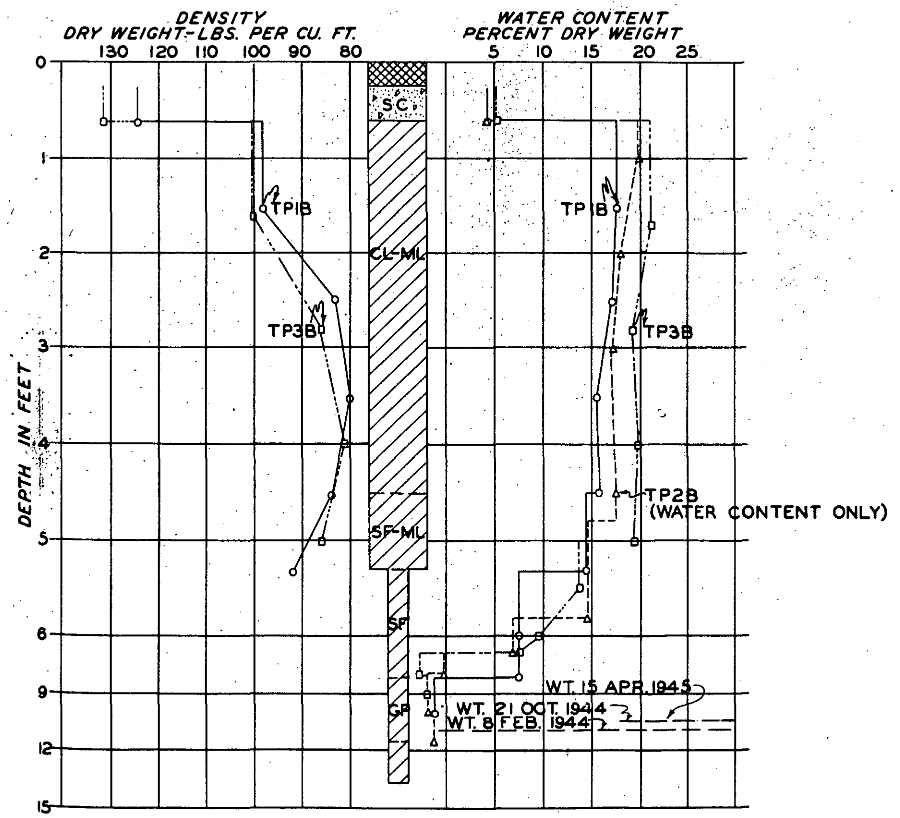


CUMULATIVE PRECIPITATION
(MONTHLY)

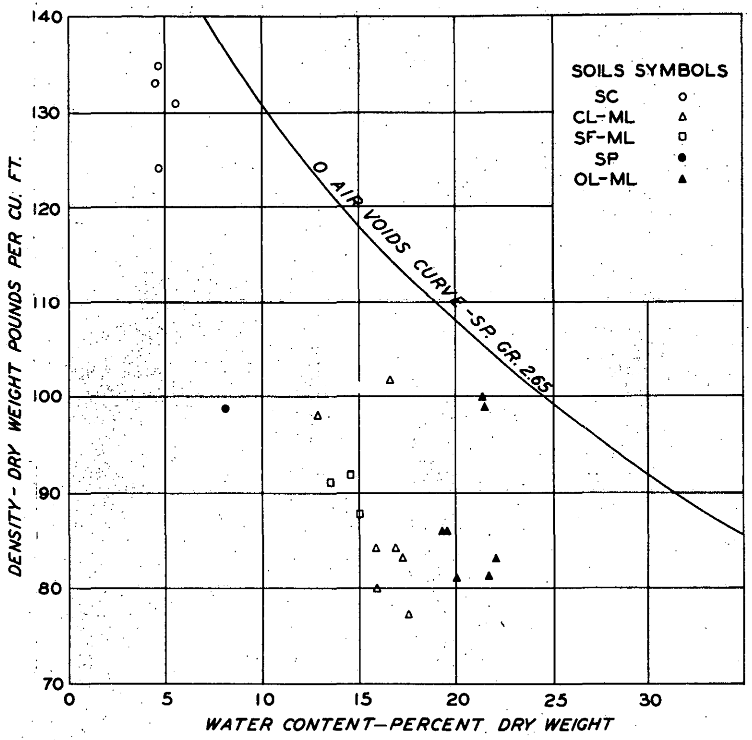
SNOWFALL 1944-1945				
MONTH	PRECIP-ITATION INCHES	DEPARTURE FROM NORMAL INCHES	UNMELTED SNOW INCHES	
OCT.	0.12	-0.79	T	0
NOV.	2.56	+1.99	7.7	7.7
DEC.	T	-0.48	T	7.7
JAN.	0.39	-0.06	4.9	12.6
FEB.	0.21	-0.23	4.2	16.8
MAR.	0.98	+0.09	2.5	19.3
NOTE: T= TRACE				



TEST AREA	TEST PIT	STATION	DATE	SYMBOL
A	TP1A	8+75	20 OCT. 1944	○
A	TP2A	8+66	7 FEB. 1945	△
A	TP3A	8+87	14 APR. 1945	□



TEST AREA	TEST PIT	STATION	DATE	SYMBOL
A	TP1B	9+75	21 OCT. 1944	○
A	TP2B	9+66	8 FEB. 1945	△
A	TP3B	9+86	15 APR. 1945	□



NATURAL WATER CONTENT VERSUS NATURAL DENSITY

LEGEND

▩ PAVEMENT

▒ BASE

▨ SUBGRADE

FROST INVESTIGATION
BISMARCK MUNICIPAL AIRFIELD
BISMARCK, NORTH DAKOTA

WEATHER, WATER CONTENT AND DENSITY DATA

SCALE: AS SHOWN

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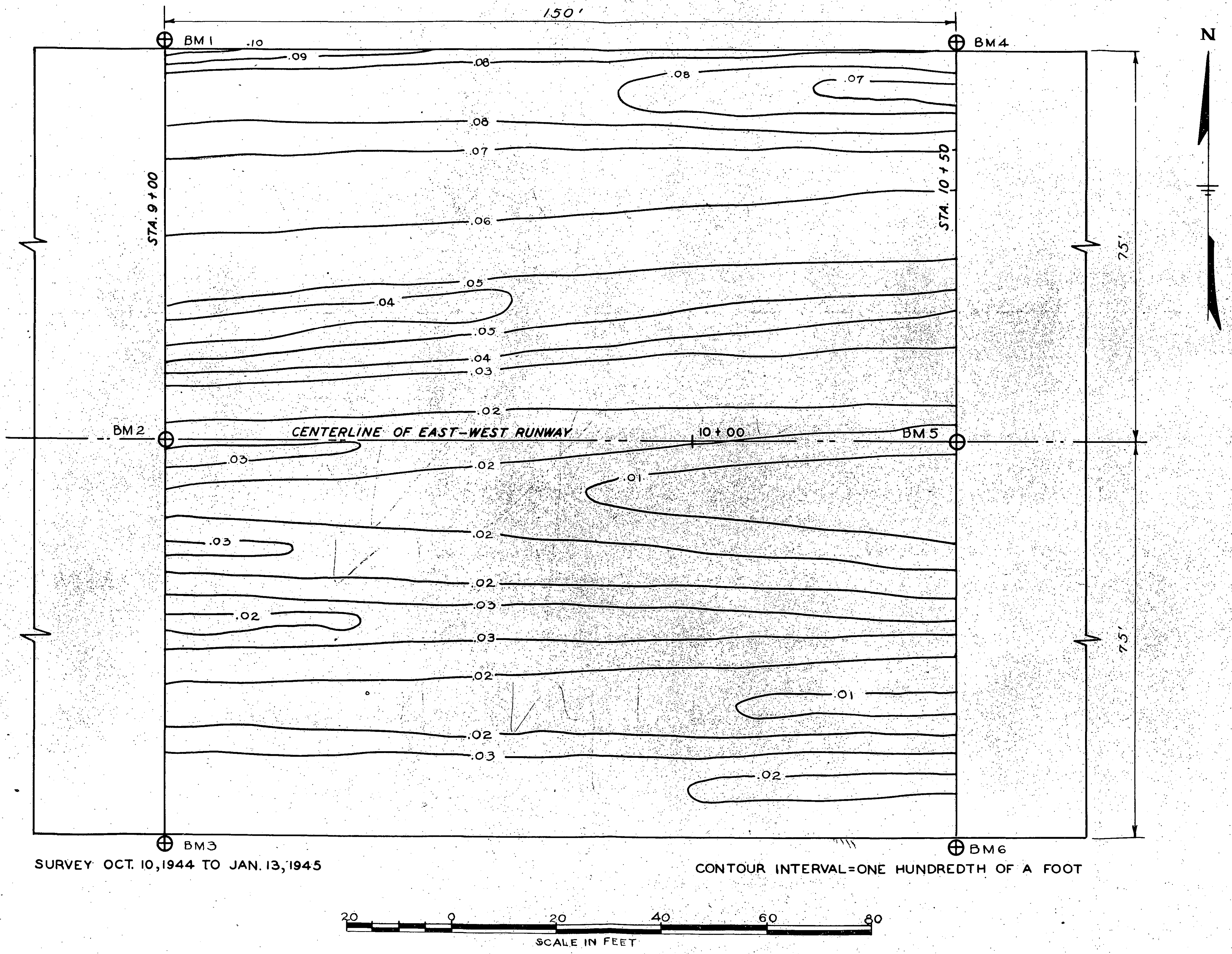
MISSOURI RIVER DIV., OMAHA, NEBR. JUNE, 1945

PLATE 4

WAR DEPARTMENT

CORPS OF ENGINEERS. U.S. ARMY



SURVEY OCT. 10, 1944 TO JAN. 13, 1945

CONTOUR INTERVAL=ONE HUNDREDTH OF A FOOT

FROST INVESTIGATION
BISMARCK MUNICIPAL AIRFIELD
BISMARCK, NORTH DAKOTA

FROST HEAVE CONTOURS
TEST AREA A

SCALE: AS SHOWN

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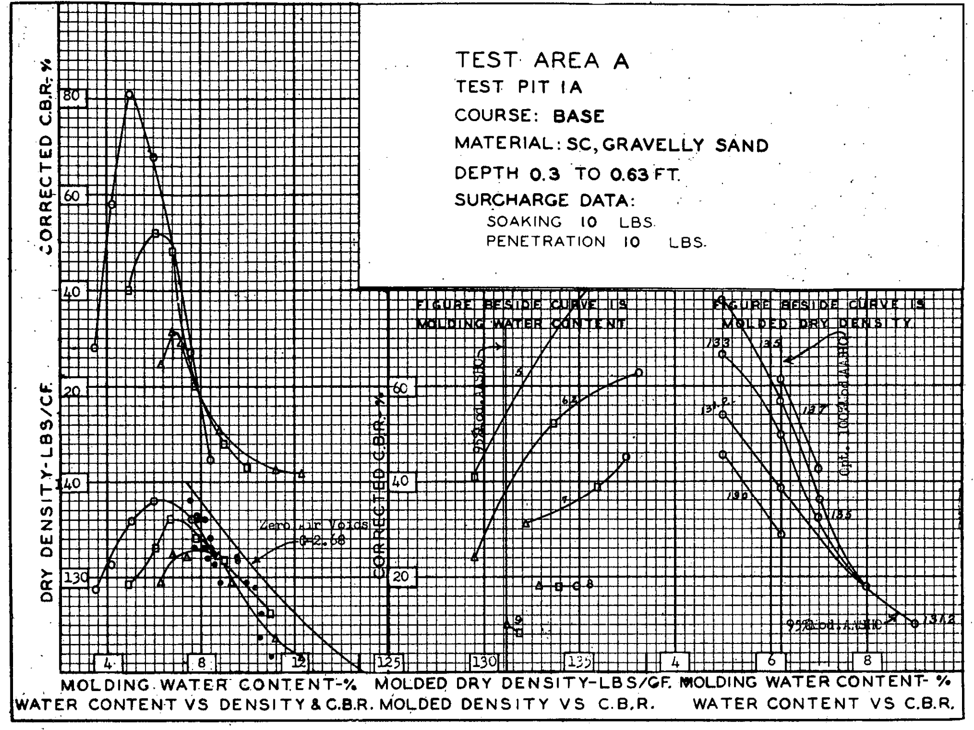
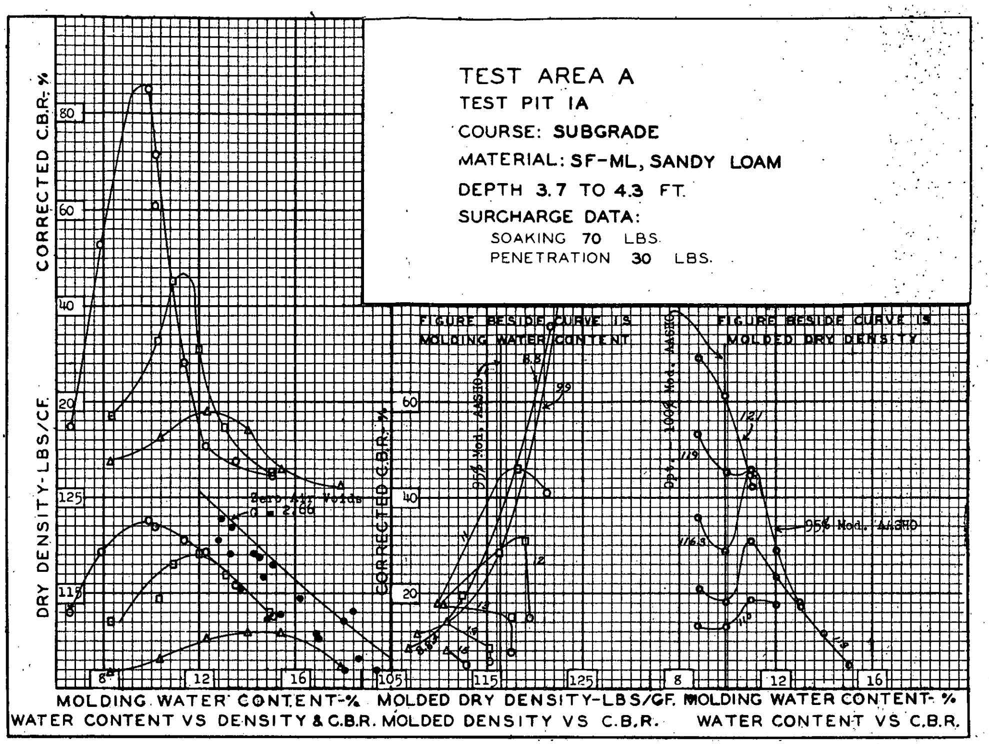
MISSOURI RIVER DIV., OMAHA, NEBR. JUNE, 1945

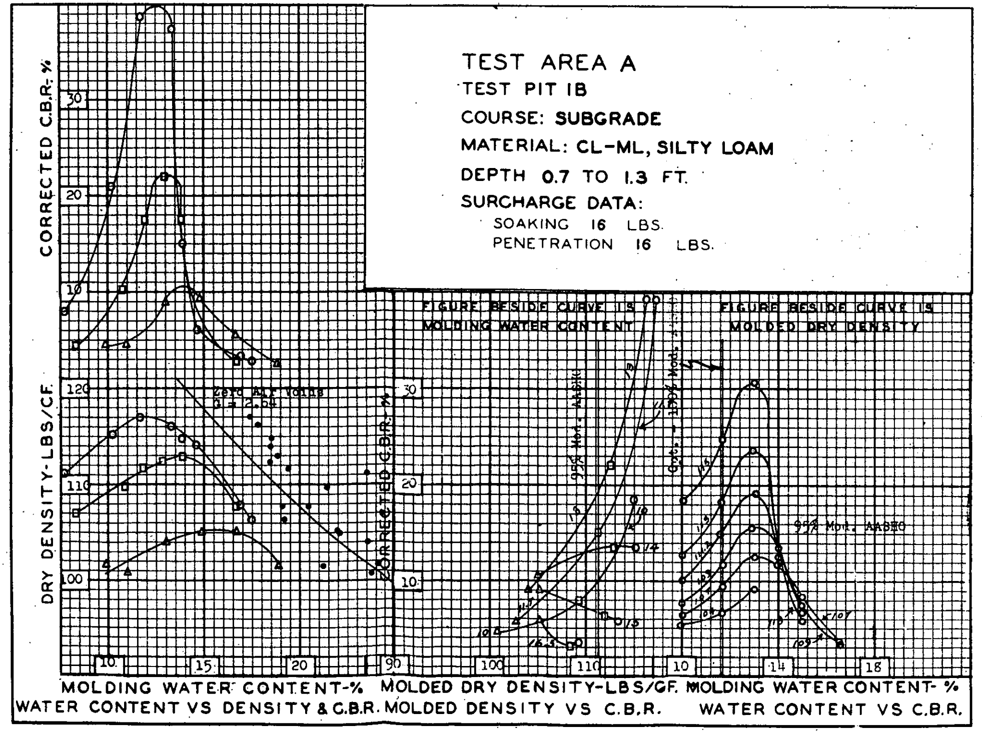
PLATE 5



TEST AREA A
TEST PIT 1A
COURSE: BASE
MATERIAL: SC, GRAVELLY SAND
DEPTH 0.3 TO 0.63 FT.
SURCHARGE DATA:
SOAKING 10 LBS.
PENETRATION 10 LBS.



TEST AREA A
TEST PIT 1A
COURSE: SUBGRADE
MATERIAL: SF-ML, SANDY LOAM
DEPTH 3.7 TO 4.3 FT.
SURCHARGE DATA:
SOAKING 70 LBS.
PENETRATION 30 LBS.



TEST AREA A
TEST PIT 1B
COURSE: SUBGRADE
MATERIAL: CL-ML, SILTY LOAM
DEPTH 0.7 TO 1.3 FT.
SURCHARGE DATA:
SOAKING 16 LBS.
PENETRATION 16 LBS.

LEGEND

- ○ 55 BLOWS PER LAYER
- □ 25 BLOWS PER LAYER
- △ 10 BLOWS PER LAYER
- • WATER CONTENT, TOP INCH

GENERAL NOTES:

ALL SPECIMENS SOAKED TOP AND BOTTOM FOR 4 DAYS.

ALL SPECIMENS COMPACTED IN 5 LAYERS, 10 LB. HAMMER, 18" DROP, IN CBR MOLD.

FROST INVESTIGATION
BISMARCK MUNICIPAL AIRFIELD
BISMARCK, NORTH DAKOTA

CALIFORNIA BEARING RATIO STUDIES

SCALE: AS SHOWN

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MISSOURI RIVER DIVISION, OMAHA, NEBR. JUNE, 1945