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Nuclear moisture and density measurements were taken on samples of roadway excavation and structure backfill from various locations throughout the state under a variety of field and laboratory test conditions. Increasing percentage of plus 3/4-inch rock did not affect nuclear moisture content, dry density or percent relative compaction in any systematic manner. Data obtained confirms that the sand volume method is no more reliable than the nuclear gage method when wet densities are compared with the measured wet weight unit volume of soil obtained by direct measurements. The depth of nuclear gage below the surface of surrounding soil and the proximity of a concrete structure to the gage both affect nuclear moisture determinations. Horizontal clearance around the gage is also found to affect nuclear readings, but to a lesser degree than the depth variable.

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# HIGHWAY RESEARCH REPORT

# EFFECT OF PLUS 3/4-INCH ROCK AND OTHER FIELD VARIABLES ON NUCLEAR GAGE MOISTURE AND DENSITY DETERMINATIONS

70-39

STATE OF CALIFORNIA

BUSINESS AND TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

NO. M & R 642978-2

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STATE OF CALIFORNIA—TRANSPORTATION AGENCY

RONALD REAGAN, Governor

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
5900 FOLSOM BLVD., SACRAMENTO 95819

January 1970

Final Report
M&R No. 642978-2

Mr. J. A. Legarra
State Highway Engineer

Dear Sir:

Submitted herewith is a research report titled:

EFFECT OF PLUS 3/4-INCH ROCK AND
OTHER FIELD VARIABLES

on

NUCLEAR GAGE MOISTURE AND DENSITY DETERMINATIONS

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Very truly yours,

JOHN L. BEATON
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REFERENCE: Smith, Travis; Hirsch, Albin D.; Kleiman, William F., "Effect of plus 3/4-inch Rock and Other Field Variables on Nuclear Gage Moisture and Density Determinations," State of California, Department of Public Works, Division of Highways, Materials and Research Department. Research Report 642978-2, 1970.

ABSTRACT: Nuclear moisture and density measurements were taken on samples of roadway excavation and structure backfill from various locations throughout the state under a variety of field and laboratory test conditions. Increasing percentage of plus 3/4-inch rock did not affect nuclear moisture content, dry density or percent relative compaction in any systematic manner. Data obtained confirms that the sand volume method is no more reliable than the nuclear gage method when wet densities are compared with the measured wet weight unit volume of soil obtained by direct measurements. The depth of nuclear gage below the surface of surrounding soil and the proximity of a concrete structure to the gage both affect nuclear moisture determinations. Horizontal clearance around the gage is also found to affect nuclear readings, but to a lesser degree than the depth variable.

KEY WORDS: Nuclear moisture-density determination, nuclear applications, relative compaction, soils, excavation, backfill, structures, concrete structures, corrugated metal pipe, steel pipe.

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TABLE OF CONTENTS


| | Page |
|---|---|
| INTRODUCTION | 1 |
| DEFINITION OF TERMS | 2 |
| OBJECTIVES | 4 |
| CONCLUSIONS | 4 |
| RECOMMENDATIONS | 5 |
| TESTING DETAILS | 6 |
| ANALYSIS | 8 |
| REFERENCES | |
| TABLES | |
| FIGURES | |
| ADDENDUM A | |
| ADDENDUM B | |


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## INTRODUCTION

This project was initiated as a result of difficulties experienced early in 1968 in District 08 while using a Troxler Nuclear Gage for determining moisture and densities on structure backfill containing approximately 15% plus 3/4-inch rock. The project is located on Road 08-SBd-15,31,138 (Cajon Pass), Contract No. 08-049114.

The initial plan of this project was to investigate three to five sources of roadway excavation material which would be representative of soil used in construction of embankments, and one or two sources of structure backfill, exclusive of material from the Cajon Pass job in District 08.

The materials would be tested for moisture and density in the laboratory after compaction in an aluminum mold 18" square by 12" high. Individual specimens would contain 0%, 10%, 20% and 30% plus 3/4-inch rock. Relative compaction would be determined using the conventional sand volume method and direct transmission nuclear gages from two different manufacturers. Testing would also be done in the field, on compacted material, by the sand volume method and with the same nuclear gages. The testing in the field would be done at each of six sites covering an area approximately 30 feet by 150 feet.

Laboratory testing was done on three samples of roadway excavation and two samples of structure backfill (one sample from the Cajon Pass job). Field testing was done on three samples of roadway excavation after compaction of the embankment. No field testing was done on structure backfill because the work could not be synchronized with the contractor's operations.

After a large portion of the above testing was completed a moisture study was conducted on structure backfill that was used on the Cajon Pass job in District 08. This study was limited to determining the effect of Corrugated Metal Pipe, Structural Plate Pipe and Portland Cement Concrete on moisture determinations when the nuclear gage is in close proximity to these structures. The results of this study were submitted to District Engineer, Mr. C. V. Kane, in memorandum-type report dated June 18, 1968 and was distributed state-wide to each District Engineer with cover memorandum dated September 10, 1968. The two memoranda are attached as Addendum A.

A second modification to the project consisted of studying the effect of horizontal clearance on nuclear gage moisture determinations when the bottom of the gage is below the surface of structure backfill. Testing was done with and without an adjacent concrete slab to measure its influence on nuclear determinations. The results of the study based on the Troxler data were reported to Mr. C. V. Kane with memorandum dated December 4, 1968.

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The results of duplicate testing with a Portaprobe gage and the second moisture study on the District 08 structure backfill was published in an interim report titled "Effect of Field Variables on Nuclear Gage Moisture Determinations" dated March, 1969. This report is attached as Addendum B.

All of the testing described above was done by Materials and Research Department personnel, with assistance from District personnel on the field portion of the project.

In order to obtain as much relevant data as possible for this research project, test results from various locations within the state were obtained from several Districts. The criteria for selection of the test data were as follows: (1) The material contained a minimum of 10% rock retained on the 3/4-inch sieve, with emphasis on greater percentages of plus 3/4". (2) Density and moisture determinations were obtained with a nuclear gage; (3) density was obtained by the sand volume method at the same site; (4) Moisture was determined by the oven-dry method; (5) a 3-point impact test (moisture-density curve) was performed on material from the site.

The major portion of the remainder of this report deals with the effect of plus 3/4-inch rock on nuclear gage moisture and density determinations.

## DEFINITION OF TERMS

The following definitions and test references are used throughout this text.

1. NUCLEAR DETERMINATIONS - Test Method No. Calif. 231 (10-7-68)

METHOD OF TEST FOR RELATIVE COMPACTION OF SOILS BY THE AREA CONCEPT UTILIZING NUCLEAR GAGES

General - This test method provides a procedure for determining the in-place density and moisture of soils and aggregates by the use of nuclear methods and the area concept. The in-place density is the density of a soil or aggregate as it exists in either the natural ground, in constructed earthwork, or after being processed and compacted. The test maximum density is determined as specified in Test Method No. Calif. 216.

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Area Concept - The area concept involves random testing, with a series of in-place density tests, within a designated area. The relative compactions of the in-place densities are calculated utilizing test maximum densities. On the basis of established acceptance criteria, the relative compaction values are then used to determine the acceptance or rejection of compaction within the designated area.

Relative Compaction -

$$\text{Percent Relative Compaction} = \frac{L_{(nuclear)}}{g_m} \times 100$$

Where:

$L_{(nuclear)}$ = in-place wet density as determined by the use of the nuclear gages herein described.

$g_m$ = maximum adjusted wet density of compacted test specimens, Test Method No. Calif. 216.

Calibration Curves - A calibration curve is established based on relative count for a fixed period of time versus soils of known density. This calibration curve is then used to determine the wet density of the soil in the field.

2. SAND VOLUME DETERMINATION - Test Method No. Calif. 216

METHOD OF TEST FOR RELATIVE COMPACTION OF UNTREATED AND TREATED SOILS AND AGGREGATES

General - This method of test is used to determine the relative compaction of untreated soils, Aggregate Subbases, Aggregate Bases and Classes "C" and "D" Cement Treated Bases.

In-Place density is the density of a soil or aggregate as it exists in either the natural ground or in constructed earthwork.

Density is defined as the unit weight of the soil or aggregate expressed as pounds per cubic foot. The unit weight is referred to as the dry density if the soil or aggregate is oven-dried to constant weight at a temperature of 221°F to 230°F. The term wet density applied when the in-place moisture is included in the calculation of density.

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Relative Compaction - Relative compaction is defined as the ratio of the in-place density of a soil or aggregate to the test maximum density of the same soil or aggregate when compacted by a specific test method.

$$\text{Percent Relative Compaction} = \frac{\text{In-Place dry density}}{\text{Test maximum dry density}} \times 100$$

3. MOLD METHOD OF MEASURING DENSITIES - In this study the mold density is the wet weight per unit volume of soil compacted in an 18" square by 12" deep aluminum mold. In contrast with sand volume and nuclear gage test methods, mold density is obtained by direct measurements.

## OBJECTIVES

The objectives of this project are: (1) to study the effect of more than 10% of plus 3/4-inch rock fragments on soil density and moisture as determined by nuclear gages; (2) to study the effect on nuclear moisture determinations when corrugated metal pipe, structural plate pipe, and portland cement concrete are in close proximity to the nuclear gage.

## CONCLUSIONS

Extensive nuclear testing on structure backfill and roadway excavation material clearly indicates no systematic error results with increasing percentage of plus 3/4-inch rock. Thus, with increasing percentage of plus 3/4-inch there is no significant increase or decrease in the variance of nuclear or sand volume wet densities when compared with mold wet densities. This finding is based on samples containing up to 53% plus 3/4-inch rock. As a result of these findings, operators are encouraged to use nuclear gages as extensively as is practical without concern for the percentage of plus 3/4-inch rock.

The detailed findings of the effect of structural materials on nuclear moisture readings were reported earlier by this department. A copy of these reports are included in Addenda A and B. The salient findings are summarized below.

The concrete slab was found to exert greater effect upon increasing nuclear moisture determinations than did either the 8" CMP or section of 108-inch diameter structural plate pipe. Duplicate testing with Troxler and Portaprobe gages indicate large differences in sensitivity to moisture determinations. These differences are intrinsic to the manufacturer's construction of the gages. The presence of concrete slabs affect Troxler moisture readings out to a distance of approximately eight inches from the slab. Portaprobe readings are estimated

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to be influenced out to a distance somewhat greater than eight inches. The size of test pit utilized was insufficient to determine a limiting distance beyond which any influence produced by the concrete slab can be ignored in normal construction control.

The degree to which nuclear readings are affected by various structural elements is a function of the composition of the structural elements, the vertical and horizontal clearances involved, the moisture content of the soil and the particular nuclear gage used.

Laboratory experimental data obtained from measurements of mold density, which we consider to be the most reliable scale for the measurement of wet densities, indicate that the range and deviation of nuclear densities from mold densities do not exceed those obtained by the sand volume method. These results confirm earlier findings by this department.

Previous time studies indicate that several nuclear tests can be performed in the same amount of time required for one sand volume test. Hence, it would appear that the nuclear method, rather than the sand volume method, would give a more thorough coverage of density for a large soil mass.

## RECOMMENDATIONS

1. Nuclear gages, as specified by the California Division of Highways, are recommended for construction control of highway embankments.

2. Operators should use nuclear gages for moisture and density determinations without regard to the percentage of plus 3/4-inch rock.

3. The minimum horizontal and vertical clearance between nuclear gages and structural objects necessary to eliminate erroneous readings cannot be given an exact value but will depend upon several factors. Data from our research indicate the minimum clearance can range from 0" to over 2 feet depending on various factors. We recommend that each gage be calibrated by District personnel as the need arises.

4. Calibration blocks have been manufactured and tested by this department and will be furnished to each District for use with their nuclear gages. However, if discrepancies in nuclear readings do occur, it may be necessary for the Districts to establish calibration curves with the materials and the specific gage for a particular project.

5. This report confirms previous findings that density determinations made with a properly calibrated nuclear gage are as reliable as density determinations made by the sand volume

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method, when compared with mold density. We believe that mold density, i.e., density determined by direct measurement of volume and direct determination of weight, is the most accurate method of determining density.

## TESTING DETAILS

Large bulk samples, approximately 2500 to 4000 pounds, were obtained from five active construction jobs as listed in the following tabulation:

| Road | Contract No. | M & R Dept. Sample No. |
|---|---|---|
| 01-DN-101 - 4.7/6.1 | 01-043954 | 68-1395 |
| 02-Tri-3 - 67.8/73.5 | 02-044914 | 68-1377 |
| 02-Sis-5 - 54.2/58.5 | 02-046734 | 68-1378 |
| 08-SBd-15,31,138 | 08-049114 | 68-1636 |
| 10-Sol-80 - 8.0/12.5 | 10-081104 | 68-1503 |

Field testing was done on the construction projects in Del Norte, Trinity and Siskiyou Counties, but was not done on the construction projects in San Bernardino and Solano Counties. It was not possible to synchronize the research testing with the contractor's operations in San Bernardino and Solano Counties. Table 1 shows a breakdown of the materials sources, locations and number of tests performed.

### FIELD WORK

Field work consisted of density and moisture determinations with two nuclear gages (Troxler Gage Scaler Model No. 650, Probe Model No. SCM-257-1967 and Portaprobe Gage Model No. A-1967), in compliance with Test Method No. Calif. 231. The work also entailed density determinations by the sand volume method (Test Method No. Calif. 216) and moisture content determinations by the oven-dry method (Test Method No. Calif. 226).

The testing was done at each of six sites covering an area of approximately 30 ft. by 150 ft. of rocky material on the three construction projects mentioned above. Sufficient material was obtained from each site to determine maximum density according to Test Method No. 216.

### LABORATORY WORK

The laboratory work consisted of compacting the bulk sample in an aluminum mold with inside dimensions of 18" square by 12" deep. Maximum particle size was limited to 1½-inch and specimens were fabricated with 0%, 10%, 20% and 30% plus 3/4-inch rock. These specimens were tested for density by the sand volume method and moisture content by the oven-dry method. Nuclear

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density and moisture determinations were made with the Troxler and Portaprobe gages. Test maximum density was also determined for each of the specimens according to Test Method No. Calif. 216.

Although testing of the material from the San Bernardino project was not done on the going contract, it can be assumed that field conditions were simulated for the moisture study on this material. The study of the effect of plus 3/4-inch rock on moisture and density determinations obtained with the two nuclear gages is rather limited as most of the material was used on the moisture study entailing effect of metal pipe, concrete and positions of gage on moisture and density determinations.

DISCUSSION OF BASIC SOIL DATA

Figure 1 is a summary of the soil properties for each of the five locations under study. The corresponding impact test curves are shown on Figure 2. Material from Klamath, Coffee Creek and Anderson Grade consists of roadway excavation while structural backfill material was obtained from San Bernardino (Cajon Wash) and Red Rock Quarry.

DENSITY CALIBRATION CURVES

The Troxler and Portaprobe gages were both calibrated for density with three calcium and three silicon California standard calibration blocks fabricated at the Materials and Research Department in Sacramento. The density of the blocks range from 93 lbs/cu ft to 170 lbs/cu ft. and are approximately three cubic feet in volume. The calibration curves plotted from these standard blocks were used throughout this research project.

The density calibration curves for the two gages and the individual test points for the five types of materials are shown on Figure No. 3. The scatter of individual points from the calibration curves for the materials from Klamath, Coffee Creek, Anderson Grade and Red Rock Quarry are considered to be within the limits of accuracy of the nuclear gage density test. The test data for the San Bernardino material indicates that the standard calibration curve is not valid for this material. Some shifting of the curve would have been desirable. However, any adjustment would not affect the conclusions of this study as the primary purpose of research on the San Bernardino material was to determine the effect of metal pipe and portland cement concrete on moisture readings when the nuclear gages are in close proximity to these structures.

MOISTURE CALIBRATION CURVES

The Troxler and the Portaprobe gages were calibrated for moisture with two molds, 1.86 feet in diameter and one foot deep, filled with American River sand. The moisture content of the sand in the two molds was 3.5 lbs/cu ft and 22.0 lbs/cu ft, respectively. These curves were adjusted in all cases for each

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type of material encountered. An adjustment of approximately 6½ lbs was made for the Coffee Creek and Anderson Grade materials. Adjustments of one to four lbs were necessary for the other materials. The moisture calibration curves for the above five locations are shown on Figure 4.

## ANALYSIS

### A. KLAMATH, COFFEE CREEK, ANDERSON GRADE AND RED ROCK QUARRY

Figures 5 through 11 summarize the research findings from the field and mold data obtained from the above four locations. The distributions for the three variables - moisture, dry density and percent relative compaction are calculated with respect to oven-dry moisture contents and sand volume densities. However, attention is directed to the fact that these deviations can also be considered relative to nuclear standards. Thus, for the purpose of the discussions which follow, the oven-dry moisture content and sand-volume density are not to be thought of as the correct or absolute value from which nuclear determinations vary, but rather as a reference for plotting purposes. No field data was obtained from the American Canyon Project.

#### 1. MOISTURE CONTENT

Figure 5 is a plot of nuclear moisture contents relative to oven-dry moistures as a function of percent plus 3/4-inch rock for field and mold data from each of the four locations.

Figure 6 is a frequency distribution showing nuclear moisture readings relative to oven-dry moisture contents for each of the four locations. Also shown is a cumulative distribution curve for all four locations.

The total range of nuclear moisture variation from oven-dry moisture content is -5 to +4 lbs/cu ft as shown on Fig. 6. The total field variation is split nearly equally above and below the oven-dry, i.e., 51% of the field readings were below and 49% were above. The nuclear moisture contents of the mold samples reveal 72% of the samples were below oven-dry moisture determinations.

A review of the distribution curves for each of the individual projects indicates a definite skewness to the left for mold data obtained from Klamath with a skewness to the right for data obtained from American Canyon.

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2. DRY DENSITY

Figure 7 is a plot of nuclear dry densities relative to sand volume dry densities as a function of percent plus 3/4-inch material for field and mold data obtained for each of the four locations.

Figure 8 is a frequency distribution showing nuclear dry densities relative to sand volume dry densities for each of the four locations. Also shown is a cumulative distribution curve for the four locations. The total range of nuclear dry densities from sand volume dry densities is -9 to +6 lbs/cu ft as shown on Figure 8. Distribution from individual locations show a wide dispersion of results. Field data from Coffee Creek show a 15-lb/cu ft range of nuclear densities.

3. RELATIVE COMPACTION

Figure 9 is a plot of nuclear percent relative compaction with respect to sand volume percent relative compaction as a function of percent plus 3/4-inch material for field and mold data for each of the four locations.

Figure 10 is a frequency distribution showing nuclear percent relative compaction with respect to sand volume relative compaction for each of the four locations. Also shown is a cumulative distribution curve for all four locations.

The total range of nuclear relative compaction determination from sand volume is -6 to +4 lbs/cu ft. Nuclear readings show that 52% mold data and 57% field data are below relative compaction values obtained by sand volumes.

B. SAN BERNARDINO

The San Bernardino data are analyzed separately because "field" testing was conducted in a laboratory dug test pit rather than testing under routine construction as was done for the other three field locations.

Results of moisture, percent relative compaction and dry density distribution of the differences between sand volume and nuclear readings are shown on Fig. 11. Frequency distribution plots for these variables similar to those prepared for the previously mentioned locations are shown on Fig. 12.

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C. VARIOUS LOCATIONS

Results of moisture, dry density and percent relative compaction distributions of the differences between sand volume and nuclear readings are shown on Figure 13. The types of gages used were not reported. Only one gage was used by district personnel for each nuclear determination from "various locations" in contrast with duplicate testing using the Troxler and Portaprobe gages for testing done by Materials and Research personnel. As shown on Figure 14 the nuclear moisture variation from oven-dry moisture are more in agreement than are nuclear and sand volume determinations of dry density and percent relative compaction.

STATISTICAL ANALYSIS

Table 2 summarizes the statistical properties of the distributions between means for nuclear and sand volume determinations. The following conclusions are based on analysis of the data obtained from the Klamath, Coffee Creek, Anderson Grade, Red Rock Quarry and Various Locations samples.

1. In all six distributions (moisture, dry density and percent relative compaction for both field-mold (Figs. 6, 8, 10) and various locations, (Fig. 14) there exists a significant difference between the two test methods at the 95% level of confidence.

2. In all six of the above distributions the nuclear means are less than the corresponding sand volume test results.

3. Testing done by Materials and Research Department personnel on the field-mold study reflect less discrepancy on each distribution between nuclear and sand volume data than the test results obtained at various locations where the type of gage or validity of test results were not recorded. The difference between average nuclear moisture content and oven-dry moisture content is slightly more than twice as great for data obtained from various locations as for data obtained from field-mold conditions. This ratio is 3.3 for percent relative compaction and 2.7 for dry density. These conclusions are paralleled by calculations of standard deviations.

   We believe that the precision of the control exercised by field personnel can be improved with better liaison between Materials and Research Department personnel and District personnel.

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Fig. 15 summarizes the variations of nuclear determinations of moisture content, dry density and relative compaction with respect to oven-dry moisture content and sand volume determinations of dry density and relative compaction as a function of percentage of plus 3/4-inch rock. The data is grouped according to: (1) mold study of the five projects, (2) field study of the five projects, and (3) various locations.

Fig. 15 clearly demonstrates that no systematic variation exists between percentage of plus 3/4-inch rock and any of the three variables. Also, there does not occur any increase or decrease in the variance of individual test points with increasing percentage of plus 3/4-inch rock.

MOLD ANALYSIS

1. The data from sand volume and nuclear wet densities are compared with mold wet densities as shown on Figure 16. The tabulation of this data is shown on Table 3. The nuclear gage method is found to be as reliable as the sand volume method when compared with wet densities obtained by the mold method of determining density as defined on page 4.

2. With increasing percent of plus 3/4-inch material the density determination by sand volume and nuclear gages reflect both higher and lower densities than determinations by the mold method. The data shows that the particular material tested has a greater influence upon density determinations by either sand volume or nuclear devices than does increasing percentages of plus 3/4-inch rock.

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## TABLE 1
## TEST PROGRAM

| ROUTE DESIGNATION | COMMON NAME (TEST NUMBER) | NUMBER OF TESTS USING TROXLER AND PORTAPROBE GAGE | |
|---|---|---|---|
| | | MOLD DATA | FIELD DATA |
| 01-DN-101 PM ≃ 7 | KLAMATH (68-1395) | 4 | 6 |
| 02-Tri-3 STA. 485± TO 487± | COFFEE CREEK (68-1377) | 4 | 6 |
| 02-Sis-5 STA. 812± | ANDERSON GRADE (68-1378) | 4 | 6 |
| 08-SBd-15,31,138 | CAJON WASH (68-1636) | 3 | 3 |
| 10-Sol-80 PM ≃ 10 | RED ROCK QUARRY (68-1503) | 4 | NONE |
| VARIOUS LOCATIONS THROUGHOUT CALIFORNIA | | TYPE GAGE NOT SPECIFIED | |
| | | NONE | 44 INDIVIDUAL TESTS |

## TABLE 2
## NUCLEAR MEASUREMENTS RELATIVE TO SAND VOLUME

| VARIABLE | FIELD-MOLD COMBINED* | | | | VARIOUS LOCATIONS | | | |
|---|---|---|---|---|---|---|---|---|
| | AVERAGE | STD. DEV. | $T_{FACTOR}$ | SAMPLE SIZE | AVERAGE | STD. DEV. | $T_{FACTOR}$ | SAMPLE SIZE |
| MOISTURE ($LBS/FT^3$) | -0.49 | 1.85 | -2.16 | 68 | -1.02 | 2.49 | -2.72 | 44 |
| DRY DENSITY ($LBS/FT^3$) | -1.01 | 3.53 | -2.37 | 68 | -2.73 | 7.64 | -2.34 | 44 |
| RELATIVE COMPACTION (PERCENT) | -0.74 | 2.48 | -2.44 | 68 | -2.43 | 5.80 | -2.64 | 40 |

* STATISTICAL ANALYSIS BASED UPON DATA FROM KLAMATH, COFFEE CREEK, ANDERSON GRADE AND RED ROCK QUARRY.

642978-2

# TABLE 3
## SUMMARY OF WET DENSITIES BY SAND VOLUME AND NUCLEAR GAGES RELATIVE TO MOLD WET DENSITIES

| COMMON NAME RTE. DESIGNATION (TEST NUMBER) | PERCENT RETAINED ON 3/4" | MOLD WET DENSITY LB/FT$^3$ | WET SAND VOLUME LB/FT$^3$ | DIFF. | WET TROXLER LB/FT$^3$ | DIFF. | WET PORTAPROBE LB/FT$^3$ | DIFF. |
|---|---|---|---|---|---|---|---|---|
| KLAMATH | 0 | 128.4 | 127.9 | −0.5 | 128.7 | +0.3 | 127.0 | −1.4 |
| 01-DN-101 | 10 | 129.1 | 129.5 | +0.4 | 128.5 | +0.6 | 130.9 | +1.8 |
| PM ≃ 7 | 20 | 129.9 | 131.0 | +1.1 | 128.0 | −1.9 | 128.0 | −1.9 |
| (68-1395) | 30 | 128.1 | 126.5 | −1.6 | 124.0 | −4.1 | 126.0 | −2.1 |
| COFFEE CREEK | 0 | 127.5 | 127.8 | +0.3 | 128.0 | +0.5 | 126.5 | −1.0 |
| 02-Tri-3 | 10 | 126.7 | 130.3 | +3.6 | 128.5 | +1.8 | 127.5 | +0.8 |
| STA. 485± TO 487± | 20 | 130.0 | 136.1 | +6.1 | 136.5 | +6.5 | 134.6 | +4.6 |
| (68-1377) | 30 | 134.0 | 135.8 | +1.8 | 137.0 | +3.0 | 136.5 | +2.5 |
| ANDERSON GRADE | 0 | 140.0 | 140.8 | +0.8 | 139.5 | −0.5 | 137.5 | −2.5 |
| 02-Sis-5 | 10 | 135.6 | 143.7 | +8.1 | 142.0 | +6.4 | 139.1 | +3.5 |
| STA. 812± | 20 | 139.3 | 146.0 | +6.7 | 147.5 | +8.2 | 143.0 | +3.7 |
| (68-1378) | 30 | 141.0 | 149.2 | +82 | 148.7 | +7.7 | 145.5 | +4.5 |
| CAJON WASH | 0 | 125.6 | 121.3 | −4.3 | 128.9 | +3.3 | 131.3 | +5.7 |
| 08-SBd-15, 31, 138 | 9 | 130.2 | 136.5 | +6.3 | 133.0 | +2.8 | 132.4 | +2.2 |
| (68-1636) | 15 | 127.2 | 134.2 | +7.0 | 128.9 | +1.7 | 127.2 | 0 |
| AMERICAN CANYON | 0 | 129.5 | 133.8 | +4.3 | 131.5 | +2.0 | 129.0 | −0.5 |
| 10-Sol-80 | 10 | 136.4 | 141.5 | +5.1 | 141.0 | +4.6 | 137.5 | +1.1 |
| PM ≃ 10 | 20 | 137.9 | 140.1 | +2.2 | 138.0 | +0.1 | 134.1 | −3.8 |
| (68-1503) | 30 | 129.5 | 129.1 | −0.4 | 132.0 | +2.5 | 128.2 | −1.3 |

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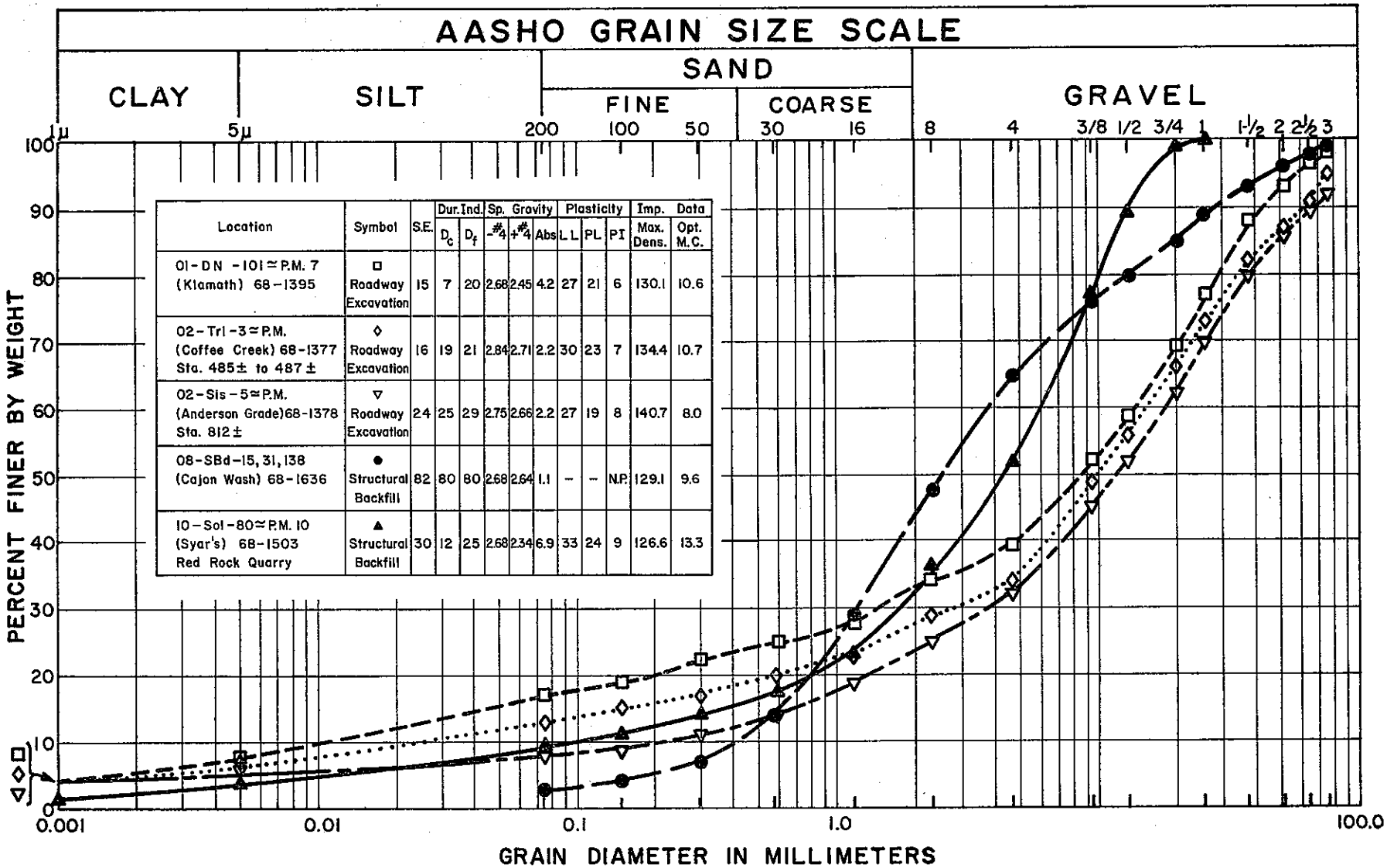
# SUMMARY OF SOIL PROPERTIES




| Location | Symbol | S.E. | Dur. Ind. $D_c$ | Dur. Ind. $D_f$ | Sp. Gravity -#4 | Sp. Gravity +#4 | Sp. Gravity Abs | Plasticity L.L. | Plasticity PL | Plasticity PI | Imp. Data Max. Dens. | Imp. Data Opt. M.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01-DN -101≃P.M. 7 (Klamath) 68-1395 | □ Roadway Excavation | 15 | 7 | 20 | 2.68 | 2.45 | 4.2 | 27 | 21 | 6 | 130.1 | 10.6 |
| 02-Trl-3≃P.M. (Coffee Creek) 68-1377 Sta. 485± to 487± | ◇ Roadway Excavation | 16 | 19 | 21 | 2.84 | 2.71 | 2.2 | 30 | 23 | 7 | 134.4 | 10.7 |
| 02-Sis-5≃P.M. (Anderson Grade) 68-1378 Sta. 812± | ▽ Roadway Excavation | 24 | 25 | 29 | 2.75 | 2.66 | 2.2 | 27 | 19 | 8 | 140.7 | 8.0 |
| 08-SBd-15, 31, 138 (Cajon Wash) 68-1636 | ● Structural Backfill | 82 | 80 | 80 | 2.68 | 2.64 | 1.1 | – | – | N.P. | 129.1 | 9.6 |
| 10-Sol-80≃P.M. 10 (Syar's) 68-1503 Red Rock Quarry | ▲ Structural Backfill | 30 | 12 | 25 | 2.68 | 2.34 | 6.9 | 33 | 24 | 9 | 126.6 | 13.3 |

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Figure 1

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Figure 2

# MOISTURE-DENSITY CURVES
# (CALIF. IMPACT TEST NO. 216)

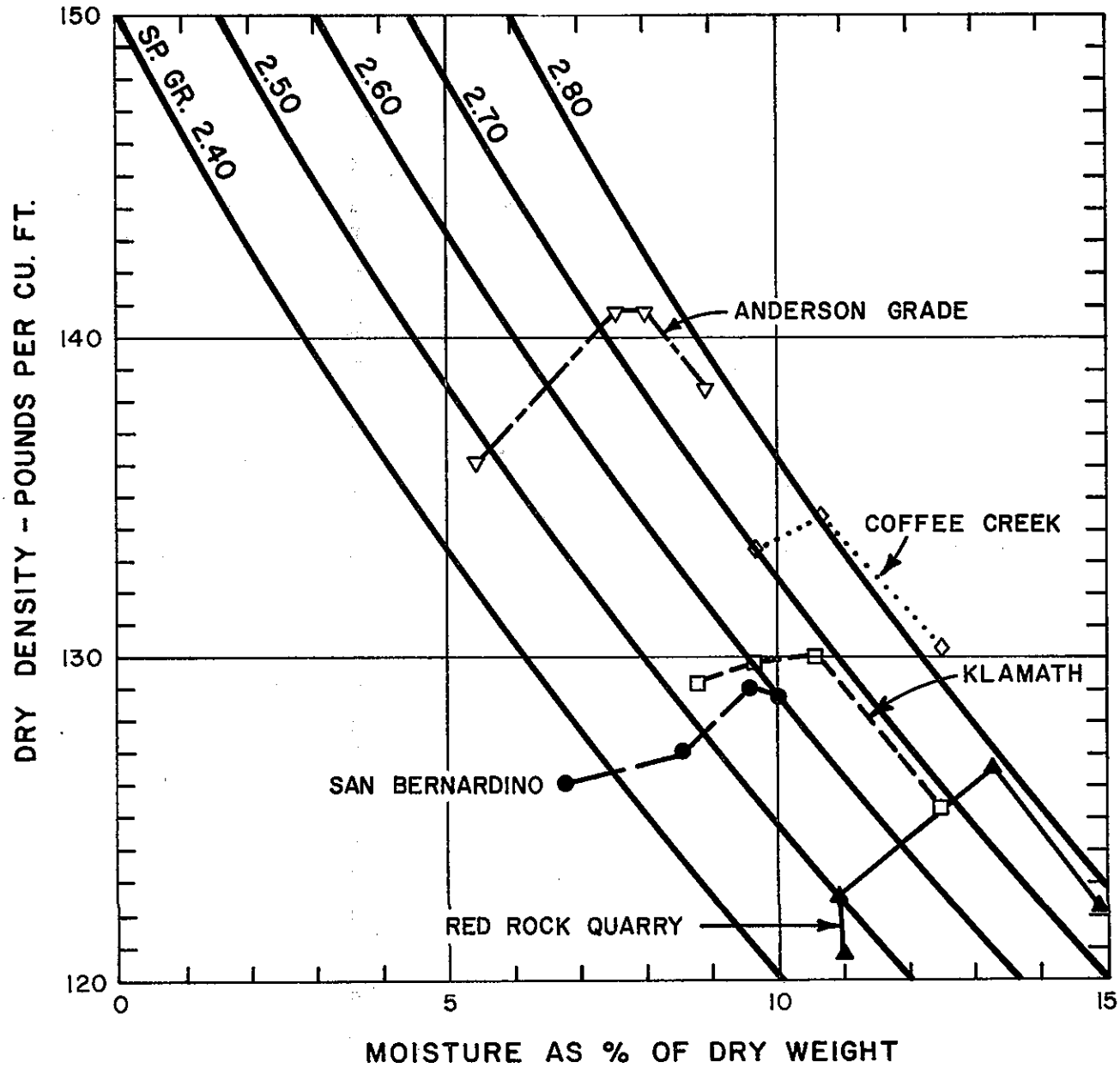


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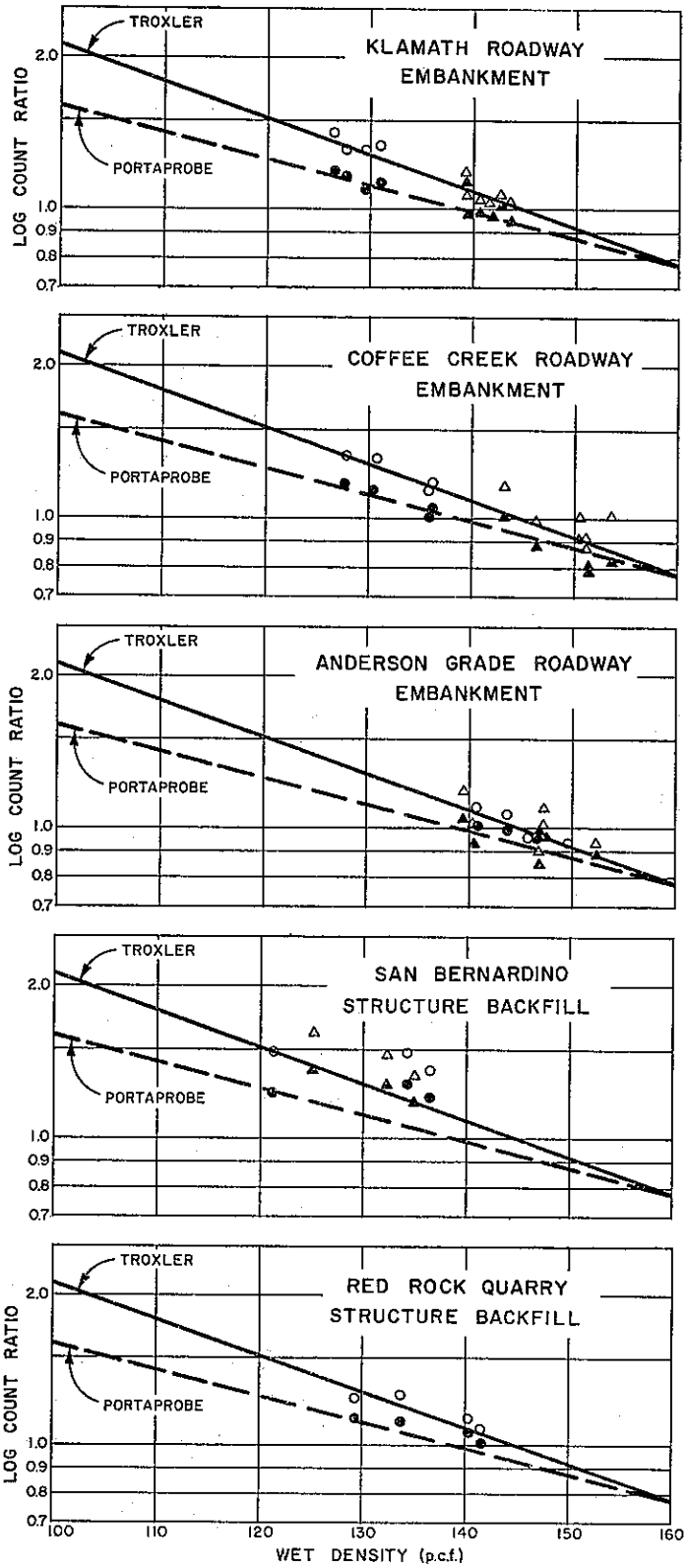
FIGURE 3

# DENSITY CALIBRATION CURVES

TROXLER
SCALER NO. 106, MODEL 650
PROBE NO. 114, MODEL SMC-257-1967

PORTAPROBE
GAGE NO. 0010, MODEL A-1967

| CURVES CALIBRATED JUNE 1968 | | |
|---|---|---|
| | TROXLER | PORTAPROBE |
| AL MOLD | ○ | ● |
| FIELD DATA | △ | ▲ |

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# MOISTURE CALIBRATION CURVES

TROXLER
SCALER NO. 106, MODEL 650
PROBE NO. 114, MODEL SMC-257-1967

PORTAPROBE
GAGE NO. 0010, MODEL A-1967

| CURVES CALIBRATED JUNE 1968 | | |
|---|---|---|
| | TROXLER | PORTAPROBE |
| AL MOLD | ○ | ● |
| FIELD DATA | △ | ▲ |

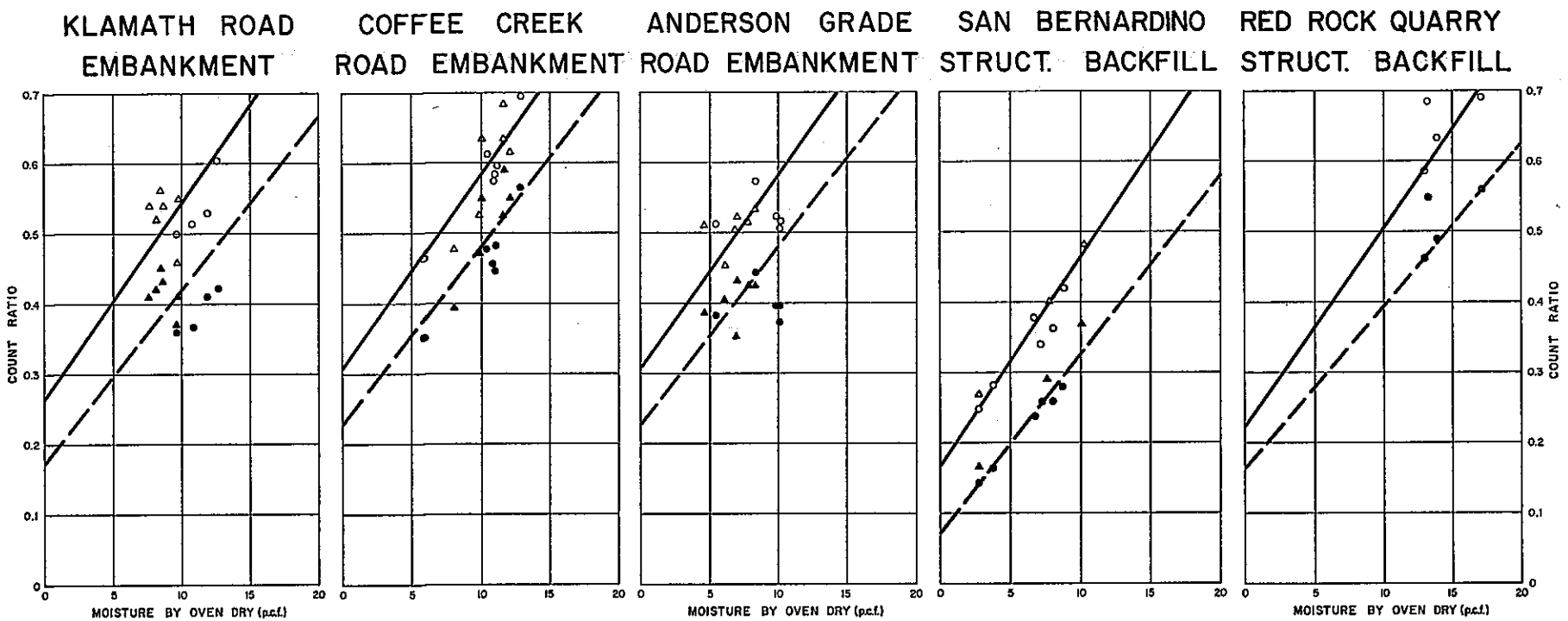


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FIGURE 4

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Figure 5

# DIFFERENCE IN MOISTURE BETWEEN NUCLEAR GAGE AND OVEN DRY METHODS RELATIVE TO PERCENT ROCK RETAINED ON 3/4-INCH SIEVE

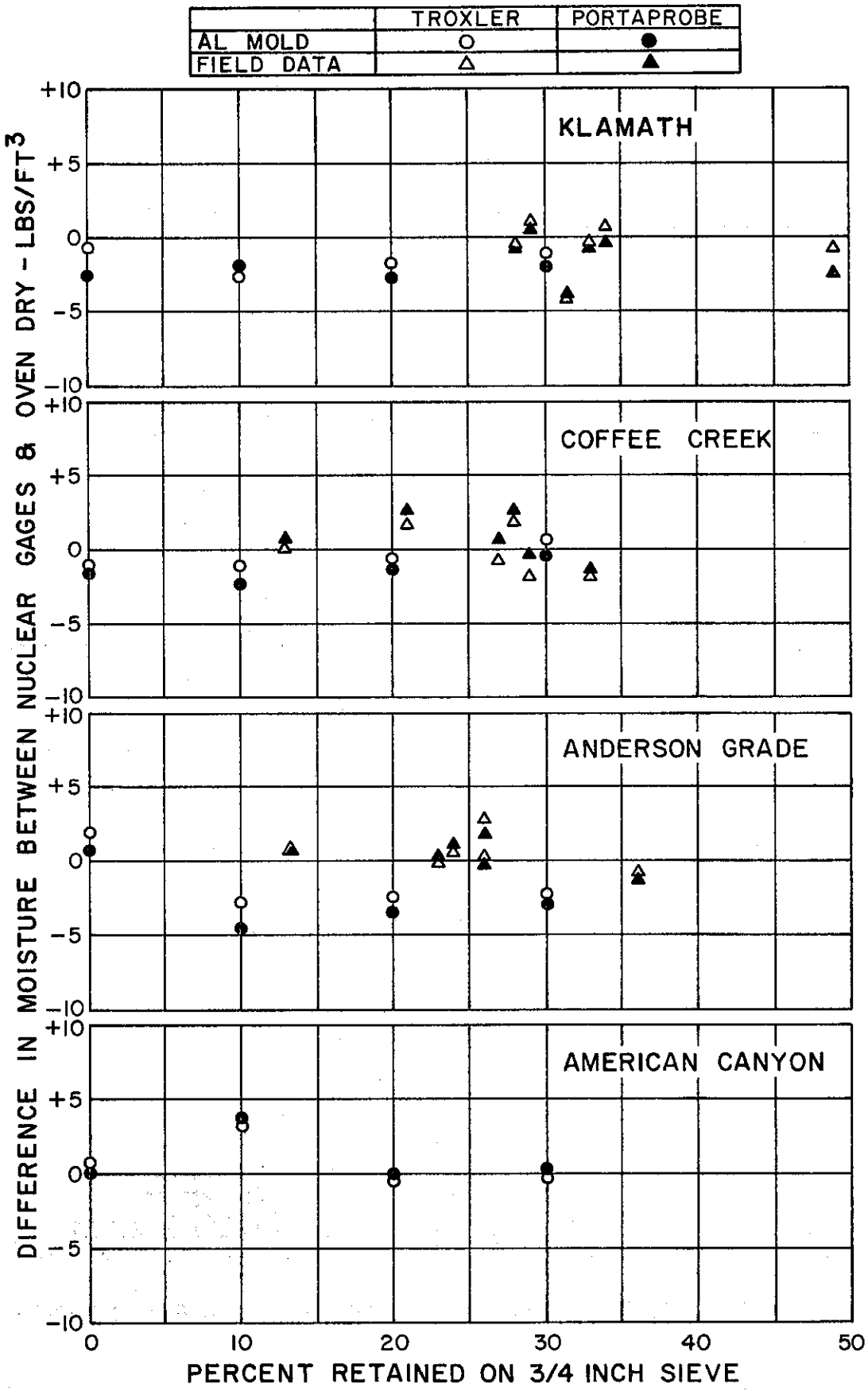


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Figure 6

FREQUENCY DISTRIBUTION OF NUCLEAR VERSUS OVEN DRY MOISTURE CONTENT

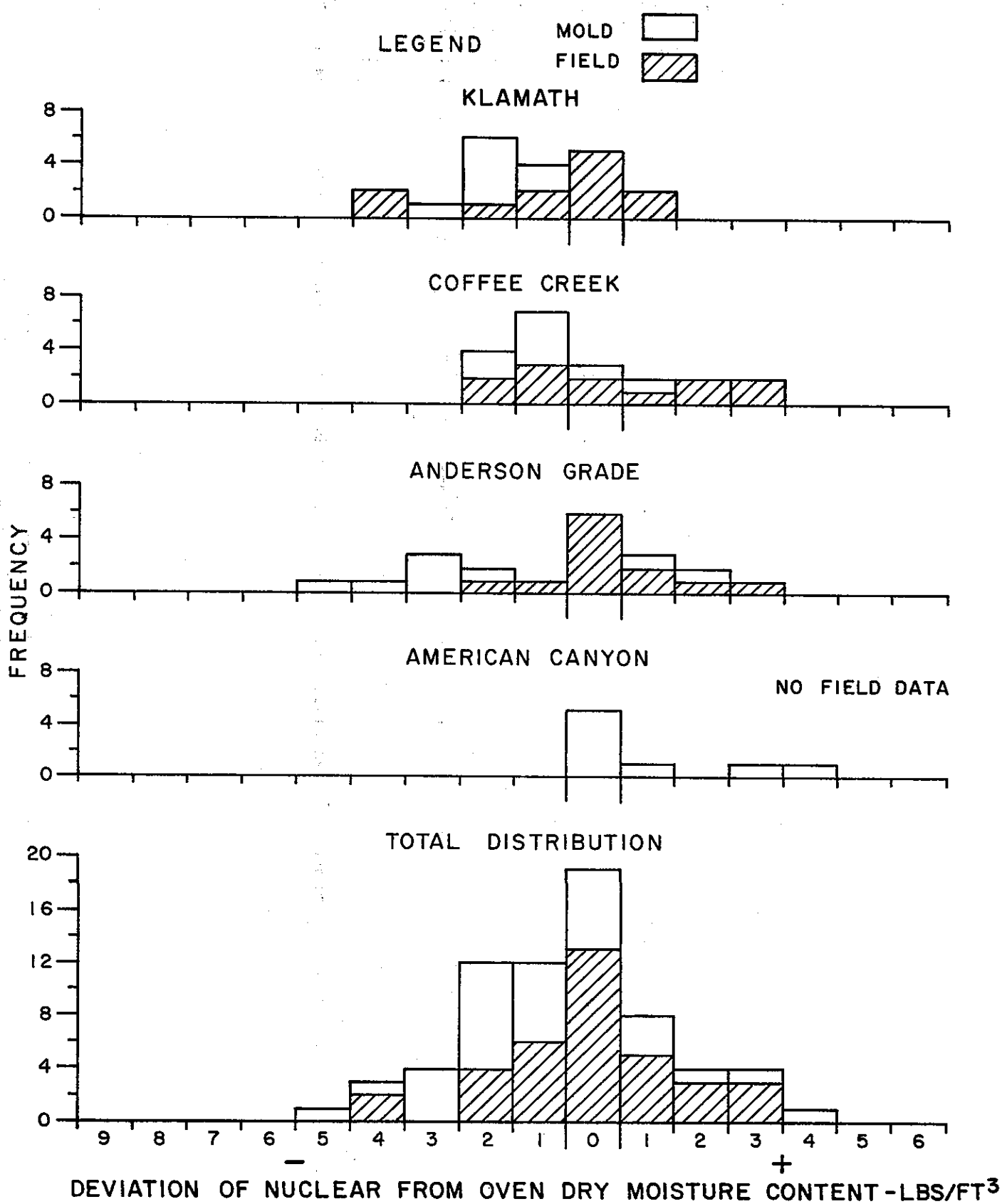


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Figure 7

# DIFFERENCE IN DRY DENSITY BETWEEN NUCLEAR GAGE AND SAND VOLUME METHODS RELATIVE TO PERCENT ROCK RETAINED ON 3/4-INCH SIEVE

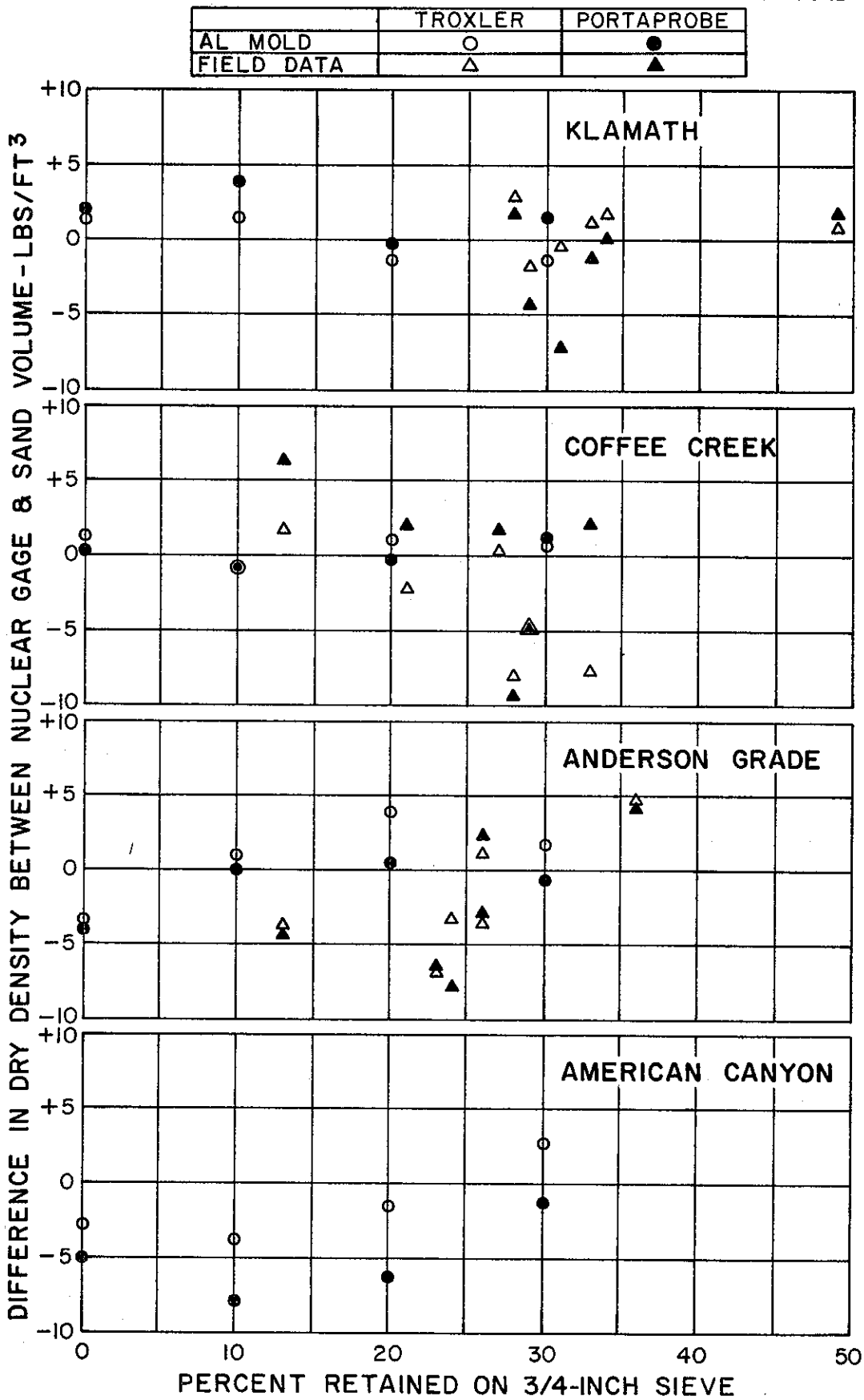


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Figure 8

FREQUENCY DISTRIBUTION OF NUCLEAR VERSUS SAND VOLUME DRY DENSITIES

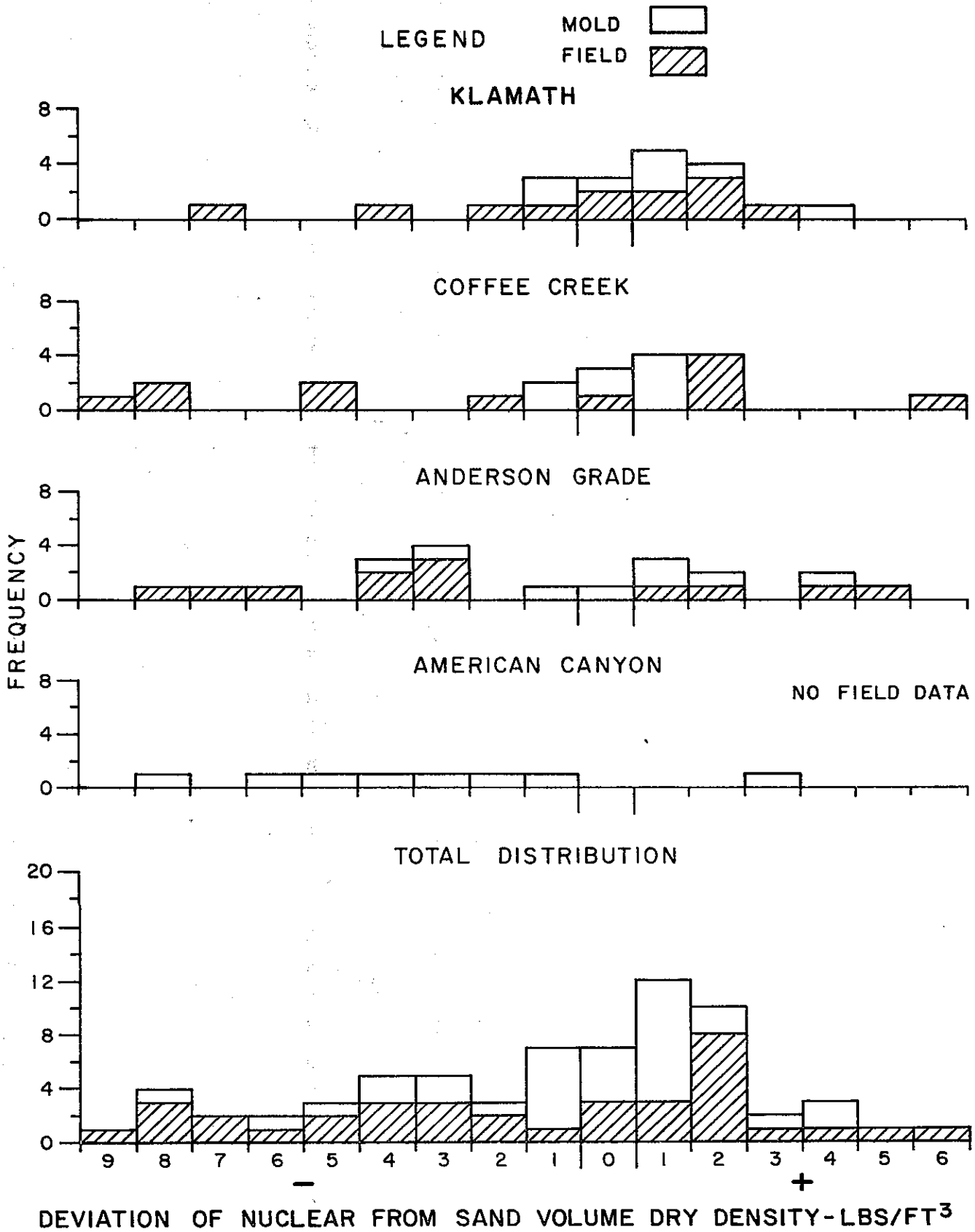


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Figure 9

# DIFFERENCE IN RELATIVE COMPACTION BETWEEN NUCLEAR GAGE & SAND VOLUME METHODS RELATIVE TO PERCENT ROCK RETAINED ON 3/4-INCH SIEVE

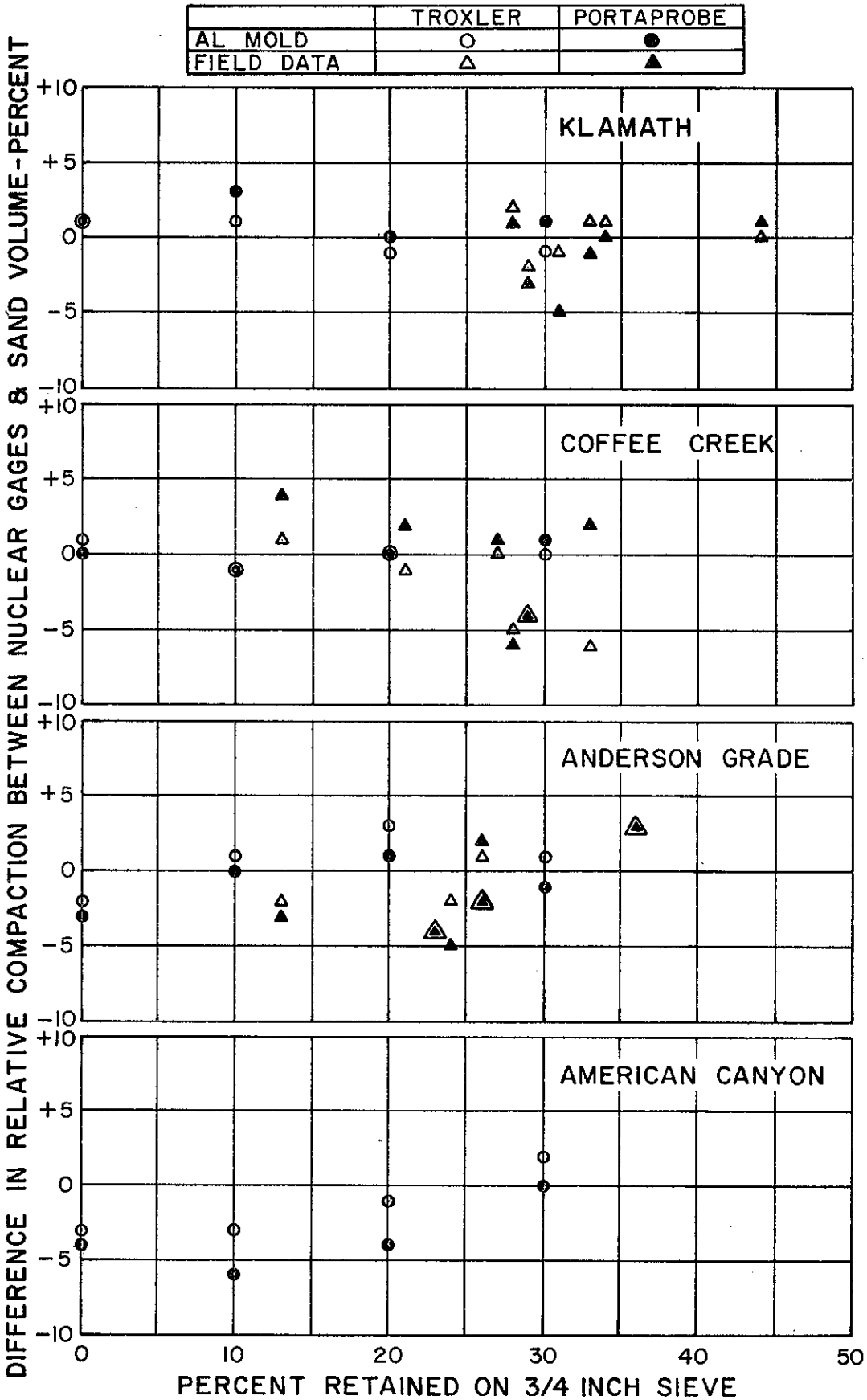


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Figure 10

FREQUENCY DISTRIBUTION OF NUCLEAR VERSUS SAND VOLUME PERCENT RELATIVE COMPACTION

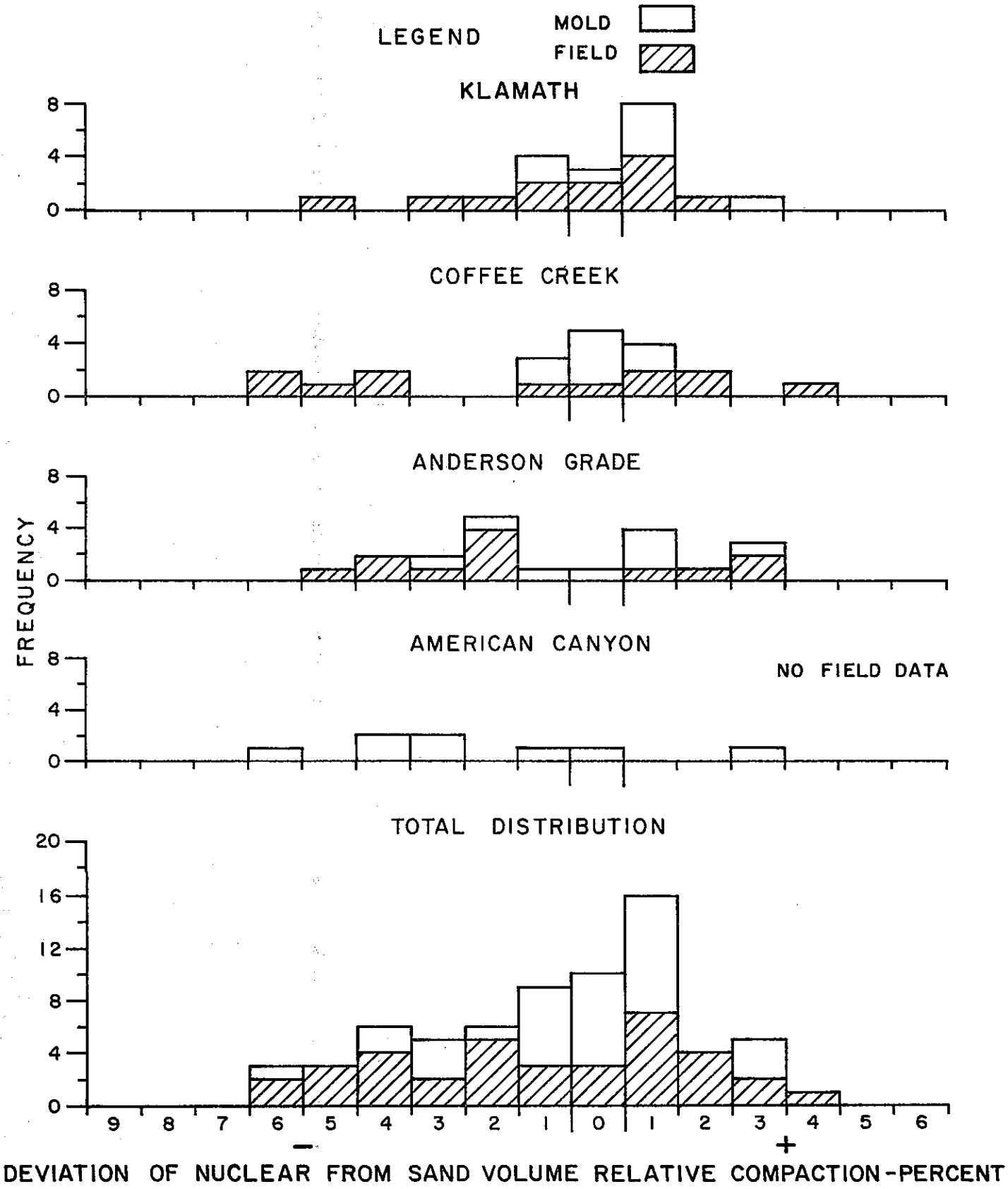


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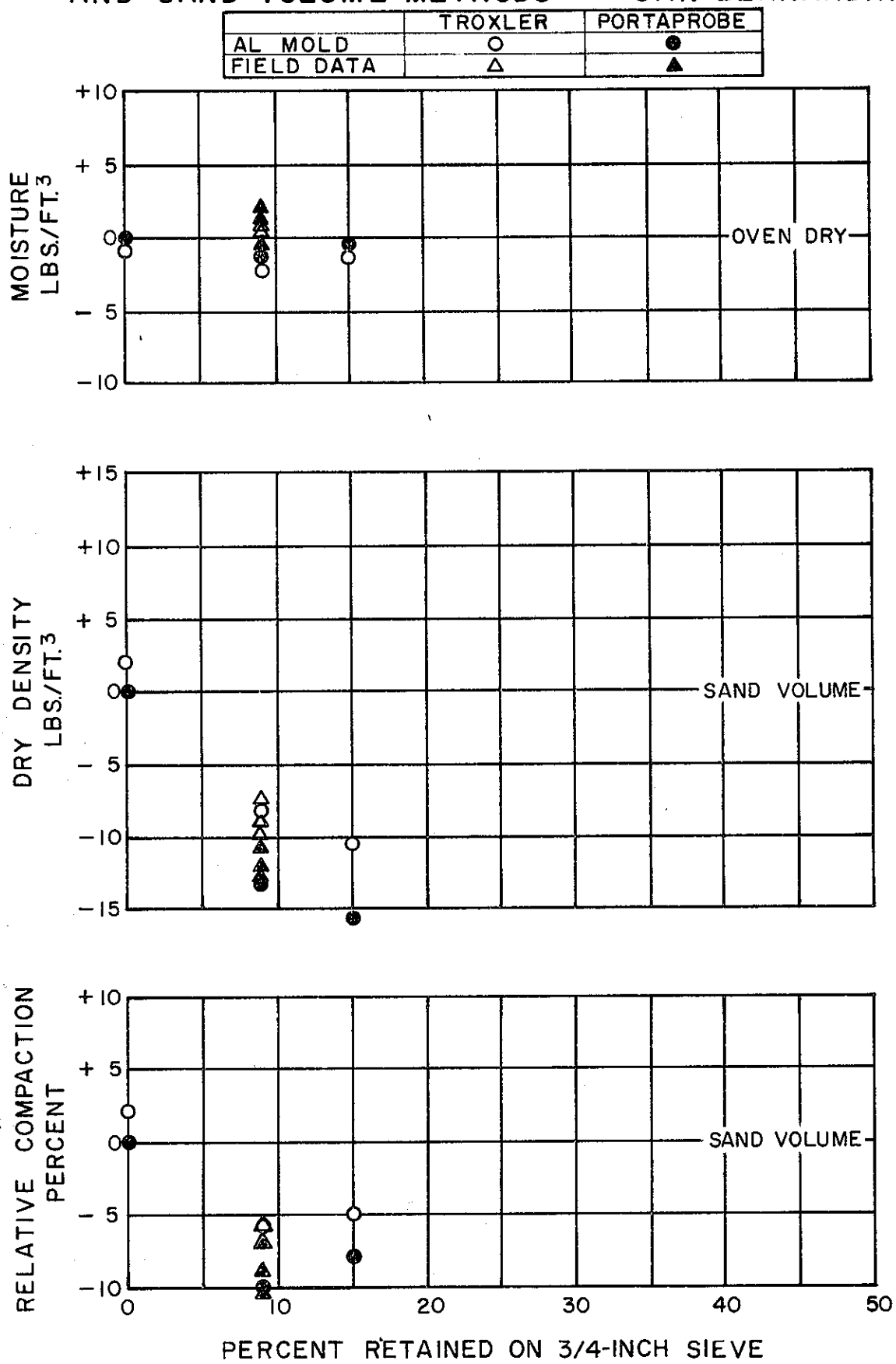
Figure 11

# DIFFERENCES BETWEEN MOISTURE, DRY DENSITY AND RELATIVE COMPACTION AS DETERMINED BY NUCLEAR AND SAND VOLUME METHODS — SAN BERNARDINO

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# FREQUENCY DISTRIBUTION OF NUCLEAR VERSUS SAND VOLUME MOISTURE, DRY DENSITY AND RELATIVE COMPACTION SAN BERNARDINO

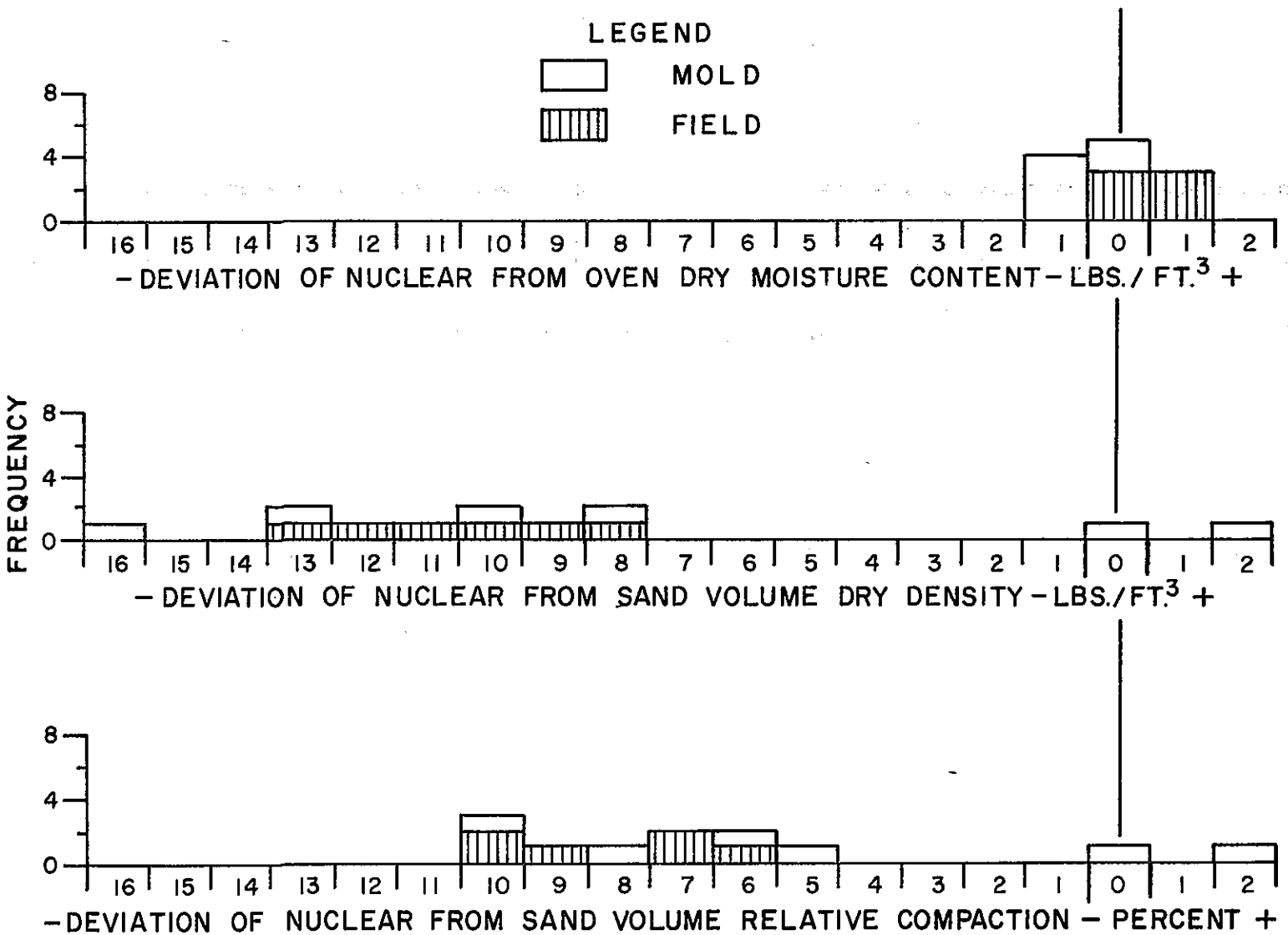


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Figure 12

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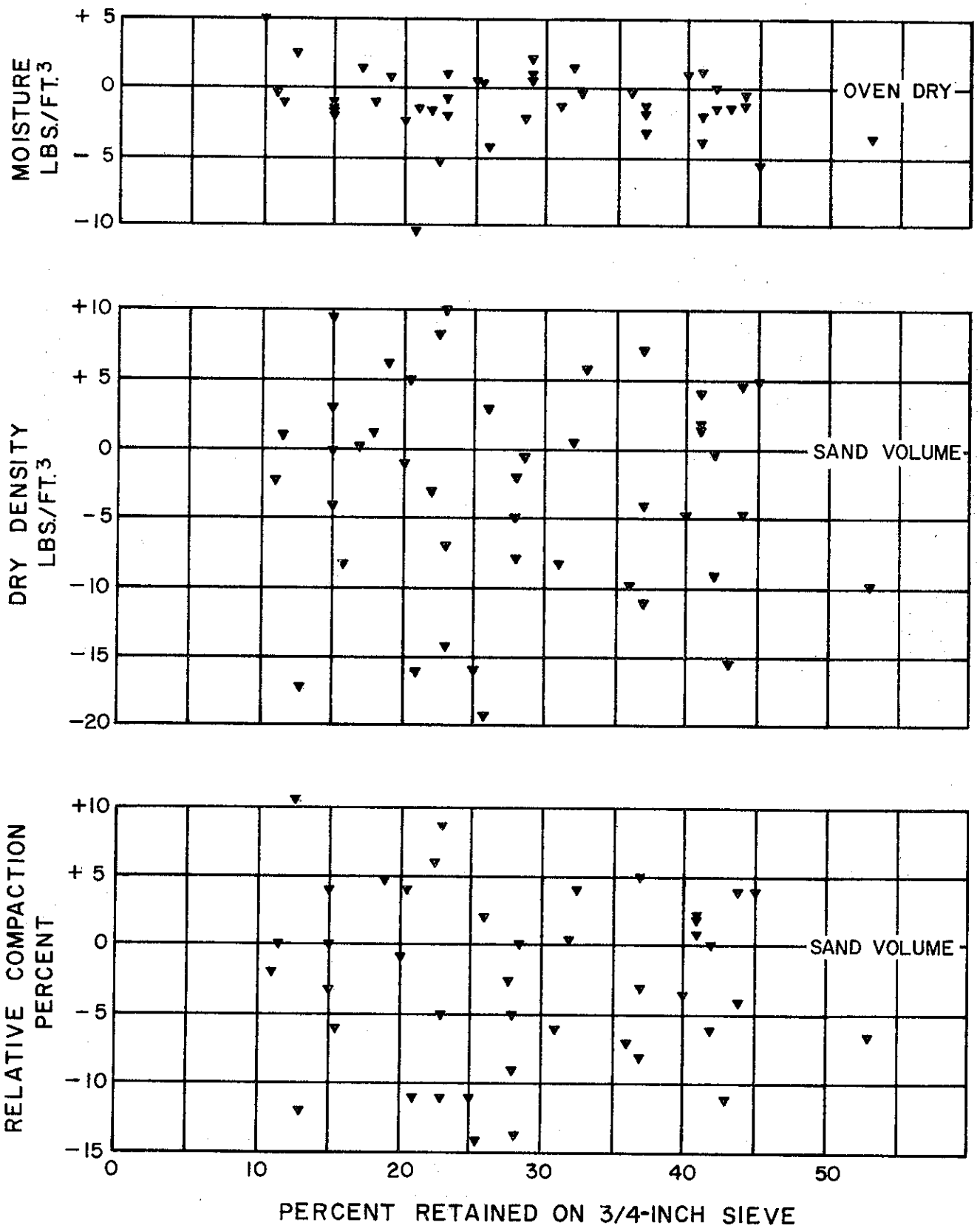
Figure 13

# DIFFERENCES BETWEEN MOISTURE, DRY DENSITY AND RELATIVE COMPACTION AS DETERMINED BY NUCLEAR AND SAND VOLUME METHODS AT VARIOUS LOCATIONS

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# FREQUENCY DISTRIBUTION OF NUCLEAR VERSUS SAND VOLUME MOISTURE, DRY DENSITY AND RELATIVE COMPACTION VARIOUS LOCATIONS

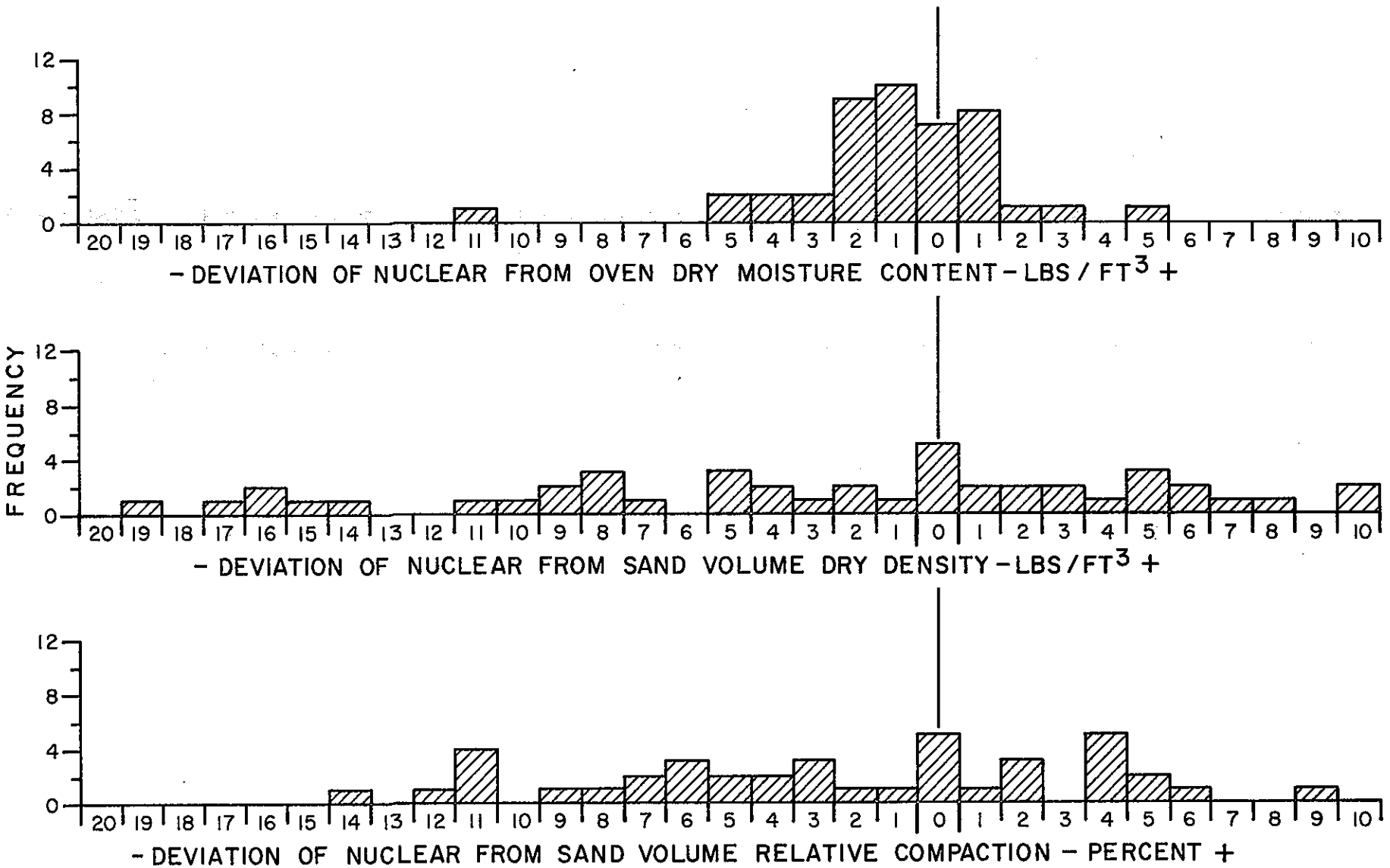


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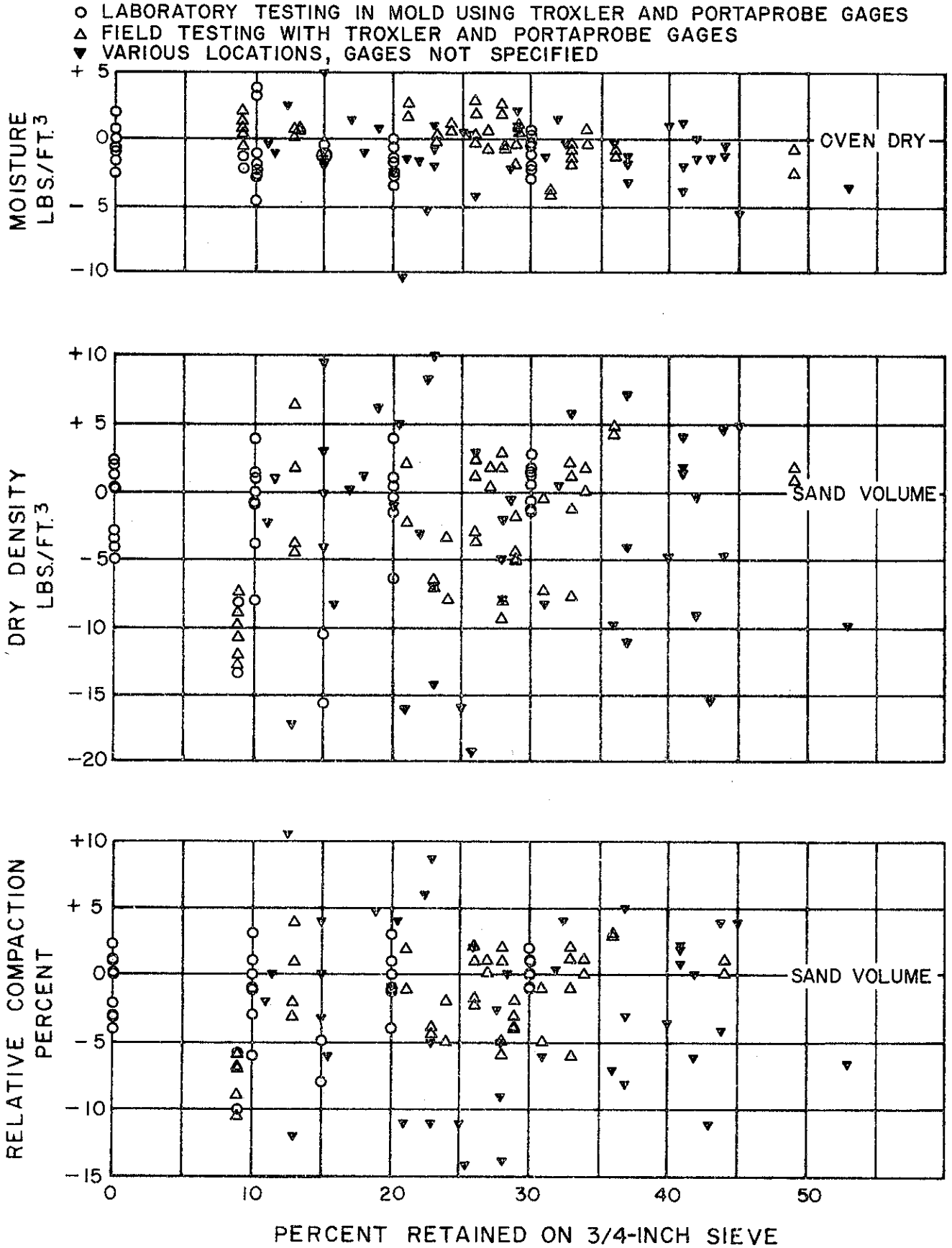
Figure 14

Figure 15

## SUMMARY OF DEVIATIONS OF NUCLEAR FROM SAND VOLUME TEST DATA WITH RESPECT TO PERCENT ROCK RETAINED ON 3/4-INCH SIEVE

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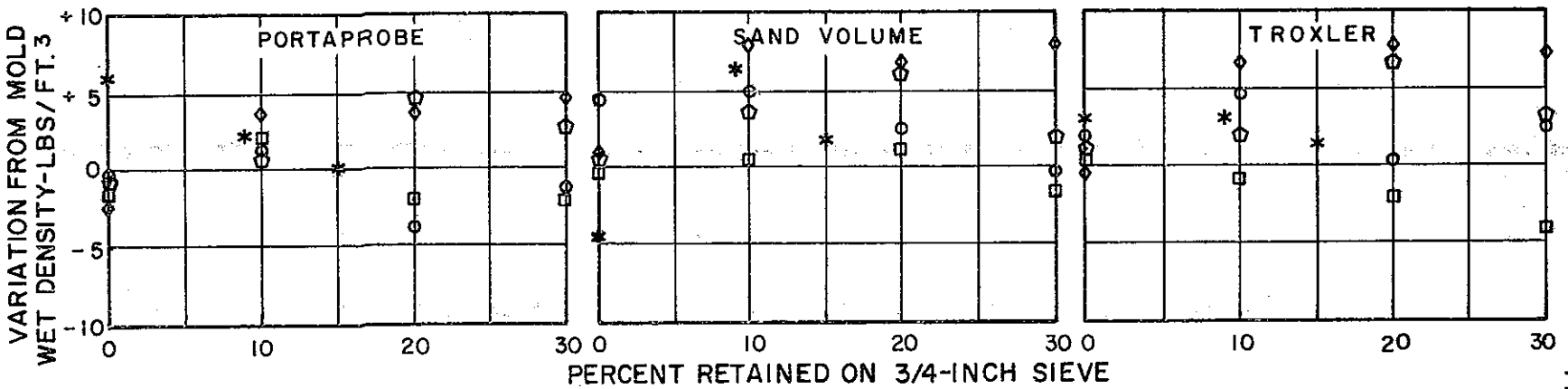
## WET DENSITY BY SAND VOLUME AND NUCLEAR GAGES RELATIVE TO MOLD WET DENSITY WITH RESPECT TO VARIOUS PERCENTAGES OF ROCK RETAINED ON 3/4"-SIEVE

LOCATIONS

□ KLAMATH ○ AMERICAN CANYON
⬠ COFFEE CREEK * SAN BERNARDINO
◇ ANDERSON GRADE




## RANGES OF WET DENSITY DEVIATIONS BY NUCLEAR GAGE AND SAND VOLUME METHODS RELATIVE TO MOLD WET DENSITY WITH RESPECT TO VARIOUS PERCENTAGES OF ROCK RETAINED ON A 3/4"-SIEVE

| | PORTAPROBE | SAND VOLUME | TROXLER |
|---|---|---|---|
| AMERICAN CANYON, ANDERSON GRADE, COFFEE CREEK, KLAMATH | | | |
| SAN BERNARDINO ONLY | * | * | * |

NUCLEAR GAGE DATA IS SLIGHTLY OFFSET FROM TRUE PERCENTAGES FOR ILLUSTRATIVE PURPOSES

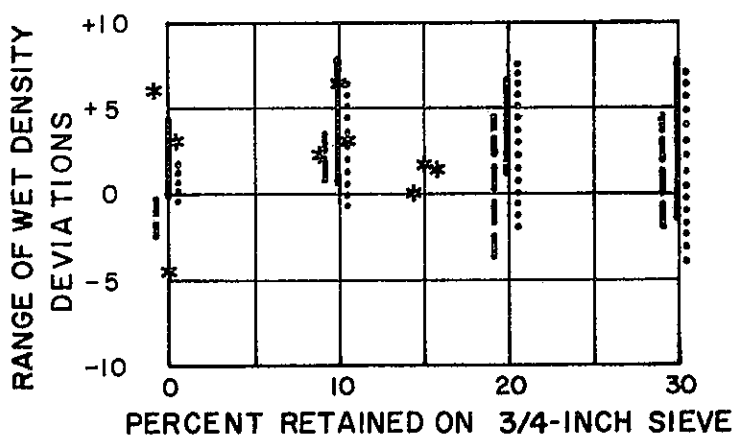



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Figure 16

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# ADDENDUM A

# NUCLEAR GAGE MOISTURE STUDY
# ROAD 08-SBd-15, 31, 138

September , 1968

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State of California | Highway Transportation Agency

# Memorandum

To : Individually addressed to each District Engineer

Date : September 10, 1968

File : Nuclear Gage-Moisture Study
E.A. No. 642978
08-SBd-15,31,138

From : Department of Public Works—Division of Highways
Materials and Research Department

Subject:

Attached is a copy of a memorandum to District 08 Engineer, Mr. C. V. Kane, presenting our recent findings concerning the effect of metal pipes and a concrete slab on moisture determinations made with a Troxler nuclear gage.

This information is being distributed to bring the Districts up to date on what is being done on the nuclear gage-moisture determination problem. The data forwarded to District 08 was limited to findings with a Troxler gage and structure backfill (a gravelly sand) from Cajon Wash which was used on Contract No. 08-049114, Road 08-SBd-15,31,138, P.M. on Rte. 15 - 12.9/22.7. The Troxler gage data are shown on Fig. 1 through Fig. 14.

The entire testing operation was duplicated with a Portaprobe gage and these data are shown on Fig. 1, 2 and Fig. 15 through Fig. 26. The effect of the metal pipes and concrete slab on the Portaprobe readings are somewhat similar to the effect on the Troxler readings. However, the distance within which the gages are affected by the objects is greater for the Portaprobe gage than for the Troxler gage.

The conclusions in the attached memorandum should not be applied to all materials throughout the state, but the data can serve as a guide if it is necessary to make corrections in moisture determinations when the gage is used in close proximity to a metal pipe or a concrete wall.

Due to inconsistencies or variations between gages it must be remembered that the calibration curves furnished with each gage must be checked with the actual project materials and with the particular gage which will be used to test the material. This is so stated in Part C. Calibration of Test Method No. Calif. 231.



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If any of the districts are experiencing difficulty in obtaining reliable test results with the nuclear gage, we would want to become aware of it, and hopefully would cooperate with the district in order to eliminate or minimize poor results.

Additional moisture studies are underway on the San Bernardino material. The study consists of determining the effect of horizontal clearance (1", 2" and 3") around the gage and depth of gage (1" to 6") below the surface of the material being tested. This was done when the gage was placed near a concrete slab and when the slab was removed from the test area. The material was tested at two moisture contents: (1) slightly below optimum and (2) slightly above optimum. A report of these findings will be distributed in the near future.

JOHN L. BEATON
Materials and Research Engineer

By Travis Smith
Travis Smith
Assistant Materials and
Research Engineer - Foundation

WFK:ml
Attach
cc:LR Gillis
JR Jorgenson
AC Estep
Materials Engineer
Dist. Const. Engrs.
Radiation Administrative Officer

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State of California

Highway Transportation Agency

# Memorandum

To :

Mr. C. V. Kane - District 08

Atten: Mr. L. M. Barnett

Date: June 18, 1968

File : Troxler Gage-Moisture Study
E.A. No. 642978
08-SBd-15,31,138

From : Department of Public Works—Division of Highways
Materials and Research Department

Subject:

This project was initiated as a result of difficulties experienced by District 08 on Contract No. 08-049114 on Road 08-SBd-15,31,138 (Cajon Pass Job) when determining moisture and densities with a Troxler nuclear gage on structure backfill containing approximately 15% plus 3/4" fragments.

This memorandum-type report is limited to determining the effect of Corrugated Metal Pipe, Structural Plate Pipe and Portland Cement Concrete when in close proximity of a Troxler gage when obtaining counts for moisture content in structure backfill. The work described herein is part of a much larger research project which will be described in some detail at the end of this memorandum.

A large bulk sample, approximately 4000 lbs., was obtained from two locations on the contract and all of the material was from the same Cajon Wash source.

The testing details will be described later but the conclusions are as follows:

1. The proximity of an 8-inch, 16-gauge CMP, within about 10 or 12 inches, does not affect the moisture determinations made with the Troxler gage. This is shown on Figures 3 and 5.

2. The concrete slab <u>does</u> affect the moisture determinations when the gage is less than about 8" from the slab. This is shown on Figures 7 and 9.

3. The proximity of a 3/8" gauge, 108" diameter structural plate pipe, within about 10" to 12", does not affect the moisture determinations made with the Troxler gage. This is shown on Figures 11 and 13. There may be a slight effect when the gage is at zero or two inches from the pipe as shown on Figure 11.

FORM WH-38 REV.

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Summary

We believe that it is not necessary to make corrections on moisture contents determined with a Troxler gage when the gage is in close proximity of a metal pipe.

The data indicates that a correction should be made on the moisture contents when the gage is less than 8" from a concrete slab. This is true whether the material being tested is at the ground surface or 6" below the ground surface. If the gage is placed in a random manner with respect to the long axis of the gage and the structure the data on Figures 7 and 9 can be used to determine the correction.

We presume that, in practice, the gage is placed so that its long axis is parallel to the structure. If that is the case, the correction should be made after averaging the values shown on Figures 8 and 10 for sides A and C. This average will give a higher correction than using the average of the four sides.

Testing Details

For this nuclear-moisture study, the material was scalped on the 1½" sieve for compacting in the 12" deep aluminum mold or the 12" deep hole in the ground. Compaction was done with a 10-lb hammer, 18" drop, equipped with a 4-inch square foot. The specimens were compacted in four 3-inch lifts.

The moisture calibration curve was established by compacting four specimens at four different moisture contents, ranging between 4.7 and 8.7 lbs. per cu. ft., in an aluminum mold with inside dimensions of 18" square by 12" deep and recording nuclear counts on each of four specimens. The calibration curve, moisture vs. count ratio*, is shown on Figure 1. These moisture contents were determined by the oven-dry method.

The field testing of this San Bernardino County material has consisted of testing it after compaction in a 3' square by 12" deep hole dug in the native soil in Sacramento. The testing was performed at density and moisture conditions similarly obtained on the actual contract. Dry densities ranged from 124.1 to 127.0 lbs. per cu. ft. and moisture contents ranged from 4.8 to 6.1%. The structural materials used on the project consisted of: A. Two 8-inch, 16-gauge helical CMP, one above the other, so that the mid-point of the upper pipe would be at the surface of the structure backfill and the original ground. B. The concrete slab actually consisted of two slabs, 3' wide x 4' high, with a combined thickness of approximately 7", C. A 34-inch section of

---

$$*\text{Count Ratio} = \frac{\text{Test Count}}{\text{Standard Count}}$$

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63-inch arc length, 108-inch diameter, 3/8" gauge, structural plate pipe. The structure backfill was compacted in four 3-inch layers and the nuclear gage readings were recorded at the 6-inch level and the 12-inch level (level with ground surface). These conditions are illustrated in Figure 2.

On each of the two levels, readings were taken when each of the four sides of the Troxler gage was zero, 2", 4", 6", 8", 10" and 12" from and parallel to the metal pipe or concrete slab. The identification of the four sides is shown on Figure 4. These four readings for each point are shown on Figures 4, 6, 8, 10, 12, and 14. The average of each of the group of four readings is shown on Figures 3, 5, 7, 9, 11 and 13.

Additional laboratory work will be done on this material in the 18" x 18" x 12" aluminum mold.

Additional Work on this Research Project

Large bulk samples, approximately 2500 to 3500 pounds, have been obtained from other current construction jobs as follows:

1. Road 02-Tri-3-67.8/73.5 Cont. No. 02-044914
2. Road 02-Sis-5-54.2/58.5 Cont. No. 02-046734
3. Road 01-DN-101-4.7/6.1 Cont. No. 01-043954
4. Road 10-Sol-80-8.0/12.5 Cont. No. 10-081104

Field work consisting of density determination by sand volume method and moisture content by oven dry method and density and moisture determinations with two nuclear gages (Troxler and Portaprobe) has been done on the Trinity, Siskiyou and Del Norte projects. Six sites, covering an area of approximately 30' x 150' of rocky embankment material were tested on each project. Sufficient material was obtained from each site to determine test maximum density (impact test) according to Test Method No. Calif. 216-F.

Laboratory work has consisted of compacting the bulk sample material in an aluminum mold 18" square by 12" deep. Four specimens, with varying percentages of +3/4" fragments, i.e., 0%, 10%, 20% and 30%, of the samples from the projects where the field work has been done, have been compacted and tested for density by sand volume method, moisture by oven-dry method and density and moisture determinations with the two nuclear gages. Test maximum density has been determined for each of the specimens.

The testing of the material from Trinity, Siskiyou and Del Norte Counties is 100% complete. About 75% of the testing has been done on the material from Solano County.

Some plotting and anlysis has been done and the one tentative conclusion may be as follows:

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The percentage of +3/4" fragments, in the range tested, 0 - 35%, does not affect the density or moisture determinations made with the nuclear gages.

It is anticipated that the results of all this work will be reported in the next month or so.

Original signed by

JOHN L. BEATON
Materials and Research Engineer

WFK:ic:ml
Attach
cc:LR Gillis
JF Jorgensen
Fred Marshall
Charles Jackson

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Figure I

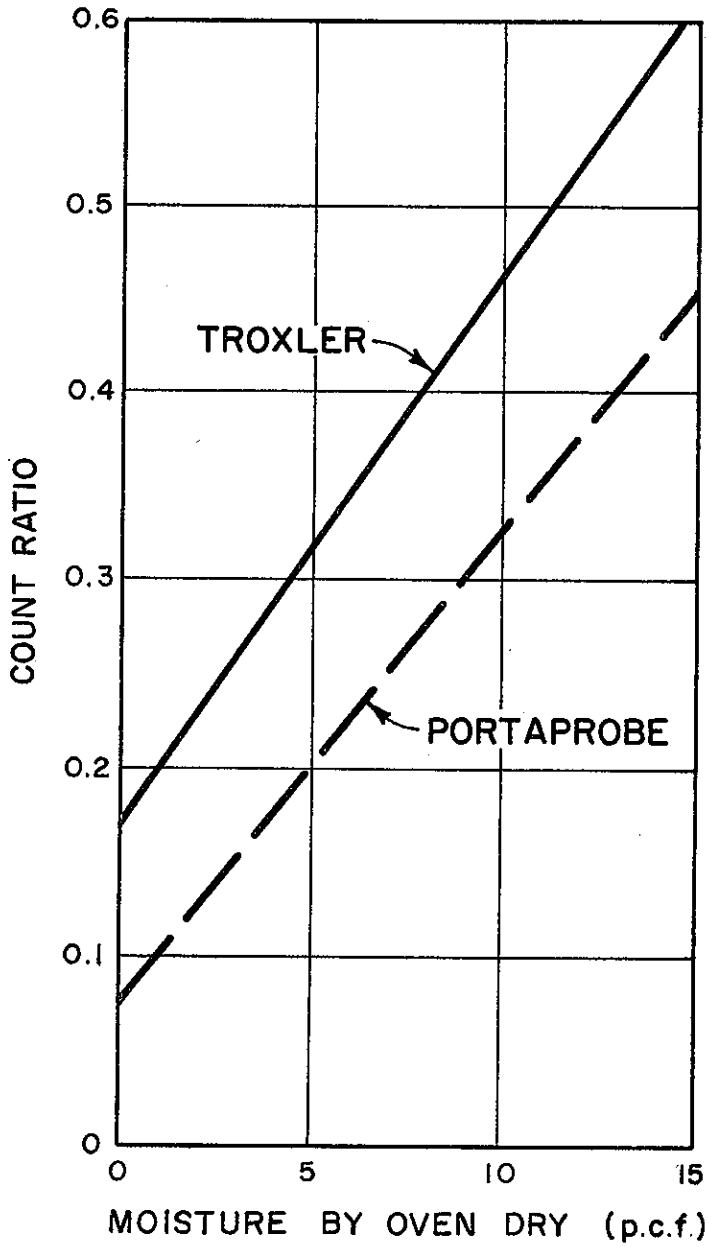
# MOISTURE CALIBRATION
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

LEGEND

TROXLER
SCALER #106
PROBE #114

PORTAPROBE
GAGE #0010

CURVES CALIBRATED JUNE 1968




CURVES CALIBRATED FROM AL MOLD AND FIELD DATA

MATERIALS AND RESEARCH DEPARTMENT
NO M.&R. 642978

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Figure 2

# STRUCTURAL MATERIALS USED IN TROXLER GAGE MOISTURE STUDY

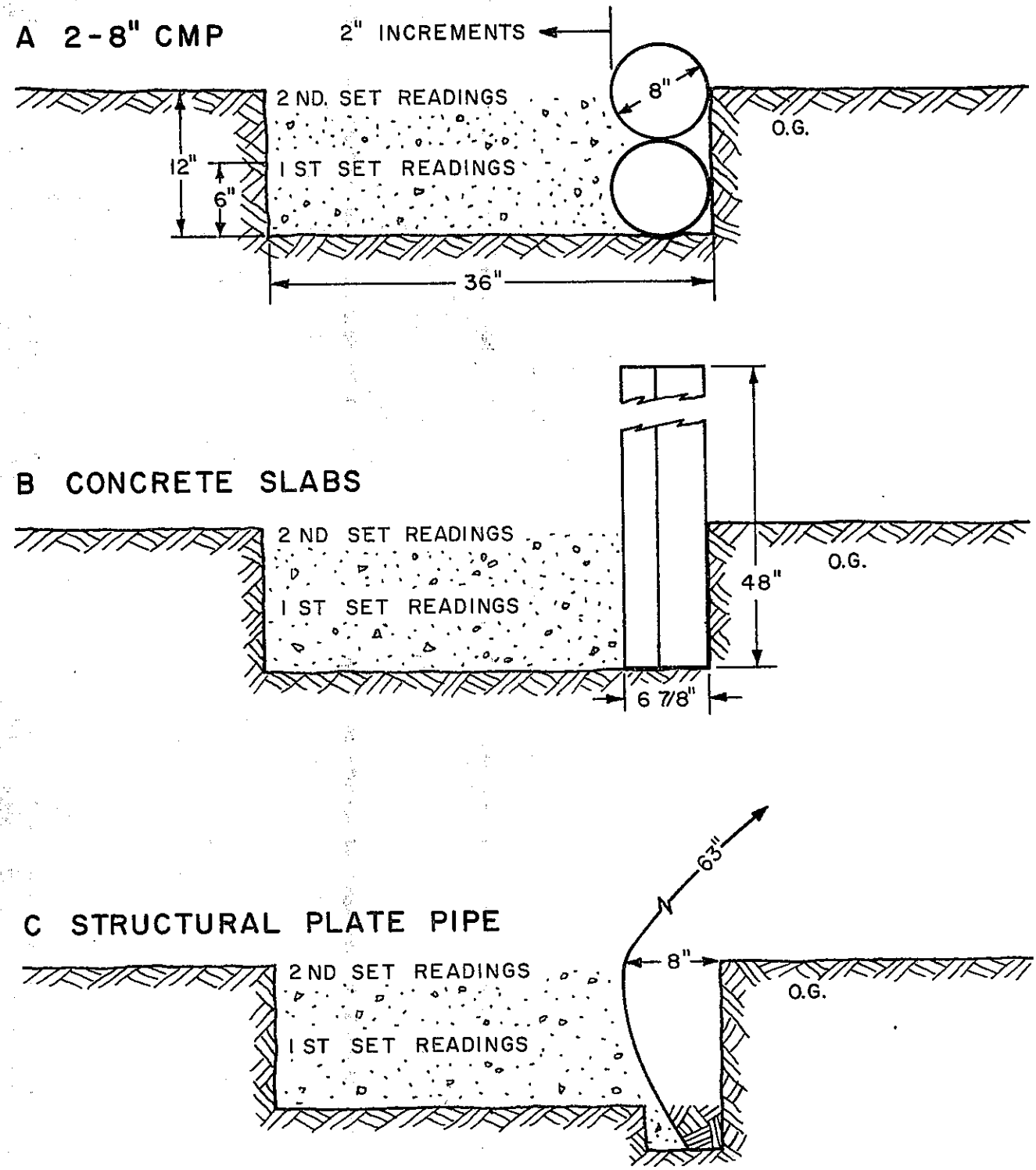


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Figure 3

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

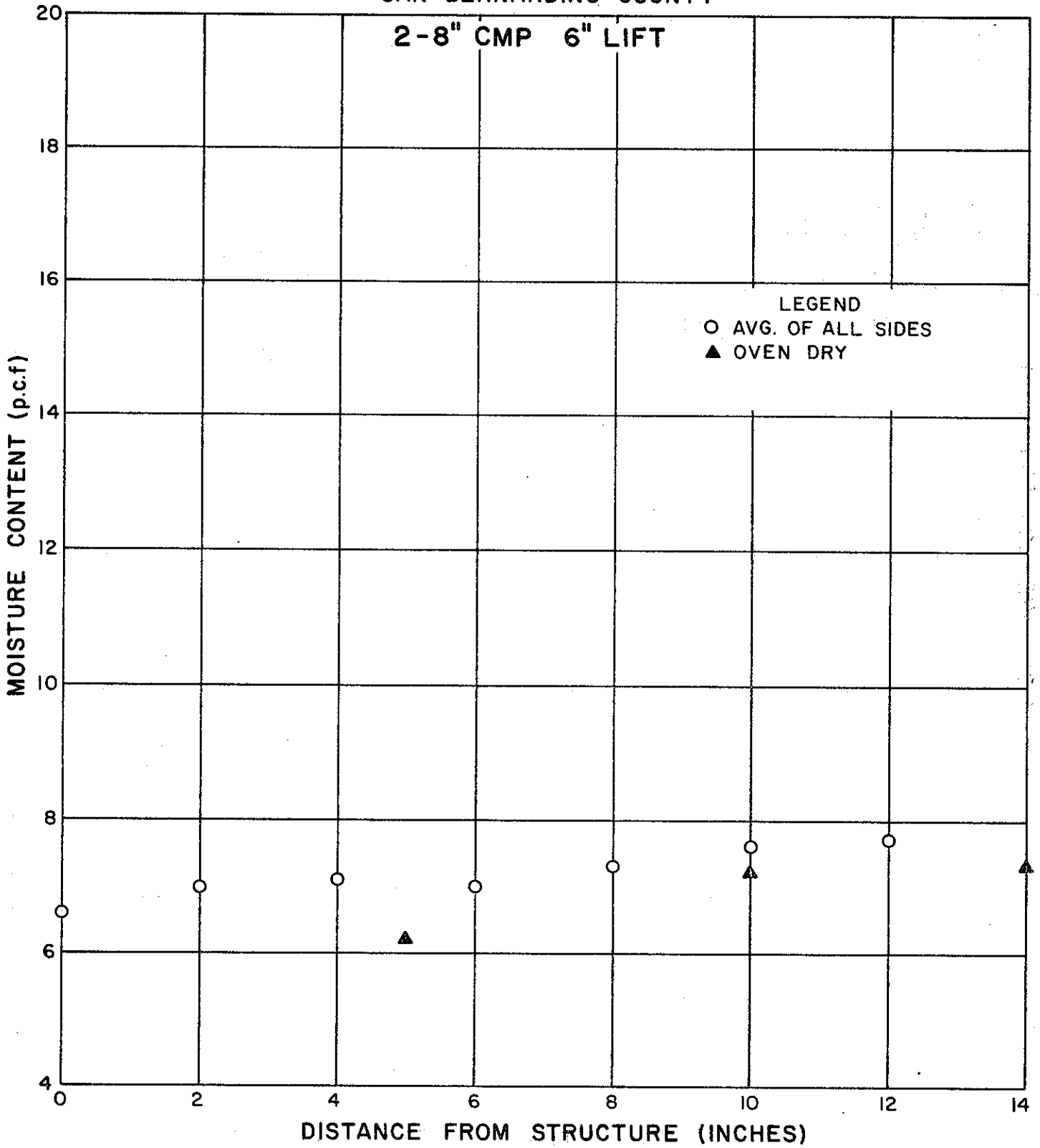


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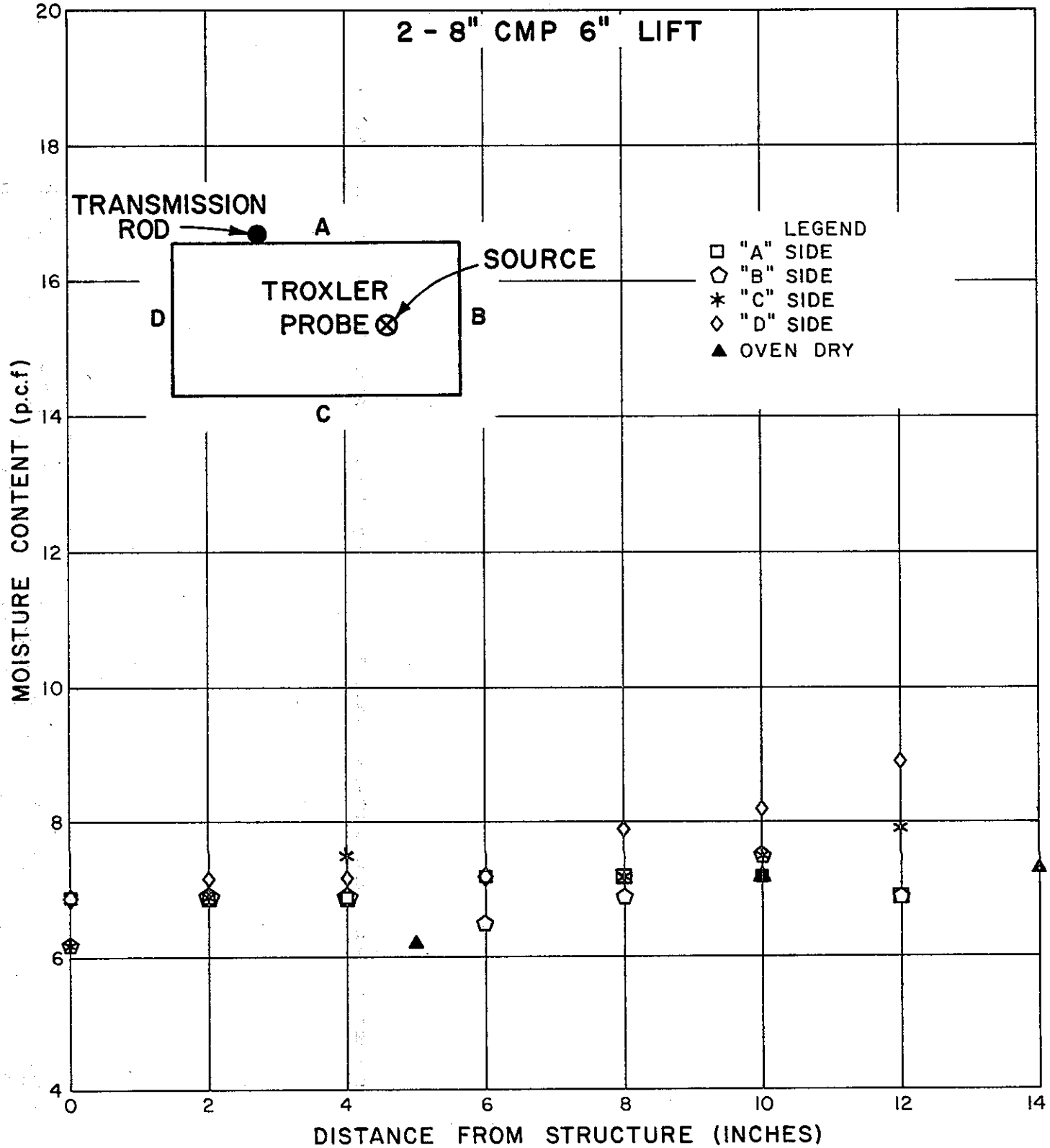
Figure 4

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

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NO. M&R 642978

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Figure 5

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

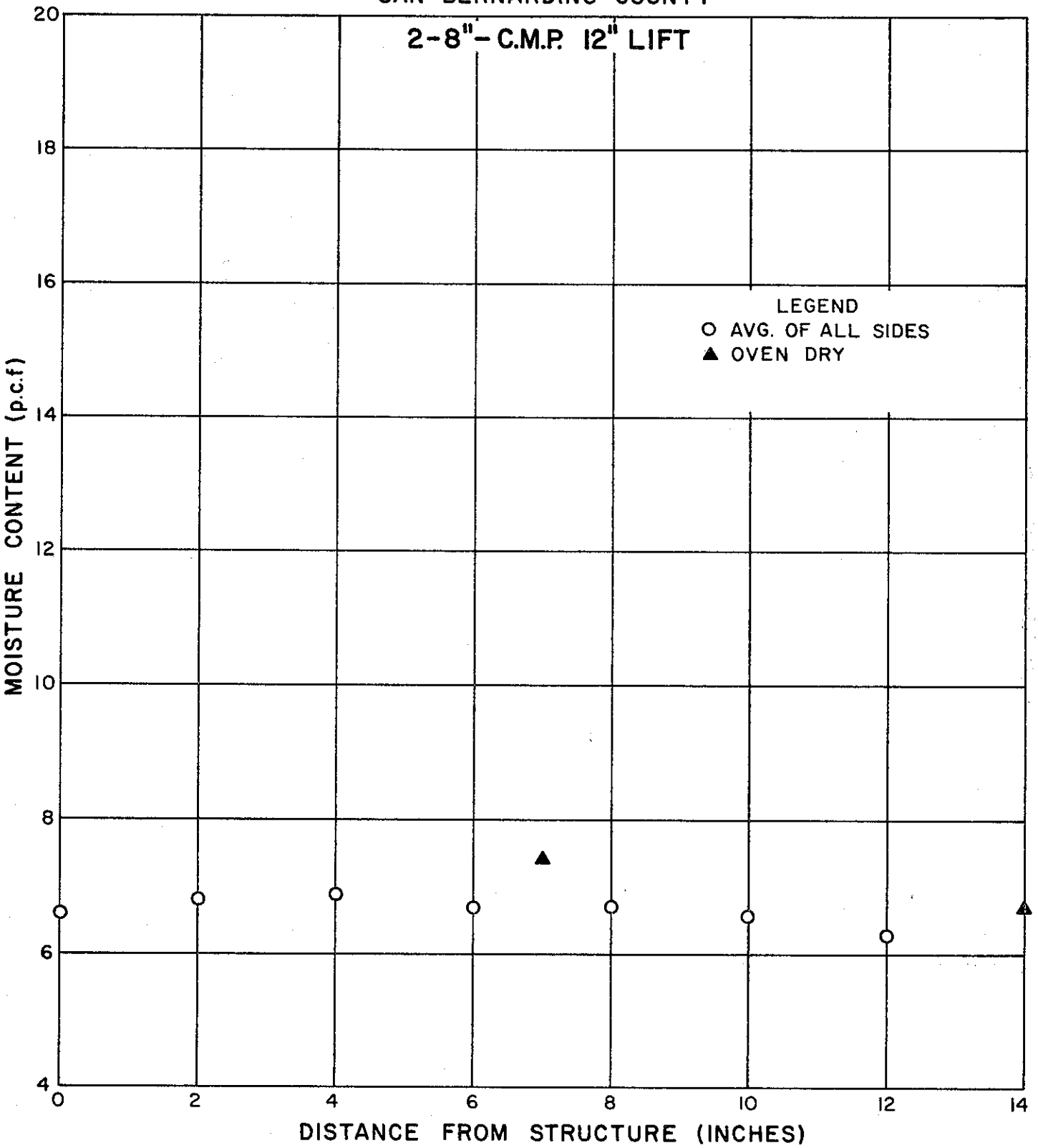


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Figure 6

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

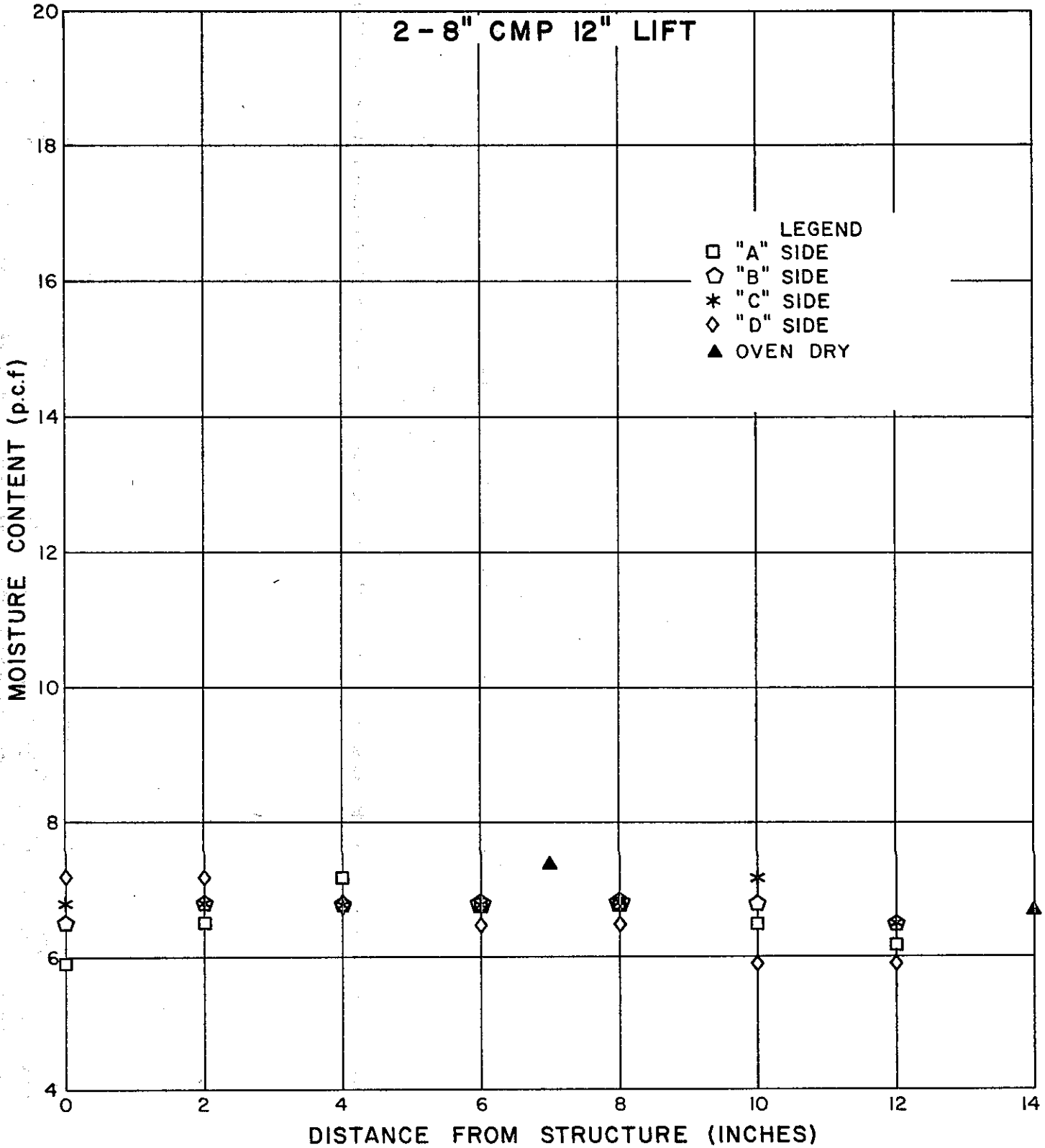


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Figure 7

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

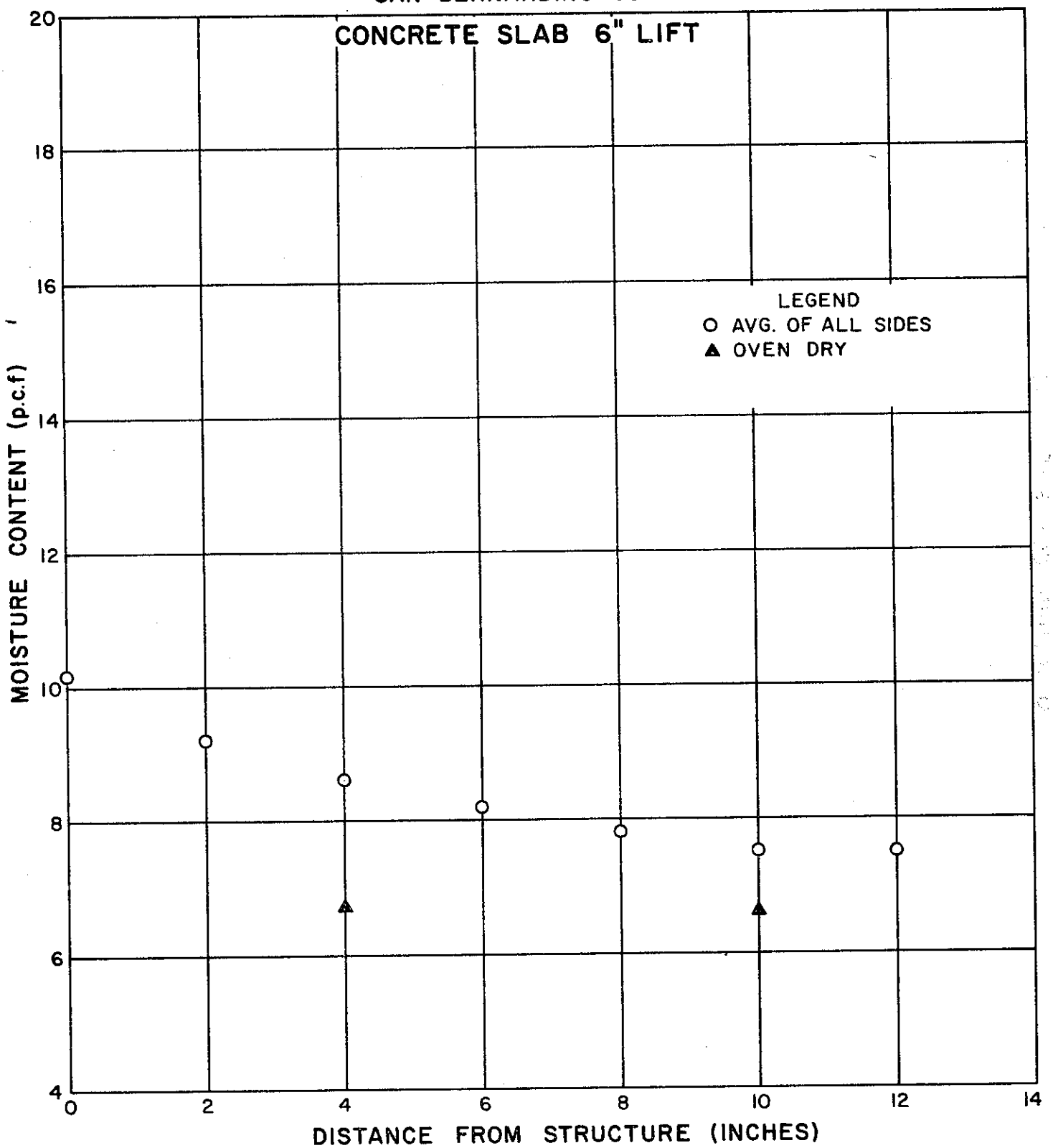


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Figure 8

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

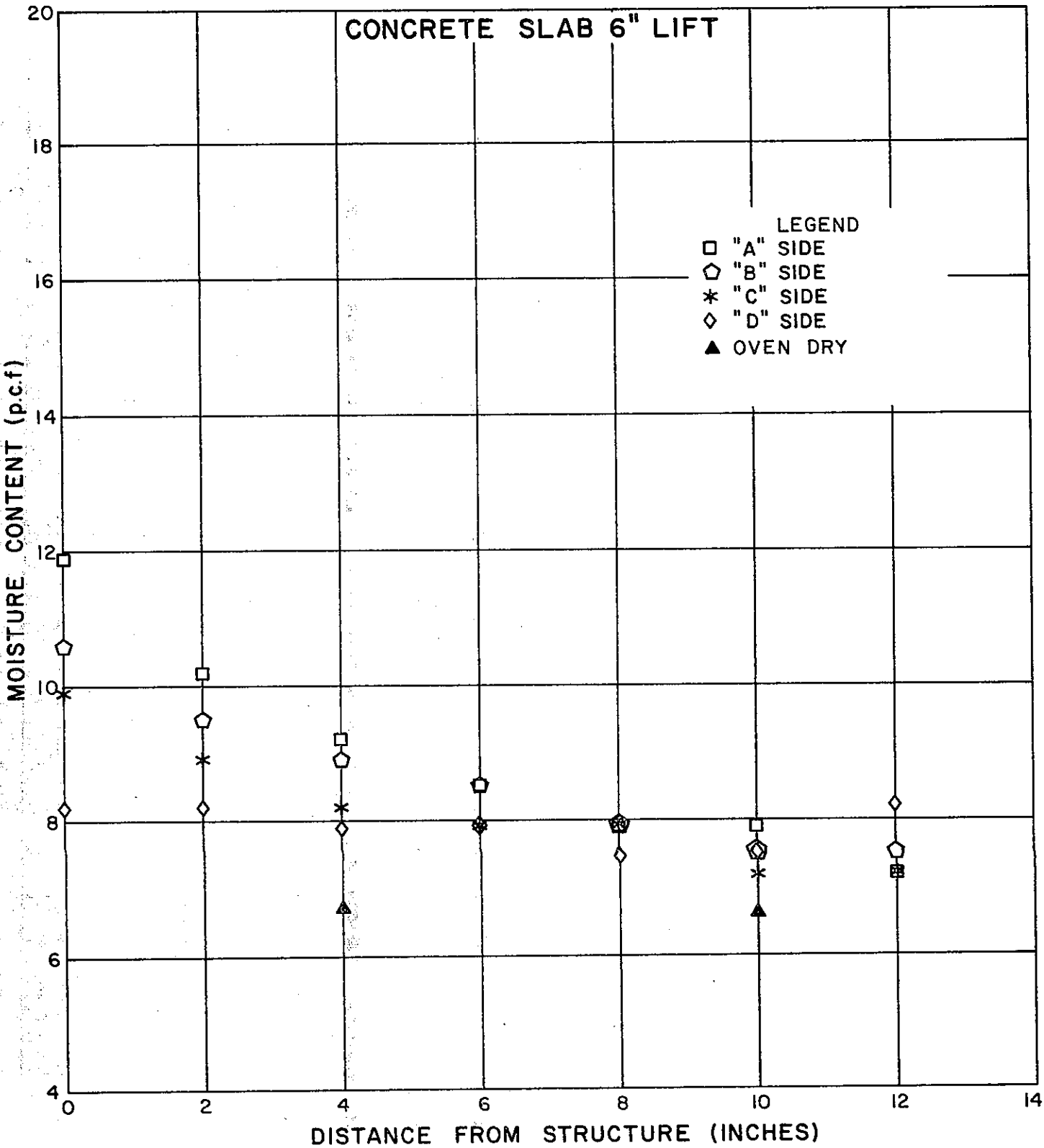


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Figure 9

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

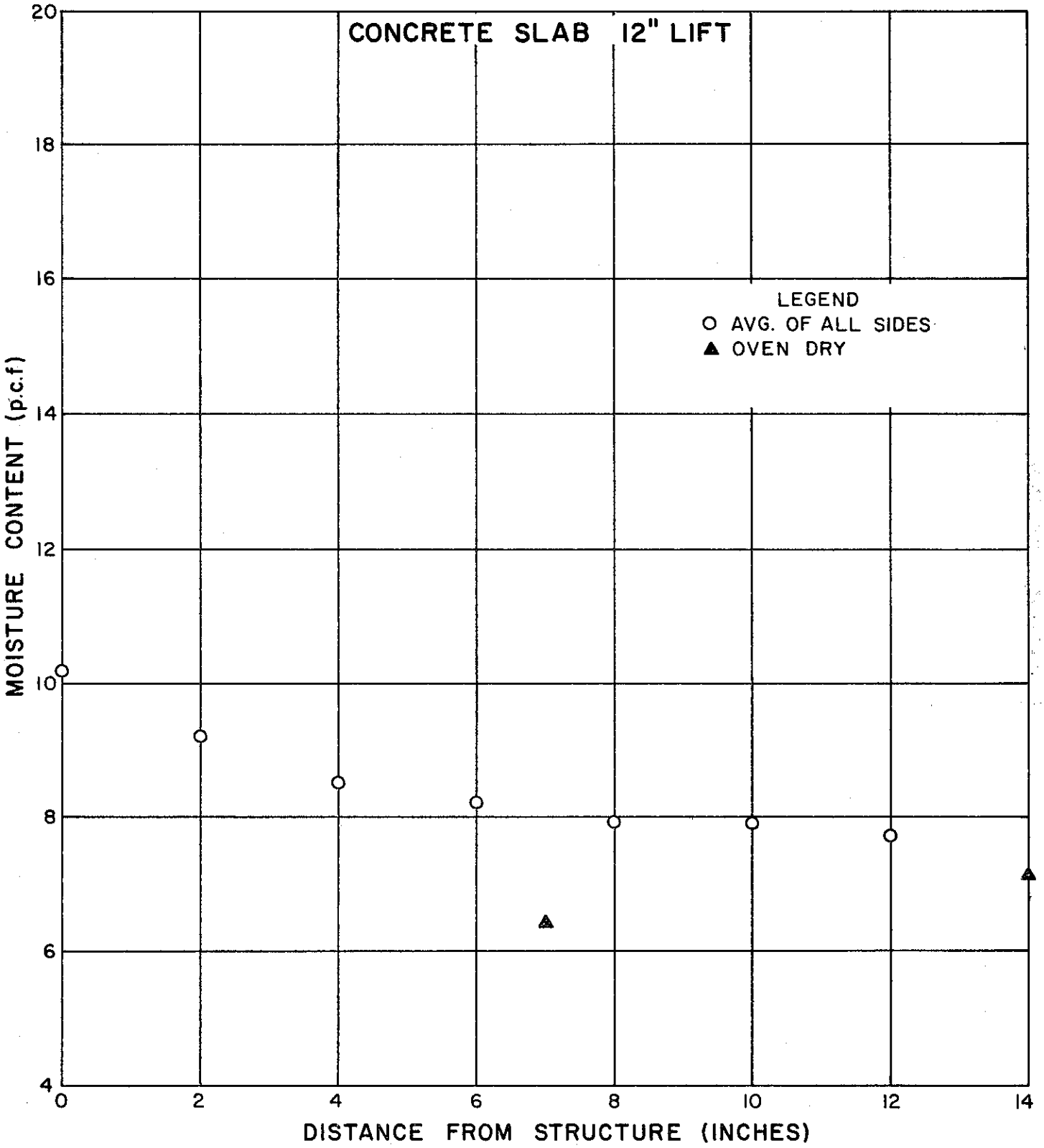


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Figure 10

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

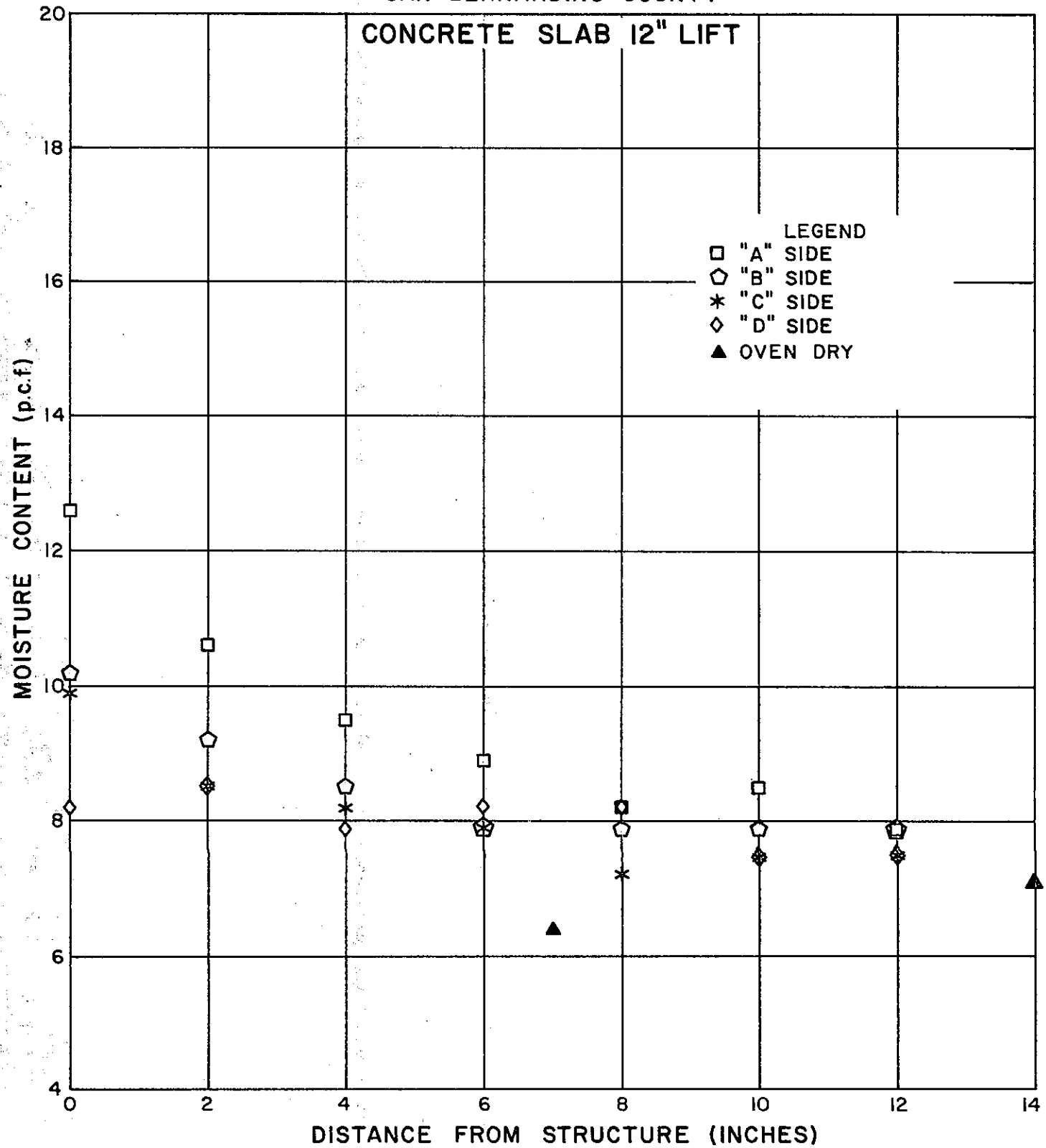


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Figure 11

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

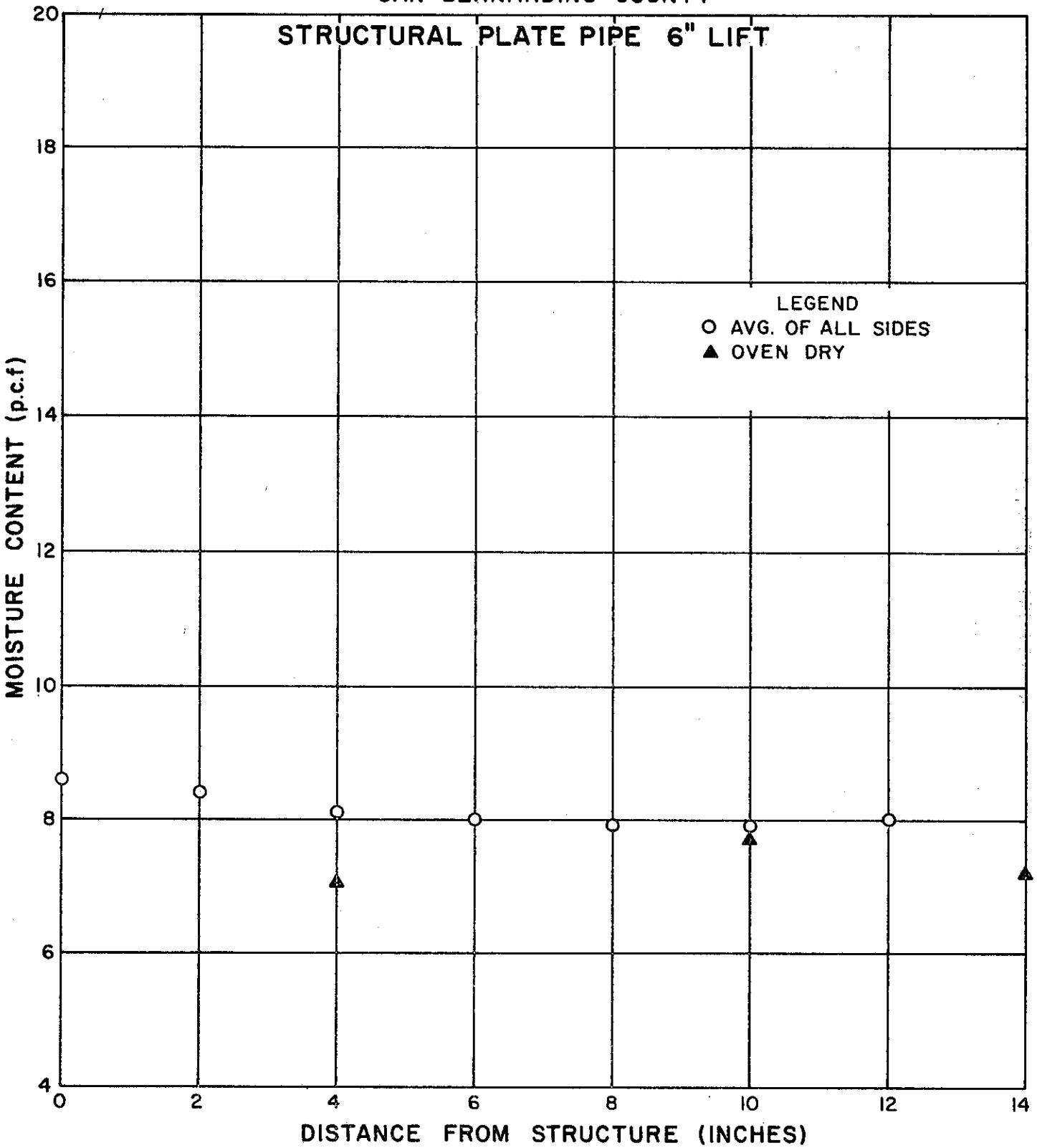


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Figure 12

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

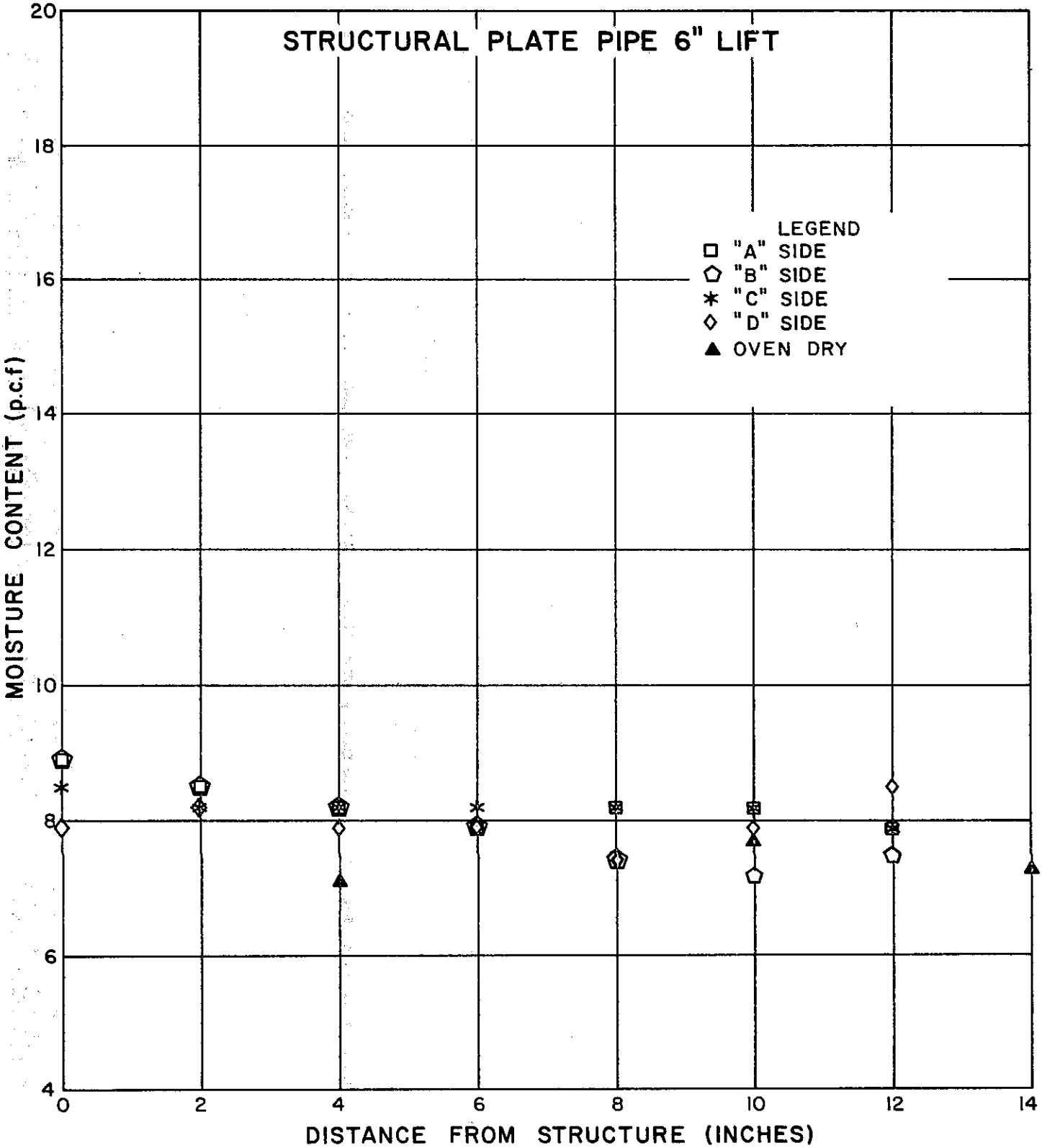


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Figure 13

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

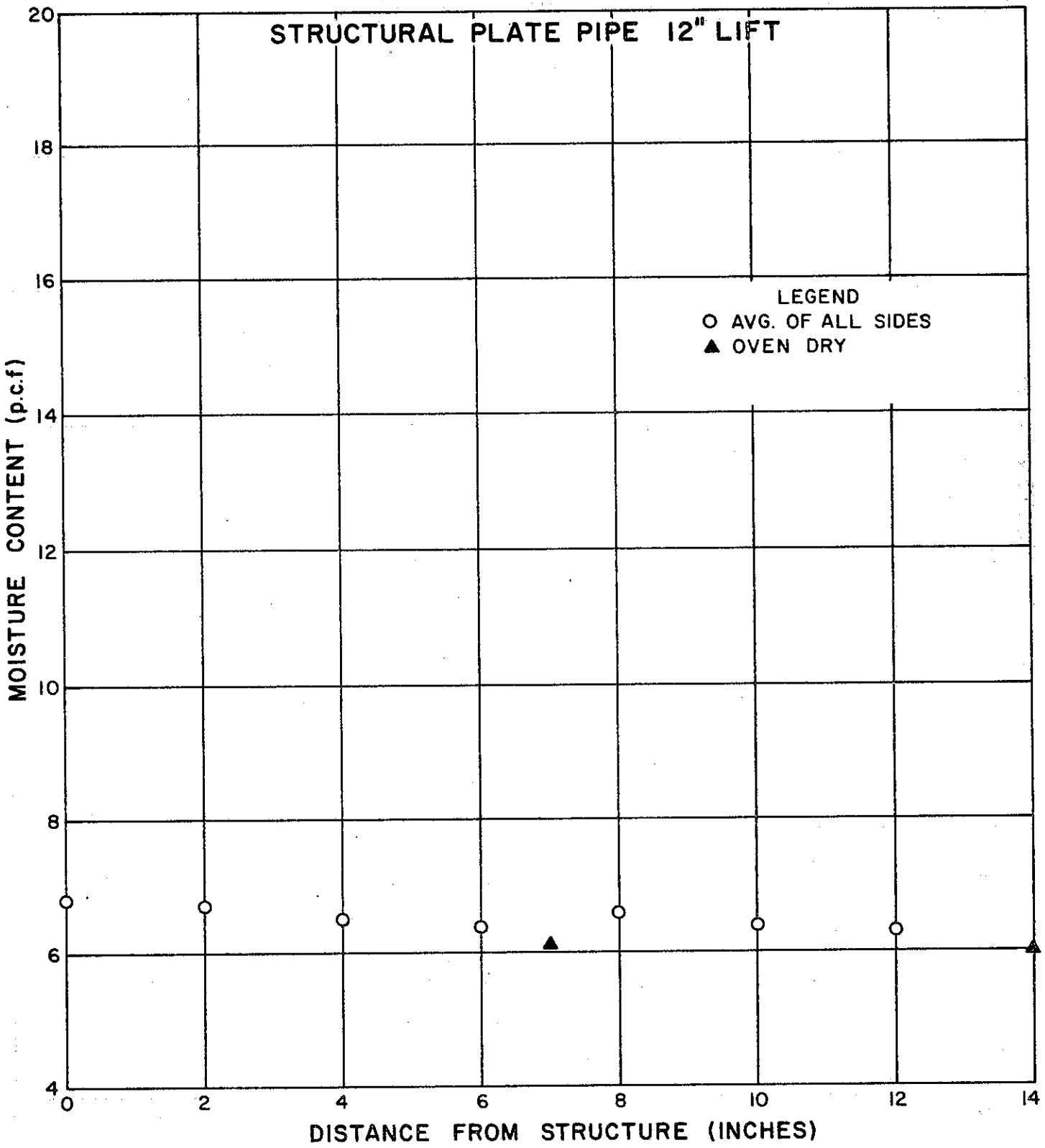


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Figure 14

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

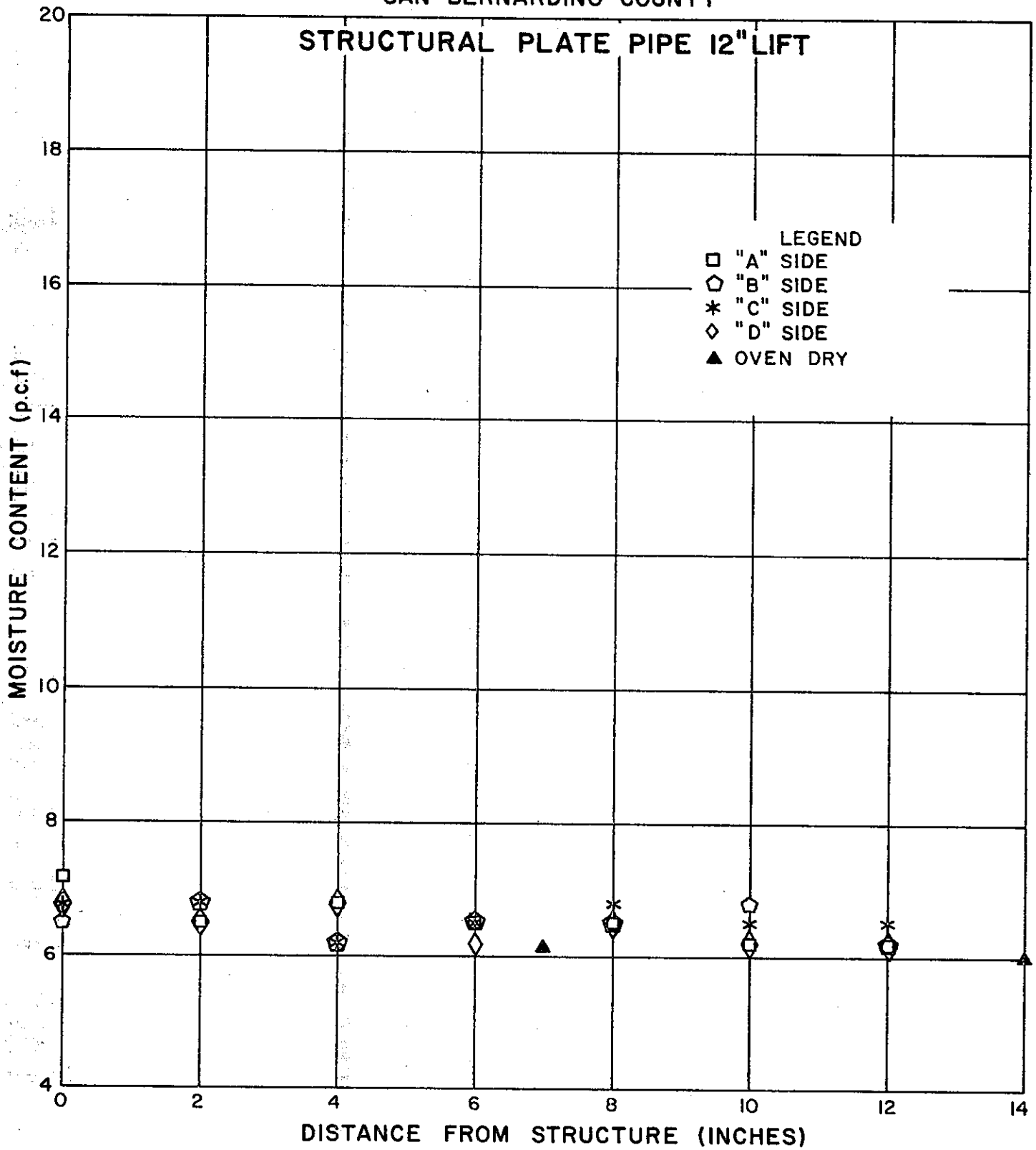


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Figure 15

# PORTAPROBE GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

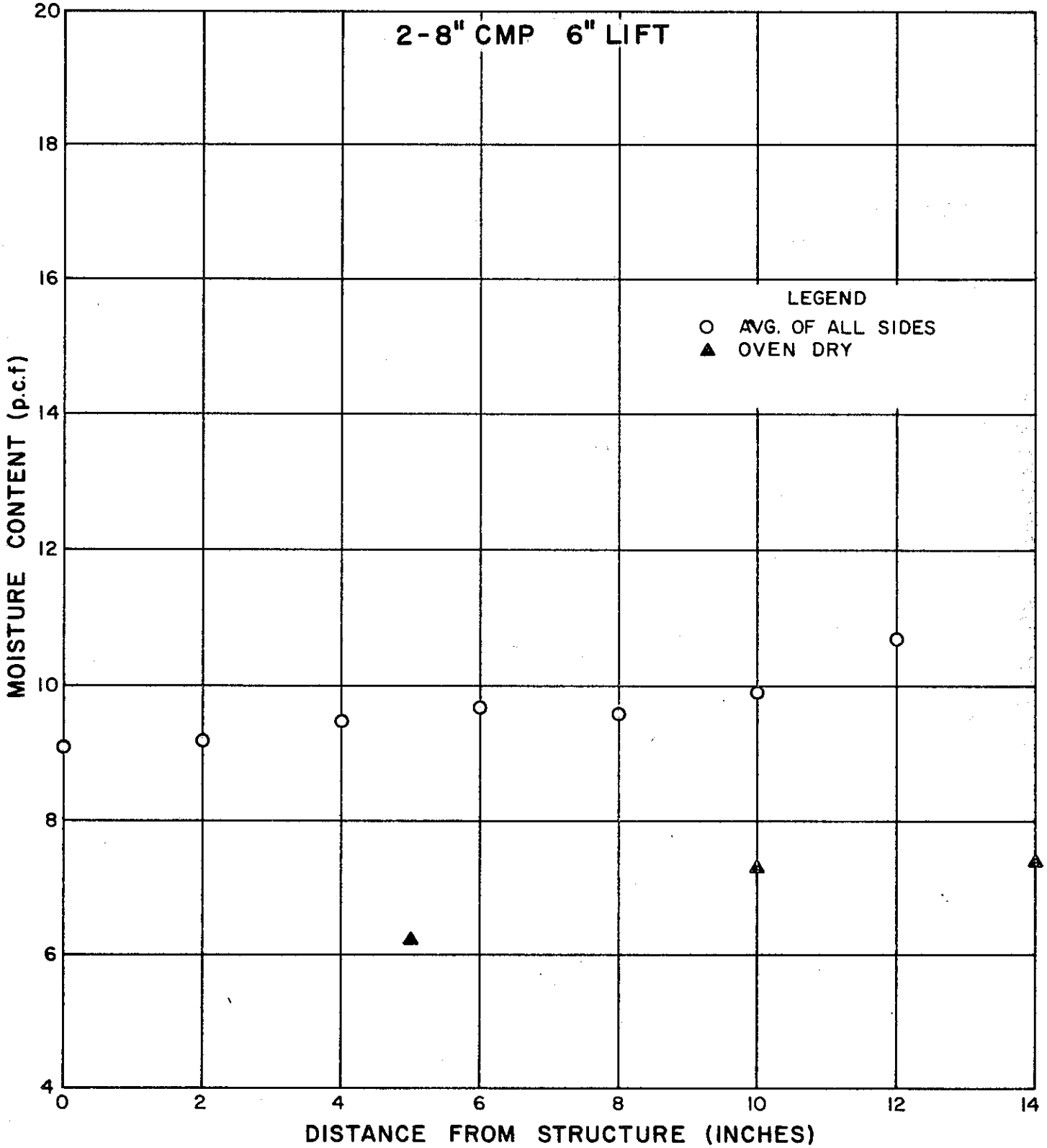


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Figure 16

# PORTAPROBE GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

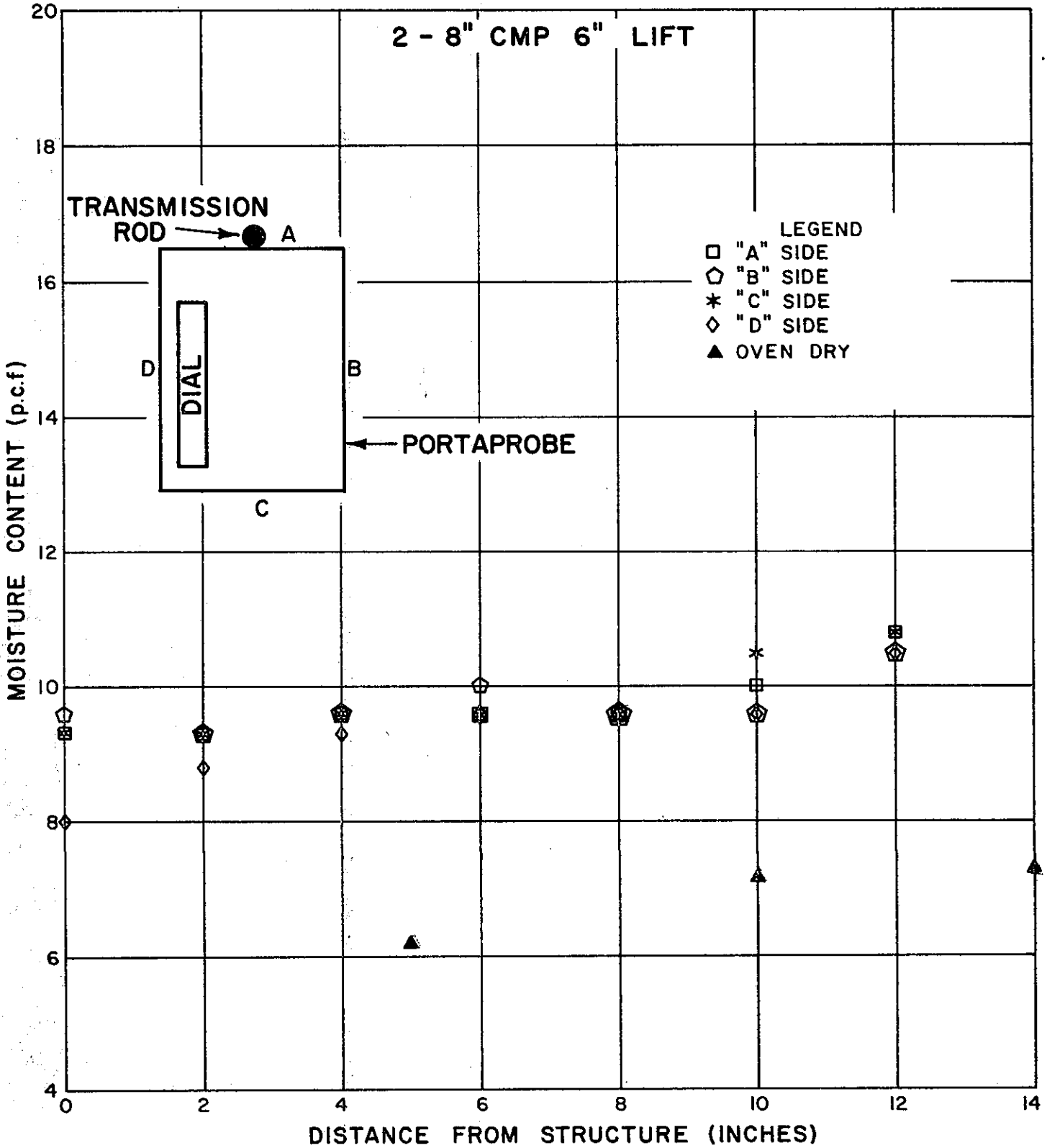


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Figure 17

# PORTAPROBE GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

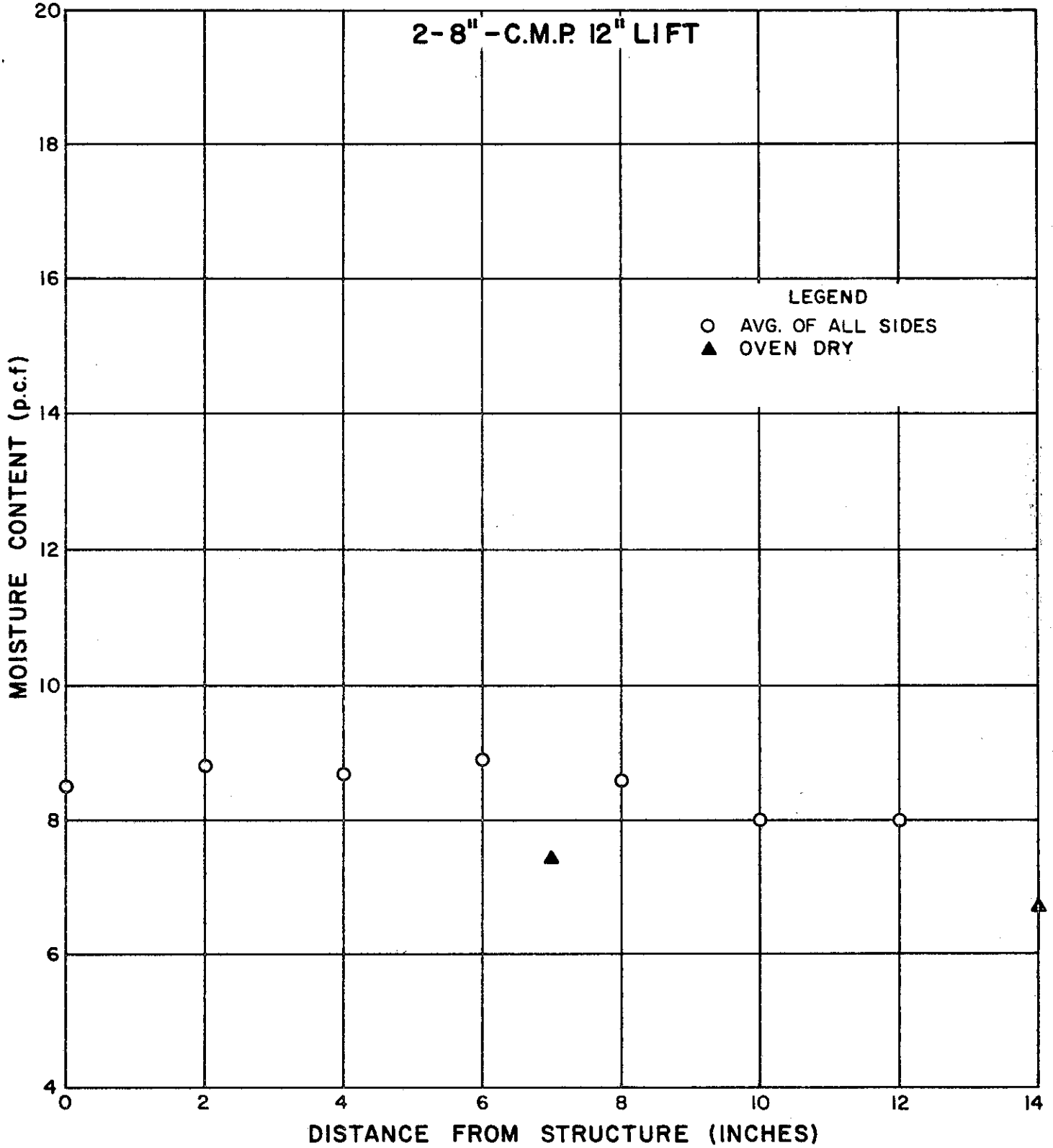


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Figure 18

# PORTAPROBE GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

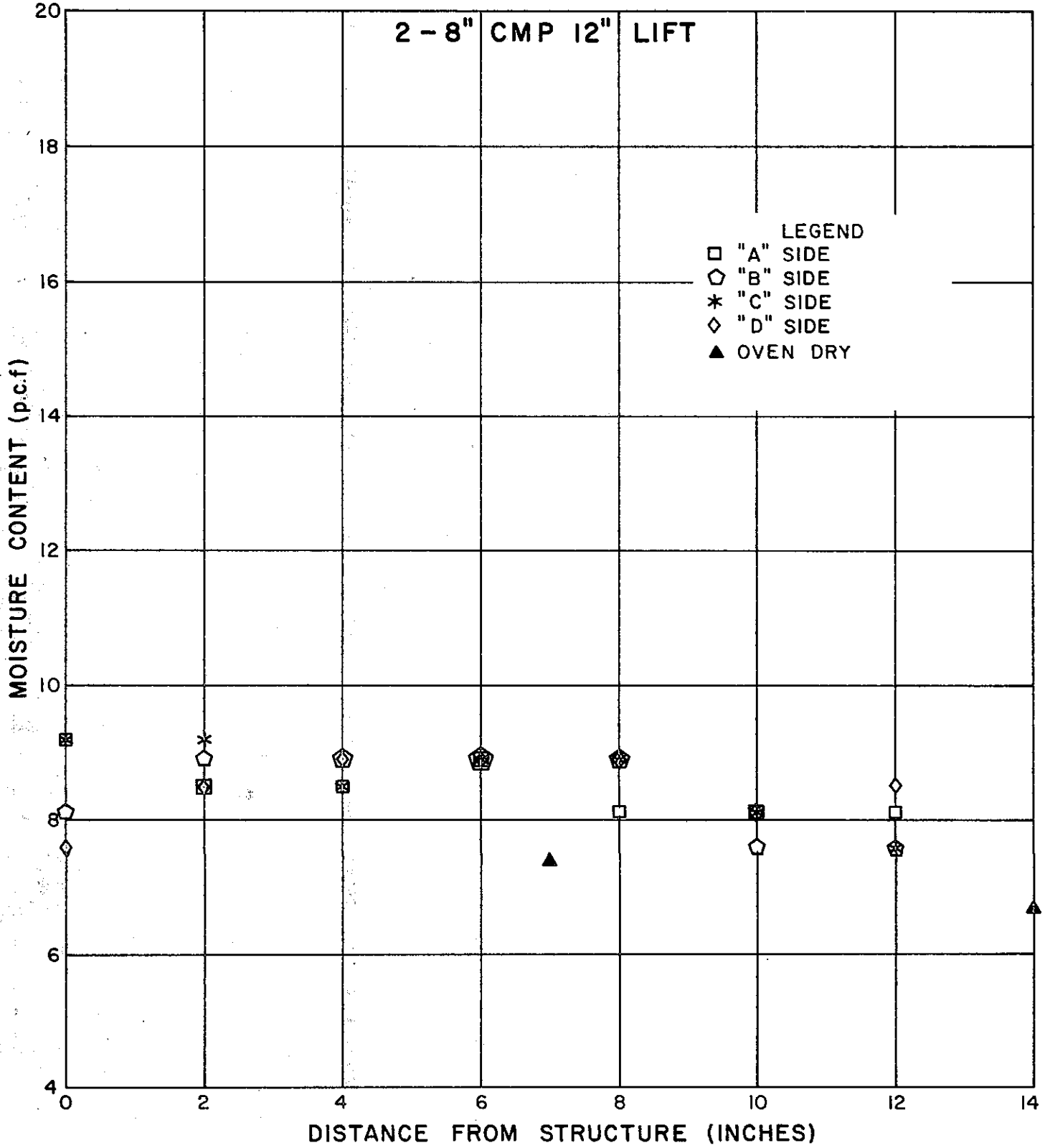


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Figure 19

# PORTAPROBE GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

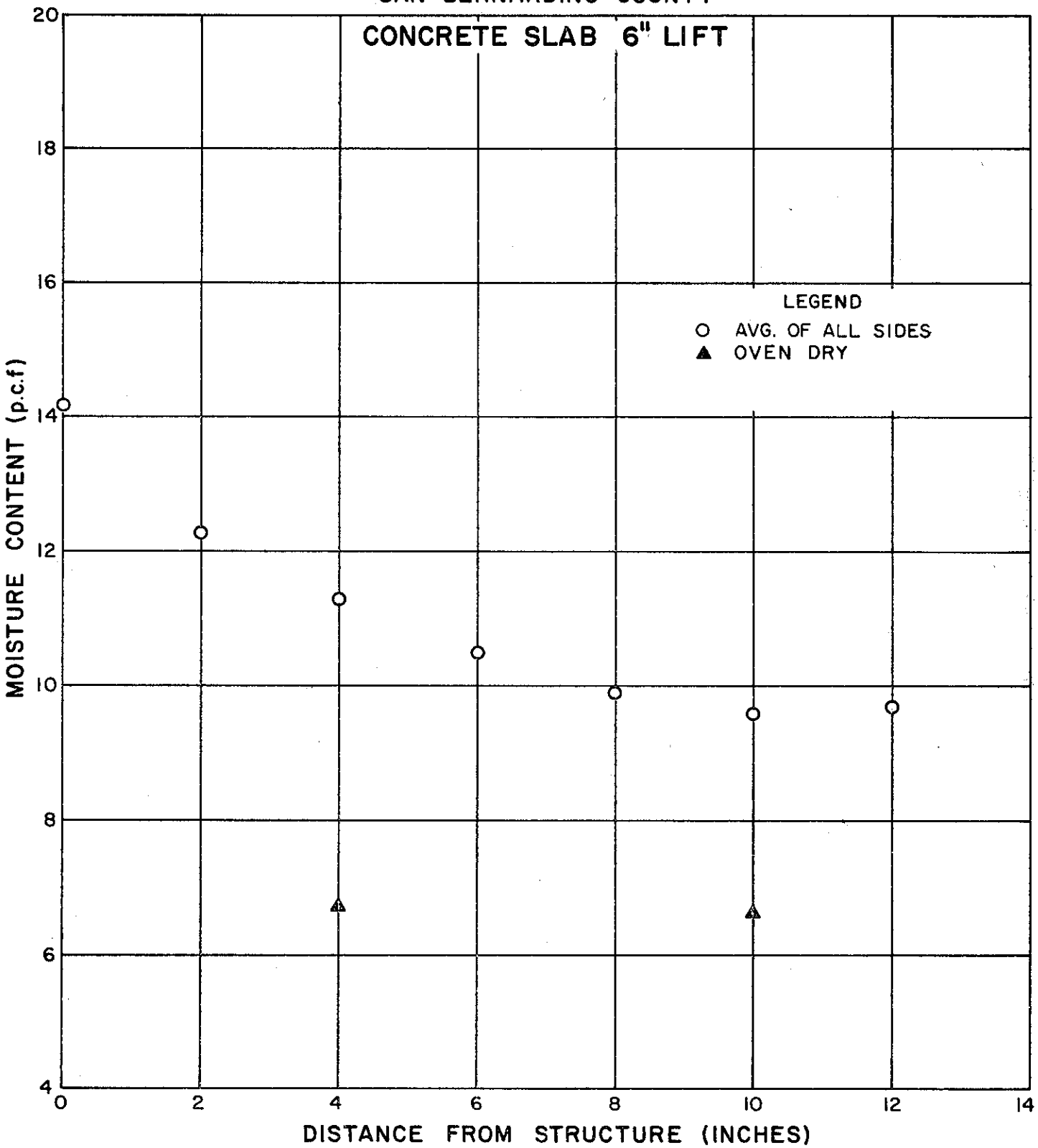


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Figure 20

# PORTAPROBE GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

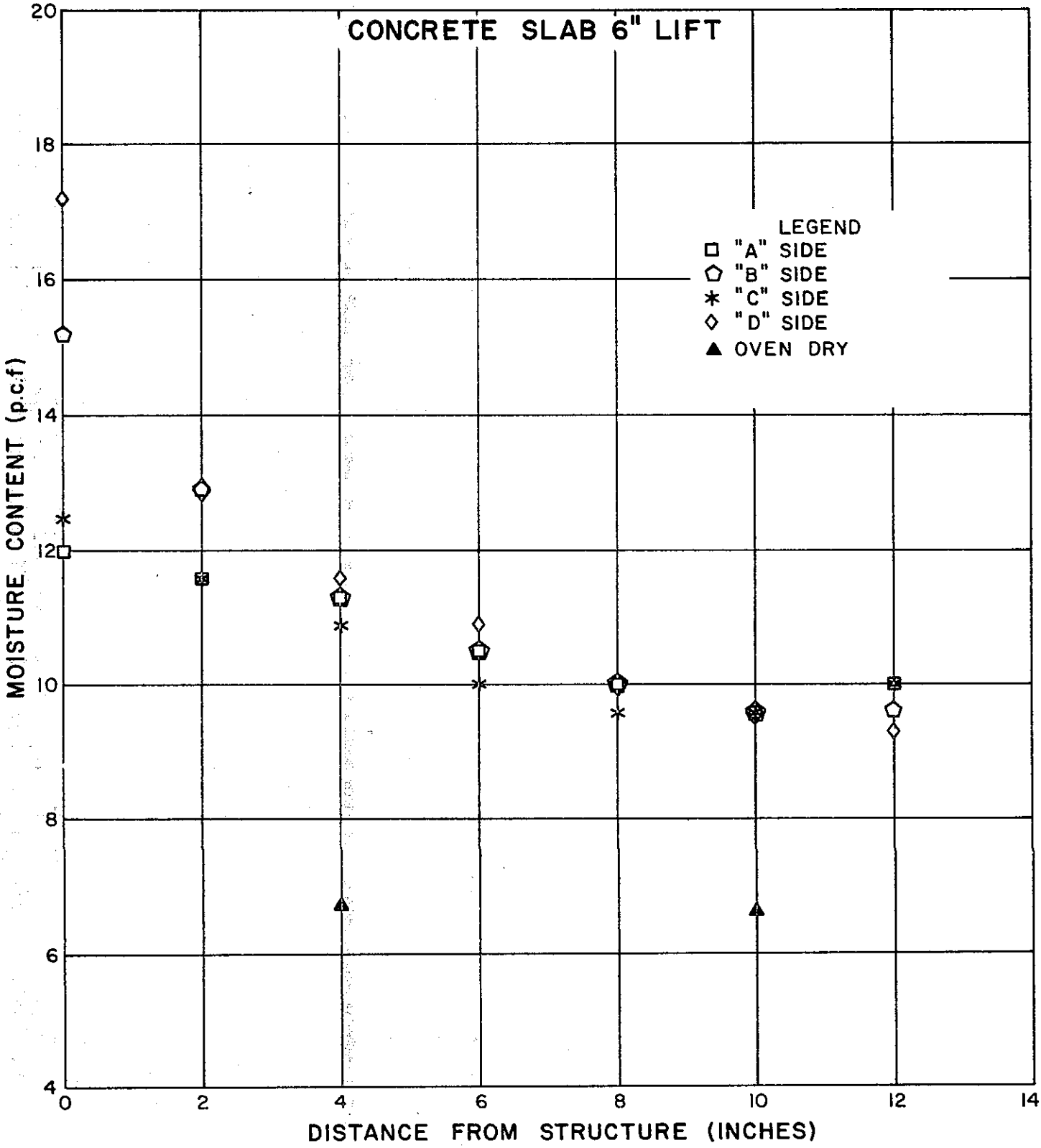


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Figure 21

# PORTAPROBE GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

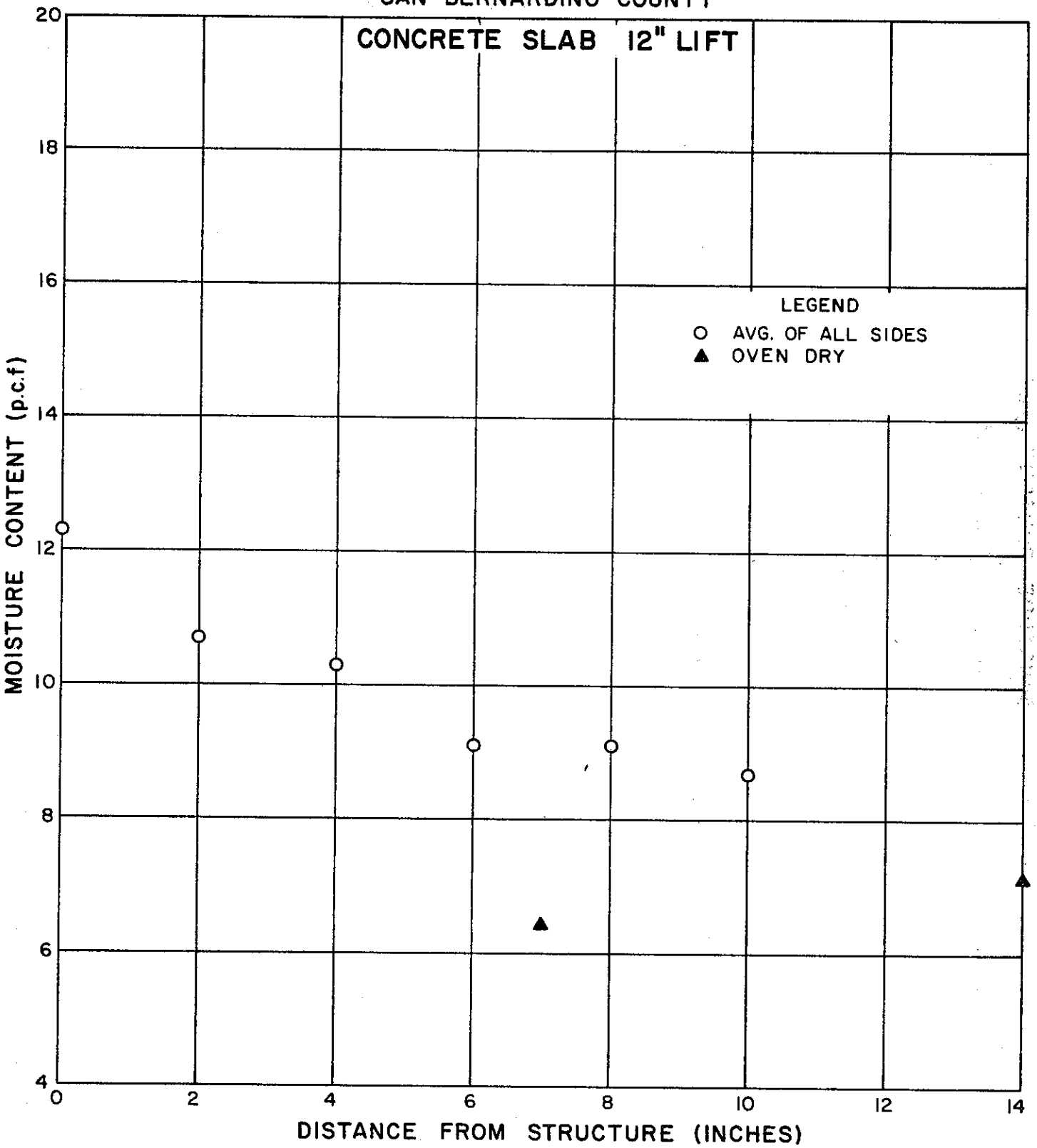


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Figure 22

# PORTAPROBE GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

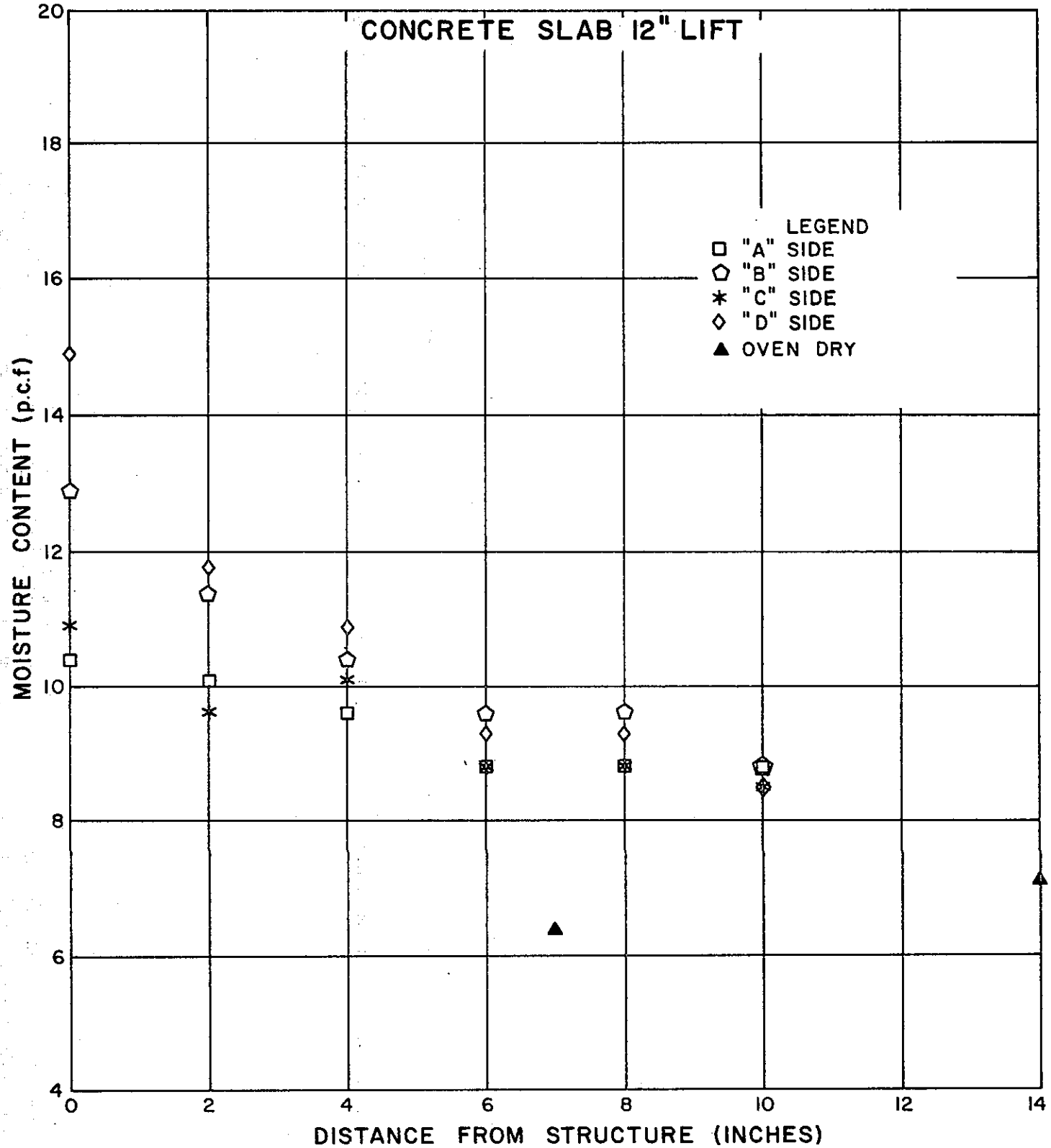


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Figure 23

# PORTAPROBE GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

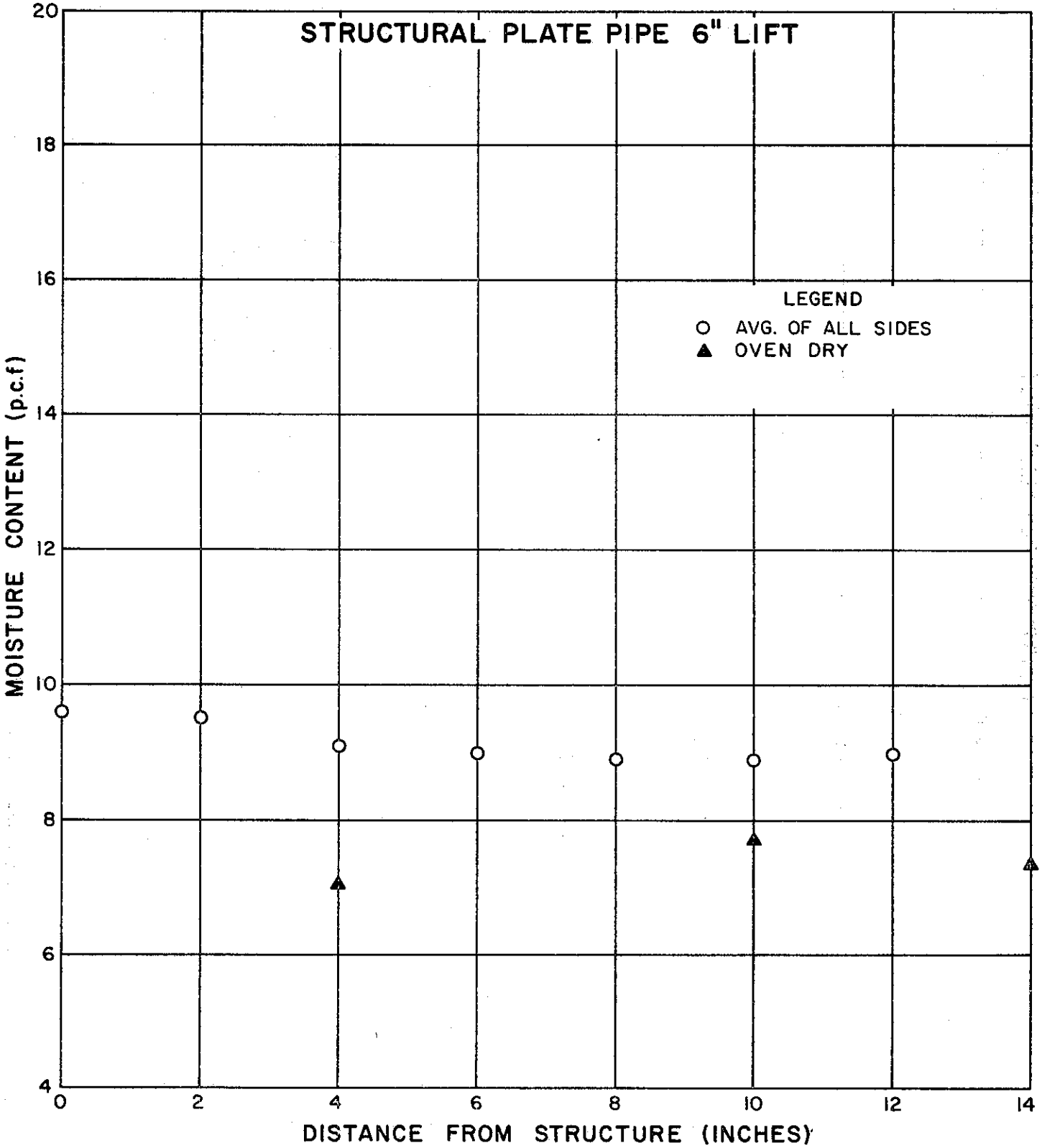


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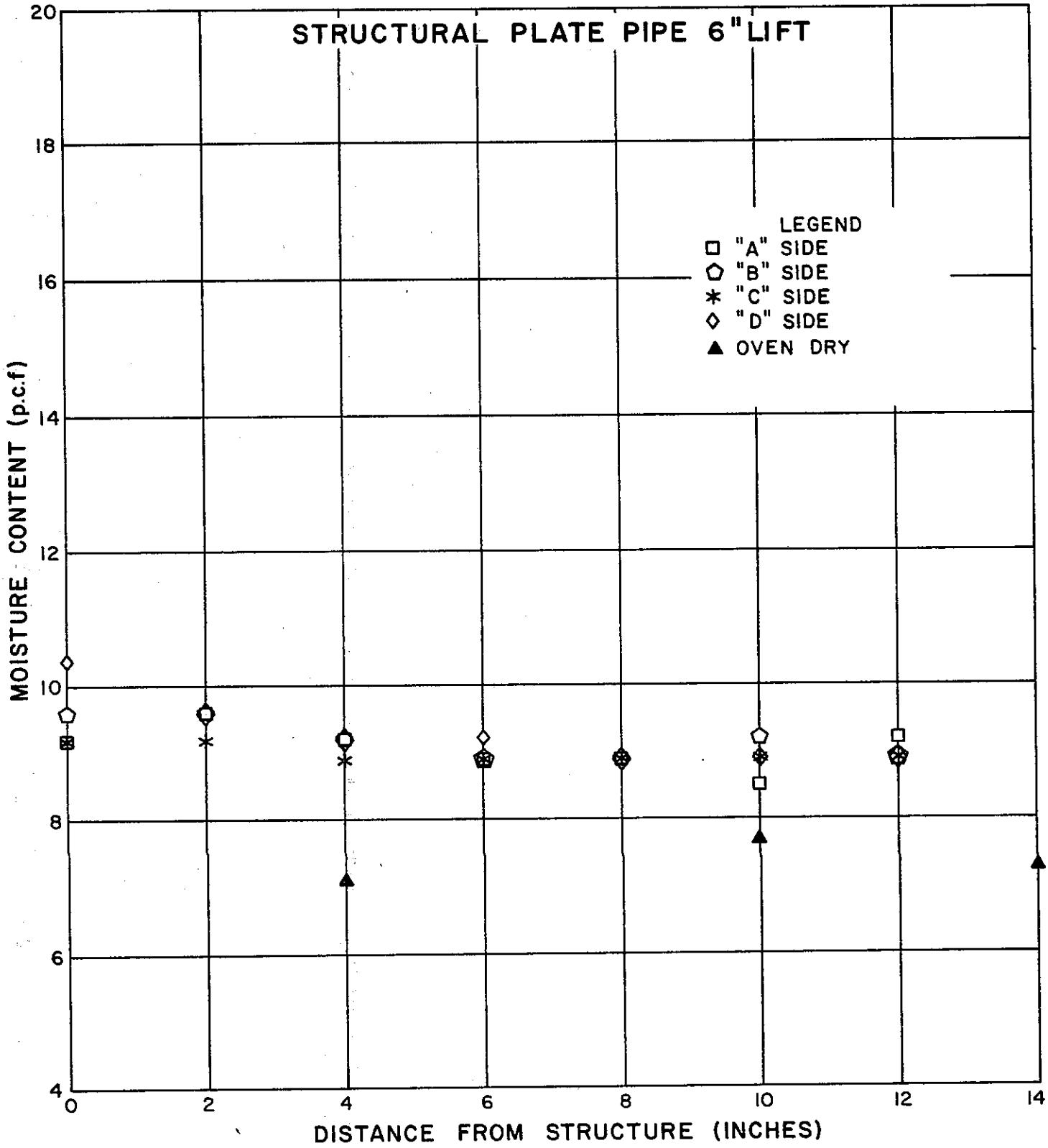
Figure 24

# PORTAPROBE GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY




MATERIALS AND RESEARCH DEPARTMENT
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Figure 25

# PORTAPROBE GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY

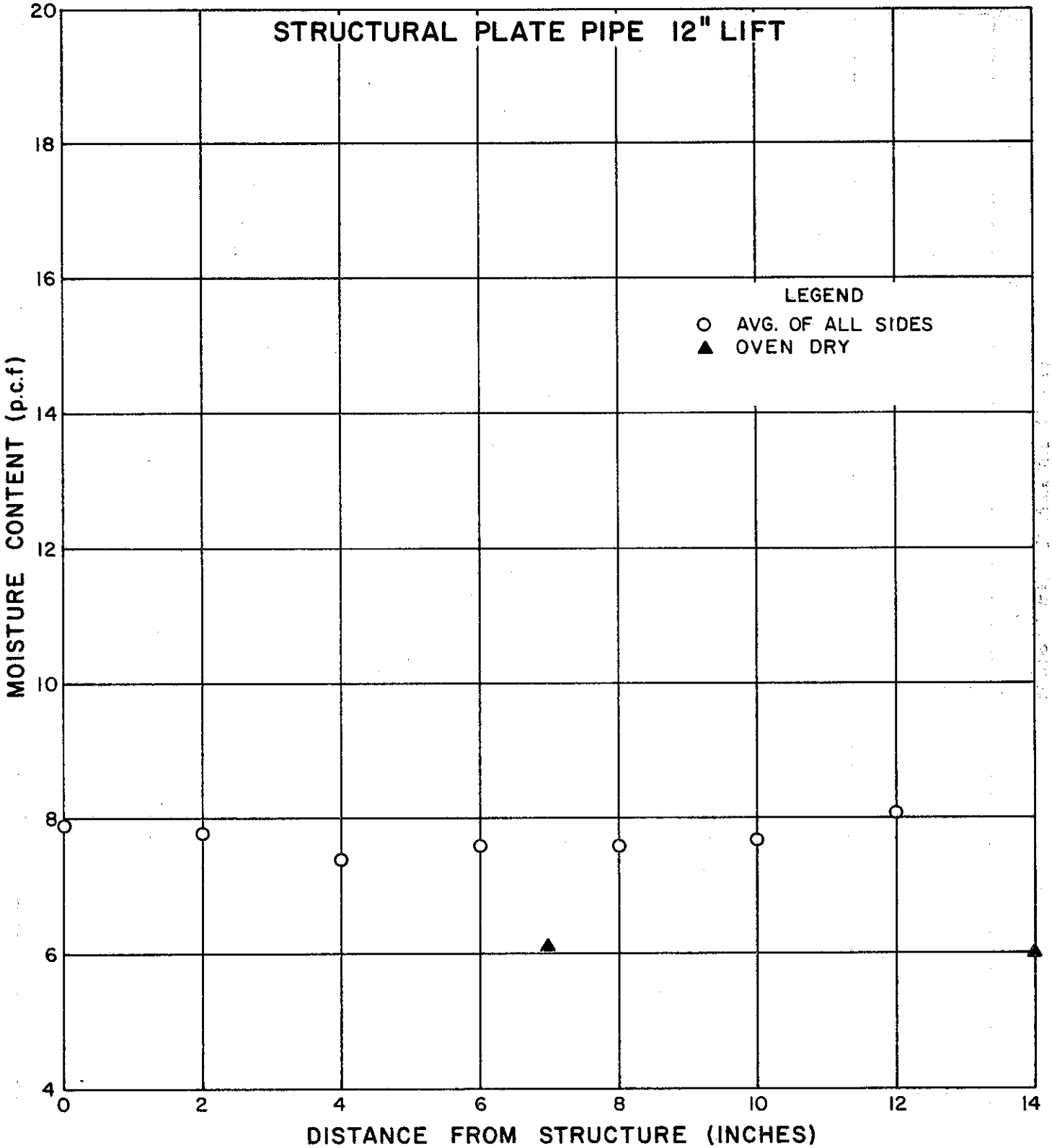


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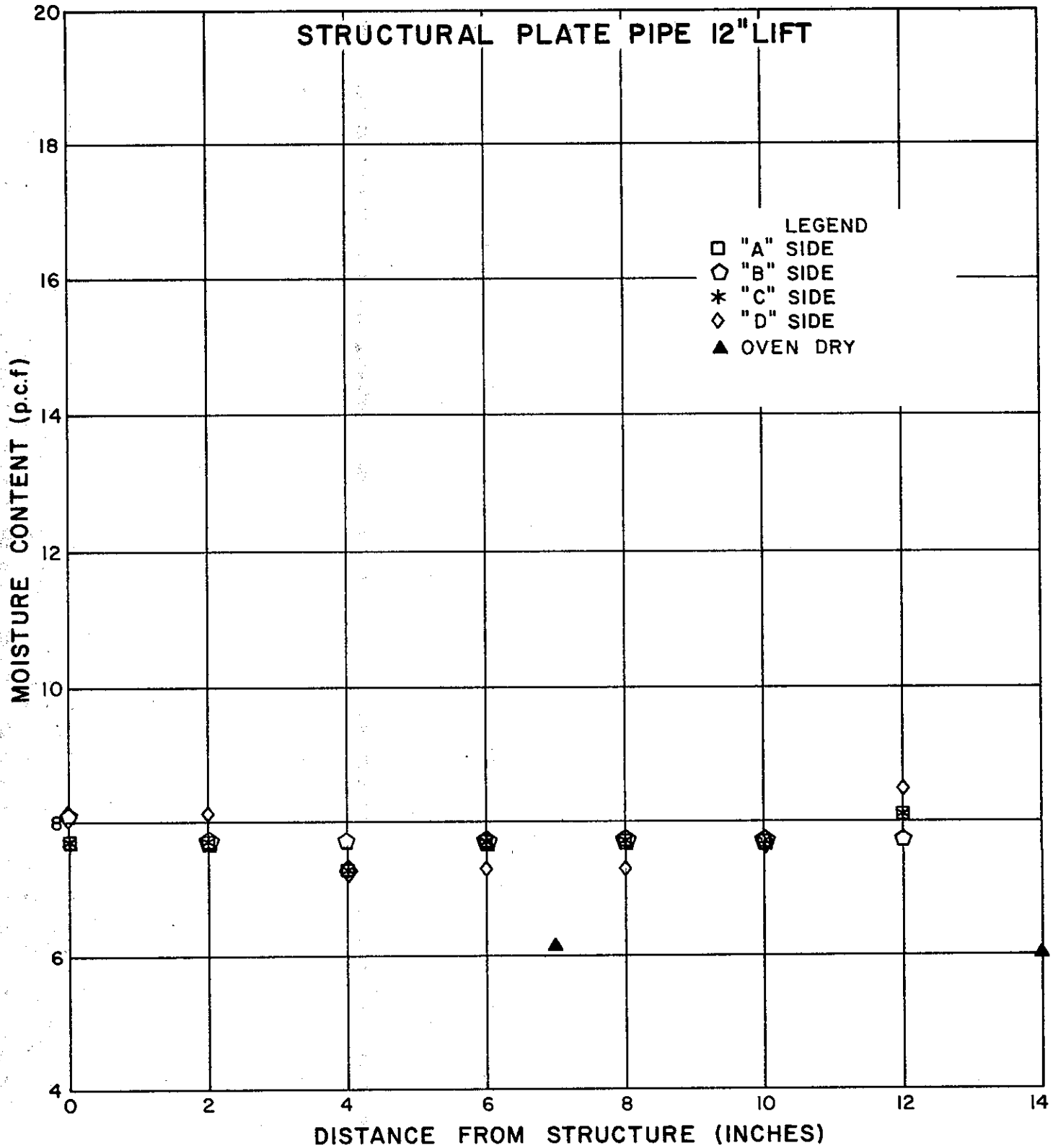
Figure 26

# PORTAPROBE GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY




MATERIALS AND RESEARCH DEPARTMENT
NO. M&R 642978

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## REFERENCES

1. Beaton, John L., "Troxler Gage-Moisture Study,, E.A.No. 642978, 08-SBd-15, 31, 138," memorandum to Mr. C. V. Kane - District 08, dated June 18, 1968.

2. Beaton, John L., "Troxler Gage-Moisture Study, E. A. No. 642978, 08-SBd-15, 31, 138," memorandum to each District Engineer dated September 10, 1968.

3. Beaton, John L., "Troxler Gage-Moisture Study,, E. A. No. 642978, 08-SBd-15, 31, 138, memorandum to Mr. C. V. Kane-District 08, dated December 4, 1968.

4. Weber, William G., Jr., "Laboratory and Field Evaluation of Nuclear Surface Gages for Determining Soil Moisture and Density," presented at Highway Research Board Meeting, Washington, D.C., January, 1964.

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A considerable amount of plotting and analysis of data has been done and the one tentative conclusion is:

The percentage of +3/4" fragments, in the range tested, 0-35%, does not affect the density or moisture determinations made with the nuclear gages.

The results of all the work done on the materials from Del Norte, Siskiyou, Trinity, San Bernardino and Solano Counties will be presented in the final report for this research project.

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The individual points on Figures 8 through 11 for the Troxler gage and on Figures 20 through 23 for the Portaprobe gage show reversing curves and varying differences between nuclear and oven-dry moisture determinations. It can be assumed that if the moisture was uniformly distributed throughout the sample, the nuclear readings would show a linear decrease in moisture content as the horizontal clearance is increased from one inch to three inches. In order to show this trend, the data were analyzed through several stages of averaging and adjusting moisture contents.

The data were separated into two categories: (1) averaging the surface, one-inch depth, and two-inch depth readings; and (2) averaging the four-inch, five-inch, and six-inch depth readings. See Figure 12 for the Troxler data and Figure 24 for the Portaprobe data. These reversing curves and various differences still do not lend themselves to a clear analysis of the data.

The oven-dry moistures were adjusted by moving the data for the one-inch and three-inch horizontal clearance conditions up or down to agree with the data for the two-inch horizontal clearance condition. The nuclear data for the same conditions were adjusted a similar amount. Figures 13 and 25 show the oven-dry moisture plotted as a straight horizontal line to compare with the adjusted nuclear moisture values for the Troxler gage and the Portaprobe gage, respectively. This is further clarified on Figures 14 and 26 where a zero base line is assumed for the oven-dry moistures and the plotted values of the nuclear readings are the differences between the oven-dry and the nuclear determinations.

## ADDITIONAL WORK

Large bulk samples, approximately 2500 to 3500 pounds, have been obtained from other current construction jobs as follows:

| | | |
|---|---|---|
| 1. | Road 02-Tri-3-67.8/73.5 | Cont. No. 02-044914 |
| 2. | Road 02-Sis-5-54.2/58.5 | Cont. No. 02-045734 |
| 3. | Road 01-DN-101-4.7/6.1 | Cont. No. 01-043954 |
| 4. | Road 10-Sol-80-8.0/12.5 | Cont. No. 10-081104 |

Field work consisting of density determination by sand volume method and moisture content by oven-dry method and density and moisture determinations with the same two nuclear gages (Troxler and Portaprobe) has been done on the Trinity, Siskiyou and Del Norte Counties projects. Six sites, covering an area of approximately 30' x 150' of rocky embankment material were tested on each project. Sufficient material was obtained from each site to determine test maximum density (impact test) according to Test Method No. Calif. 216.

Laboratory work has consisted of compacting the bulk sample material in an aluminum mold 18" square by 12" deep. Four specimens, with varying percentages of +3/4"fragments, i.e., 0%, 10%, 20% and 30%, of the samples from the projects where the field work has been done, have been compacted and tested for density by sand volume method, moisture by oven-dry method and density and moisture determinations with the two nuclear gages. Test maximum density has been determined for each of the specimens.

Similar laboratory work has been done on the sample from the Solano County project, which is structure backfill from the Red Rock Quarry near Vallejo.

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The initial testing was done with the structure backfill relatively dry and a horizontal clearance of one inch. The depth of the probe, below the surface, was increased in one-inch increments to a maximum depth of six inches. This testing was repeated with horizontal clearances of two and three inches. The whole procedure was repeated with the structure backfill relatively wet.

The second phase of testing consisted of duplicating the above procedure, but without the presence of the concrete slab.

## ANALYSIS

It has been previously concluded that a correction should be made on the moisture contents when the Troxler probe is less than 8" from a concrete slab. This was mentioned in our memorandum to District 08 Engineer Mr. C. V. Kane, dated June 18, 1968, which was given statewide distribution with memorandum dated September 10, 1968. This data and Portaprobe data will be included in the final report for this project.

The interim report includes data applicable to nuclear moisture determinations made when the probe is within three inches of a concrete slab.

Figures 3 through 6 show the Troxler data and Figures 15 through 18 show the Portaprobe data plotted with depth of probe as the abscissa and moisture content, in pounds per cubic foot, as the ordinate. Figures 8 through 11, and 20 through 23, show the same data plotted with horizontal clearance as the abscissa and moisture content as the ordinate.

It is our opinion that the variation of the individual points from a straight line as shown in these data, is to be expected when determining moisture contents with either the nuclear gage or with the oven-dry method.

Figures 7 and 19 show the average of all test results and indicates that:

1. If the material is relatively dry and the concrete slab is absent the nuclear readings are in agreement with the oven-dry determinations when the gage is two inches or less below the surface. This is evident with the Portaprobe gage as well as the Troxler gage.

2. If the material is relatively dry and the concrete slab is within three inches of the gage, the Troxler gage indicates moisture contents of four to eight pounds per cubic foot higher than the moisture contents determined by the oven-dry method. This increase with depth from zero to six inches is on an approximate linear relationship. The Portaprobe gage shows higher moisture contents of 6-14 pounds per cubic foot under the same test conditions.

The same relationship exists if the material is relatively wet but the data is approximately two to four pounds per cubic foot higher on the moisture content scale.

It is quite difficult to study the data and assign equal importance to each individual point on the figures. For this reason, average values have been plotted as shown on Figures 7, 12, 13 and 14 for the Troxler gage and on Figures 19, 24, 25 and 26 for the Portaprobe gage.

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5. Test data from both gages show a general decrease in the difference between nuclear moisture determinations and oven-dry moisture determinations as the horizontal clearance is increased from one to three inches.

6. Correction factors for both gages have been developed which can be applied to nuclear moisture determinations if the field conditions are similar to the test conditions for this research project.

## RECOMMENDATIONS

The conclusions in this report cannot be applied to all nuclear gages or to all materials throughout the state of California. The data can serve as a model for a minor research project, if it is necessary to make corrections in moisture determinations when the gage readings on a construction project do not fit a valid calibration curve.

Due to inconsistencies or variations between gages it must be remembered that the calibration curves furnished with each gage must be checked with the actual project materials and with the particular gage which will be used to test the material. This is so stated in Part C, Calibration, of Test Method No. Calif. 231.

## TESTING DETAILS

Field conditions were somewhat simulated for this study. The material used on this project was from District 08 (Cajon Pass Job) Contract No. 08-049114 on Road 08-SBd-15, 31, 138. A large bulk sample of structure backfill (gravelly sand), approximately 4000 lbs., was obtained from two locations on the contract and all of the material was from the same Cajon Wash source.

For this nuclear-moisture study, the material was scalped on the 1-1/2" sieve for compaction in a 12" deep aluminum mold or a 12" deep hole in the ground. Compaction was done with a 10-lb. hammer equipped with a 4-inch square foot and an 18" drop. The specimens were compacted in four 3-inch lifts. Nuclear counts were obtained with a Troxler gage Scaler Model 650 and Probe Model SCM-257-1967 and a Portaprobe gage Model A-1967.

The moisture calibration curves were established by compacting four specimens at four different moisture contents, ranging between 4.7 and 8.7 lbs. per cu. ft., in an aluminum mold with inside dimensions of 18" square by 12" deep and recording nuclear moisture counts on each of our specimens. Several additional points were obtained in the field when the material was compacted in the test pit to assure valid calibration curves. The calibration curves, oven dry moisture content vs. count ratio*, are shown on Figure 1.

Field research of this San Bernardino County material was done in a test pit 39" wide by 42" long x 12" deep dug in the native soil in Sacramento. Two concrete slabs, 35" x 48", with a combined thickness of approximately seven inches, were placed vertically along one side of the hole and the remainder of the hole was filled with structure backfill. See Fig. 2. The testing was performed at densities similar to those obtained on the actual contract. Duplicate testing was done at two different moisture contents, i.e., (1) slightly above and (2) slightly below optimum. The moisture contents ranged from approximately 2-7%.

---

$$*\text{Count ratio} = \frac{\text{Test Count}}{\text{Standard Count}}$$

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## INTRODUCTION

This project was initiated as a result of difficulties experienced by District 08 on Contract No. 08-049114 on Road 08-SBd-15, 31, 138 (Cajon Pass Job) when determining moisture and densities with a Troxler nuclear gage on structure backfill containing approximately 15% plus 3/4" fragments.

This interim report is limited to determining the effect of a concrete structure, within three inches of a nuclear gage, and the effect of the position of the gage with reference to horizontal clearance (within three inches) of structure backfill, and depth of gage below the surface (down to six inches) of structure backfill on moisture determinations made with a Troxler gage and a Portaprobe gage.

The work described herein is part of a larger research project which will be described in some detail at the end of this report.

## OBJECTIVE

The objective of this portion of the overall research project is to determine if a correction factor can be applied to the moisture determinations made with nuclear gages.

We believe that the data presented in this report can be used to determine a correction factor to be applied to moisture determinations made with a Troxler gage and a Portaprobe gage if the field conditions are similar to the test conditions for this research project.

## CONCLUSIONS

1. The Portaprobe nuclear gage moisture content determinations are approximately 10-50% greater than the Troxler gage determinations depending on the particular test conditions (presence or absence of concrete slab, relatively dry or wet structure backfill, depth of gage and horizontal clearance around the gage).

2. There is a relatively uniform increase in the difference between nuclear moisture determinations and the oven-dry moistures as the depth of either gage is increased below the surface of the structure backfill.

3. There is a greater difference between oven-dry moisture content and nuclear moisture content when the material is relatively dry than when the material is relatively wet.

4. With the concrete slab present, nuclear moisture contents determined with either gage are markedly increased when the horizontal clearance is less than three inches. This is evident even at depths of only one or two inches and applies both to the "wet" and "dry" conditions.

Without the slab, and at depths of one or two inches, the nuclear gage moisture determinations agree with the oven dry moisture determinations. At greater depths the readings are affected more by the depth of gage than by the horizontal clearance.

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REFERENCE: Smith, Travis, Hirsch, Albin D., Kleiman, William F.

"Effect of Field Variables on Nuclear Gage Moisture Determinations," State of California, Department of Public Works, Division of Highways, Materials and Research Department. Research Report 642978-1, March, 1969.

ABSTRACT: The depth that a nuclear gage is below the surface of surrounding soil and the proximity of a concrete structure to the gage affects the nuclear gage moisture determinations. This interim report is limited to the findings made with a Troxler Gage Scaler Model No. 650, Probe Model SCM-257-1967 and a Portaprobe Gage Model No. A-1967 on Structure Backfill (a gravelly sand) representative of material from Road 08-SBd-15, 31, 138, Contract No. 08-049114. The testing was done after the material was compacted in a test pit 39" wide x 42" long by 12" deep, with and without a concrete slab along one side of the hole, and at two moisture contents, i.e., (1) slightly above and (2) slightly below optimum. Initial gage readings were recorded when the horizontal clearance was one inch and the depth of probe, below the surface, was increased in one-inch increments to a depth of six inches. This procedure was repeated with horizontal clearances of two and three inches. Samples were taken for oven-dry moisture determinations to compare with each set of nuclear gage readings. The test data can be used to determine a correction factor to be applied to nuclear moisture determinations made with a similar Troxler gage or a similar Portaprobe gage if the field conditions are similar to the test conditions for this research project.

KEY WORDS: Troxler, Portaprobe, nuclear moisture determinations, structure backfill, concrete structures, test results, soils.

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TABLE OF CONTENTS


| | Page |
|---|---|
| INTRODUCTION | 1 |
| OBJECTIVE | 1 |
| CONCLUSIONS | 1 |
| RECOMMENDATIONS | 2 |
| TESTING DETAILS | 2 |
| ANALYSIS | 3 |
| ADDITIONAL WORK | 4 |
| REFERENCES | 6 |
| FIGURES | |


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STATE OF CALIFORNIA—TRANSPORTATION AGENCY

RONALD REAGAN, Governor

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
5900 FOLSOM BLVD., SACRAMENTO 95819

March 1969

Interim Report
M&R No. 642978

Mr. J. A. Legarra
State Highway Engineer

Dear Sir:

Submitted herewith is a research report titled:

EFFECT OF FIELD VARIABLES

ON

NUCLEAR GAGE MOISTURE DETERMINATIONS

TRAVIS SMITH
Principal Investigator

ALBIN D. HIRSCH and WILLIAM F. KLEIMAN
Co-Investigators

Assisted by

B. Zeiler
B. Lister

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

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If any of the districts are experiencing difficulty in obtaining reliable test results with the nuclear gage, we would want to become aware of it, and hopefully would cooperate with the district in order to eliminate or minimize poor results.

Original signed by

JOHN L. BEATON
Materials and Research Engineer

WFK:ic:sc

CC: DLWeiman

Attachment

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State of California | Highway Transportation Agency

# Memorandum

To : Mr. L. R. Gillis
Operations

Date : March 28, 1969

File : 642978

From : Department of Public Works—Division of Highways
Materials and Research Department

Subject: Approval of an Interim Report

Submitted for your approval is an interim report titled "Effect of Field Variables on Nuclear Gage Moisture Determinations" on the Materials and Research Department research project 642978, "Nuclear Gage Density - 3/4 Material."

This research project was initiated due to difficulties experienced by District 08 with the use of a Troxler nuclear gage when determining relative compaction of structure backfill on Road 08-SBd-15, 31, 138, Contract No. 08-049114. The results of findings with a Troxler gage and the effect of the proximity of a concrete slab, an 8-inch corrugated perforated metal pipe and a 108-inch structural plate pipe were submitted to District 08 in memorandum dated June 18, 1968. These and similar data obtained with a Portaprobe gage were given statewide distribution in memorandum dated September 10, 1968.

Additional findings, effect of horizontal clearance and depth of probe of a Troxler gage in a mass of structure backfill were forwarded to District 08 in memorandum dated December 4, 1968.

The attached interim report, intended for statewide distribution, presents the findings obtained with a Troxler nuclear gage and a Portaprobe nuclear gage when used in the proximity of a concrete slab and the probe is in a hole in the structure backfill.

It must be emphasized that the conclusions in this interim report should not be applied to all nuclear gages and all materials that are encountered throughout the state. However, the report can serve as a guide to District personnel if nuclear gage moisture determinations are questionable.

The influence of horizontal clearance, depth of probe and proximity of a concrete slab on nuclear moisture determinations is clearly shown in this interim report. The data indicate that field conditions similar to the test conditions described herein should be avoided, if at all possible, when moisture determinations are being made with a nuclear gage.



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# ADDENDUM B

# EFFECT OF FIELD VARIABLES ON NUCLEAR GAGE MOISTURE DETEMINATIONS

INTERIM REPORT

March, 1969

NO. M&R 642978-1

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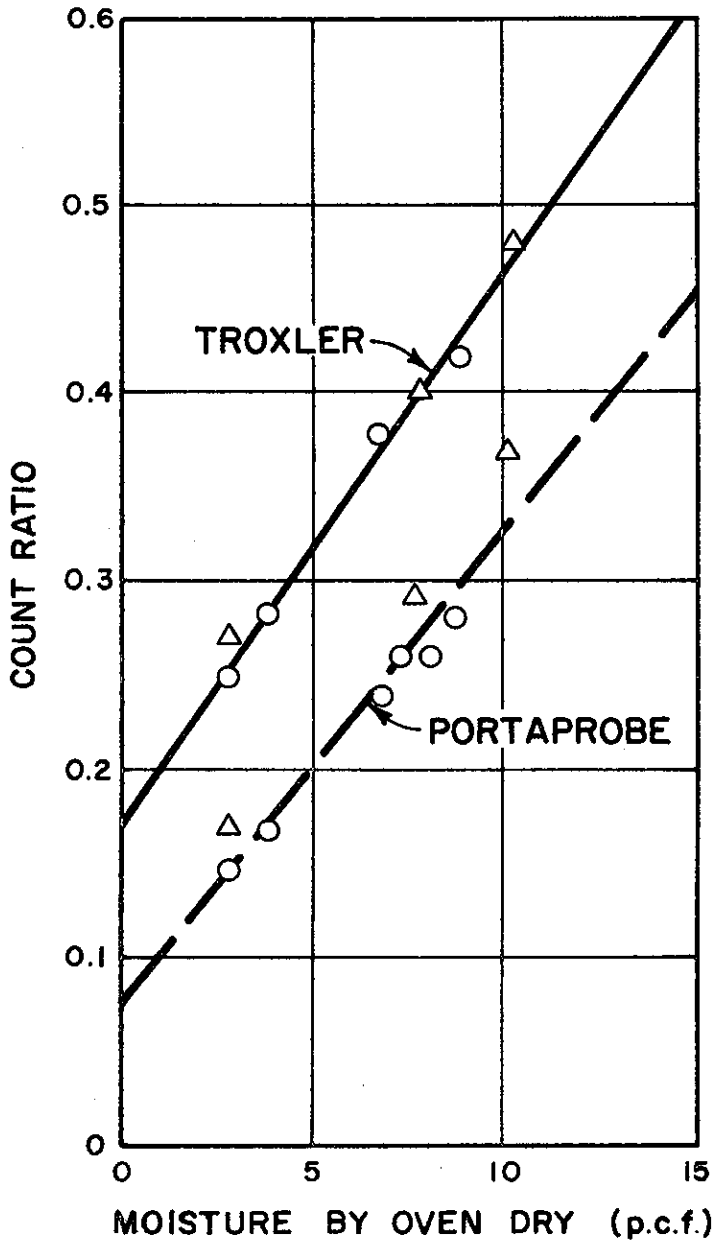
Figure I

# MOISTURE CALIBRATION
# STRUCTURE AND BRIDGE BACKFILL
## SAN BERNARDINO COUNTY

LEGEND

TROXLER
SCALER NO. 106, MODEL 650
PROBE NO. 114, MODEL SMC-257-1967

PORTAPROBE
GAGE NO. 0010, MODEL A-1967




CURVES CALIBRATED
FROM AL MOLD - ○
AND FIELD DATA - △
JUNE 1968

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NO M.&R. 642978

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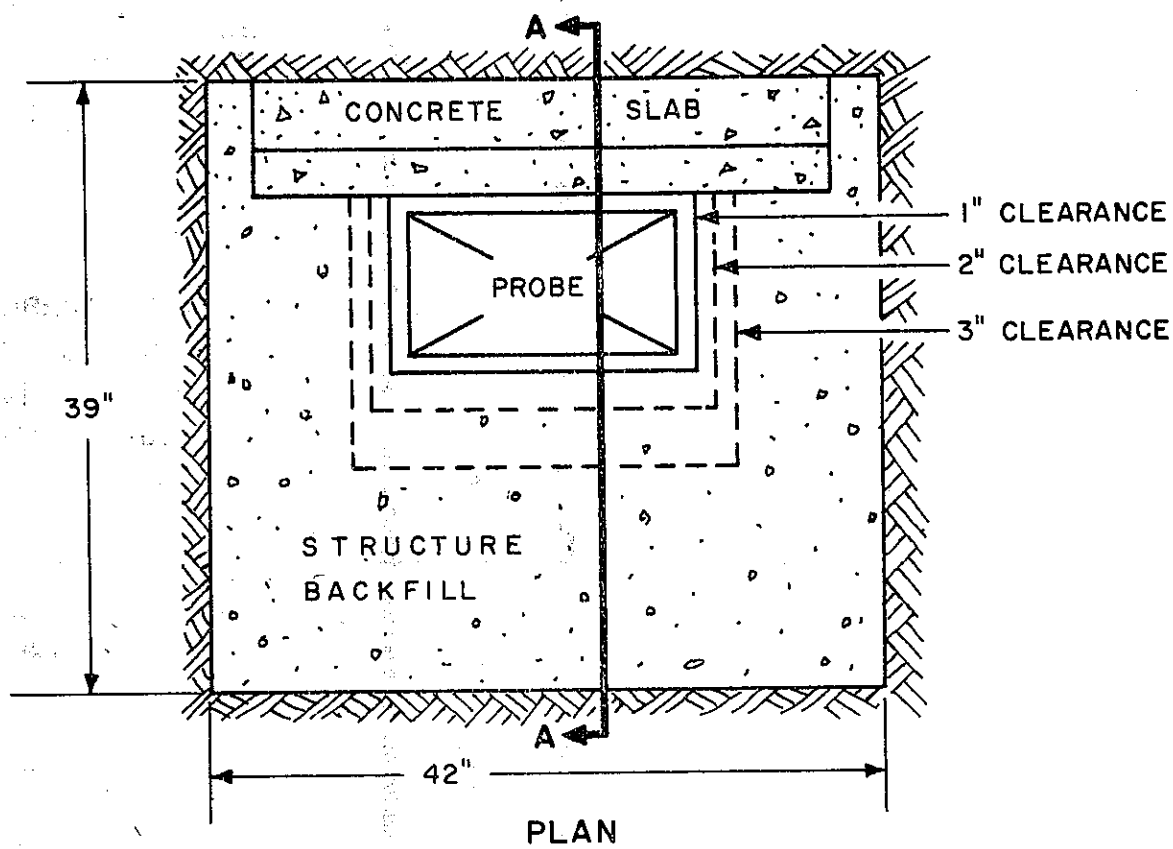
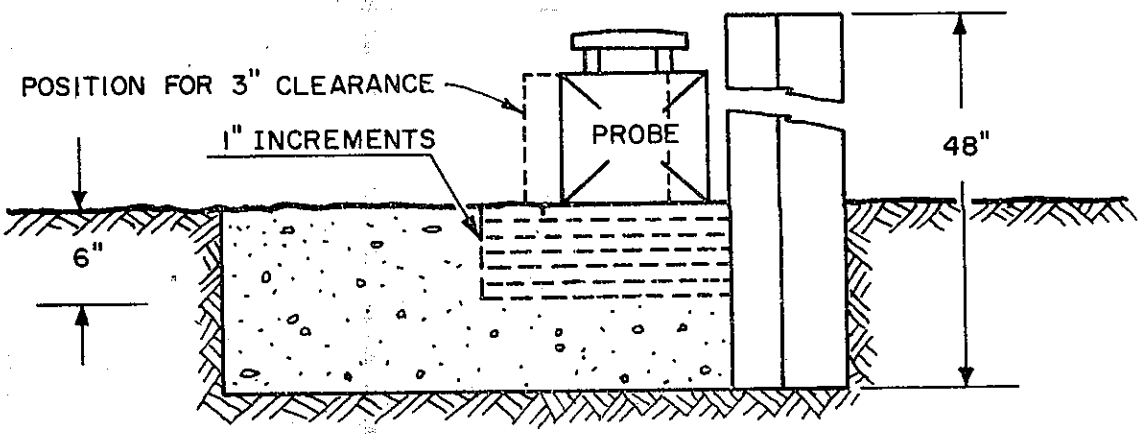
Figure 2

# CONCRETE SLAB USED IN NUCLEAR GAGE MOISTURE STUDY




PLAN




SECTION A – A

SCALE 1" = 1'

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Figure 3

# TROXLER GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY

| HORIZONTAL CLEARANCE FROM NUCLEAR PROBE | 1" | 2" | 3" |
|---|---|---|---|
| NUCLEAR MOSTURE CONTENT | ○ | △ | □ |
| OVEN DRY MOISTURE CONTENT | ● | ▲ | ■ |

RELATIVELY DRY BACKFILL WITH CONCRETE SLAB.

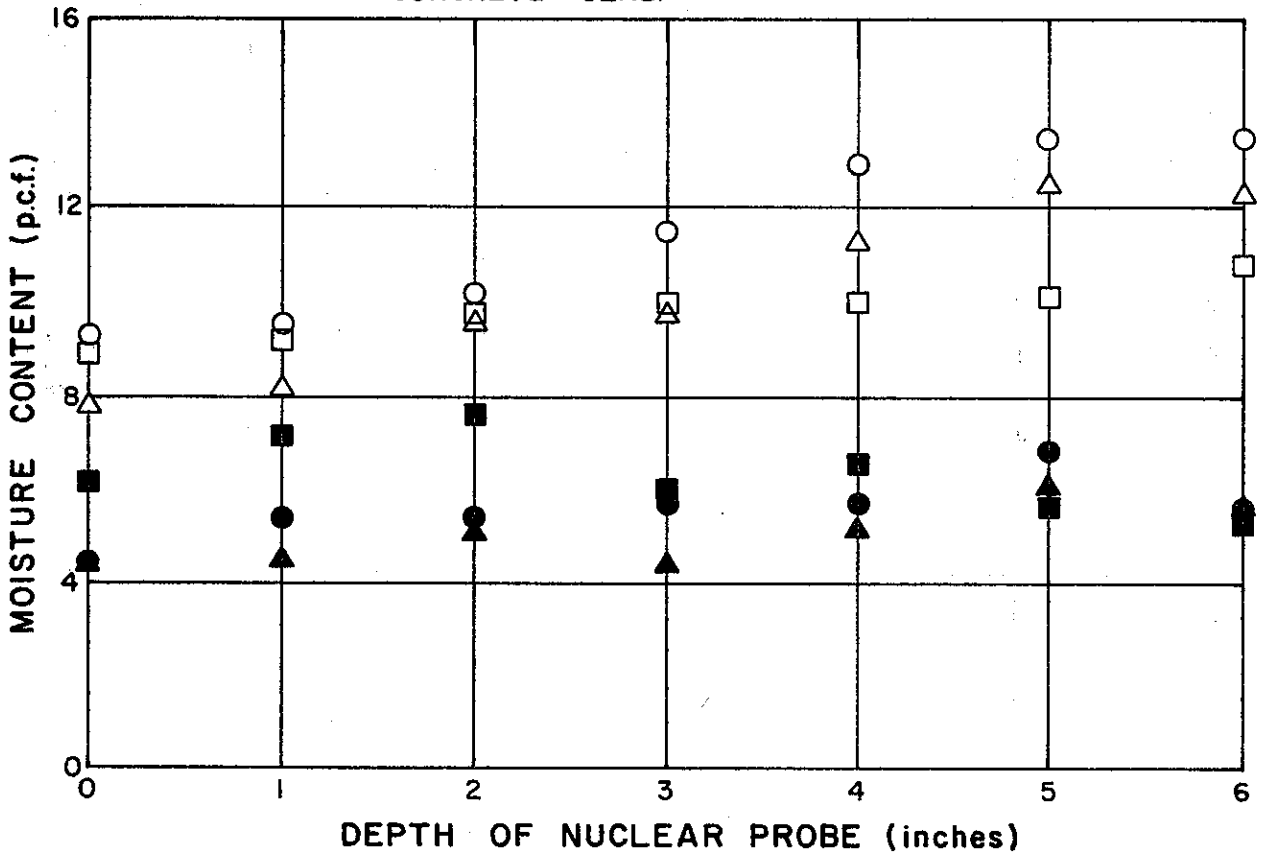


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Figure 4

# TROXLER GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY

| HORIZONTAL CLEARANCE FROM NUCLEAR PROBE | 1" | 2" | 3" |
|---|---|---|---|
| NUCLEAR MOSTURE CONTENT | ○ | △ | □ |
| OVEN DRY MOISTURE CONTENT | ● | ▲ | ■ |

RELATIVELY WET BACKFILL WITH CONCRETE SLAB

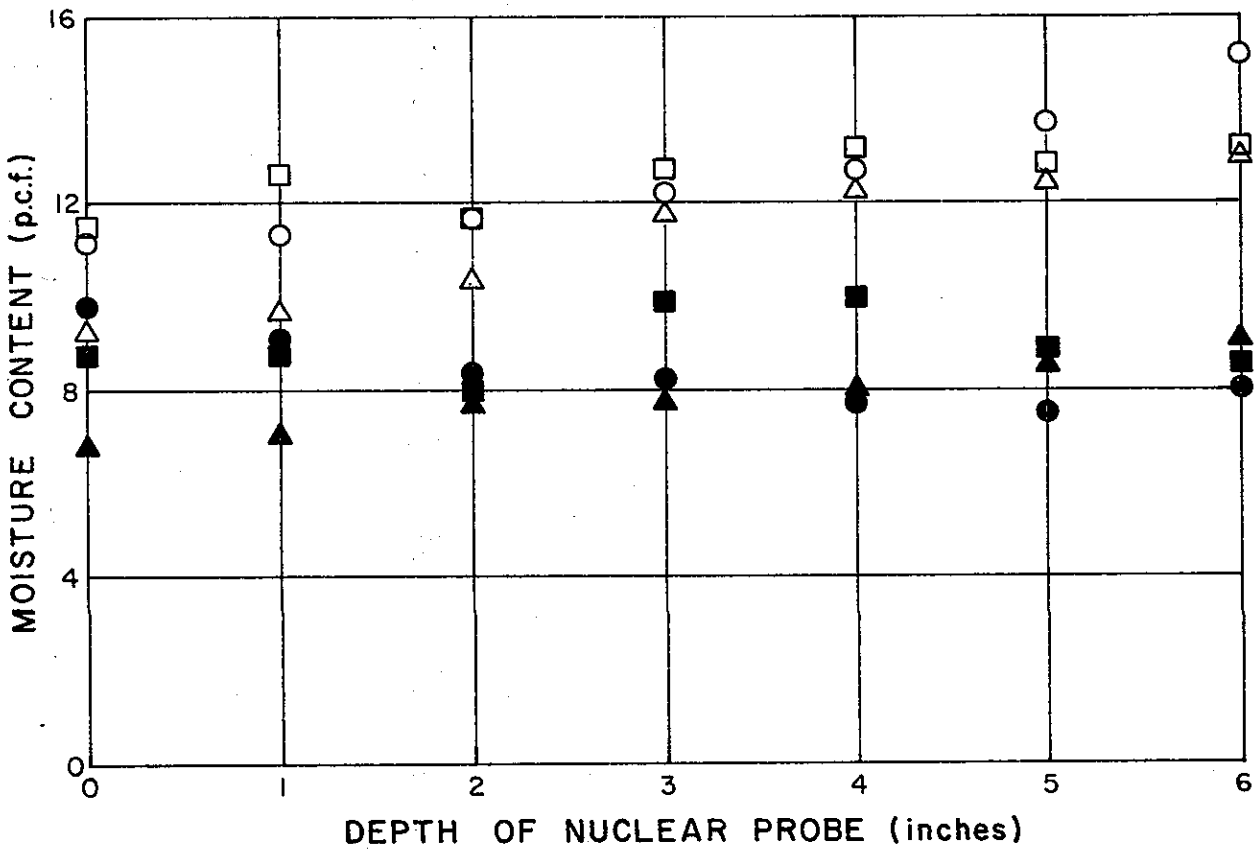


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Figure 5

# TROXLER GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY

| HORIZONTAL CLEARANCE FROM NUCLEAR PROBE | 1" | 2" | 3" |
|---|---|---|---|
| NUCLEAR MOSTURE CONTENT | ○ | △ | □ |
| OVEN DRY MOISTURE CONTENT | ● | | ■ |

RELATIVELY DRY BACKFILL WITHOUT CONCRETE SLAB.

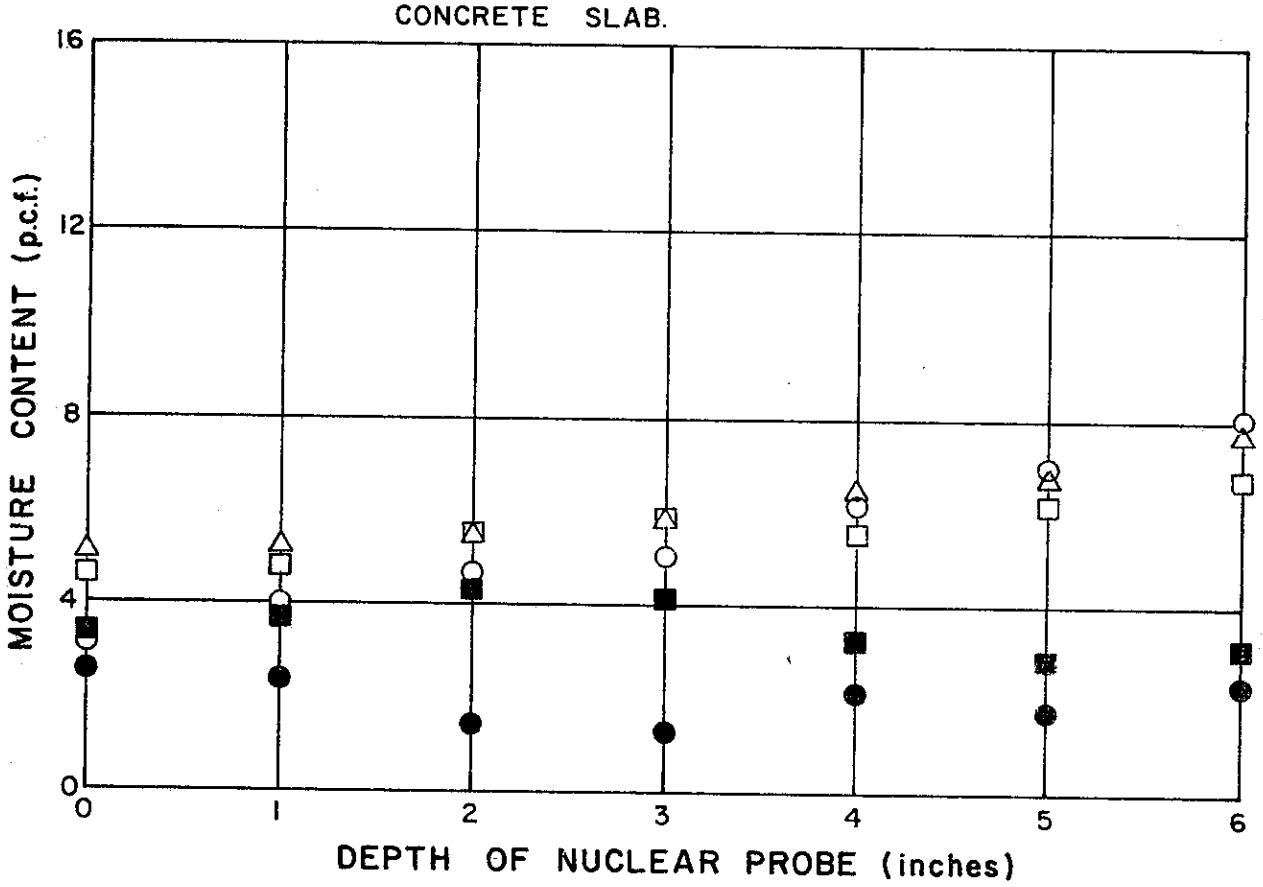


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Figure 6

# TROXLER GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY

| HORIZONTAL CLEARANCE FROM NUCLEAR PROBE | 1" | 2" | 3" |
|---|---|---|---|
| NUCLEAR MOSTURE CONTENT | ○ | △ | □ |
| OVEN DRY MOISTURE CONTENT | ● | ▲ | ■ |

RELATIVELY WET BACKFILL WITHOUT CONCRETE SLAB.

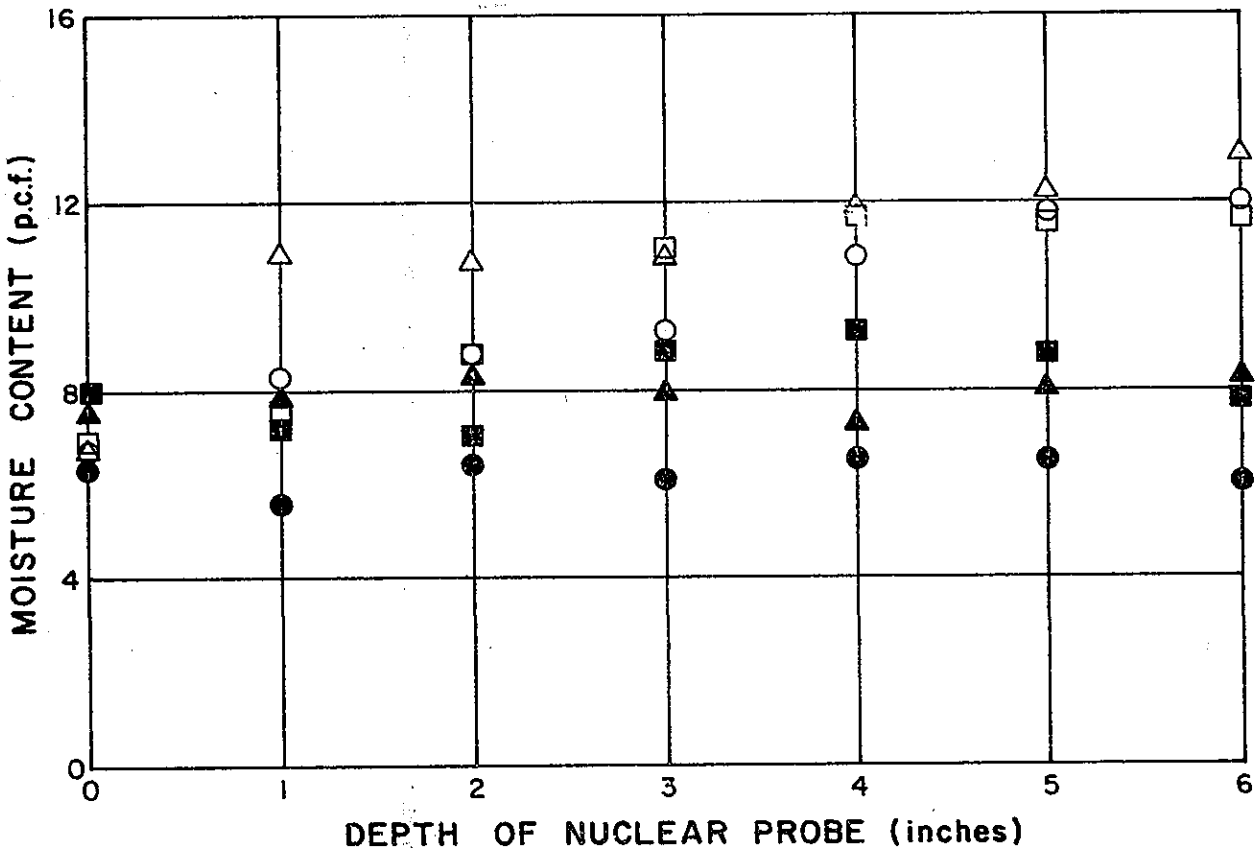


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Figure 7

# TROXLER GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY

| AVERAGE MOISTURE CONTENT FOR 1", 2" & 3" CLEARANCE | BACKFILL RELATIVELY DRY | BACKFILL RELATIVELY WET |
|---|---|---|
| NUCLEAR – WITH CONCRETE SLAB | ○ | □ |
| NUCLEAR – WITHOUT CONCRETE SLAB | △ | ◇ |
| OVEN DRY – WITH & WITHOUT CONCRETE SLAB | ✚ | ★ |

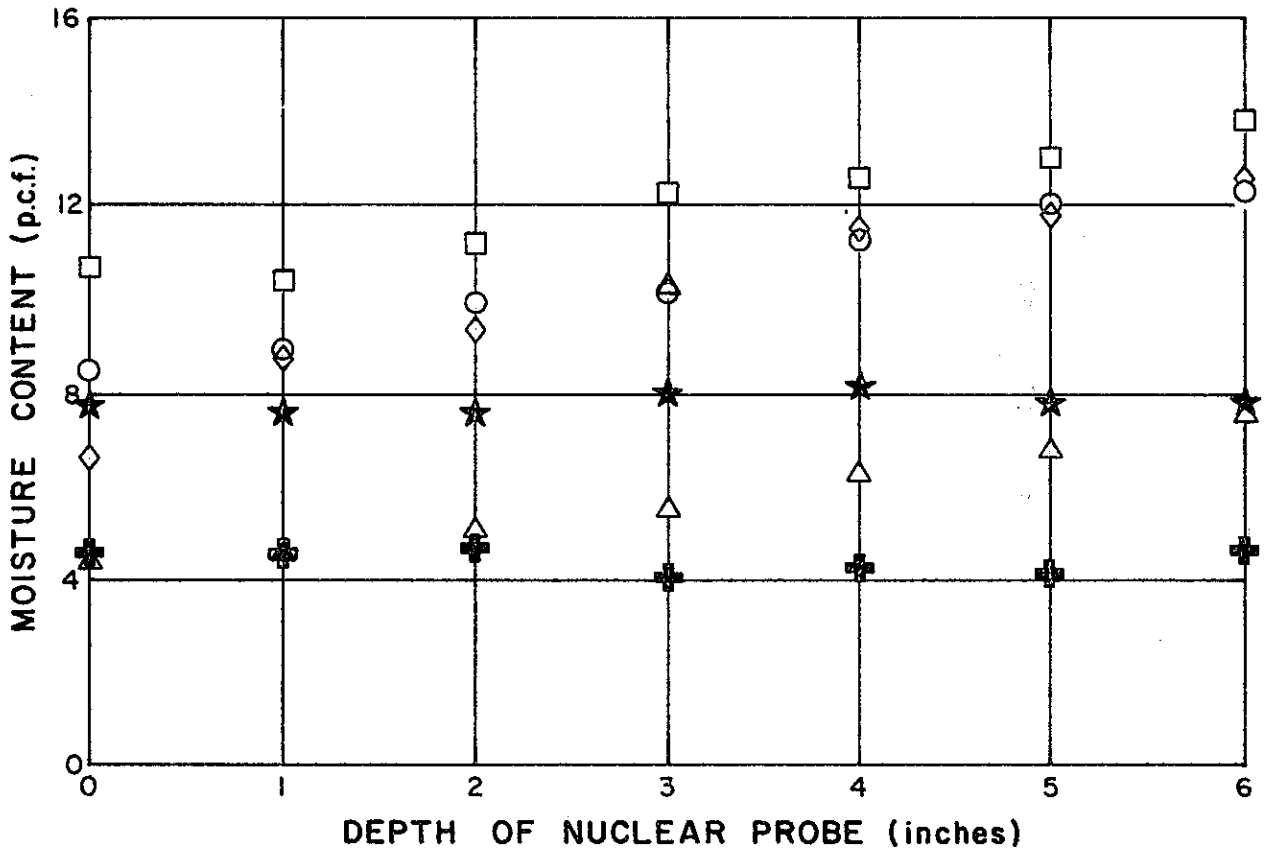


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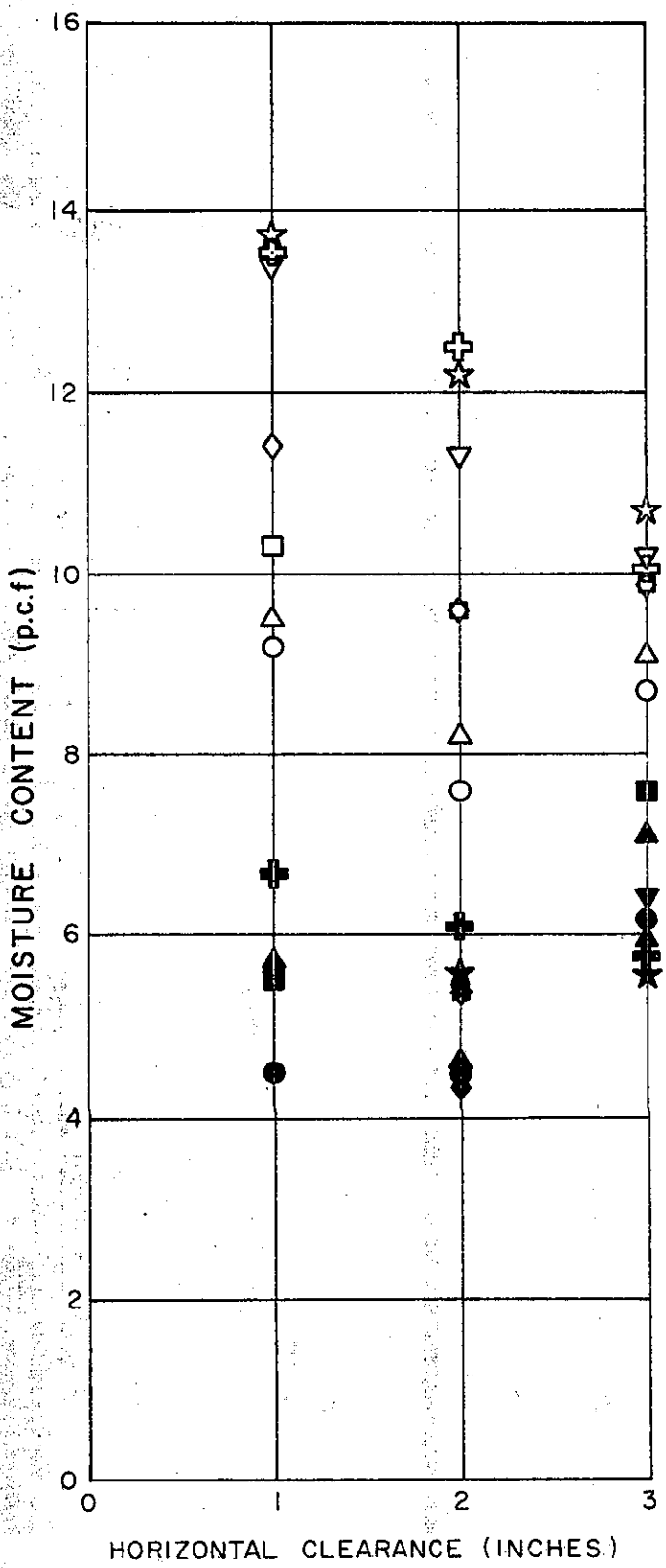
Figure 8

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY




| DEPTH OF PROBE | NUCLEAR MOISTURE CONTENT | OVEN DRY MOISTURE CONTENT |
|---|---|---|
| SURFACE | ○ | ● |
| 1" | △ | ▲ |
| 2" | □ | ■ |
| 3" | ◇ | ◆ |
| 4" | ▽ | ▼ |
| 5" | ✚ | ✚ |
| 6" | ☆ | ★ |

RELATIVELY DRY BACKFILL WITH CONCRETE SLAB.

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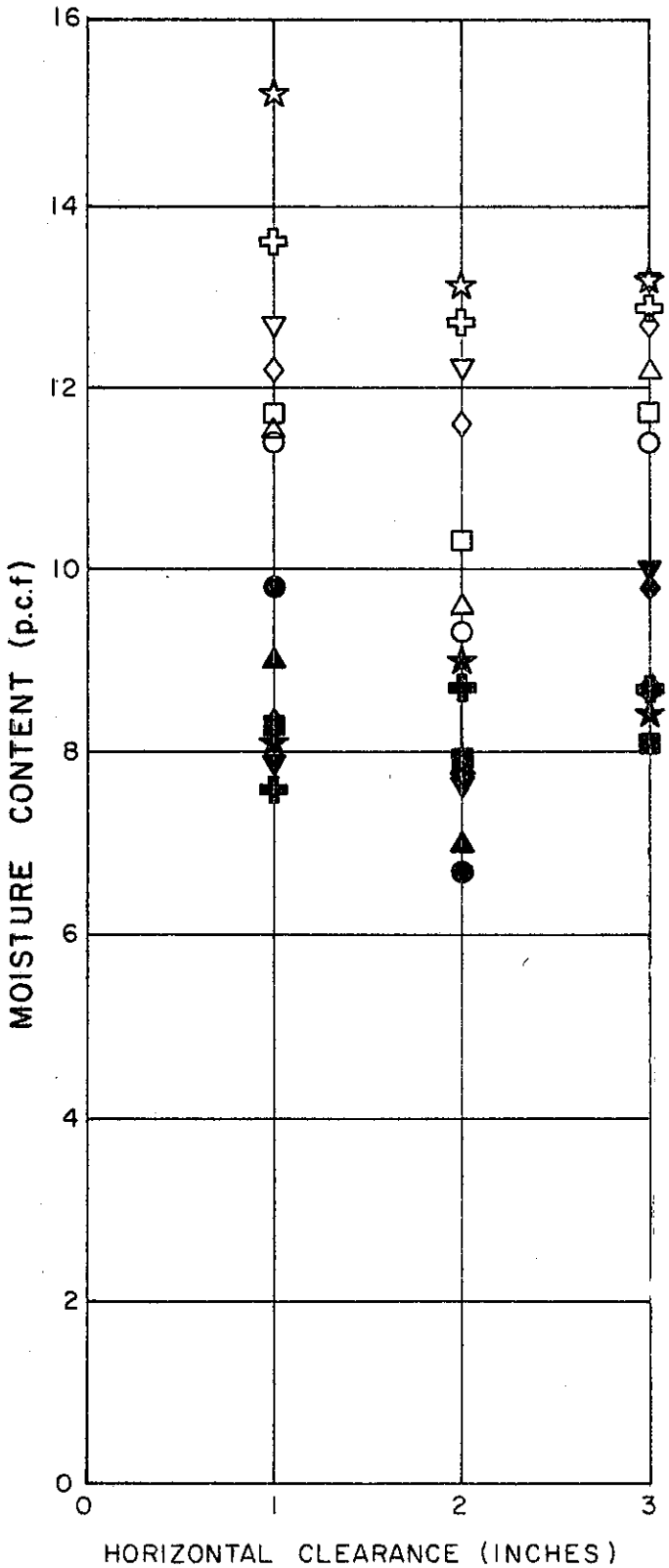
Figure 9

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL

SAN BERNARDINO COUNTY




| DEPTH OF PROBE | NUCLEAR MOISTURE CONTENT | OVEN DRY MOISTURE CONTENT |
|---|---|---|
| SURFACE | ○ | ● |
| 1" | △ | ▲ |
| 2" | □ | ■ |
| 3" | ◇ | ◆ |
| 4" | ▽ | ▼ |
| 5" | ✚ | ✚ |
| 6" | ☆ | ★ |

RELATIVELY WET BACKFILL WITH CONCRETE SLAB.

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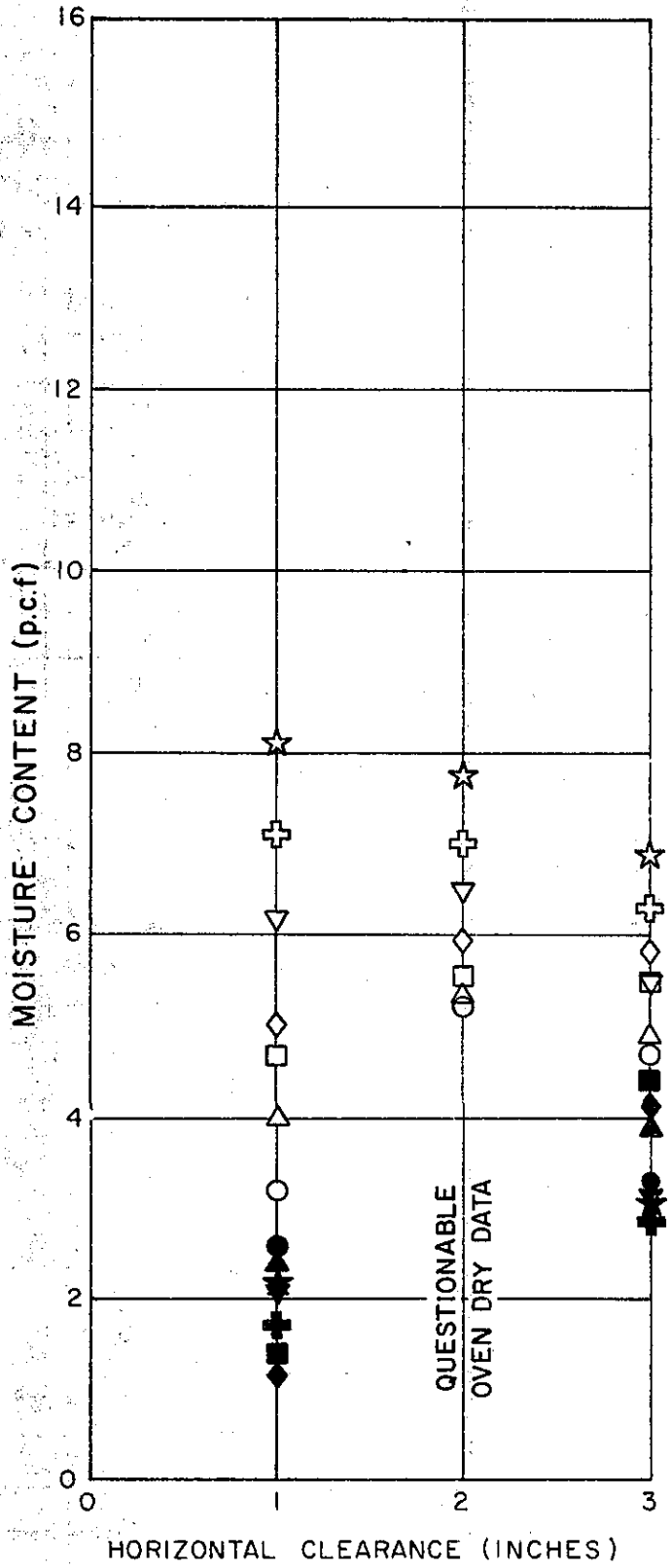
Figure 10

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY




| DEPTH OF PROBE | NUCLEAR MOISTURE CONTENT | OVEN DRY MOISTURE CONTENT |
|---|---|---|
| SURFACE | ○ | ● |
| 1" | △ | ▲ |
| 2" | □ | ■ |
| 3" | ◇ | ◆ |
| 4" | ▽ | ▼ |
| 5" | ✚ | ✚ |
| 6" | ☆ | ★ |

RELATIVELY DRY BACKFILL WITHOUT CONCRETE SLAB.

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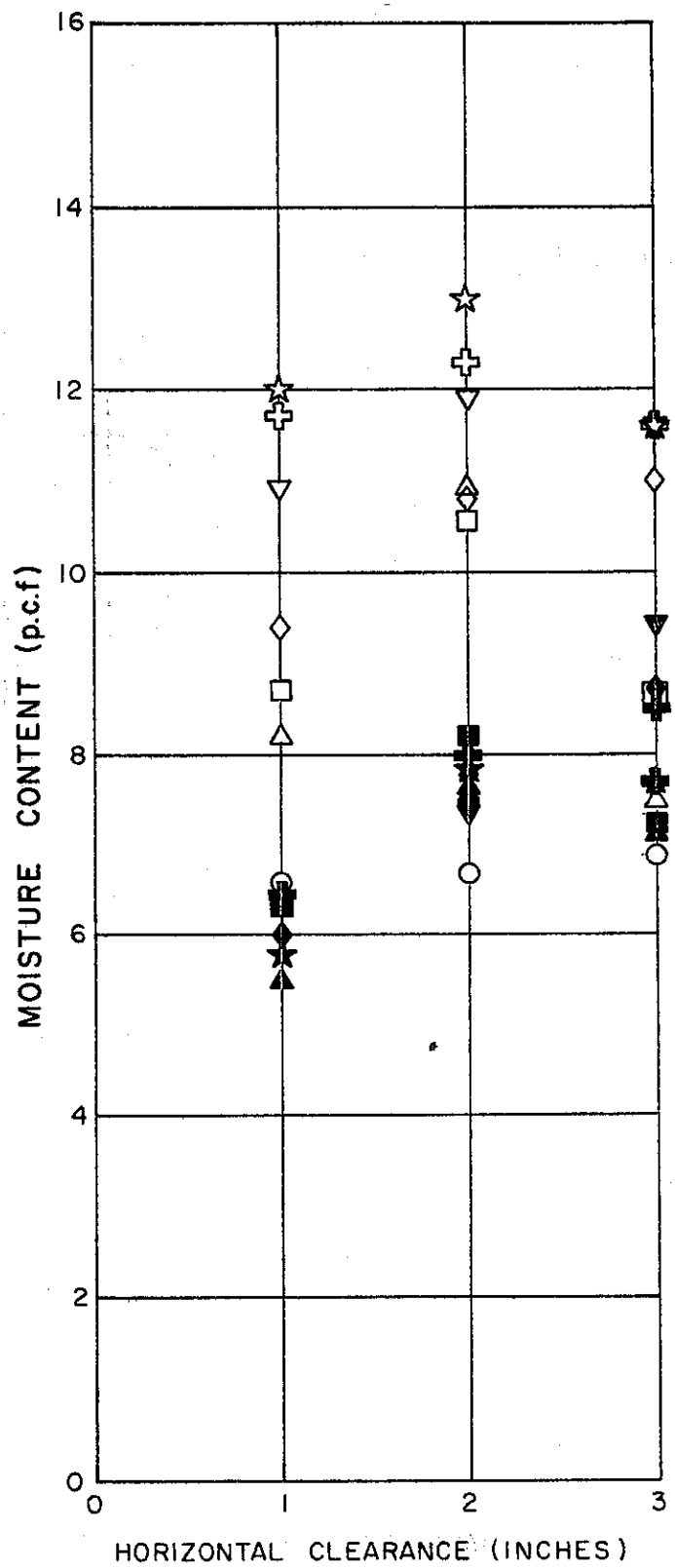
Figure 11

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY




| DEPTH OF PROBE | NUCLEAR MOISTURE CONTENT | OVEN DRY MOISTURE CONTENT |
|---|---|---|
| SURFACE | ○ | ● |
| 1" | △ | ▲ |
| 2" | □ | ■ |
| 3" | ◇ | ◆ |
| 4" | ▽ | ▼ |
| 5" | ✚ | ✚ |
| 6" | ☆ | ★ |

RELATIVELY WET BACKFILL WITHOUT CONCRETE SLAB.

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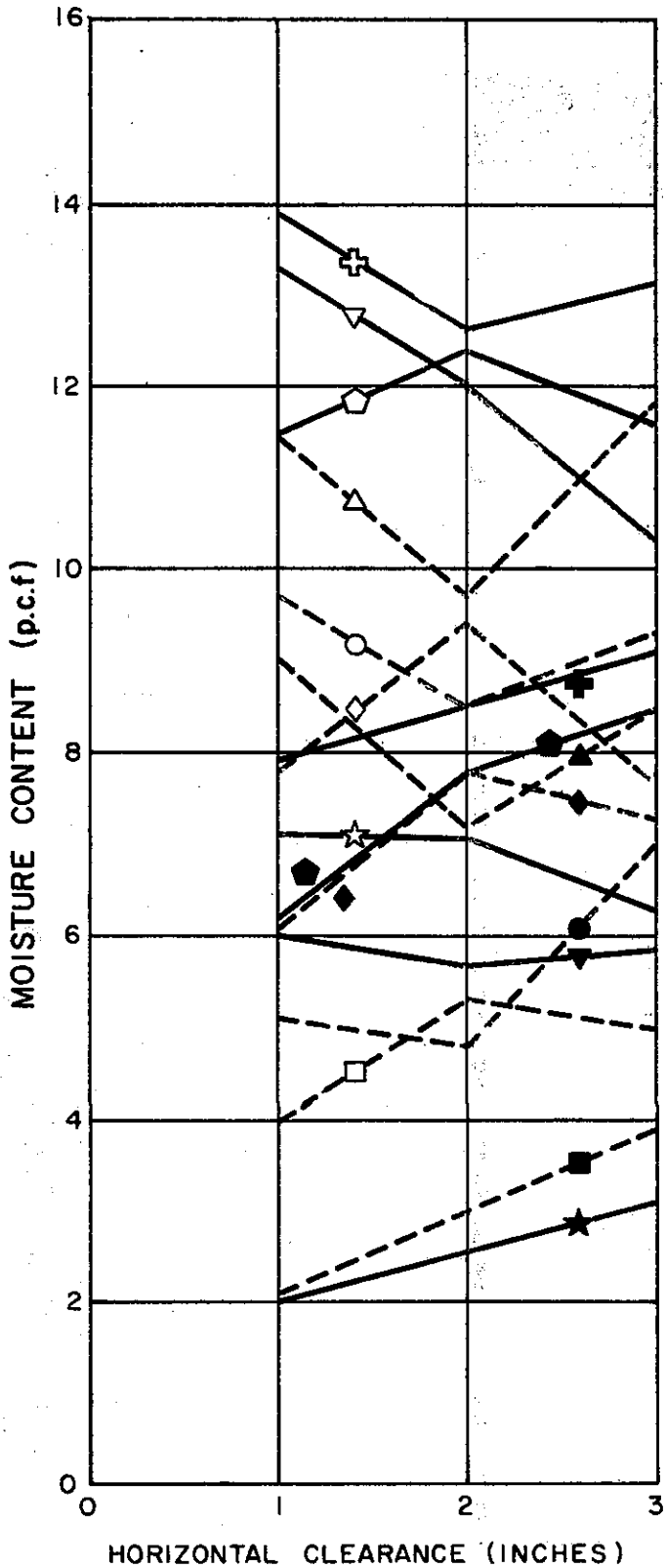
Figure 12

# TROXLER GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY




| DEPTH OF PROBE | ADJUSTED MOISTURE CONTENT | | BACKFILL MOISTURE CONDITION RELATIVELY | | CONCRETE SLAB | |
|---|---|---|---|---|---|---|
| | NUCLEAR | OVEN DRY | DRY | WET | PRESENT | ABSENT |
| SURFACE 1" & 2" | ○ | ● | ✓ | | ✓ | |
| | △ | ▲ | | ✓ | ✓ | |
| | □ | ■ | ✓ | | | ✓ |
| | ◇ | ◆ | | ✓ | | ✓ |
| 4", 5", & 6" | ▽ | ▼ | ✓ | | ✓ | |
| | ✚ | ✚ | | ✓ | ✓ | |
| | ☆ | ★ | ✓ | | | ✓ |
| | ⬠ | ⬟ | | ✓ | | ✓ |

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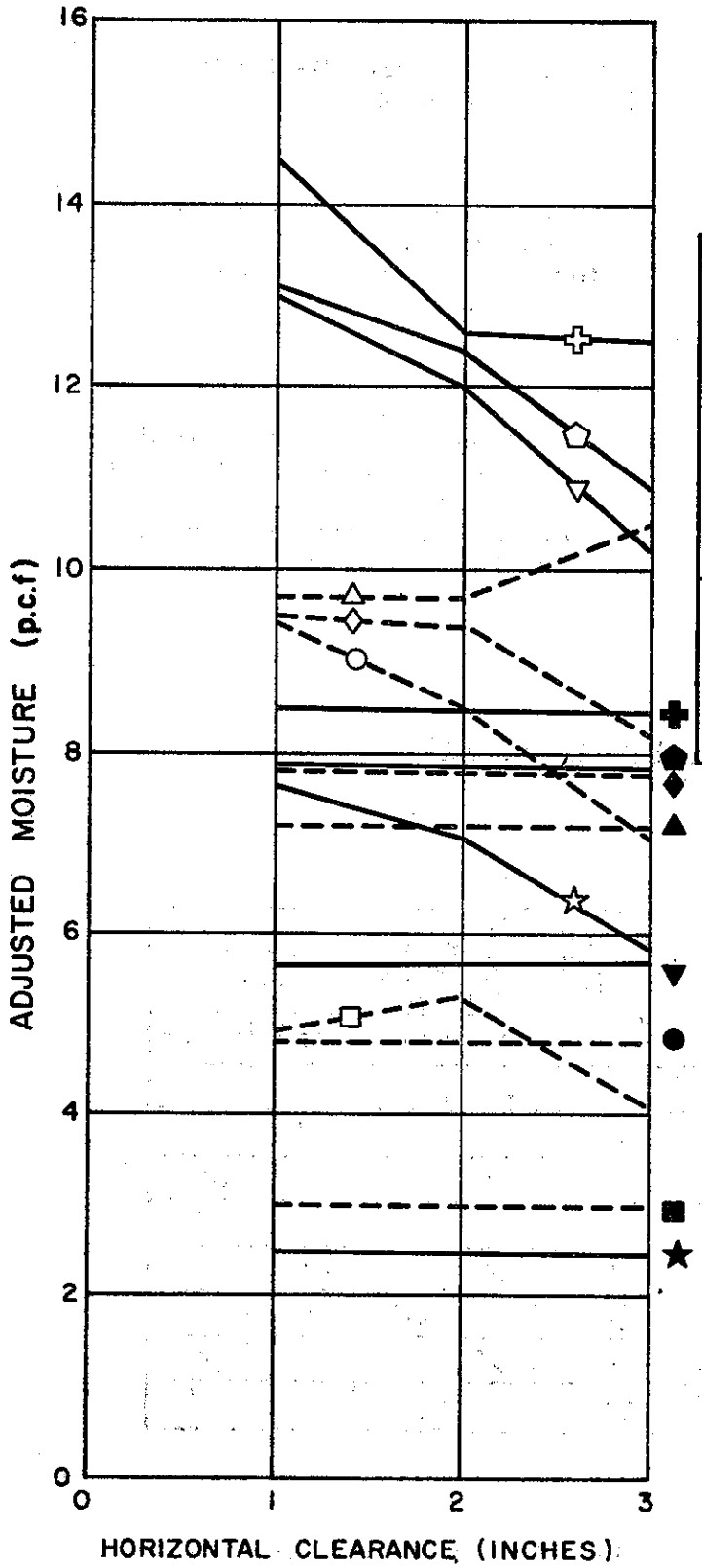
Figure 13

# TROXLER GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY




| DEPTH OF PROBE | ADJUSTED MOISTURE CONTENT | | BACKFILL MOISTURE CONDITION RELATIVELY | | CONCRETE SLAB | |
|---|---|---|---|---|---|---|
| | NUCLEAR | OVEN DRY | DRY | WET | PRESENT | ABSENT |
| SURFACE 1" & 2" | ○ | ● | ✓ | | ✓ | |
| | △ | ▲ | | ✓ | ✓ | |
| | □ | ■ | ✓ | | | ✓ |
| | ◇ | ◆ | | ✓ | | ✓ |
| 4", 5", & 6" | ▽ | ▼ | ✓ | | ✓ | |
| | ✚ | ✚ | | ✓ | ✓ | |
| | ☆ | ★ | ✓ | | | ✓ |
| | ⬠ | ⬟ | | ✓ | | ✓ |

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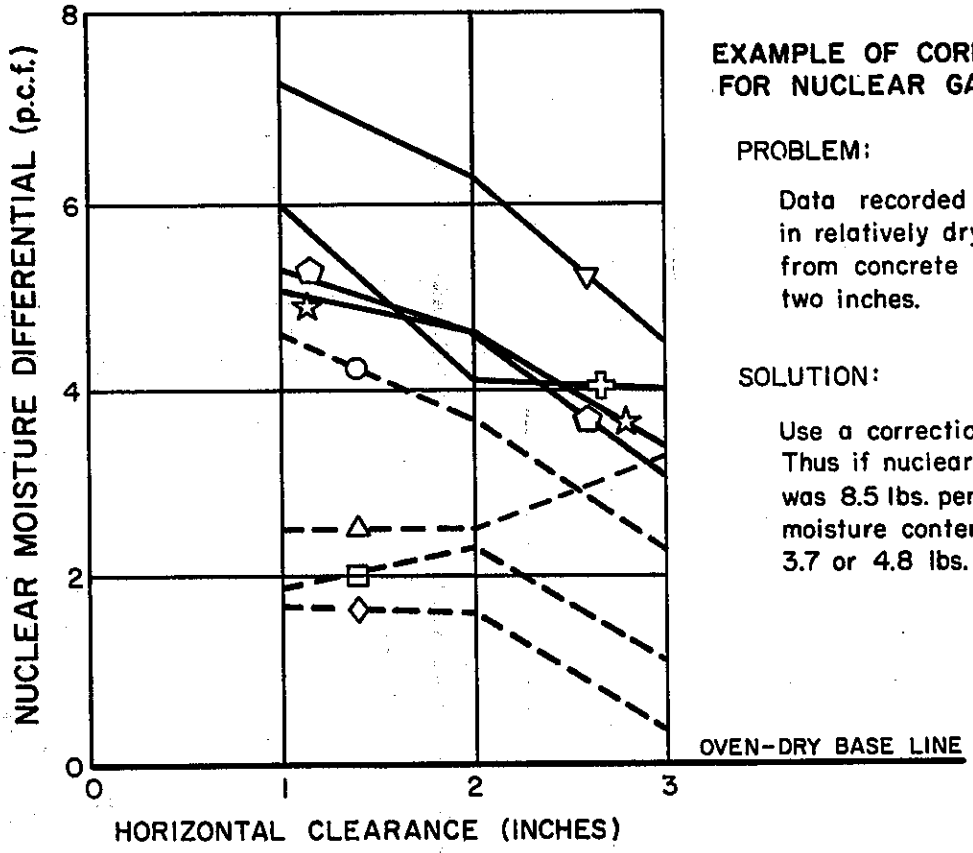
Figure 14

# TROXLER GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY




**EXAMPLE OF CORRECTION FACTOR FOR NUCLEAR GAGE.**

PROBLEM:

Data recorded when Troxler probe in relatively dry soil two inches from concrete slab at a depth of two inches.

SOLUTION:

Use a correction of 3.7 lbs. per. cu. ft.. Thus if nuclear moisture determination was 8.5 lbs. per. cu. ft., the corrected moisture content would be 8.5 minus 3.7 or 4.8 lbs. per. cu. ft..

| DEPTH OF PROBE | NUCLEAR MOISTURE DIFFERENTIAL | BACKFILL MOISTURE CONDITION RELATIVELY | | CONCRETE SLAB | |
|---|---|---|---|---|---|
| | | DRY | WET | PRESENT | ABSENT |
| SURFACE 1" & 2" — — — | ○ | ✓ | | ✓ | |
| | △ | | ✓ | ✓ | |
| | □ | ✓ | | | ✓ |
| | ◇ | | ✓ | | ✓ |
| 4", 5", & 6" ——— | ▽ | ✓ | | ✓ | |
| | ✚ | | ✓ | ✓ | |
| | ☆ | ✓ | | | ✓ |
| | ⬠ | | ✓ | | ✓ |

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Figure 15

# PORTAPROBE GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY

| HORIZONTAL CLEARANCE FROM NUCLEAR PROBE | 1" | 2" | 3" |
|---|---|---|---|
| NUCLEAR MOSTURE CONTENT | ○ | △ | □ |
| OVEN DRY MOISTURE CONTENT | ● | ▲ | ■ |

RELATIVELY DRY BACKFILL WITH CONCRETE SLAB.

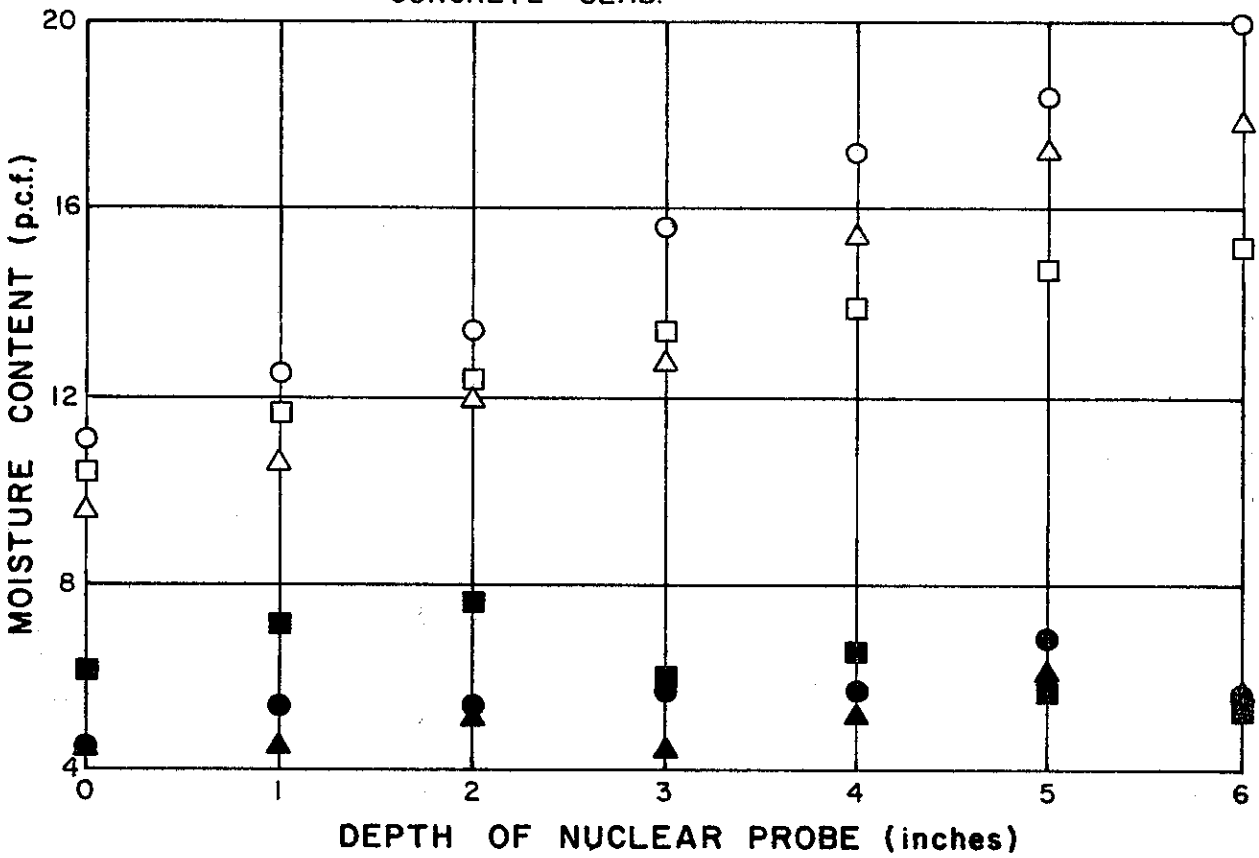


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Figure 16

# PORTAPROBE GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY

| HORIZONTAL CLEARANCE FROM NUCLEAR PROBE | .1" | 2" | 3" |
|---|---|---|---|
| NUCLEAR MOISTURE CONTENT | ○ | △ | □ |
| OVEN DRY MOISTURE CONTENT | ● | ▲ | ■ |

RELATIVELY WET BACKFILL WITH
CONCRETE SLAB

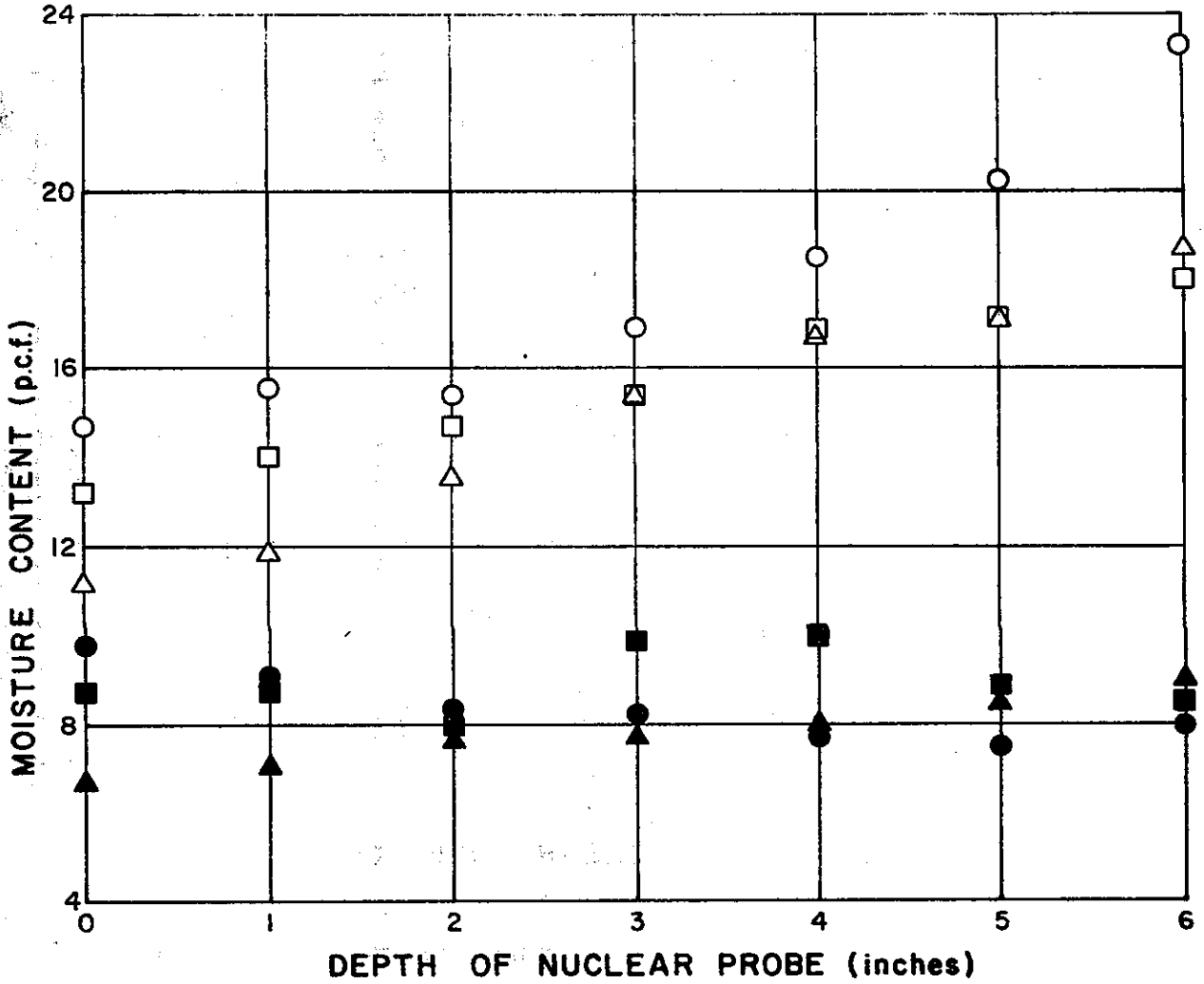


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Figure 17

# PORTAPROBE GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY

| HORIZONTAL CLEARANCE FROM NUCLEAR PROBE | 1" | 2" | 3" |
|---|---|---|---|
| NUCLEAR MOSTURE CONTENT | ○ | △ | □ |
| OVEN DRY MOISTURE CONTENT | ● | | ■ |

RELATIVELY DRY BACKFILL WITHOUT CONCRETE SLAB.

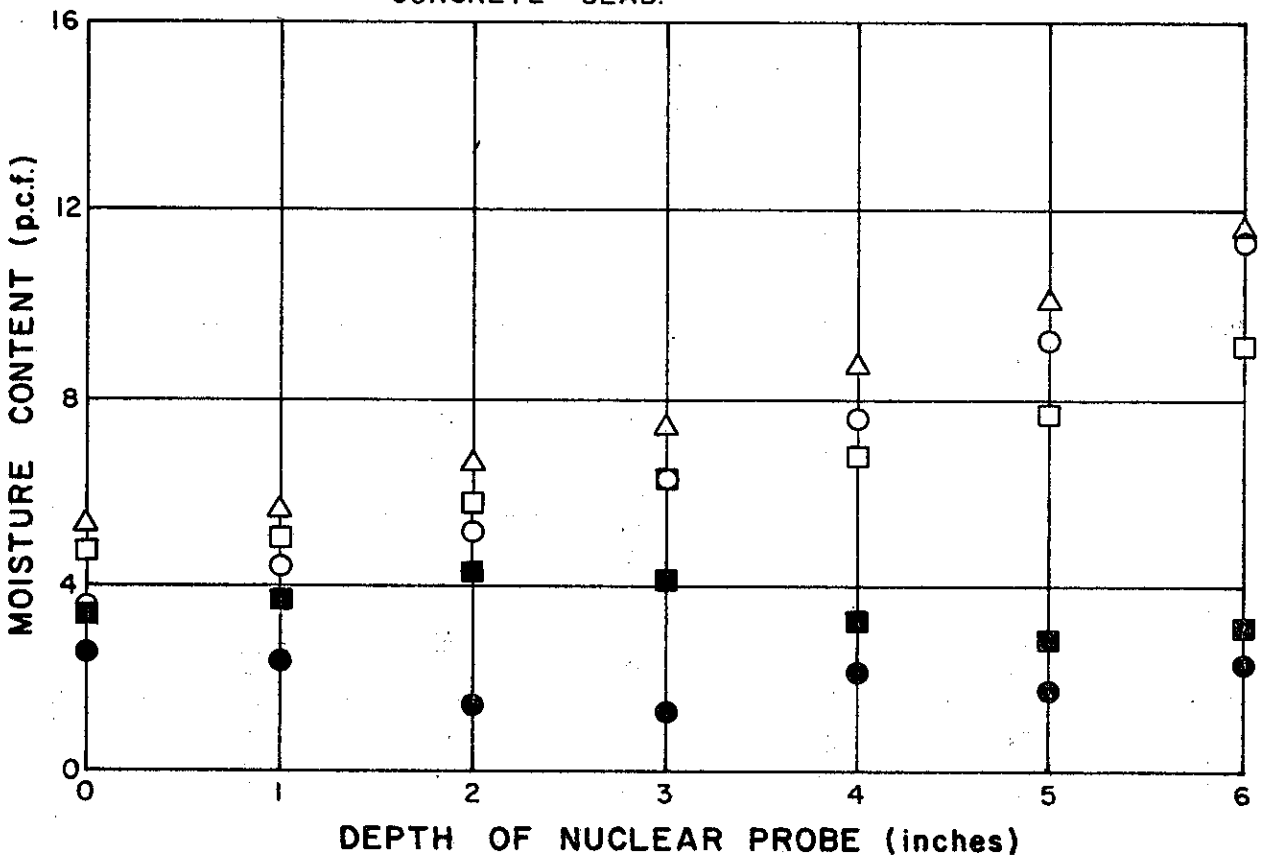


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Figure 18

# PORTAPROBE GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY

| HORIZONTAL CLEARANCE FROM NUCLEAR PROBE | 1" | 2" | 3" |
|---|---|---|---|
| NUCLEAR MOSTURE CONTENT | ○ | △ | □ |
| OVEN DRY MOISTURE CONTENT | ● | ▲ | ■ |

RELATIVELY WET BACKFILL WITHOUT CONCRETE SLAB.

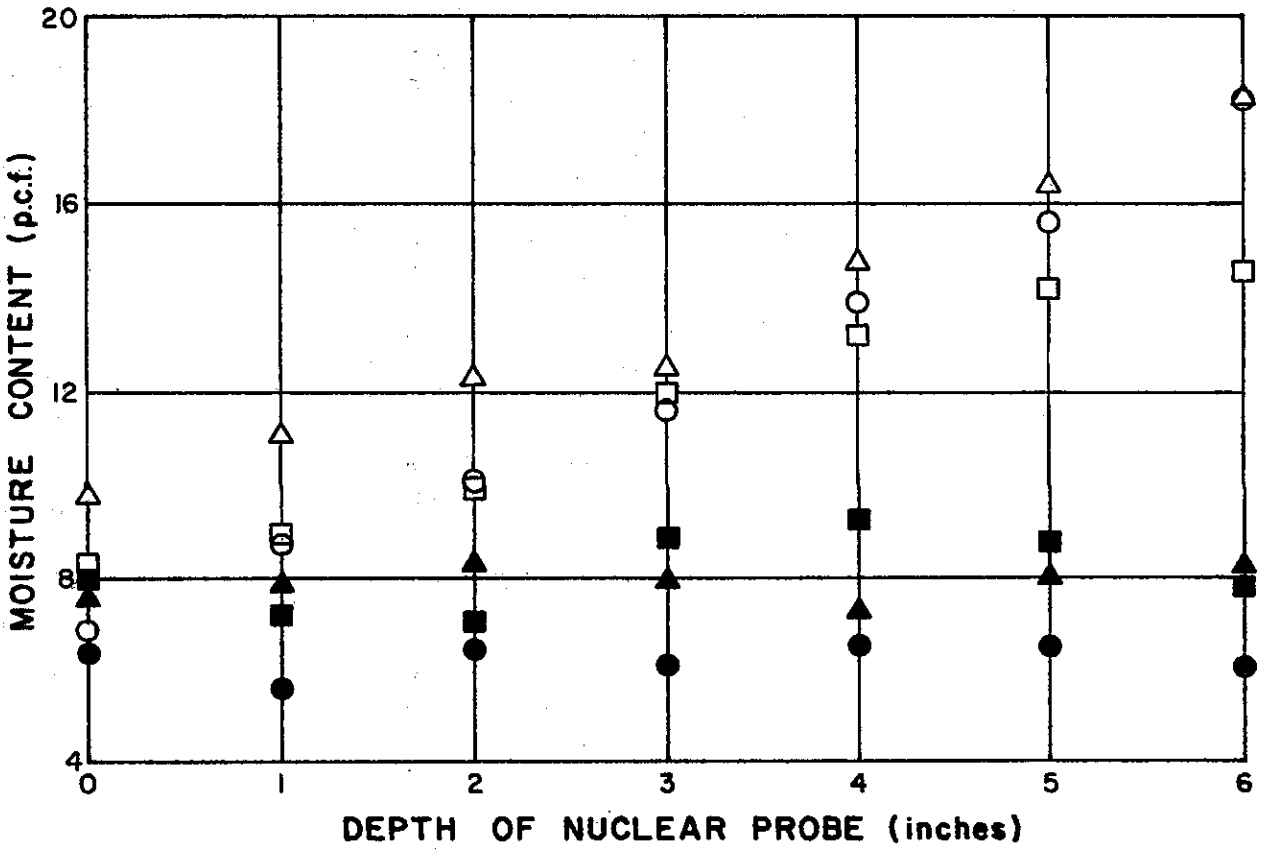


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Figure 19

# PORTAPROBE GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY

| AVERAGE MOISTURE CONTENT FOR 1", 2" & 3" CLEARANCE | BACKFILL RELATIVELY DRY | BACKFILL RELATIVELY WET |
|---|---|---|
| NUCLEAR – WITH CONCRETE SLAB | ○ | □ |
| NUCLEAR – WITHOUT CONCRETE SLAB | △ | ◇ |
| OVEN DRY – WITH & WITHOUT CONCRETE SLAB | ✚ | ★ |

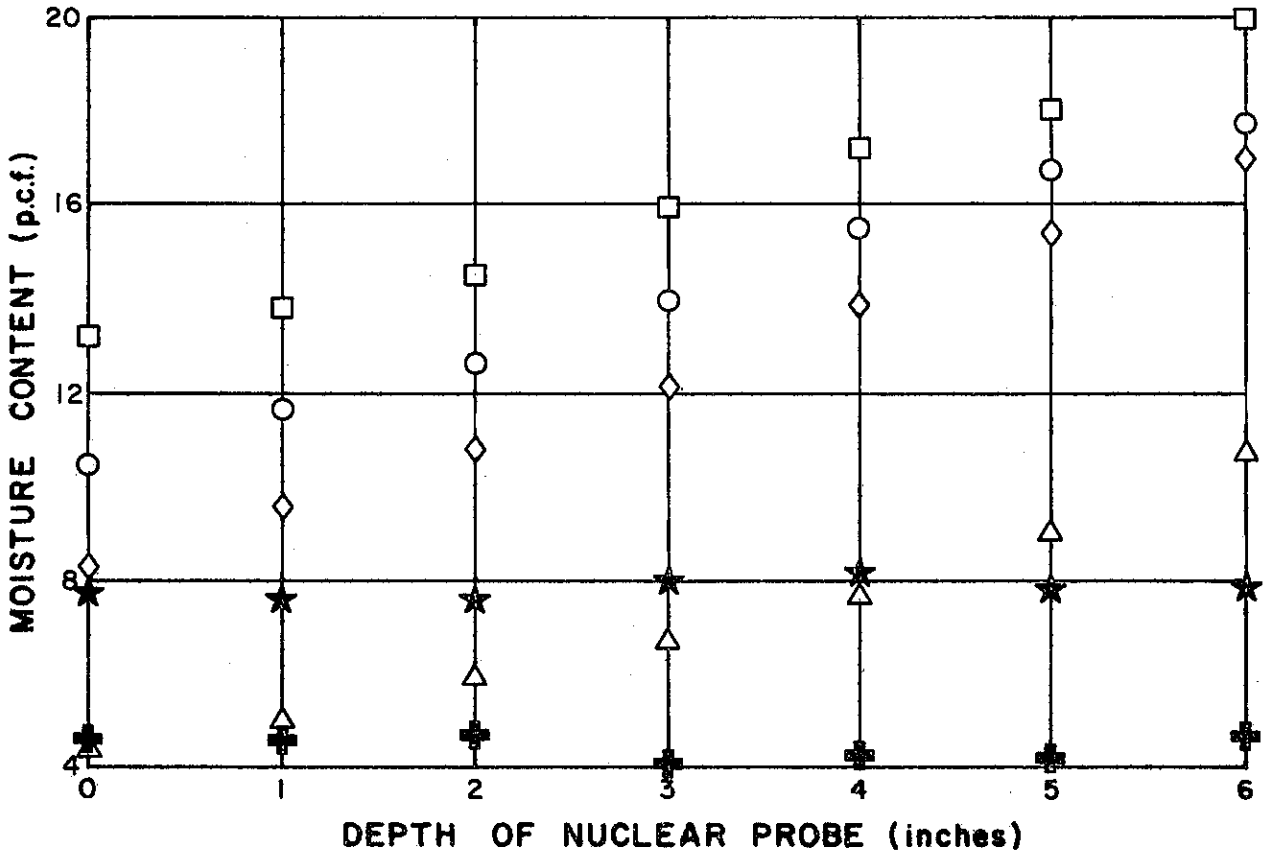


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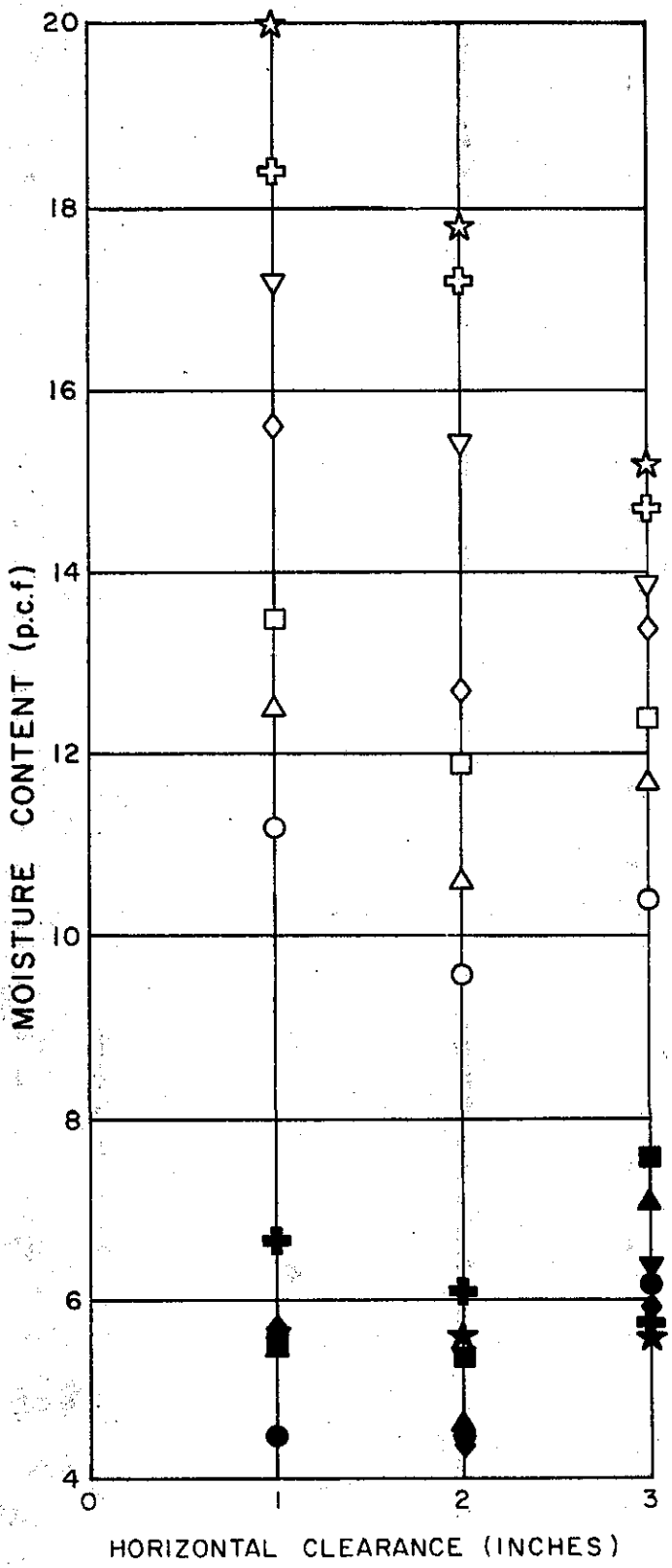
Figure 20

# PORTAPROBE GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY




| DEPTH OF PROBE | NUCLEAR MOISTURE CONTENT | OVEN DRY MOISTURE CONTENT |
|---|---|---|
| SURFACE | ○ | ● |
| 1" | △ | ▲ |
| 2" | □ | ■ |
| 3" | ◇ | ◆ |
| 4" | ▽ | ▼ |
| 5" | ✚ | ✚ |
| 6" | ☆ | ★ |

RELATIVELY DRY BACKFILL WITH CONCRETE SLAB.

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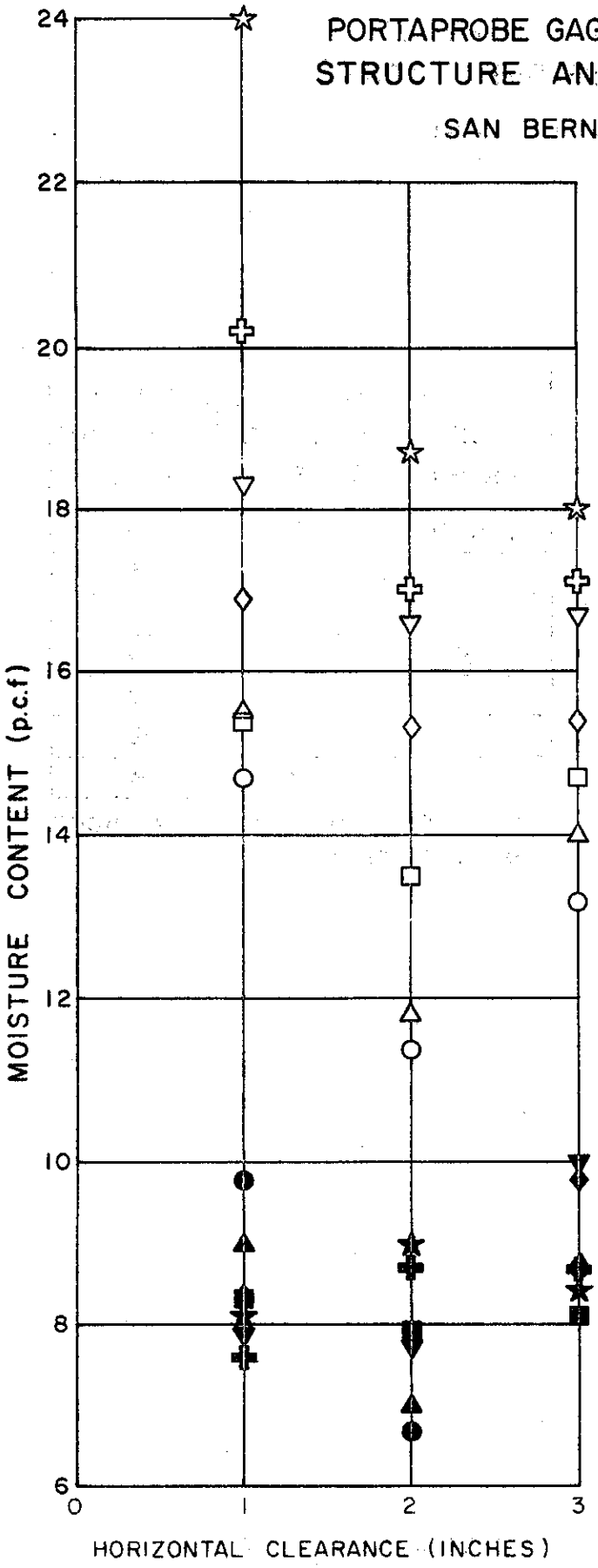
Figure 21

# PORTAPROBE GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY




| DEPTH OF PROBE | NUCLEAR MOISTURE CONTENT | OVEN DRY MOISTURE CONTENT |
|---|---|---|
| SURFACE | ○ | ● |
| 1" | △ | ▲ |
| 2" | □ | ■ |
| 3" | ◇ | ◆ |
| 4" | ▽ | ▼ |
| 5" | ✚ | ✚ |
| 6" | ☆ | ★ |

RELATIVELY WET BACKFILL WITH CONCRETE SLAB.

MATERIALS AND RESEARCH DEPARTMENT
NO. M & R 642978

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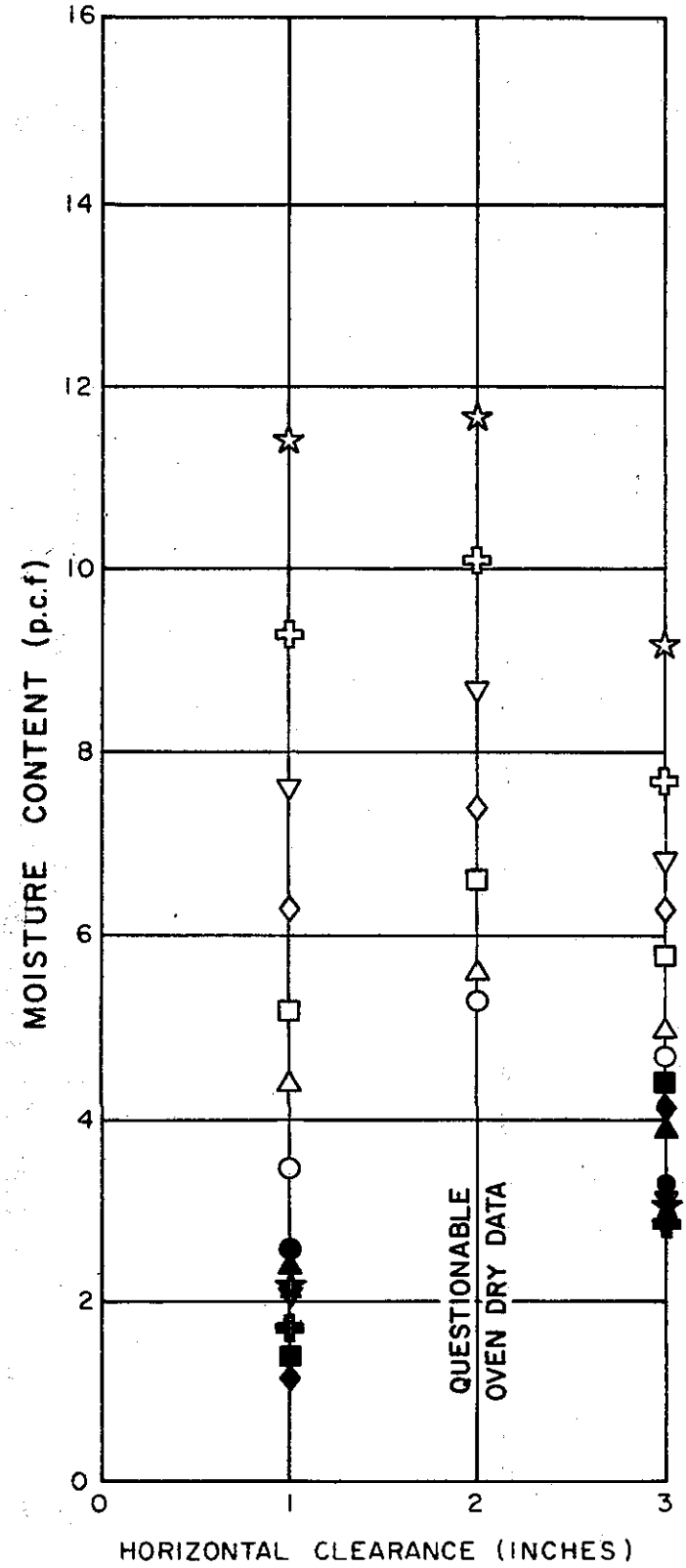
Figure 22

# PORTAPROBE GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY




| DEPTH OF PROBE | NUCLEAR MOISTURE CONTENT | OVEN DRY MOISTURE CONTENT |
|---|---|---|
| SURFACE | ○ | ● |
| 1" | △ | ▲ |
| 2" | □ | ■ |
| 3" | ◇ | ◆ |
| 4" | ▽ | ▼ |
| 5" | ✚ | ✚ |
| 6" | ☆ | ★ |

RELATIVELY DRY BACKFILL WITHOUT CONCRETE SLAB.

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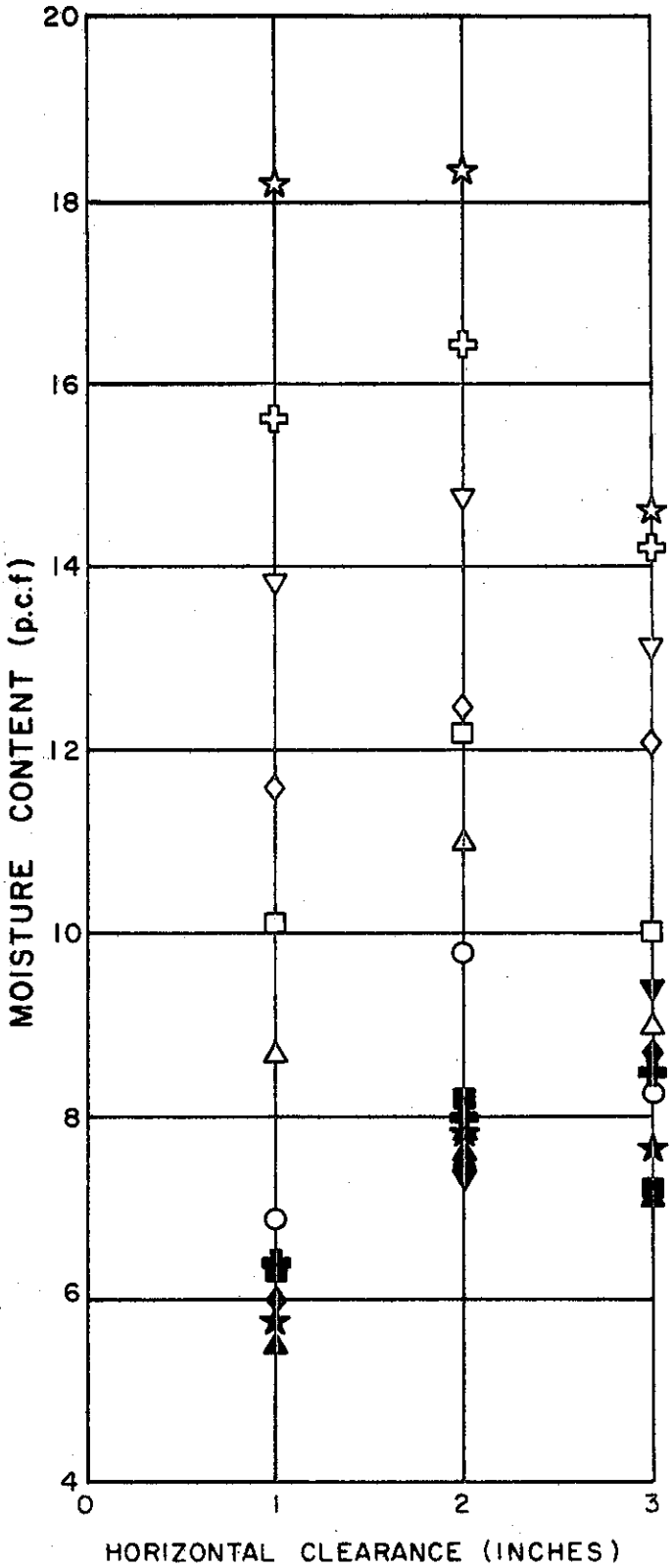
Figure 23

# PORTAPROBE GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY




| DEPTH OF PROBE | NUCLEAR MOISTURE CONTENT | OVEN DRY MOISTURE CONTENT |
|---|---|---|
| SURFACE | ○ | ● |
| 1" | △ | ▲ |
| 2" | □ | ■ |
| 3" | ◇ | ◆ |
| 4" | ▽ | ▼ |
| 5" | ✚ | ✚ |
| 6" | ☆ | ★ |

RELATIVELY WET BACKFILL WITHOUT CONCRETE SLAB

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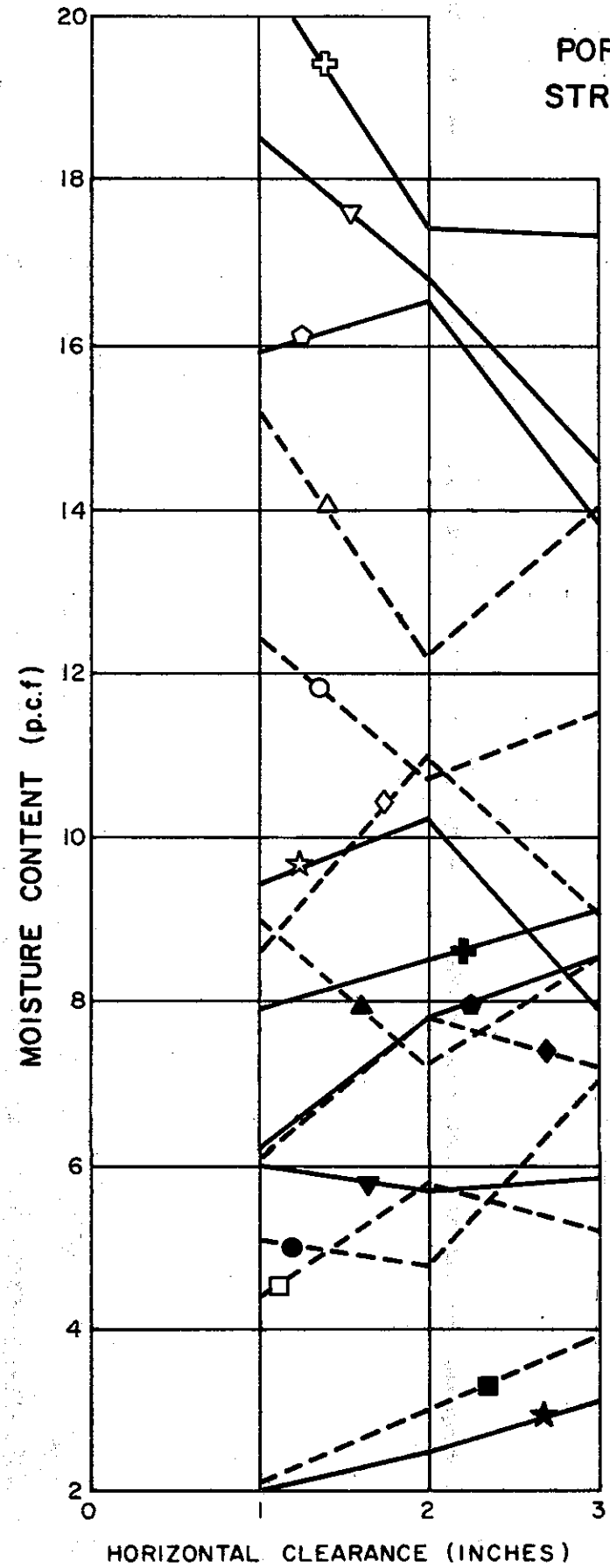
Figure 24

# PORTAPROBE GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY




| DEPTH OF PROBE | ADJUSTED MOISTURE CONTENT | | BACKFILL MOISTURE CONDITION RELATIVELY | | CONCRETE SLAB | |
|---|---|---|---|---|---|---|
| | NUCLEAR | OVEN DRY | DRY | WET | PRESENT | ABSENT |
| SURFACE 1" & 2" | ○ | ● | ✓ | | ✓ | |
| | △ | ▲ | | ✓ | ✓ | |
| | □ | ■ | ✓ | | | ✓ |
| | ◇ | ◆ | | ✓ | | ✓ |
| 4", 5", & 6" | ▽ | ▼ | ✓ | | ✓ | |
| | ✚ | ✚ | | ✓ | ✓ | |
| | ☆ | ★ | ✓ | | | ✓ |
| | ⬠ | ⬟ | | ✓ | | ✓ |

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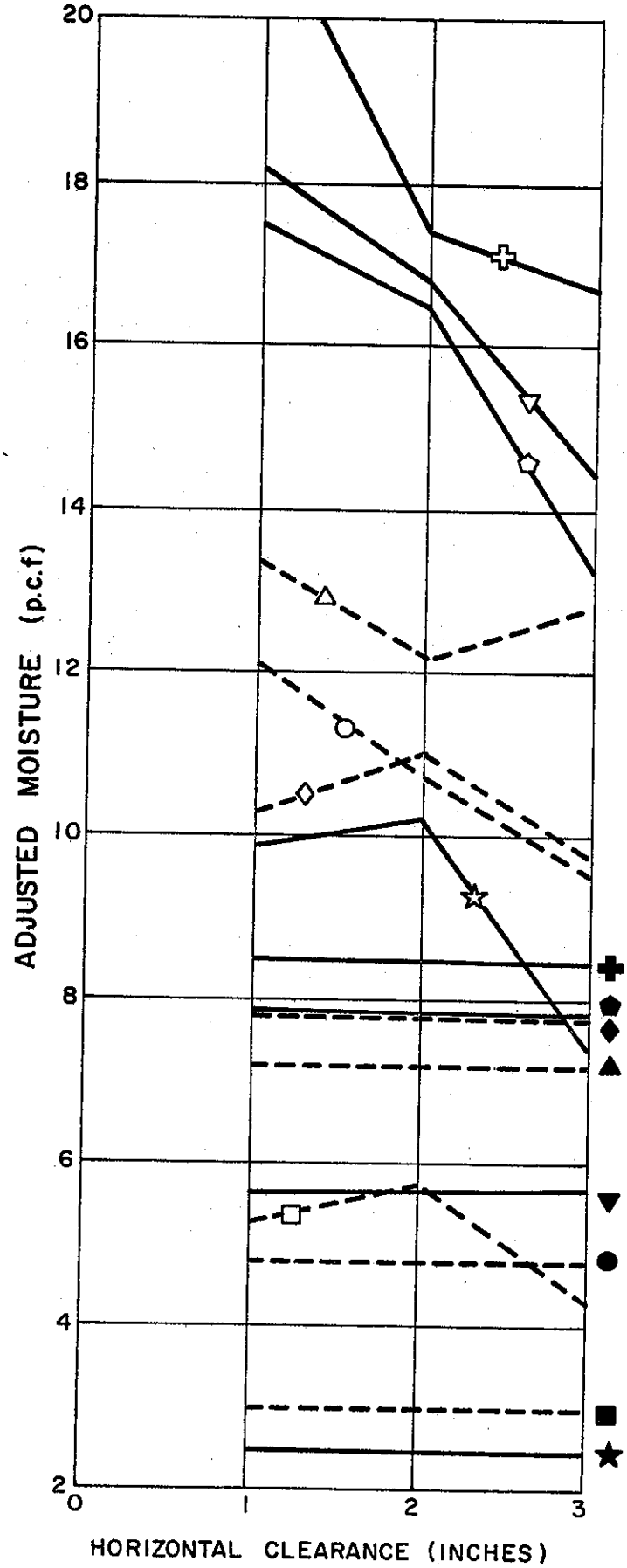
Figure 25

# PORTAPROBE GAGE MOISTURE STUDY
## STRUCTURE AND BRIDGE BACKFILL
### SAN BERNARDINO COUNTY




| DEPTH OF PROBE | ADJUSTED MOISTURE CONTENT | | BACKFILL MOISTURE CONDITION RELATIVELY | | CONCRETE SLAB | |
|---|---|---|---|---|---|---|
| | NUCLEAR | OVEN DRY | DRY | WET | PRESENT | ABSENT |
| SURFACE 1" & 2" | ○ | ● | ✓ | | ✓ | |
| | △ | ▲ | | ✓ | ✓ | |
| | □ | ■ | ✓ | | | ✓ |
| | ◇ | ◆ | | ✓ | | ✓ |
| 4", 5", & 6" | ▽ | ▼ | ✓ | | ✓ | |
| | ✚ | ✚ | | ✓ | ✓ | |
| | ☆ | ★ | ✓ | | | ✓ |
| | ⬠ | ⬟ | | ✓ | | ✓ |

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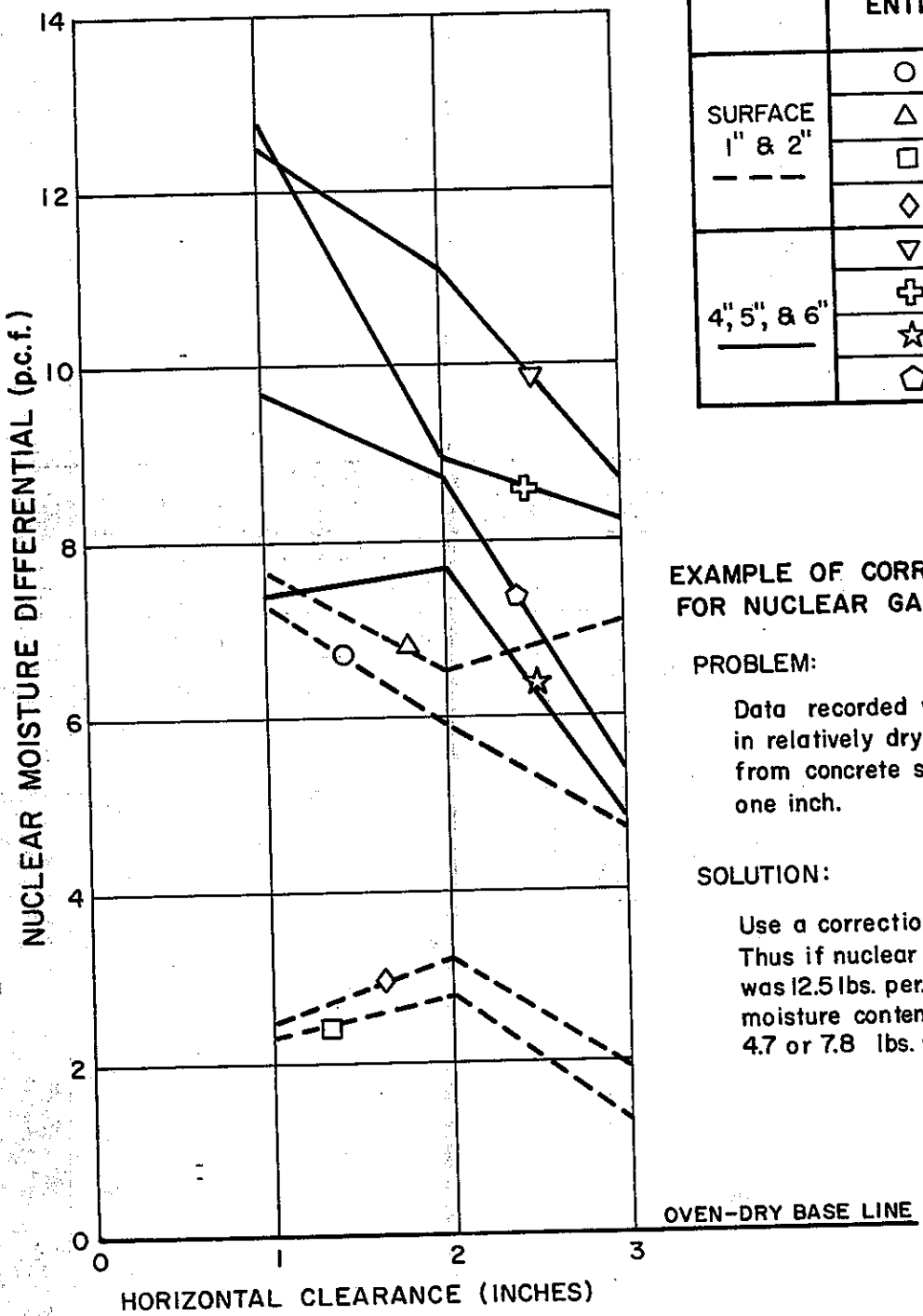
Figure 26

# PORTAPROBE GAGE MOISTURE STUDY
# STRUCTURE AND BRIDGE BACKFILL

## SAN BERNARDINO COUNTY

| DEPTH OF PROBE | NUCLEAR MOISTURE DIFFERENTIAL | BACKFILL MOISTURE CONDITION RELATIVELY | | CONCRETE SLAB | |
|---|---|---|---|---|---|
| | | DRY | WET | PRESENT | ABSENT |
| SURFACE 1" & 2" | ○ | ✓ | | ✓ | |
| | △ | | ✓ | ✓ | |
| | □ | ✓ | | | ✓ |
| | ◇ | | ✓ | | ✓ |
| 4", 5", & 6" | ▽ | ✓ | | ✓ | |
| | ✚ | | ✓ | ✓ | |
| | ☆ | ✓ | | | ✓ |
| | ⬠ | | ✓ | | ✓ |




EXAMPLE OF CORRECTION FACTOR FOR NUCLEAR GAGE.

PROBLEM:

Data recorded when Portaprobe in relatively dry soil three inches from concrete slab at a depth of one inch.

SOLUTION:

Use a correction of 4.7 lbs. per. cu. ft.. Thus if nuclear moisture determination was 12.5 lbs. per. cu. ft., the corrected moisture content would be 12.5 minus 4.7 or 7.8 lbs. per. cu. ft..

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