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16. ABSTRACT
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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

October 1978

TL No. 643213

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have approved and now submit for your information this final research project report titled:

ACCELERATED CURING PROCEDURE FOR
CEMENT TREATED BASE SAMPLES

Study made by . . . . Roadbed & Concrete

Under the Supervision of . . . . Donald L. Spellman

Principal Investigator . . . . Robert N. Doty

Co-Investigator . . . . Max L. Alexander

Report Prepared by . . . . Max L. Alexander

Very truly yours,

NEAL ANDERSEN
Chief, Office of Transportation Laboratory

Attachment
MLA:cj

[illegible]

ACKNOWLEDGEMENT

This report contains the findings of the state financed research project titled "Accelerated Curing Procedure for Cement Treated Base Samples", E/A No. 643213. The author wishes to acknowledge the efforts of Tom E. Neilson who carried out the laboratory testing for this study. In addition, appreciation is extended to Carol Johnson and Eileen Howe who provided typing and editorial assistance during the preparation of this report.

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INTRODUCTION

The California Department of Transportation's Standard Specifications have never required a job strength determination for cement treated bases as the criteria for acceptance because of the relatively long (7 day) curing period necessary before performing unconfined compression tests. Controversies over the reliability of some of the other acceptance tests, however, have made it extremely desirable to be able to quickly determine this very important engineering property. The purpose of this study was to develop an accelerated curing procedure which could be used in a field laboratory to provide an evaluation of potential strength within a few hours after test specimen fabrication using the base material being produced.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are drawn from data gathered during this study:

1. Curing cement treated base materials can be accelerated sufficiently by heating the compacted test specimens to allow testing for unconfined compressive strength within a few hours after mixing.

2. Curing by immersion in boiling water is the most suitable method evaluated in this study. This method of curing results in unconfined compressive strengths equal to approximately 50 percent of the 7 day strengths (cured under ambient conditions) after immersion in hot water for only 30 minutes, and a total elapsed testing time of less than 3 hours after fabrication.

Based on these conclusions, it is recommended that the boiling water accelerated curing procedure and unconfined compressive strength tests both be used, on a trial basis, to evaluate and control the placement of cement treated base on at least two construction projects. These tests could be carried out by TransLab personnel and compared with routine CTB control tests performed by district personnel. Routine maximum density test specimens could also be cured at normal temperatures and tested for unconfined compressive strength after 7 days for comparison with the accelerated cure specimens. A tentative procedure for curing the test specimens in boiling water and a suggested specification for accepting the CTB on the basis of the unconfined compressive strength are attached.

IMPLEMENTATION

A tentative procedure has been prepared for determining the unconfined compressive strength of representative test specimens on the same day that cement treated base material is placed on the roadway. This method should be used on a trial basis on on-going projects to evaluate its validity prior to adoption of a specification requiring its use as a routine quality control procedure. A tentative specification for applying an unconfined compressive strength requirement has also been prepared. The application of this specification can also be studied on the trial projects.

BACKGROUND

Although compressive strength is one of the most important engineering properties of cement treated base, it is not actually measured when evaluating the in-place material for acceptance during construction. Unconfined compressive strength tests are used in the laboratory to determine the proportions of aggregate, cement and water necessary to provide a mixture which will produce the desired strengths. The strength test, however, is not suited to quality control in the field because of the normally required 7-day curing period. Current specifications are predicated on the assumption that the desired strengths are being achieved when the placed material meets all of the requirements for the aggregate, cement type and content, moisture content, and relative compaction.

The quality of the untreated aggregate, as well as the moisture content and relative compaction of the in-place mixture, is relatively easy to determine, and the test results are generally reliable and accepted. There has been considerable dispute, however, over the reliability of the titration test used for determining cement content. Several claims have been filed against the State in the last few years because of differences in the cement content determined by the titration test and the amount of cement the Contractor claims to have used.

Because of these problems associated with the titration test, this study was initiated to develop a curing procedure which would allow unconfined compressive strength determinations within a few hours after mixing and compacting. If the test is judged feasible it may then be appropriate to apply an end result requirement, such as unconfined compressive strength, to cement treated bases. Because of the large influence of density on compressive stength, it is essential that compaction achieved in the field be similar to that of the test specimens.

TESTING AND EVALUATION

Aggregates from three different sources were tested for optimum moisture content, recommended cement content, and unconfined compressive strength according to Test Method No. Calif. 312-E. Strengths were determined with cement contents of 3, 4, 5 and 6 percent. The results of these test were used as standards for comparison of strengths when alternate methods of curing were applied.

It was initially thought that the accelerated curing methods described in ASTM C684 could be applied. These procedures were ruled out, however, since both the warm water method and the boiling water method require more than 24 hours to complete the test. Several other combinations of curing methods, curing temperatures and curing times were tried. These various methods and the resulting unconfined compressive strengths are recorded in Table 1 and discussed briefly below.

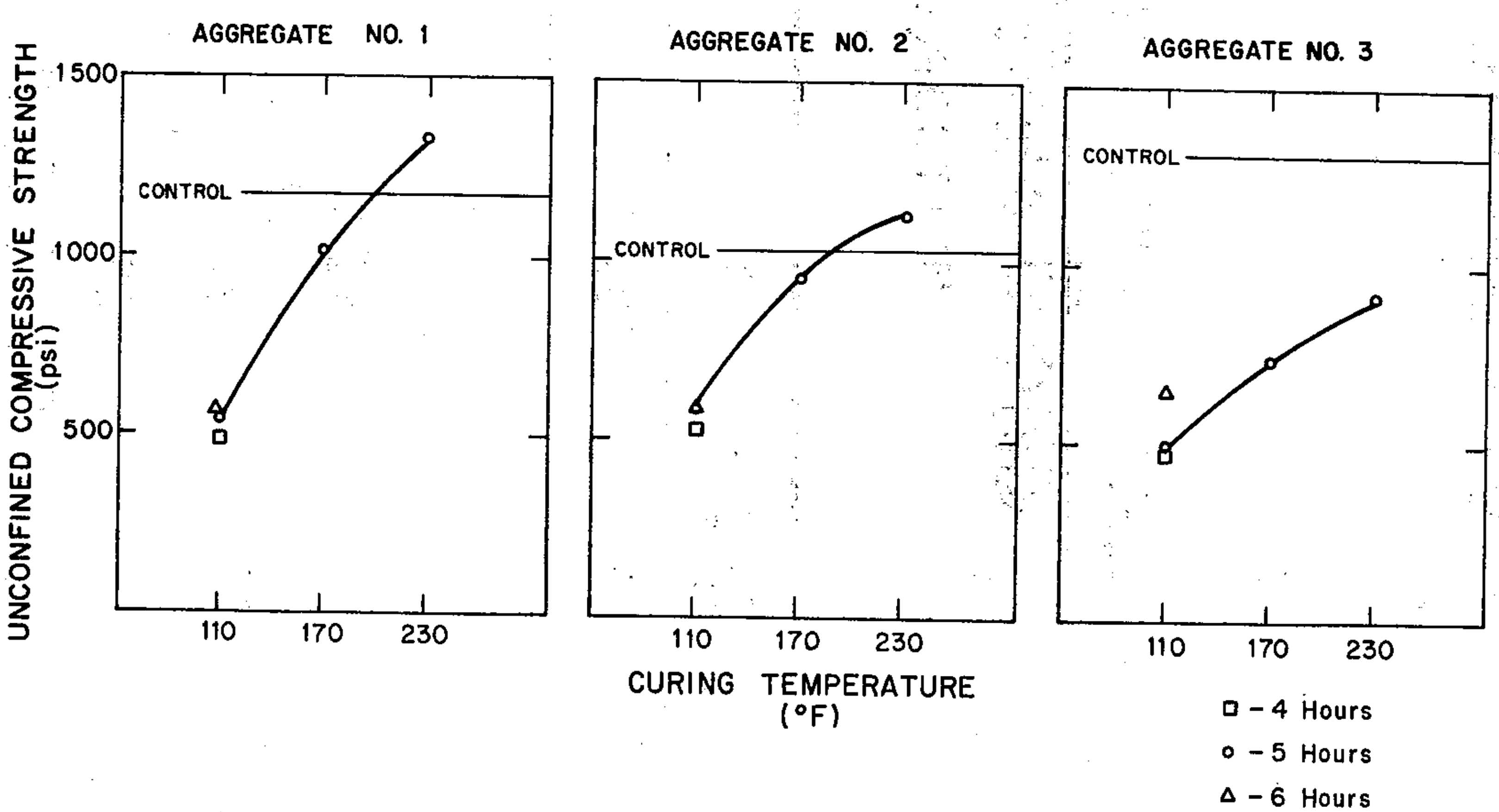
The first several series of test specimens were cured in a circulating air oven at temperatures of 110, 170 and 230°F to accelerate the curing. Curing times of 4, 5 and 6 hours were used with the 110°F temperature but because of restrictions of time and expenditures only the 5 hour cure was used with the 170°F and 230°F temperatures.

The unconfined compressive strengths of the test specimens treated with 5 percent cement and cured at the different temperatures are plotted in Figure 1. The strengths developed after different lengths of curing time at 110°F are also plotted along with the strengths of the control specimens containing 5 percent cement.

TABLE 1

Unconfined Compressive Strengths of CTB when Cured by Various Methods

%	72°F	Oven						Low Pressure Steam (5 psi)		Boiling Water		
		110°F				170°F	230°F					
Cem	7 days	4 hrs	5 hrs	6 hrs	18 hrs	5 hrs	5 hrs	30 min	90 min	30 min	60 min	90 min
Aggregate #1												
6	1171						1260			517		
✓	1181						1134			521		
5	1234	463	507	582		1028	1313	561	878	642	678	708
✓	1115	514	589	526		989	1354	490	979	589	665	753
4	833						1088			453		
✓	729						931			498		
3	732						676			480		
✓	655						788			433		
Aggregate #2												
6	1053									519		
✓	1000									528		
5	1034	513	601	581		990	1222			539		
✓	1035	546	590	622		928	1066			543		
4	815									482		
✓	885									498		
3	681									446		
✓	710									422		
Aggregate #3												
6	1535									620		
✓	1375									495		
5	1263	480	533	652	780	641	900			602		
✓	1354	487	458	654	918	832	929			574		
4	988									481		
✓	1023									478		
3	832									402		
✓	757									406		



STRENGTHS OF OVEN CURED SPECIMENS

FIGURE 1

All of the data indicates that oven curing, even at relatively low temperatures, accelerates the cement reaction sufficiently to allow compressive strength tests to be made within a few hours after compaction. The 230°F curing apparently offers the most potential because of the significantly greater strengths that were achieved as compared with those at the lower temperatures.

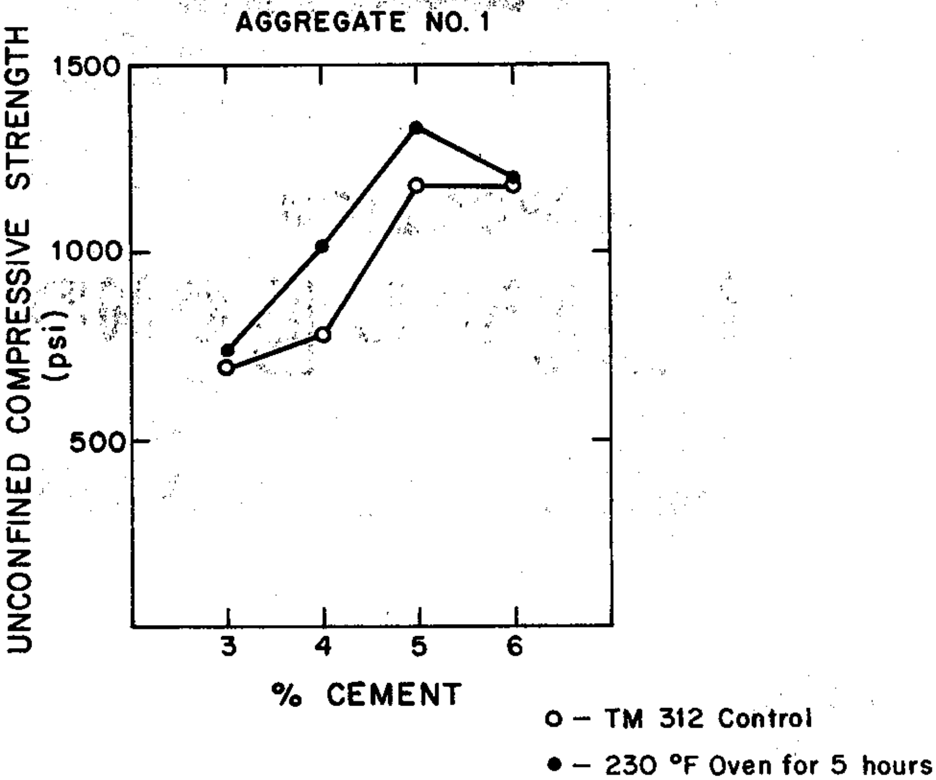
The relationship between the strengths of the accelerated tests and the Test Method 312 control tests are not constant for all of the aggregates. After 5 hours at 110°F, specimens containing aggregate No. 1 had gained 47 percent of the strength achieved after 7 days at room temperature. Using the same curing procedure, the specimens containing aggregate No. 2 had gained 57 percent of the control sample strength while those containing aggregate No. 3 had gained only 38 percent. After 5 hours at 230°F, specimens containing aggregate No. 1 had gained 113 percent of the control sample strength while specimens containing aggregate Nos. 2 and 3 gained 110 and 70 percent, respectively.

Variations in curing time (4, 5, and 6 hrs.) were applied only to test specimens cured at 110°F. The effect of increasing the curing time from 4 to 6 hours was relatively small at this temperature as compared to the effects of temperature variations. The difference in strength between samples cured for four and six hours at 110°F was less than 100 psi for two materials and less than 200 psi for the third material.

Samples containing aggregate No. 1 were also tested with cement contents of 3, 4, 5 and 6 percent and 5 hr. 230°F curing. The results of this series of tests are plotted with those for the control series in Figure 2. These tests indicate a fair correlation in unconfined compressive strengths by the two methods. The consistently higher strengths by the oven curing procedure for more common 4 and 5 percent cement indicate that the curing time could be reduced slightly for this material.

The data indicated that the oven curing method has the potential to provide rapid results which would make the unconfined compressive strength test suitable for use as a field control procedure. It was hoped, however, that the time required to determine a test value could be reduced even more.

The next approach was a low pressure steam-cure procedure. The test specimens were placed in a 21 quart canning type pressure cooker (See Figure 3) and subjected to an arbitrary pressure of 5 psi for 30 and 90 minutes. A rack was used to hold the test specimens above the boiling water and eliminate the possibility of erosion of the exposed ends by the turbulent water. The strengths developed by the mix containing aggregate No. 1 were encouraging. With only 30 minutes of steam curing, 45 percent of the control sample strength was achieved. After 90 minutes of steam curing, nearly 80 percent of the control sample strength was achieved.



COMPARISON OF STRENGTHS

230 °F OVEN CURE METHOD VS TM 312 CONTROL SERIES

FIGURE 2

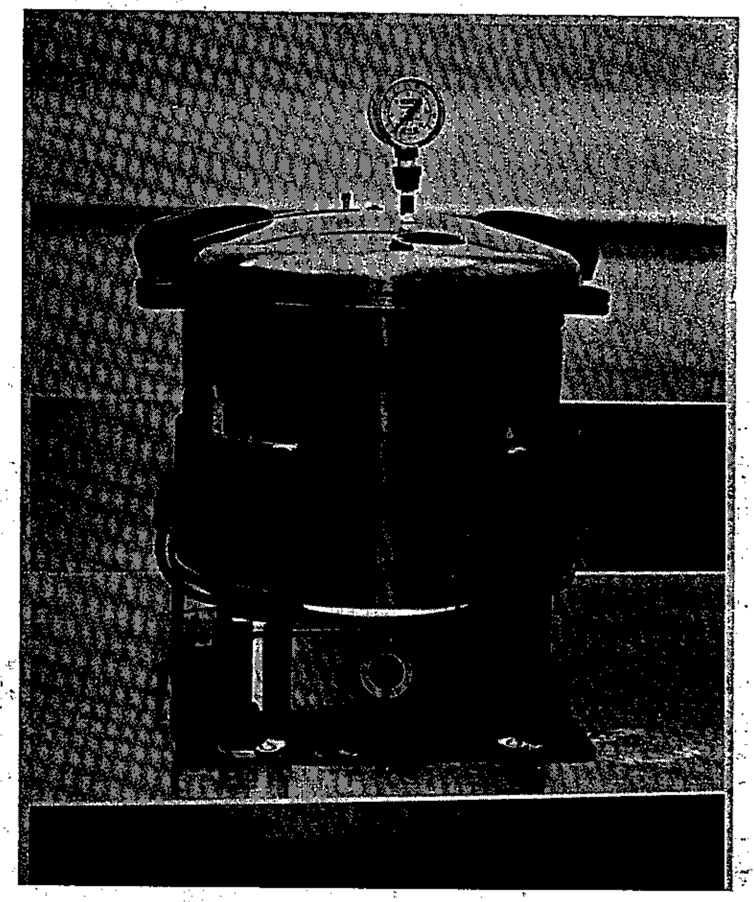


Figure 3

Although the results of the first series of tests were promising, further study of this method was set aside because of potential difficulties which were encountered. The pressure cooker has the capacity to hold several test specimens at one time which would probably be necessary to perform an adequate number of tests. It would be difficult, however, to subject all of the test specimens in a group to exactly the same curing exposure in that to repeat the curing exposure of each test specimen, each step of the procedure must be identical for each specimen. This would require that exposure to the steam follow at some prescribed time after compaction is completed. This would make it necessary to release the pressure and introduce each sample to the pressure cooker individually as the scheduling required. It would also be necessary to remove the samples at different times to maintain a constant time in the steam. This disruption of the pressure would no doubt have an effect on the curing. Another possibility would be to introduce all of the test specimens of a group to the steam curing at the same time but with variable pre-steam periods. This, however, would result in varying delay time between compaction and exposure to the steam which is known to significantly affect concrete cured in this way. Another possibility would be the use of numerous small pressure cookers.

To eliminate the problem of scheduling the curing of a series of test specimens, it was decided to simply immerse the specimens in boiling water. This would allow adding and removing specimens in the curing process without significantly affecting other specimens. This method of curing would also reduce some of the potential danger associated with the use of pressurized containers and steam.

For the boiling water series of tests, the specimens were left in the tin liners and the ends were capped and taped to prevent direct contact of the test specimen with the water (See Figure 4). Specimens containing aggregate No. 1 were tested after immersion in the boiling water for times of 30, 60, and 90 minutes. The other samples were tested after immersion for only 30 minutes because of the desire to develop the quickest procedure possible. Each of the three aggregates was tested with cement contents of 3, 4, 5 and 6 percent so that the strengths could be compared within the entire range of values established for the control series. The results of these tests are plotted in Figure 5.

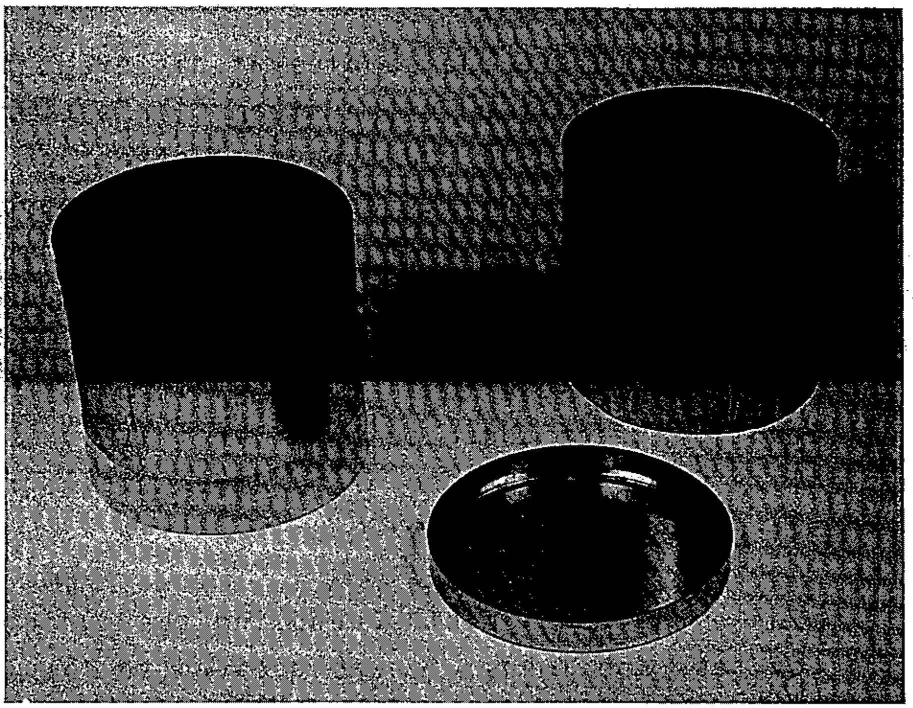
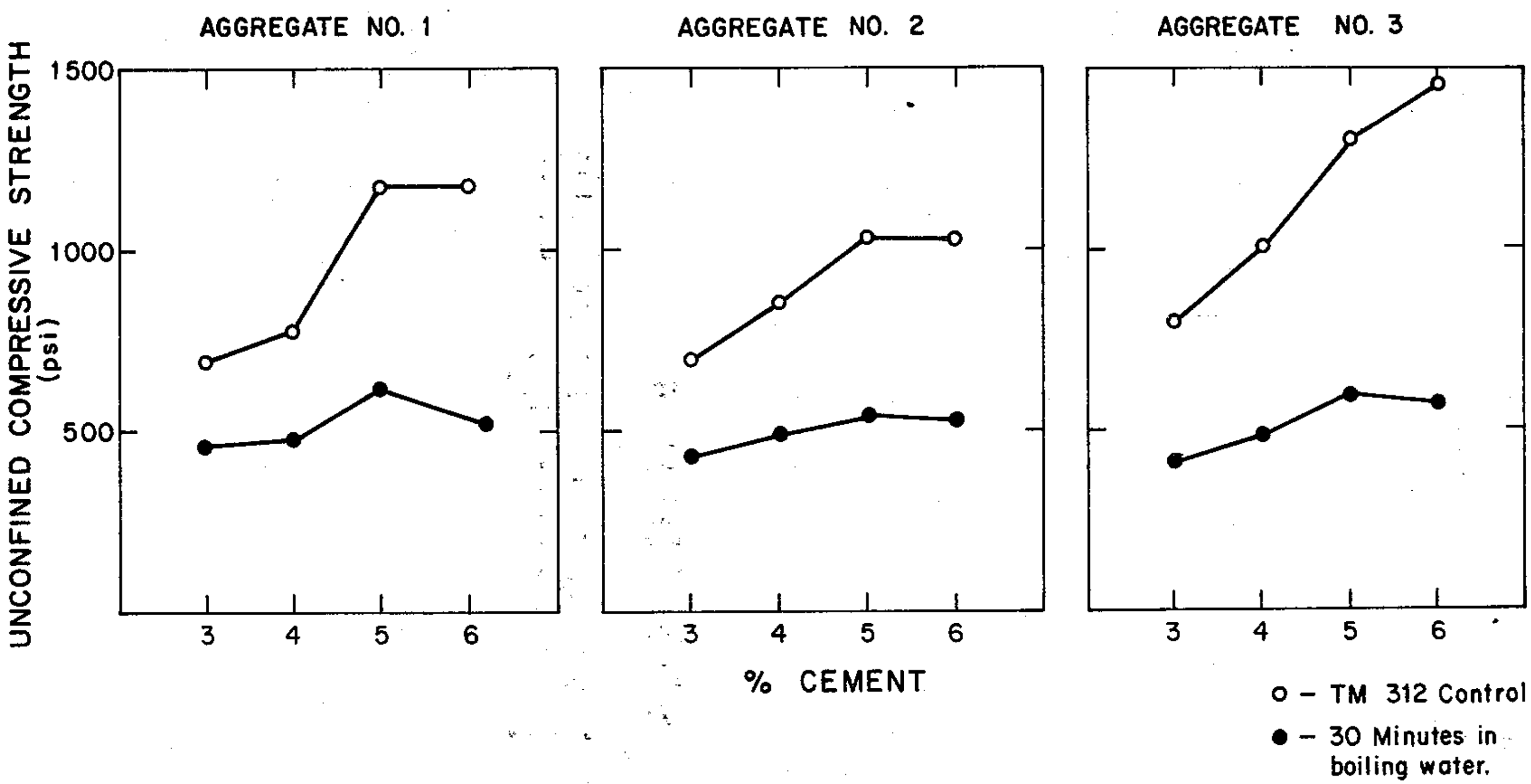


Figure 4



COMPARISON OF STRENGTHS

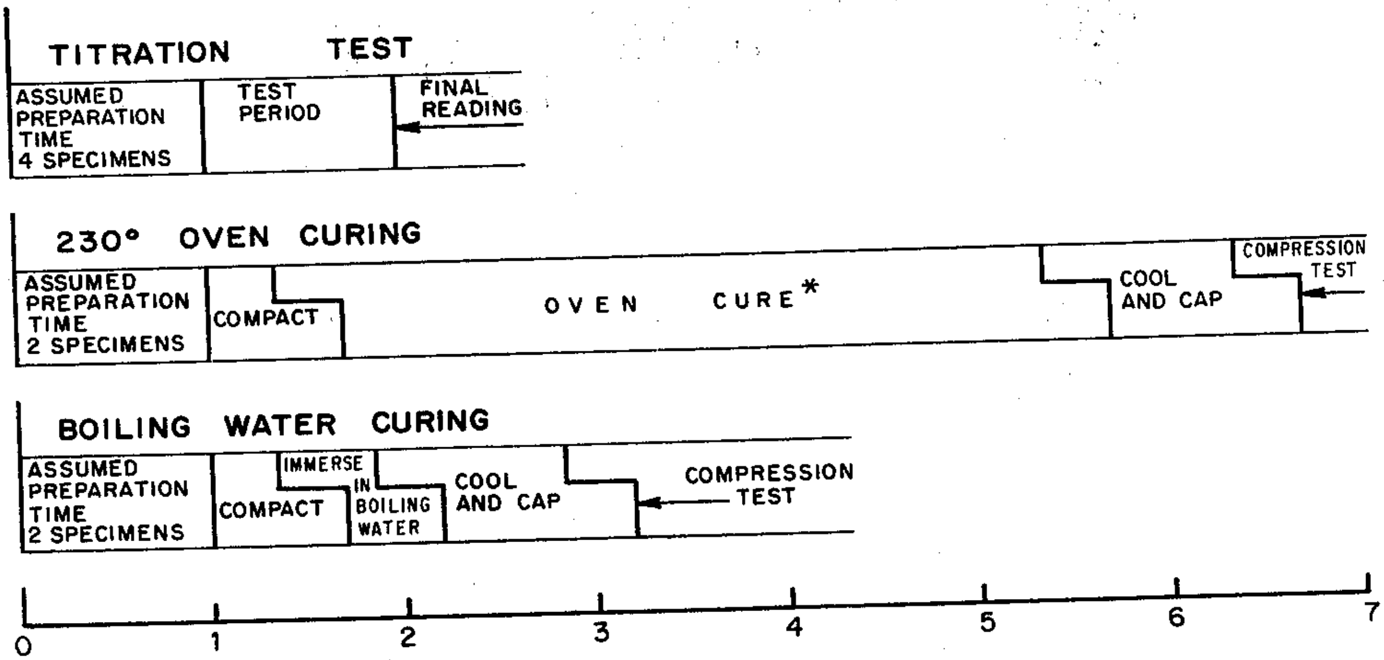
BOILING WATER METHOD VS TM 312 CONTROL SERIES

FIGURE 5

These data indicate a rapid initial strength gain of the CTB. After immersion in boiling water for only 30 minutes, the test specimens achieved approximately 50 percent of the strength gained after 7 days curing at room temperature.

Data developed in this study indicate that the boiling water method of curing has the greatest potential as a rapid field method for determining unconfined compressive strength of cement treated base. The estimated times required to complete the unconfined compressive strength tests are compared to the time required to complete the titration test in Figure 6. It can be seen that unconfined compressive strengths by the boiling water method can be determined in approximately 3 hours as compared to approximately 2 hours for the titration test. Curing by the oven method would require nearly 8 hours which would sharply limit the number and selection of sampling locations.

It is unlikely that the unconfined compressive strength procedure could be used to determine cement contents but it should provide a good basis for end result acceptance testing based upon compressive strength. Before a test procedure and specification are adopted, however, more information on the suitability of the suggested procedure should be developed by trial applications in the field. Construction personnel in several districts have already expressed a willingness to participate in the further development of this procedure.



*Assumed 4 hours as the 5-hour strengths generally exceeded the 7-day strengths per Fig. 2

COMPARISON OF TEST PERFORMANCE TIMES

FIGURE 6

APPENDIX I

Tentative Specifications for Acceptance of Cement Treated Base by Unconfined Compressive Strength

The aggregate shall conform to all of the materials requirements specified in the 1978 standard specifications.

Class A cement treated base shall also conform to the following specifications after being placed and compacted on the roadbed:

1. The moisture content shall be at least optimum moisture content less one percentage point. The optimum moisture content will be determined by California Method 312.

2. The relative compaction shall not be less than 95 percent. Said compaction shall be determined by California Method 312 or 231.

3. The average unconfined compressive strength of the mixture shall be at least 500 psi when two representative portions of the in-place material are compacted and tested according to the tentative method attached:

The test sample shall be a composite of material taken from a minimum of four random locations on the grade immediately prior to compaction. The time at which water was added to the aggregate and cement shall not differ more than 30 minutes between any two portions making up the test sample. No adjustment will be made to the moisture content.

APPENDIX II

Tentative Method for Determining the Unconfined Compressive Strength of CTB Test Specimens (Accelerated Cure)

A. Scope

This procedure, when used in conjunction with California Method 312, provides unconfined compressive strength results on the same day that the cement treated base is mixed.

B. Apparatus

1. The equipment and tools necessary to perform California Method 312.

2. A heating device and container suitable for immersing the test specimens in boiling water.

C. Fabricating Test Specimens

1. Test specimens should be prepared in duplicate following the instructions for field sampling and specimen fabrication in Parts II and III of California Method 312 except that no adjustment shall be made to the moisture content.

D. Curing

1. Immediately after capping and sealing in the tin liner, immerse the test specimen in boiling water for 30 minutes $\pm$30 sec.

2. At the end of the 30 minute boiling period, remove the test specimen from the water.

3. Remove the caps and tin liner.

a. They may be removed immediately or the specimen may be allowed to cool for a few minutes prior to cap removal.

b. Exercise caution when handling the hot specimens. The use of protective gloves is recommended.

4. Cap both ends of the test specimen with high strength capping plaster according to instructions for capping in Part V of California Method 312.

5. When the plaster caps have hardened, remove the glass forming plates.

6. Test the specimen for unconfined compressive strength according to instructions in Part V of California Method 312.

a. Begin loading the test specimen at 60 $\pm$ 1 minutes after removing from the boiling water.