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A Report on Fluctuations in Moisture Content of P.C.C. Pavement Slabs

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Tremper, Bailey and L.P. Kovanda

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16. ABSTRACT

The objectives of the tests described herein were to measure the fluctuations in moisture throughout an annual weather cycle, at all depths in concrete slabs of 8-inch thickness, laid on an Earth subgrade and on a cement-treated subgrade with bituminous seal.

The moisture content of concrete in place has been measured with indifferent success by a number of methods. The most promising results in pavement slabs have been reported by the Virginia Council of Highway Investigation and Research (references 1 and 2). In these studies, which were devoted to the effect of curing materials, Boyoucos plaster of paris cells were embedded in the pavement slabs at the time of construction. The cells were located at positions 1 inch from the top, 1 inch from the bottom and at mid-depth of 8-inch slabs. Calibration tests indicated that the accuracy in measurement was about +- 0.5 percentage points of the weight of concrete which is equivalent to about +- 10 percent of the contained water. Measurements were discontinued after 10 days following construction. While the type of subgrade treatment is not stated in the report it is unlikely that it was cement-treated or had an asphalt seal.

The Virginia investigations provided only a portion of the desired data as set forth in the opening paragraph of this report. In considering means of obtaining data the idea was conceived that changes in weight of concrete disks arranged in layers in a close fitting hole in the pavement would be representative of changes within the slab itself. The desirability of making tests in an existing pavement was recognized but difficulties in drilling holes of uniform diameter led to a decision to construct model slabs with cast-in-place holes.

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Department of Public Works
Division of Highways
Materials and Research Department

March 1, 1955

Lab. W.O. 5011-R-55

Mr. E. Withycombe
Assistant State Highway Engineer
Sacramento, California

Dear Sir:

Submitted for your consideration is:

A Report on

FLUCTUATIONS IN MOISTURE CONTENT

OF P.C.C. PAVEMENT SLABS

Study made by .... Technical Section
Under general direction of .... Bailey Tremper
Report prepared by .... Bailey Tremper and
L. P. Kovanda

Very truly yours,

F. N. Hveem
Materials and Research Engineer

cc: M. Harris
JCYoung

FLUCTUATIONS IN MOISTURE CONTENT OF P.C.C. PAVEMENT SLABS

INTRODUCTION

The objectives of the tests described herein were to measure the fluctuations in moisture throughout an annual weather cycle, at all depths in concrete slabs of 8-inch thickness, laid on an earth subgrade and on a cement-treated subgrade with bituminous seal.

The moisture content of concrete in place has been measured with indifferent success by a number of methods. The most promising results in pavement slabs have been reported by the Virginia Council of Highway Investigation and Research (references 1 and 2). In these studies, which were devoted to the effect of curing materials, Bouyoucos plaster of paris cells were embedded in the pavement slabs at the time of construction. The cells were located at positions 1 inch from the top, 1 inch from the bottom and at mid-depth of 8-inch slabs. Calibration tests indicated that the accuracy in measurement was about ± 0.5 percentage points of the weight of concrete which is equivalent to about ± 10 percent of the contained water. Measurements were discontinued after 10 days following construction. While the type of subgrade treatment is not stated in the report it is unlikely that it was cement-treated or had an asphalt seal.

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TEST PROCEDURE

Two concrete slabs were constructed at the laboratory site at 59th Street and Folsom Boulevard. As shown in Figure 1, the slabs were 3'-8" x 5'-6" x 8" thick with the top surface at the level of the surrounding ground. One slab was cast directly on the native soil. The subgrade for the other slab was constructed by removing the upper 4 inches below the surface enclosed by the forms, mixing it with cement and water in a laboratory mixer and then compacting it in a place. Emulsified asphalt was then applied at the rate of 1/4 gallon per square yard. Forms for the cast-in-place holes were machined from steel tubing to the diameter of the outside of a sheet metal 6 x 12-inch cylinder mold, which has a slight taper. Three 1/2-inch square bars were attached to the outside of the machined tubing to form grooves to contain hooked rods for placing and removing test disks from the holes.

Test cylinders were cast with concrete similar to that used in the slabs. The diameter of the cylinders was that of the inside of the mold. The clearance between disks sawed from these cylinders and the holes in the slabs was therefore the thickness of the sheet metal, about 0.01 inch. Disks slightly over 1-inch in thickness were cut from the cylinders using a diamond saw lubricated with water. The faces of the disks were then lapped to provide close contact when they were stacked. The top surface of each set of 8 disks was coated with a thin layer of mortar to more nearly represent a finished pavement surface. The disks were then allowed to dry outside to constant weight. They were then soaked in water for several weeks and weighed. The difference in weight between the saturated and sun-dry condition is termed the "evaporable water". The percentage of evaporable water by weight of the concrete was not constant among the disks because of variations in the volume of coarse aggregate. The value for evaporable water is useful as a common denominator for the losses and gains in moisture that took place during exposure.

The test cylinders were made in August, 1953 and the slabs in November. The saturated and weighed disks were put in place in the test holes on December 10, 1953. The small annular opening between the top of the disk and the slab, and the space between the grooves and the lift rods, was sealed with slightly warmed paraffin. Metal sash putty was substituted for paraffin after the first few months.

Hooks used for inserting and removing the stack of disks were 3/8-inch rods with one end flattened and bent. The upper ends of the rods were threaded and extended a short distance above the surface of the slab. A metal spider was attached to the rods for removal of the disks which was accomplished quite readily. Considerable difficulty was experienced at first in inserting the stack of disks and the set used at location D became wedged in place before it was completely inserted on January 12, 1954. Several of the disks were broken and a new set was installed on February 11. The new disks had been oven-dried. As a consequence the change in weight from saturated to dry was greater than that obtained in sun drying. An adjustment was made to give a value for evaporable water on the same basis as the other disks by multiplying the oven-dry loss by a factor which was the average loss of the sun-dried group divided by the average loss of the set of oven-dried disks.

During April the weather became warm enough to melt the paraffin seal and the top disk of group A became completely coated with paraffin. In the other locations the paraffin did not spread over significant areas of the surface. Steel sash putty was used thereafter as a sealing compound and it proved to be entirely satisfactory.

The disks were removed and weighed on January 12 and March 25, 1954 and subsequently thereafter at approximately monthly intervals until December 20, 1954, which date was slightly over one year from original installation.

The disks weighed about 1100 grams each and were weighed to the nearest gram. The evaporable water varied in individual disks from 27 to 57 grams. The change in moisture content was determined on the basis of weight change within 2 to 4 percent of the evaporable water.

TEST RESULTS AND DISCUSSION

The data on moisture fluctuation in the disks of each group is shown graphically in Figure 2. The numeral "1" designates the top disk and "8" the bottom one. Curves for disks 5, 6 and 7 are not shown. In all cases they are intermediate in position and about equally spaced between the curves for disks 4 and 8. Daily rainfall in inches (Sacramento Weather Bureau Station) is plotted at the bottom of the figure.

It will be noted that disk No. 1, representing the top 1 inch of the concrete, lost from 80 to 100 percent of its evaporable water during the dry season starting about the middle of May. Maximum loss in moisture was not reached however, until September after four months of hot, nearly rainless weather. If the top disks became thoroughly saturated by the heavy rains that fell during the second week in November and the first two weeks in December they did not remain completely saturated for many days as indicated by weighings made 3 and 10 days of cool, foggy weather after the rains. It appears from these results that once the top of the pavement has dried thoroughly it is not likely again to reach full saturation.

The No. 2 disks representing a layer from 1 to 2 inches below the surface did not lose more than about one-half of the evaporable water. With the exception of location D, the bottom disks did not lose more than 13 percent of the evaporable water at any time. The data for the bottom disk at location D appear to be inconsistent probably due to the use of an unsuitable conversion factor to adjust the oven-dry weight to sun-dry weight.

On December 20 free water was found in the bottom of the hole and between each disk at location D. Weighings indicated that each of the disks had become saturated. It is believed that the surface seal did not remain intact or that the top of the stack of disks when replaced after the previous removal was slightly below the surface of the slab. The measured results at location D on December 20 are inconsistent with those obtained at the other locations and they have not been plotted in Figure 2.

The paraffin film which spread over the top disk at location A during April retarded the loss of moisture from this disk to some extent. It is probable that the effect of the paraffin is similar to that of oil drippings on pavements under traffic.

Measurements on September 13 showed the greatest differential in moisture between top and bottom of the slabs. The data for this date are plotted in Figure 3. It will be noted that the type of subgrade, whether earth or cement-treated with bituminous seal, had very little effect on moisture content. Also seasonal fluctuations, as shown in Figure 2, were not greatly affected by the type of subgrade. It appears that water vapor passing upward through the ground is sufficient in quantity to replace water that may be lost by evaporation from the lower part of a paving slab and that the bituminous seal does not offer sufficient restriction to the passage of vapor to prevent the maintenance of a nearly saturated condition at the bottom. It was noted that the bituminous seal remained apparently intact throughout the test period at location D. It was observed to be broken however at location C when the disks were removed on August 16.

Drops of water were formed on the lower face of the bottom disks as early as August 16 in the slab on an earth subgrade. Since there had been no rainfall for three months and it is reasonably certain that there had been no artificial sprinkling in the vicinity of the slabs, the observed free moisture must have resulted from condensation of ground vapors. It is to be noted that condensed vapor did not appear until a time of year when it is conceivable that the temperature of the slab became lower than that of the subgrade at night. Free water was not found under the disks on the cement-treated subgrade until November 19, two months after it was found on the earth subgrade, a result probably due to a partial vapor barrier set up by the asphalt seal.

An assumption that the inserted concrete disks are an exact replica of a monolithic concrete slab probably is not warranted. Nevertheless there appears to be a high degree of probability that the observed fluctuations in moisture content are reasonable representations of these that would occur in a solid slab. The data add to our knowledge of probable moisture conditions within a concrete pavement.

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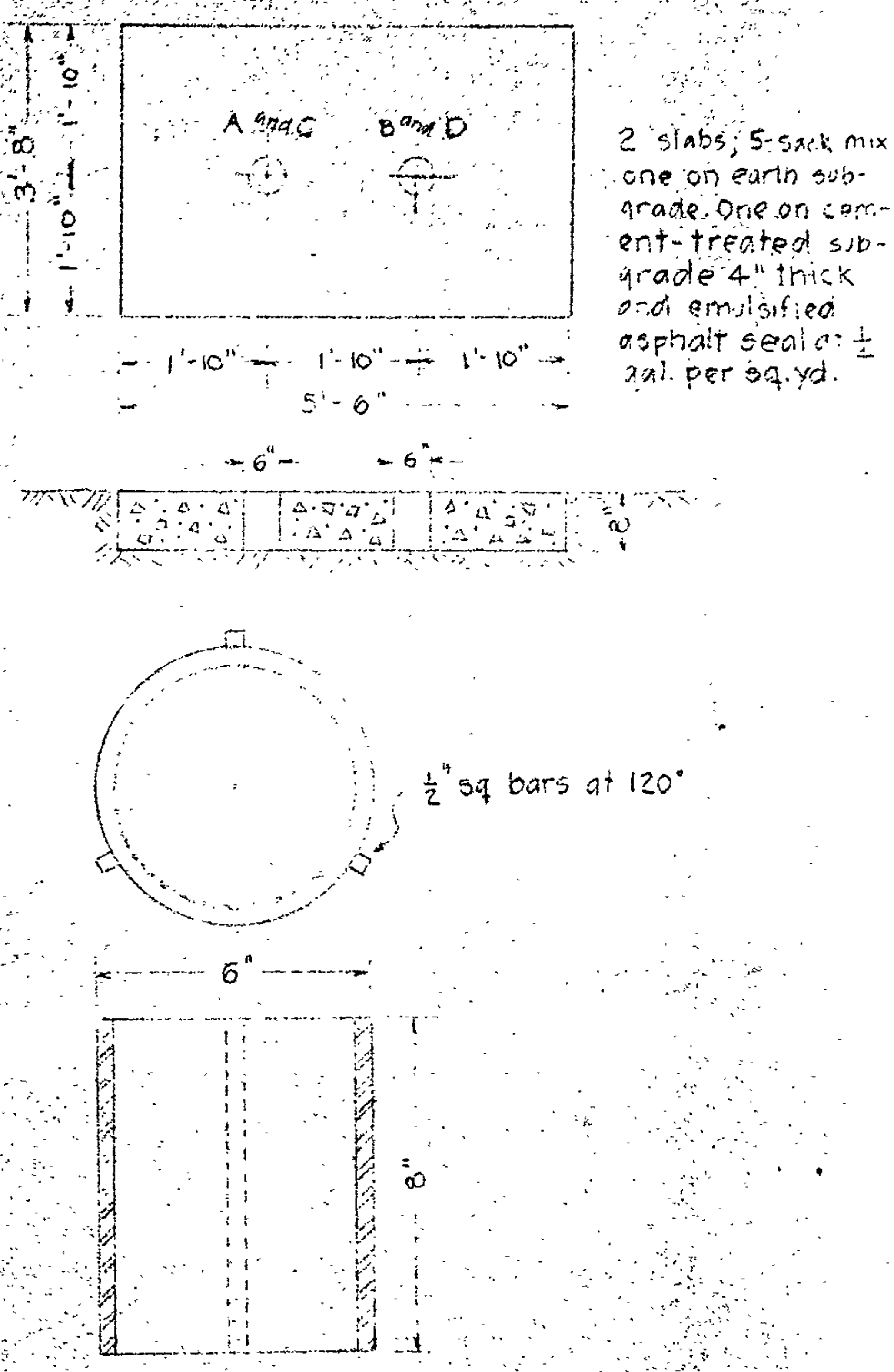

Figure 1.
TEST SLABS
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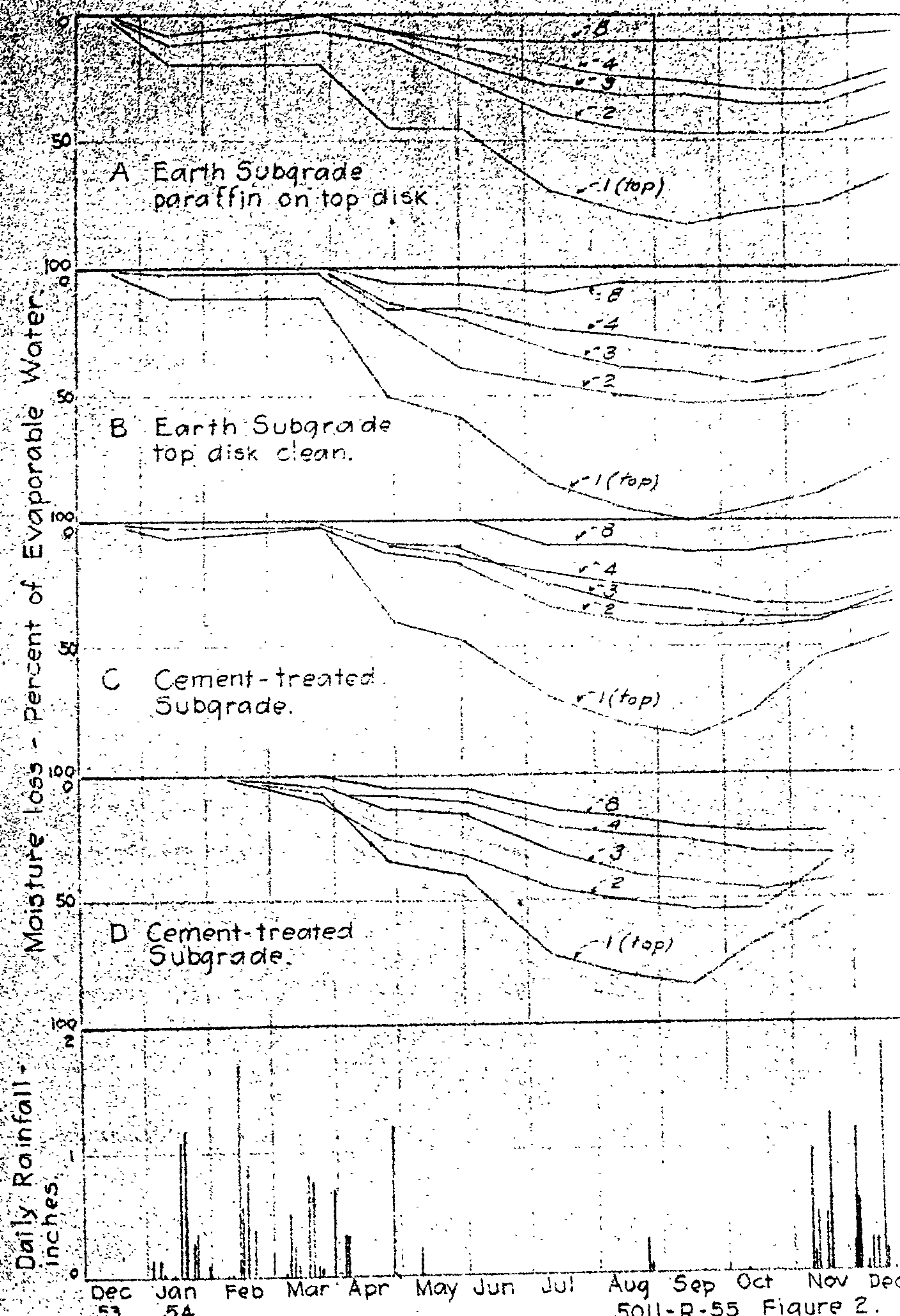

5011-R-55 Figure 2.

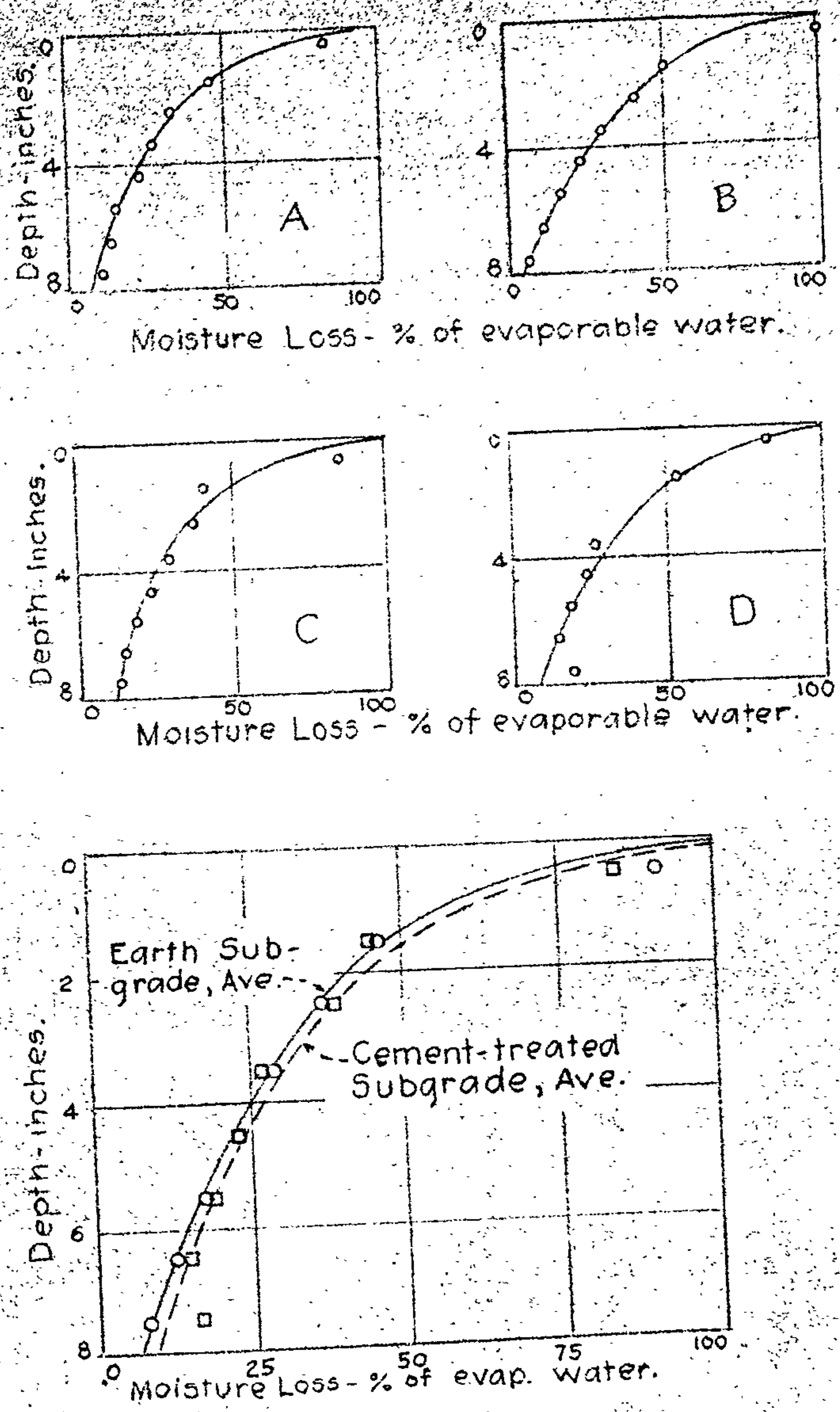

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Figure 3
Distribution of Moisture in Slabs on Sept. 13, 1954.