EVALUATION AND PREDICTION OF THE TENSILE PROPERTIES OF LIME-TREATED MATERIALS

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SUMMARY REPORT 98-5 (S)

SUMMARY OF
RESEARCH REPORT 98-5

PROJECT 3-8-66-98

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Foreword

Research Report 98-5 is the fifth report of a series describing work done on Project 3-8-66-98, entitled "Evaluation of Tensile Properties of Subbases for Use in New Rigid Pavement Design." Specifically, this is the second report dealing with the tensile properties of lime-treated materials.

Introduction

As the economical supply of suitable natural base and subbase materials has dwindled throughout the United States, highway engineers have had to rely on less desirable materials. To produce satisfactory support, these "marginal" materials must often be stabilized in some manner, such as treatment with lime, cement, or asphaltic materials.

The Center for Highway Research at The University of Texas at Austin is presently studying the tensile properties of stabilized subbase materials by means of the indirect tensile test. Three preliminary screening experiments were performed evaluating the factors affecting the tensile characteristics of asphalt-treated, cement-treated and lime-treated materials.

Research Report 98-5 attempts to clarify and reinforce the preliminary findings as previously reported in Research Report 98-4. In addition, the indirect tensile test developed by this project is compared with the conventional Texas Highway Department tests for lime-treated materials. In order to accomplish these objectives, four experiments were conducted:

(1) the factor evaluation experiment, to extend the study of the factors affecting the tensile properties of lime-treated materials;

(2) the Center for Highway Research correlation, to compare the indirect tensile test results with that of the unconfined compression test and the cohesiometer test for soil-lime specimens cured according to procedures established at the Center for Highway Research;

(3) the Texas Highway Department correlation, to compare the indirect tensile test results with the results of the unconfined compression test and the cohesiometer test for soil-lime specimens cured according to standard Texas Highway Department (THD) procedures; and

(4) the specimen size study experiment, to determine the effect of specimen size on the indirect tensile strength of soil-lime specimens.

Experimental Program

For the factor evaluation experiment, a design which provides an economical means of studying the curvilinear, interaction, and main effects of a number of factors was selected. This design consisted of a 2^5 full factorial with 32 cells, ten star points, and six center points. The factors and levels are given below.

Factor	Level				
Compactive effort, blows per layer*	75	100	125	150	175
Molding water content, %	8.0	10.5	13.0	15.5	18.0
Lime content, %	0.0	1.5	3.0	4.5	6.0
Curing temperature, °F	50	75	100	125	150
Clay content, %	25.0	37.5	50.0	62.5	75.0

*18-inch drop, 10-lb hammer

The tensile strength and horizontal failure deformation values were recorded and analyzed for 48 specimens.

The Center for Highway Research correlation experimental design consisted of a half fraction of a 2^5 factorial, or 16 observations plus three center points, for a total of 19 observations each for the indirect tensile, unconfined compression, and cohesiometer tests. The factors and levels are given below.

Factor	Level		
Compactive effort, blows per layer*	50	75	100
Molding water content, %	10.5	13.0	15.5
Lime content, %	1.5	3.0	4.5
Curing temperature, °F	75	100	125
Clay content, %	37.5	50.0	62.5

*18-inch drop, 10-lb hammer

Because the standard THD procedures fixed the compactive effort and the curing temperature, only three of the factors studied in the factor evaluation experiment could be varied in the THD correlation. Therefore, a statistical design was chosen to provide an adequate range of strengths over which to make the correlations. This design consisted of a 2^3 full factorial with eight cells, six star points, and six center points, for a total of 20 specimens per test for the indirect tensile, unconfined compression, and cohesiometer tests. The factors and levels are presented below.

Factor	Level				
Molding water content, %	8.8	10.5	13.0	15.5	17.2
Lime content, %	0.477	1.5	3.0	4.5	5.523
Clay content, %	29.0	37.5	50.0	62.5	71.0

Conclusions

All five factors included in this study, compactive effort, lime content, clay content, molding water content, and curing temperature, had a significant effect on the indirect tensile strength either as a main effect or as an interaction. Those quadratic effects interactions, and main factors which affected the tensile strength of the lime-treated materials were as follows:

Quadratic Effects
- Curing temperature
- Molding water content

Interactions
- Curing temperature × clay content
- Molding water content × clay content
- Molding water content × curing temperature
- Lime content × curing temperature

Main Effects
- Curing temperature
- Lime content
- Compactive effort
- Molding water content

As previously observed, the indirect tensile strength was increased by

(1) increasing the curing temperature,
(2) increasing the lime content, and
(3) increasing the compactive effort.

In addition, it was found that the strength increase associated with increased curing temperatures was greater in the higher temperature ranges. It was also observed that strength was maximum at an intermediate molding water content and that, therefore, there appears to be an optimum molding water content for strength, as expected.

Probably the most important factor affecting the indirect tensile strength was curing temperature. It produced the largest main effect, as shown by the analysis of variance. In addition, it was found to produce a significant quadratic effect and appeared in three out of the four significant two-factor interactions.

An equation containing ten variables that predicts the indirect tensile strength for any combination of the levels of the independent variables has been found from the regression analysis. This regression equation has a multiple correlation coefficient of .94 and a standard error of estimate of 4.03 psi.

Predictive equations are provided for indirect tensile strength in terms of unconfined compressive strength and/or cohesiometer value for both Center for Highway Research and Texas Highway Department curing procedures. High correlation exists for both types of curing and the data can be combined to cover a larger strength range.

It was found that specimen size does not have a significant effect on the indirect tensile strength of lime-treated materials. This finding is in agreement with previous theoretical and experimental evaluations of size effects.

The factors and interactions which produced highly significant effects on the vertical failure deformations of lime-treated materials were

Quadratic effects
- Molding water content
- Clay content

Main effects
- Molding water content
- Lime content

No interaction effects were found to be significant and only three of the five factors studied (lime content, clay content, and molding water content) had a significant effect either as a main or quadratic effect.

The factors and interactions which produced highly significant effects on the horizontal failure deformations of lime-treated materials were

Quadratic effects
- Lime content

Interactions
- Clay content × molding water content

Main effects
- Clay content
- Lime content

Only three of the factors considered (lime content, clay content, and molding water content) had a significant effect on the horizontal failure deformations of lime-treated materials. These three factors were the same as those having significant effects on the vertical failure deformations.

Recommendations

This is the second in a series of studies of the tensile strength of lime-treated materials. The next step is to look at the data from both studies in order to make common inferences and ascertain the effects which predominate through both experiments. These factors can then be considered in future design procedures.

In addition to strength effects, subsequent work is needed on deformation data, including an expanded study of material properties, among which are moduli of deformation and Poisson's ratio. This work is presently underway and will be reported at a later date.

Upon completion of these two phases of the study it would be profitable to study the behavior of lime-treated materials in fatigue or repeated loading. Such studies are ultimately needed if the performance of these materials under the repeated loadings of normal traffic is to be evaluated.

Utilization of Results

The results of these studies are part of an overall program to provide a better understanding of the behavior and performance of stabilized materials when used as elements in a pavement structure. As indicated in the recommendations, the results will be used in the next phase of the study, repeated loading. They will also be compared to the findings for cement-treated and asphalt-treated materials to develop overall information for stabilized materials.

Furthermore, the detailed findings with reference to the effect of individual factors on tensile strength can be used to develop design information for stabilized mixtures for immediate upgrading of approximate design techniques.

The full text of Research Report 98-5 can be obtained from R. L. Lewis, Chairman, Research and Development Committee, Texas Highway Department, File D-8 Research, 11th and Brazos Streets, Austin, Texas 78701 (512 / 475-2971).

KEY WORDS: tensile strength, cohesiometer, unconfined compression, lime stabilization, test correlation, subbase.