A RAPID METHOD FOR SOIL CEMENT DESIGN

LOUISIANA SLOPE VALUE METHOD

PART II

EVALUATION

by

C. M. HIGGINS
Soils Research Engineer
and
A. S. KEMAHLIOGLU
Soils Engineer, Design
and
VERDI ADAM
Research and Development Engineer

Research Report No. 20

Research Project No. 61-8S

Conducted by
LOUISIANA DEPARTMENT OF HIGHWAYS
Research Section
in Cooperation with
U. S. Department of Commerce
BUREAU OF PUBLIC ROADS

May 1966

SYNOPSIS

This report is an evaluation of the recently developed "Louisiana Slope Value Method" (Research Report No. 11 Louisiana Department of Highways).

The conclusions drawn are based on data from 637 separate samples representing nearly all major soil groups in Louisiana that are suitable for cement stabilization.

These data show that more than 92 percent of all cement contents recommended were within ±2 percent cement of the cement contents called for by the Wetting-Drying test. It was also demonstrated that in most cases greater repeatability was obtained with the Louisiana Slope Value Method than with the Wetting-Drying test.

Normal testing time for the "Louisiana Slope Value Method" is about eight days which is about one-fourth the time required for the Wetting-Drying test. Testing for the Louisiana Slope Value Method is easy to perform and use of the developed correlation curves and tables is simple and rapid.

INTRODUCTION:

The Louisiana Department of Highways currently uses a test procedure for cement content determination taken from standard AASHO methods and patterned after Portland Cement Association criteria.

This method is widely used and produces satisfactory results; however, it requires testing over a fairly long period of time.

In most cases the Louisiana Department of Highways now requires that the contractor furnish the material for cement stabilization. The use of current long lasting testing procedures sometimes results in construction delays. In July of 1961, research was instigated by the Department of Highways in co-operation with the United States Department of Commerce, Bureau of Public Roads with the object of developing a shorter test procedure.

This report is, in effect, an addendum to the report entitled "A Rapid Method of Soil Cement Design" published in March, 1964 and contains an evaluation of all data obtained to this time. It also contains curves for use with the slope value design method. Some of these curves have been modified since the original report for better agreement with accumulated data.

SCOPE:

This report is an evaluation of data obtained from comparison of cement contents recommended for construction projects by each of two methods. These methods are the normal LDH procedure patterned after Portland Cement Association criteria, and the recently developed Louisiana Slope Value Method (LDH Research Report #11, March, 1964).

Some modification of the original families of curves for strength versus Wetting-Drying loss relationships for the various types of soils have been made in order to increase the reliability of the cement content recommendations.

MATERIALS TESTED:

All soils which were submitted from routine Department of Highways construction projects were tested. Since soil cement projects are fairly common and wide-spread throughout the State, a good representation of soil types suitable for cement stabilization in Louisiana was achieved.

The tests were run on 637 different soil samples. The classifications tested included A-2-4, A-4, and A-6 soils with a PI of 15 or less. Also tested

were A-6 and A-7-6 soils with PI's of 15 or more which had been modified by the addition of lime to have PI's of 15 or less. Approximately 22% of the samples represented A-2-4 and A-3 soils, 15% represented non-plastic A-4 soils, 24% represented plastic A-4 soils and 39% represented A-6 soils and A-6 or A-7-6 soils modified with lime.

The cement used in this investigation was commercially available Type I Portland Cement meeting the requirements of AASHO Designation M 85-60.

TEST PROCEDURES:

As shown in report entitled "A Rapid Method of Soil-Cement Design" published in March, 1964.

METHOD OF PROCEDURE:

An arrangement was made with the soils unit of the Materials and Testing Section, whereby each soil being submitted to the unit to be tested for suitability for stabilization with cement and cement content requirement, would be tested by each of two methods.

In addition to standard Louisiana testing and concurrently, two additional cylinders of the same type used for the wetting-drying test were molded at each of the cement contents for which the wetting-drying test would be performed. These cylinders were cured in a moisture controlled room where the relative humidity was maintained near 100% for a period of seven days.

The cylinders were then removed from the moisture room, measured, capped with a commercial capping compound, immersed in water for four hours, and then tested for unconfined compressive strength. The results obtained for the two cylinders at each cement content were averaged to obtain a compressive strength value at that cement content.

Since the wetting-drying test is normally run at three cement contents, a total of six compressive strength cylinders were usually broken to obtain average strength results.

Utilizing the information obtained from this testing, the Soils Research Unit selected cement contents in accordance with the "Louisiana Slope Value Method" and compared with percentages recommended by the soils unit of the Materials and Testing Section using standard Louisiana procedures.

A copy of the revised test procedure LDH TR 422 entitled "Method of Rapid Design

for the Cement Content of Soil-Cement Mixtures by the Louisiana Slope Value Method" is included in the appendix of this report.

DISCUSSION:

Comparisons of results by the Louisiana Slope Value Method and by standard Louisiana procedures were made in each of four general soil groupings as follows:

1. A-2-4 and A-3 soils
2. A-4 soils with a plasticity index less than 3
3. A-4 soils with a plasticity index greater than 3
4. A-6 soils with a PI less than 15 and A-6 and A-7-6 soils which in the raw state had plasticity indices in excess of 15, but were modified with lime to have plasticity indices less than 15.

For the A-2-4 and A-3 soils group, an additional 98 soil samples have been tested since the initial report for a total of 139 samples. The original report for this group showed 100% of the soils tested by the Slope Value Method to be within ± 2% of the cement contents called for by the normal LDH testing. For the 139 samples now tabulated, this percentage is 92, (See Table I). Seven percent of the observations reflect recommended percentages by the Slope Value Method which are more than 2% lower than those recommended by standard Louisiana procedures and one percent of the samples tested reflect a recommended percentage which is more than 2% higher than that recommended by standard Louisiana procedure.

For A-4 samples having plasticity indices less than 3, 92 percent of the samples checked by the Slope Value Method resulted in recommendations of cement contents within ± 2 percent of the values recommended by normal LDH testing. For the eight percent of the sample not within ± 2 percent, all recommended percentages were on the conservative side of those recommended by standard Louisiana testing methods. These figures compare favorably with originally reported values. A total of 98 observations were made on soils of this type.

For the plastic A-4 soils and the A-6 or modified A-7-6 soils, the percentages within ± 2% cement content of normal LDH recommendations were 98% and 94% respectively with none of the A-4 recommendations and only one percent of the A-6 recommendations being in excess of 2% lower than the cement contents recommended by normal LDH methods. A slight modification of the A-6 and A-7-6 chart was made to improve the accuracy of the results. The modified chart is shown in Figure 4.

It was shown in the previous report on this project, that the standard deviation of the wetting-drying test is greater than that for the Louisiana Slope Value Method for all soil types except the A-4 non-plastic soils.

Considering this fact and the high percentage of samples that are within reasonable limits of the recommendations of the wetting-drying test, it is believed that the Louisiana Slope Value Method shows sufficient accuracy and repeatability to warrant its use.

This accuracy and repeatability coupled with the tremendous time savings as compared to the Wetting-Drying test, make the slope value method a valuable and dependable tool for use in Louisiana. It is believed that this method or some modification thereof can probably be used in other areas. It is recommended, however, that comparison tests, similar to those used in Louisiana, be run by any agency planning to use the method and modifications for local soils made if needed.

CONCLUSIONS:

1. A method of test for the determination of the cement content requirement of soils incorporating changes in compressive strength has been developed.

The degree of correlation with the Wetting-Drying test for each of the general soil categories is as shown below.

A-2-4 and A-3 Soils

Cement content correlation with Wetting-Drying Test	Percent of Samples
No deviation	26
within ± 1 percent cement	61
within -1 and +2 percent cement	78
within ±2 percent cement	92

A-4 Soils
(plasticity index less than 3)

Cement content correlation with *Wetting-Drying Test*	Percent of Samples
No deviation	35
within ±1 percent cement	71
within -1 and +2 percent cement	81
within ±2 percent cement	92

A-4 Soils
(plasticity index greater than 3)

Cement content correlation with Wetting-Drying Test	Percent of Samples
No deviation	32
within ±1 percent cement	63
within -1 and +2 percent	97
within ±2 percent cement	98

A-6 and Modified A-7-6 Soils

Cement content correlation with Wetting-Drying Test	Percent of Samples
No deviation	29
within ±1 percent cement	75
within -1 and +2 percent cement	86
within ±2 percent cement	94

2. The use of the slope value method results in a decrease in testing time from a minimum of 32 days to approximately 8 days.

3. The slope value testing is easy to perform and the reproducibility is satisfactory. Use of the developed correlation curves is simple, rapid, and accurate.

4. Adoption of the slope value method in lieu of the Wetting-Drying test is being considered by the Louisiana Department of Highways.

TABLE I

ACCURACY OF CEMENT REQUIREMENT DETERMINATIONS THROUGH USE OF CORRELATION CHARTS AS COMPARED WITH THOSE OBTAINED FROM WETTING-DRYING TEST LOSSES

A-2-4 AND A-3 SOILS

Number of Observations

139

Cement content correlation with Wetting-Drying Test	Percent of Samples
No deviation	26
within ± 1 percent cement	61
within - 1 and + 2 percent cement	78
within ± 2 percent cement	92

Percent Correlation with Wetting-Drying Test

	-2	-1	0	+1	+2	
7	14	14	26	21	17	1

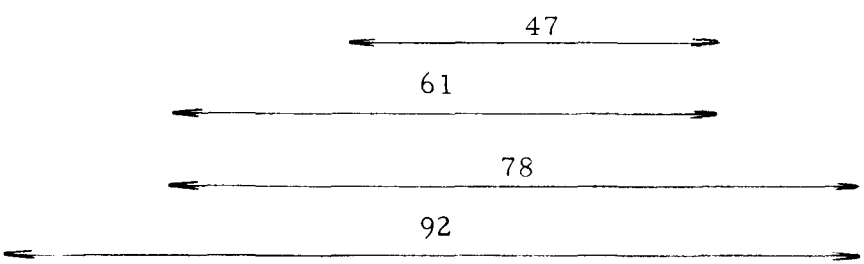


TABLE I (Cont.)

ACCURACY OF CEMENT REQUIREMENT DETERMINATIONS THROUGH USE OF CORRELATION CHARTS AS COMPARED WITH THOSE OBTAINED FROM WETTING-DRYING TEST LOSSES

NON-PLASTIC A-4 SOILS
(plasticity index less than 3)

Number of Observations

98

Cement content correlation with Wetting-Drying Test	Percent of Samples
No deviation	35
within ± 1 percent cement	71
within - 1 and + 2 percent cement	81
within ± 2 percent cement	92

Percent Correlation with Wetting-Drying Test

	-2	-1	0	+1	+2	
0	11	13	35	23	10	8

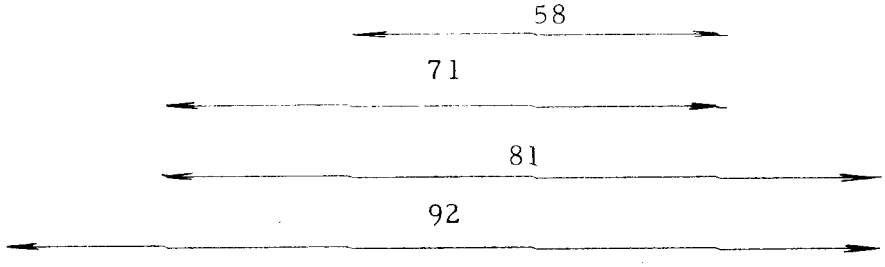


TABLE I (Cont.)

ACCURACY OF CEMENT REQUIREMENT DETERMINATIONS THROUGH USE OF CORRELATION CHARTS AS COMPARED WITH THOSE OBTAINED FROM WETTING-DRYING TEST LOSSES

PLASTIC A-4 SOILS
(plastic index greater than 3)

Number of Observations

155

Cement content correlation with Wetting-Drying Test	Percent of Samples
No deviation	32
within ± 1 percent cement	63
within - 1 and +2 percent cement	97
within ± 2 percent cement	98

Percent Correlation with Wetting-Drying Test

	-2	-1	0	+1	+2	
0	1	15	32	26	34	2

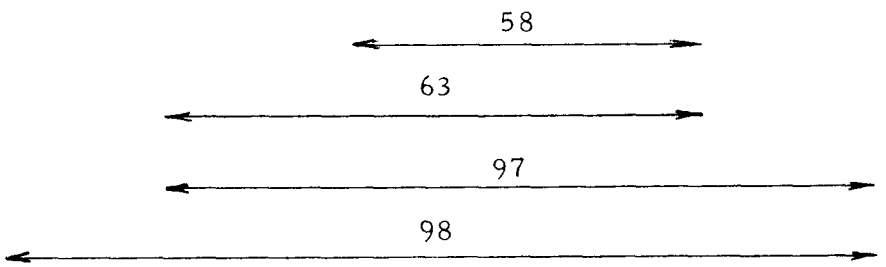


TABLE I (Cont.)

ACCURACY OF CEMENT REQUIREMENT DETERMINATIONS THROUGH USE OF CORRELATION CHARTS AS COMPARED WITH THOSE OBTAINED FROM WETTING-DRYING TEST LOSSES

A-6 AND MODIFIED A-7-6 SOILS

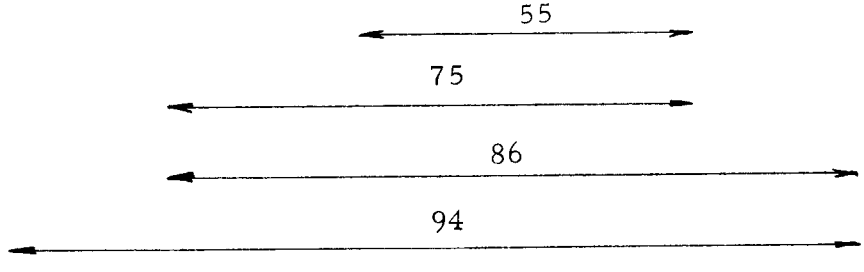
Number of Observations

245

Cement content correlation with Wetting-Drying Test	Percent of Samples
No deviation	29
within ± 1 percent cement	75
within - 1 and + 2 percent cement	86
within ± 2 percent cement	94

Percent Correlation with Wetting-Drying Test

	-2	-1	0	+1	+2	
1	8	20	29	26	11	5



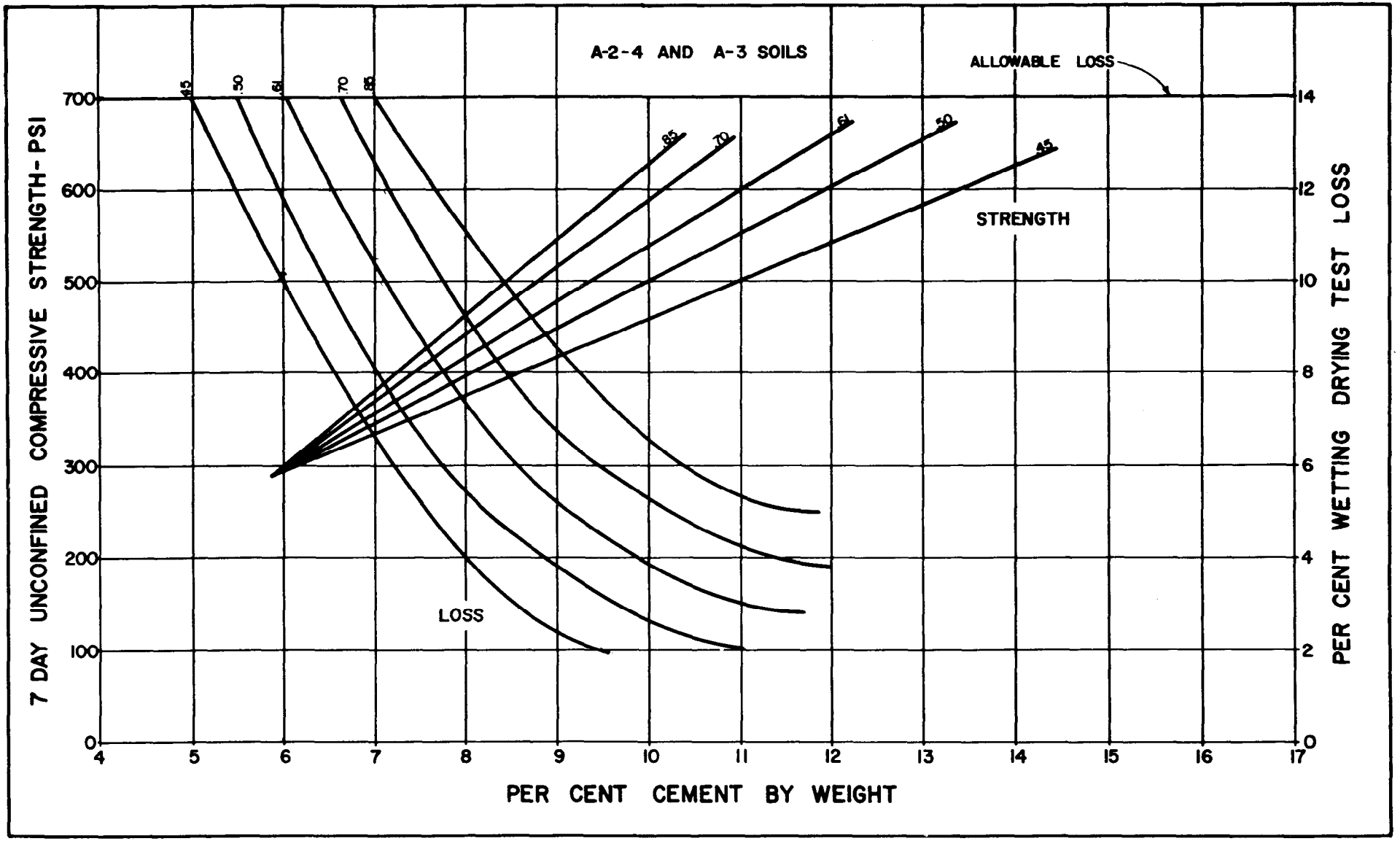


FIGURE 1 *Family of Curves for Strength Versus Wetting-Drying Loss Relationship of A-2-4 and A-3 Soils Incorporating Slope Values to Determine Minimum Cement Requirement.*

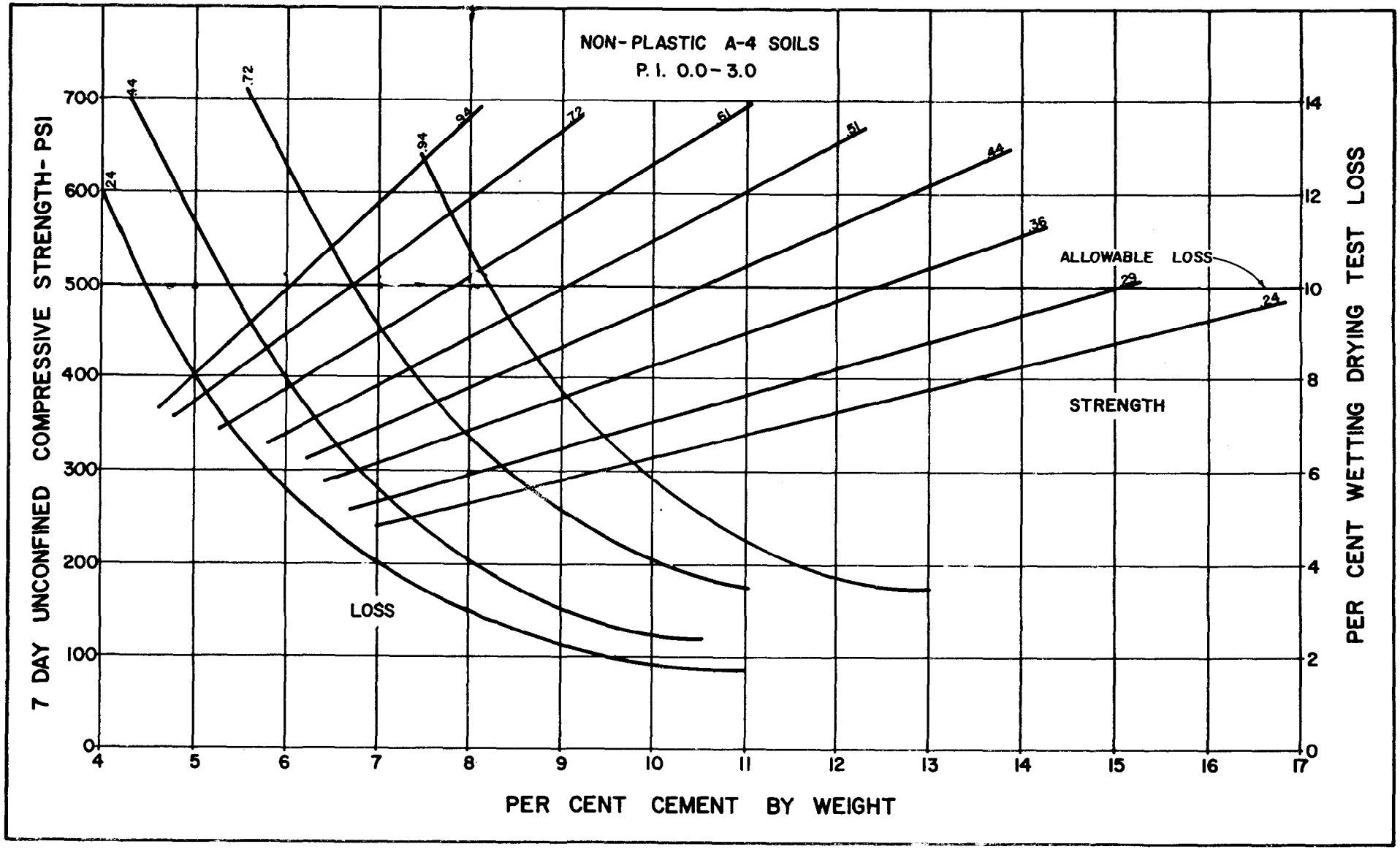


FIGURE 2 *Family of Curves for Strength Versus Wetting-Drying Loss Relationships of Non-Plastic A-4 Soils Incorporating Slope Values to Determine Minimum Cement Requirements.*

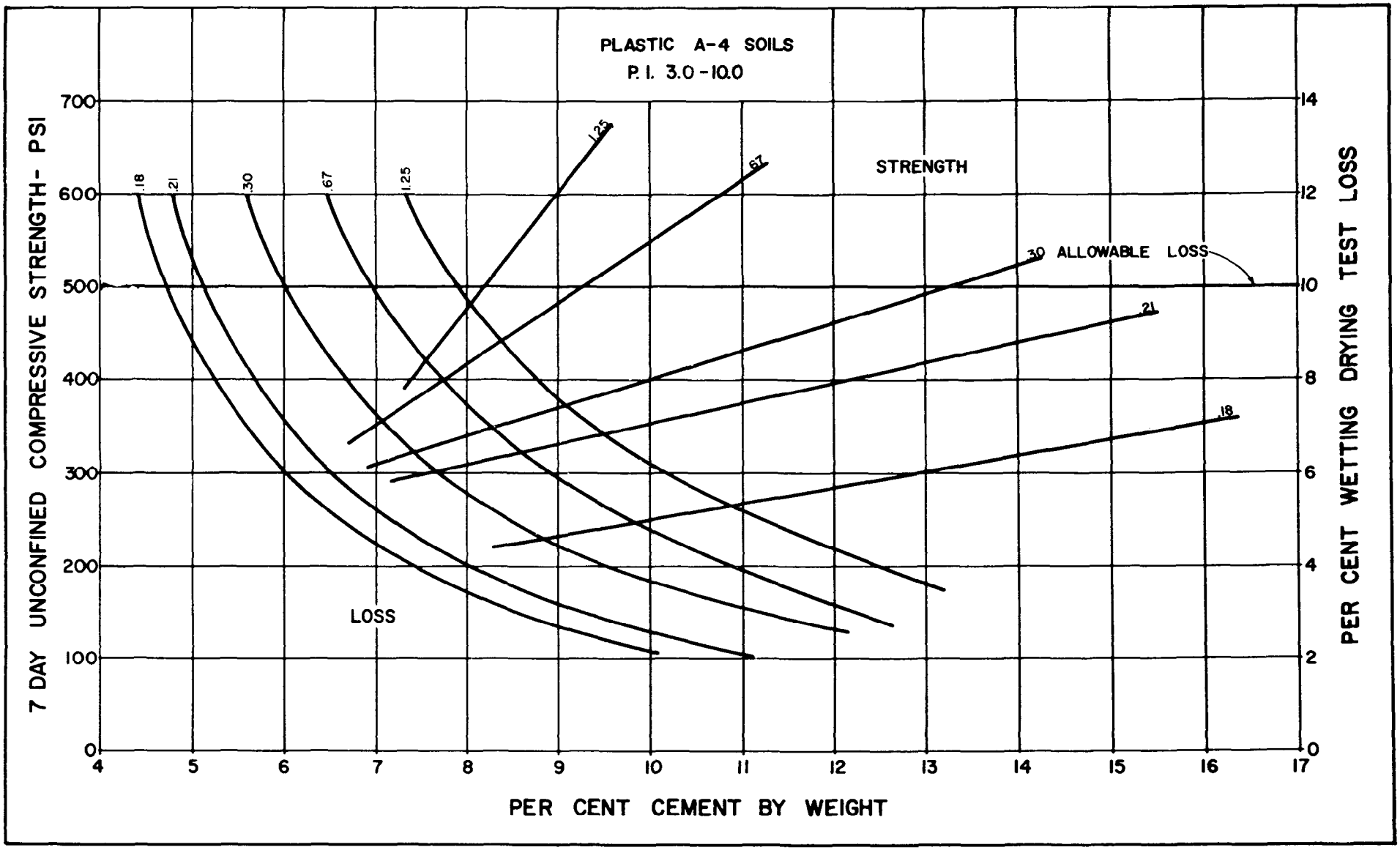


FIGURE 3 *Family of Curves for Strength Versus Wetting-Drying Loss Relationships of Plastic A-4 Soils Incorporating Slope Values to Determine Minimum Cement Requirements.*

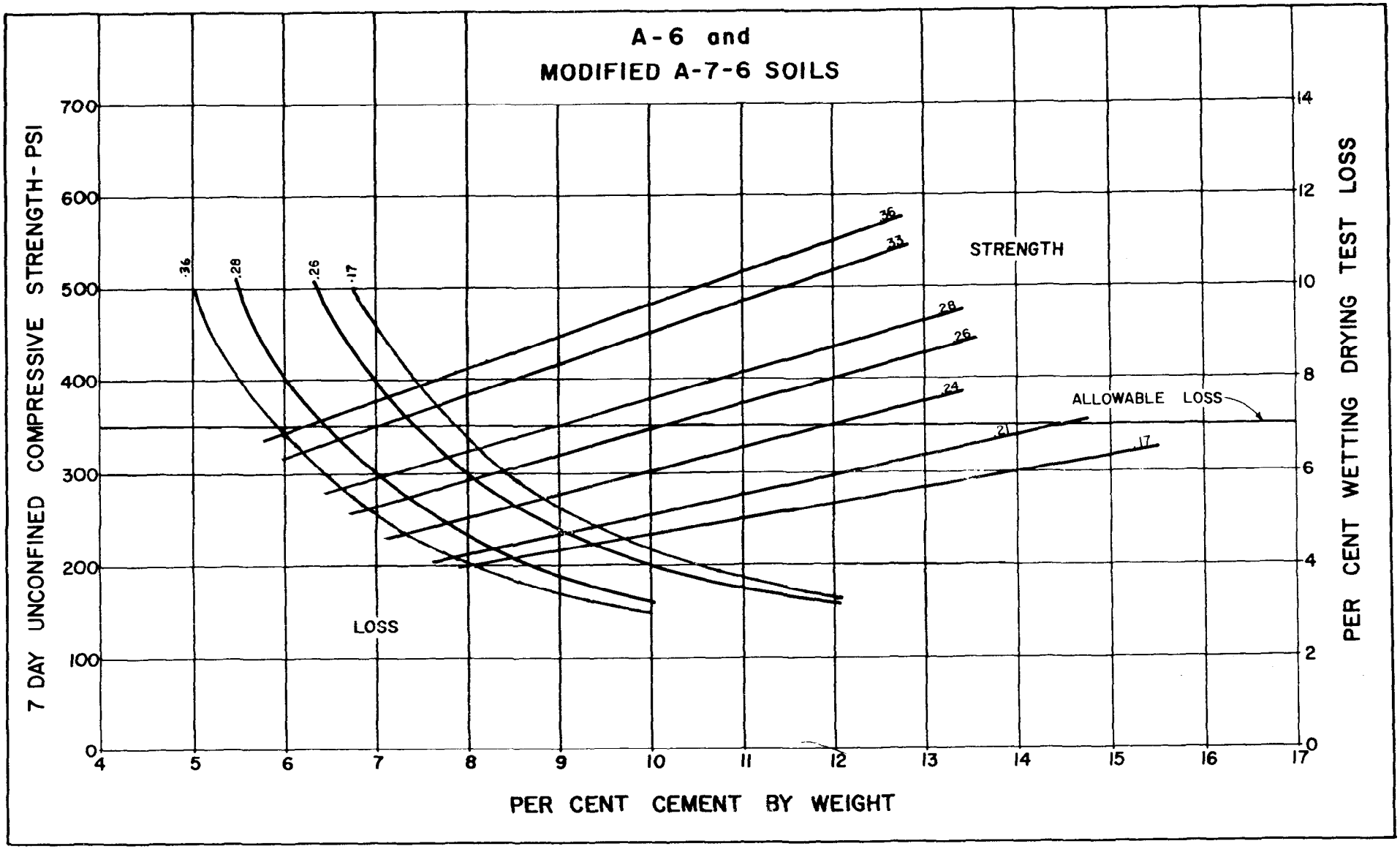


FIGURE 4 *Family of Curves for Strength Versus Wetting-Drying Loss Relationships of A-6 and Modified A-7-6 Soils Incorporating Slope Values to Determine Minimum Cement Requirements.*

APPENDIX

Method of Rapid Design for THE CEMENT CONTENT OF SOIL-CEMENT MIXTURES by THE LOUISIANA SLOPE VALUE METHOD LDH TR 422-66

SCOPE

1. This method is intended for determining the minimum cement requirement for design use in the construction of soil-cement base and subbase courses.

TEST METHODS

2. (a) Soil samples shall be prepared in accordance with AASHO Designation: T 87-49 (LDH Designation: 411-58) Standard Method of Dry Preparation of Disturbed Soil Samples for Test.

(b) Soils shall be classified in accordance with AASHO Designation: M 145-49- The Classification of Soils and Soil Aggregate Mixtures for Highway Construction Purposes.

(c) The moisture-density relations of the soil-cement mixture shall be determined by adhering to AASHO Designation: T 134-57 - Standard Methods of Test for Moisture-Density Relations of Soil-Cement Mixtures.

(d) Specimens for unconfined compressive strength determinations shall be molded in accordance with Paragraph 4, ASTM Designation: D 559-57 - Wetting and Drying Tests of Compacted Soil-Cement Mixtures.

(e) The compressive strength specimen shall be tested in accordance with ASTM Designation: D 1633-59T with the following exceptions:

(1) Test specimens shall have a diameter of 4.0 inches and a height of 4.6 inches.

(2) Specimens shall be moist room cured at approximately 100 % relative humidity for a period of seven days.

(3) Immediately upon removal from the moist room, the specimens shall be measured for height and diameter, capped with a commercial capping compound (Trade Name: Vitrobond or gypsum plaster), and immersed in clean water for a period

of four hours prior to testing.

PROCEDURE

After the soil is classified, a range of cement contents is selected according to the following: A-2-4, A-3 and A-4 should be molded at cement contents ranging from 5% to 9% by weight, and the range for A-6 soils should be from 6% to 10% by weight.

A minimum of two (preferably three) cylinders are molded at each of the three cement contents selected, tagged and cured in the moist room for the required 7 days, after which the samples are measured, capped and immersed in water for 4 hours prior to testing for unconfined compressive strength. Upon completion of the compressive strength, the appropriate "slope values" are determined by the following formula:

$$\text{Slope Value} = \frac{B - A}{Y - X} \times \frac{1}{100} \text{ or } \frac{C - B}{Z - Y} \times \frac{1}{100}$$

Where:

A = Unconfined compressive strength at the lowest cement content.

B = Unconfined compressive strength at the median cement content.

C = Unconfined compressive strength at the highest cement content.

X = Lowest cement content by weight.

Y = Median cement content by weight.

Z = Highest cement content by weight.

"Maximum Slope Value" represents the highest value obtained from the above expression and is used for A-2-4, A-3, and all A-4 soils with plasticity indices of ten or less. "Minimum Slope Value" would be the lowest value derived from the above formula and is used for the A-6 and A-7-6 groups of soils. For example:

Point	Cement Content % by Weight	Failure Stress PSI
A	5.08	342
B	6.89	455
C	8.77	603

$$\text{Maximum Slope Value} = \frac{603 - 455}{8.77 - 6.89} \times \frac{1}{100} = 0.79$$

$$\text{Minimum Slope Value} = \frac{455 - 342}{6.89 - 5.08} \times \frac{1}{100} = 0.62$$

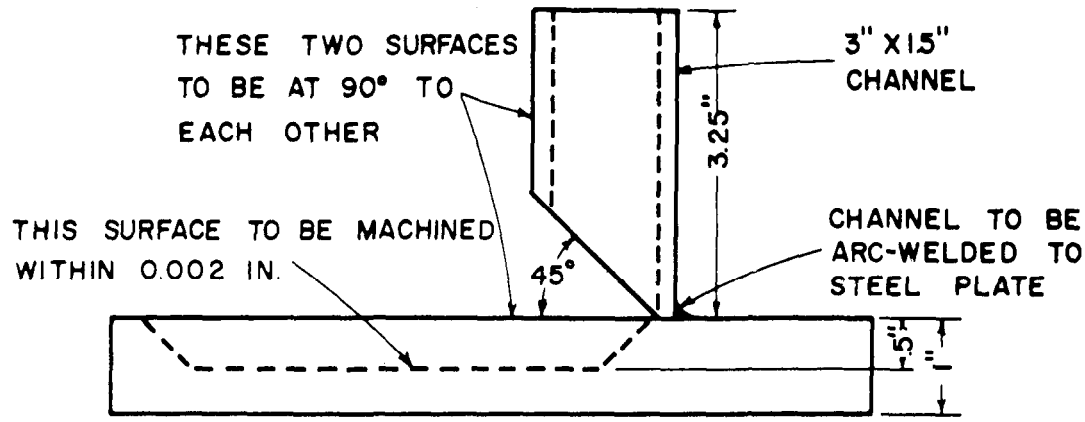
The appropriate slope value is then located on the proper chart or on the following table for the minimum cement content requirement.

MINIMUM CEMENT REQUIREMENT

USING THE LOUISIANA SLOPE VALUE METHOD

Soil Classification	Slope Value Type	Slope Value	Min. Cement Requirement by Weight, %
A-2-4, A-3	Maximum	0.46 - 0.60	6
		0.61 - 0.85	7
Non-plastic A-4 (P.I. 0.0 - 3.0)	Maximum		
		0.24 - 0.36	5
		0.37 - 0.56	6
		0.57 - 0.75	7
		0.76 - 0.90	8
		0.91 - 0.94	9
Plastic A-4 (P.I. 3.0 - 10.0)	Maximum	0.18 - 0.20	5
		0.21 - 0.30	6
		0.31 - 0.67	7
		0.68 - 1.25	8
A-6 and A-7-6	Minimum	0.17 - 0.27	8
		0.28 - 0.34	7
		0.35 - 0.36	6

Note: Slope values which vary greatly from the limiting values should be verified by the complete Wetting-Drying Test (AASHO Designation: T 135-57).



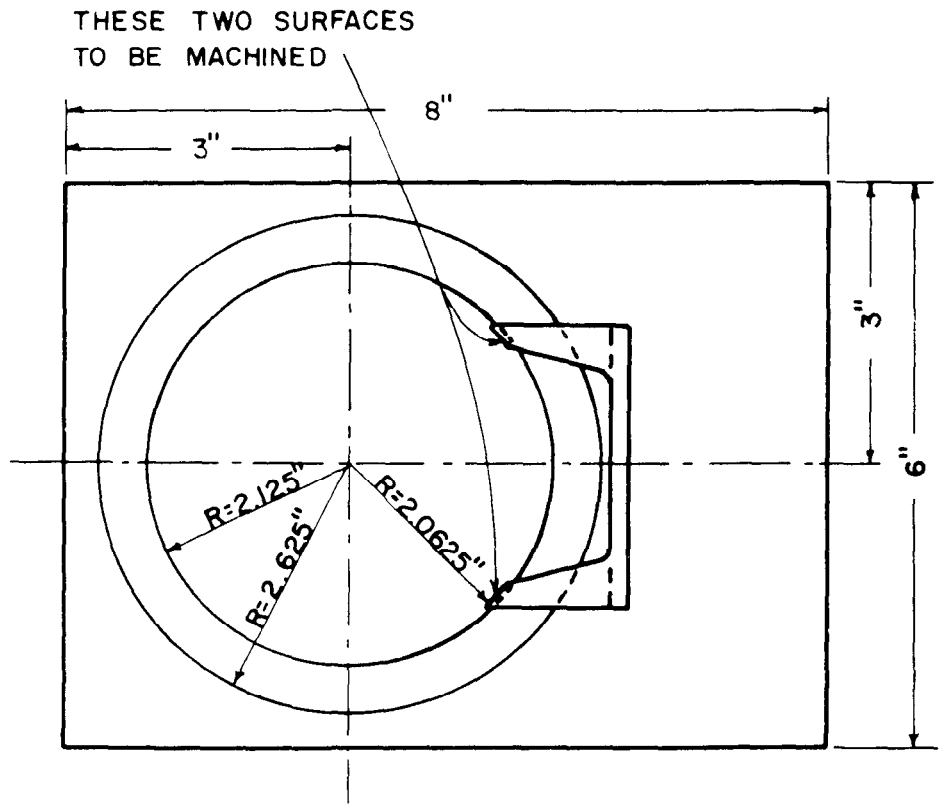


FIGURE 1

Cylinder Capping Mold

RESEARCH PUBLICATIONS

1. Concrete Pavement Research. H. L. Lehmann and C. M. Watson, Part I (1956), Part II (1958).
2. Use of Self-Propelled Pneumatic-Tired Rollers in Bituminous Construction and Recommended Procedures. A Special Report, 1958.
3. Use of Expanded Clay Aggregate in Bituminous Construction. H. L. Lehmann and Verdi Adam, 1959.
4. Application of Marshall Method in Hot Mix Design. Verdi Adam, 1959.
5. Effect of Viscosity in Bituminous Construction. Verdi Adam, 1961.
6. Slab Breaking and Seating on Wet Subgrades with Pneumatic Roller. J. W. Lyon, Jr., January 1963.
7. Lightweight Aggregate Abrasion Study. Hollis B. Rushing, Research Project No. 61-7C, February 1963.
8. Texas Triaxial R-Value Correlation. Harry L. Roland, Jr., Research Project No. 61-1S, March 1963.
9. Asphaltic Concrete Pavement Survey. S. C. Shah, Research Project No. 61-1B, April 1963.
10. Compaction of Asphaltic Concrete Pavement with High Intensity Pneumatic Roller. Part I. Verdi Adam, S. C. Shah and P. J. Arena, Jr., Research Project No. 61-7B July 1963.
11. A Rapid Method of Soil Cement Design. Harry L. Roland, Jr., Ali S. Kemahlioglu, Research Project No. 61-8S, March 1964.
12. Correlation of the Manual Compaction Hammer with Mechanical Hammers for the Marshall Method of Design for Asphaltic Concrete. P. J. Arena, Jr., Research Project No. 63-1B, September 1964.
13. Nuclear Method for Determining Soil Moisture and Density. Harry L. Roland, Jr., Research Project No. 62-1S, November 1964.
14. Service Temperature Study for Asphaltic Concrete. P. J. Arena, Jr., Research Project No. 61-3B, October 1964.
15. Quality Control Analysis, Part I - Asphaltic Concrete. S. C. Shah, Research Project No. 63-1G, November 1964.
16. Typical Moisture - Density Curves. C. M. Higgins, Research Project No. 61-11S May 1965.
17. High - Pressure Lime Injection. C. M. Higgins, Research Project No. 63-7S, August 1965.
18. Durability of Lightweight Concrete - Phase III. Hollis B. Rushing, Research Project No. 61-8C, August 1965.
19. Compaction of Asphaltic Concrete Pavement with High Intensity Pneumatic Roller, Part II - Densification Due to Traffic. S. C. Shah, Research Project No. 61-7B, October 1965.
20. A Rapid Method of Soil Cement Design, Part II - Evaluation. C. M. Higgins, A. S. Kemahlioglu, and Verdi Adam, Research Project No. 61-8S, May 1966.