TENSILE BEHAVIOR OF SUBBASE MATERIALS UNDER REPETITIVE LOADING

By

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SUMMARY REPORT 98-12 (S)

SUMMARY OF
RESEARCH REPORT 98-12

PROJECT 3-8-66-98

COOPERATIVE HIGHWAY RESEARCH PROGRAM
WITH TEXAS HIGHWAY DEPARTMENT
AND
U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

CENTER FOR HIGHWAY RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN
OCTOBER 1971

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Foreword

Research Report 98-12 summarizes the findings and conclusions obtained from an experimental program in which asphalt-treated, lime-treated, and cement-treated materials were subjected to repeated applications of tensile stresses using the indirect tensile test. This report is the twelfth in a series of reports which describe work performed for Research Project 3-8-66-98, "Evaluation of Tensile Properties of Subbases for Use in New Rigid Pavement Design." It is the first report dealing with tensile characteristics of stabilized subbase materials under repetitive loading.

Introduction

The increased use of stabilized subbases as a part of the rigid pavement structure has stimulated interest in developing a subbase design and analysis procedure. Information concerning the tensile properties of stabilized materials is needed for the development of such a procedure, since it must ultimately consider the fatigue characteristics of the materials utilized in the pavement structure.

The general objectives of this study were

(1) to determine whether or not the indirect tensile test can be used to study and evaluate the fatigue behavior of asphalt-treated, cement-treated, and lime-treated materials,

(2) to define the general nature of the relationship between applied tensile stress and the number of applications to failure and to evaluate the inherent variations associated with the relationship,

(3) to evaluate the effect on fatigue life of certain mixture and compaction variables, and

(4) to investigate the possibility of estimating the fatigue life of these treated materials either by developing a predictive equation or by establishing a correlation with other properties of the material.

Experimental Program

The factors and the levels of these factors, which were selected on the basis of the results from previous experiments concerned with the tensile characteristics of the three materials, are shown in Table 1.

TABLE 1. FACTORS AND LEVELS SELECTED FOR EVALUATION

	Factor	Levels		
		Low (−1)	Medium (0)	High (+1)
Asphalt-treated	Aggregate type	Gravel		Limestone
Asphalt-treated	Asphalt cement type*	AC-5 (8.5)	AC-10 (9.1)	AC-20 (9.6)
Asphalt-treated	Asphalt content, % by wt of total mixture	5.5	7.0	8.5
Asphalt-treated	Mixing temperature, ° F	250	300	350
Asphalt-treated	Compaction temperature, ° F	200	250	300
Asphalt-treated	Tensile stress, psi	16		32
Cement-treated	Aggregate type (stress levels)	Gravel (150 psi)		Limestone (300 psi)
Cement-treated	Cement content, % by wt of aggregate	4	6	8
Cement-treated	Molding water content, % by wt of aggregate and cement	5.25	6.5	7.75
Cement-treated	Compactive effort	85	110	135
Cement-treated	Curing temperature, ° F	75	100	125
Lime-treated	Clay content, % by wt of aggregate	37.5	50.0	62.5
Lime-treated	Lime content, % by wt of aggregate and clay	1.5	3.0	4.5
Lime-treated	Molding water content, % by wt of aggregate, clay and lime	10.5	13.0	15.5
Lime-treated	Compactive effort	100	125	150
Lime-treated	Curing temperature, ° F	75	100	125

*The asphalt cements are designated by the slopes of their logarithm temperature-logarithm viscosity relationships between 140° F and 275° F, which were constant in this temperature range.

The basic indirect tensile testing apparatus was a closed-loop electrohydraulic loading system. The actual loading device was a modified, commercially available die set with upper and lower platens constrained to remain parallel during the test. The load was controlled with a strain gage type load cell and was alternately applied and released at a sinusoidal frequency of one cycle per second. All tests were conducted at a temperature of approximately 75° F. The basic parameter evaluated in this experiment was fatigue life, i.e., the number of applications of a given tensile stress required to cause a specimen to fail.

Conclusions

General

(1) The indirect tensile test can be used to study the fatigue characteristics of asphalt-treated, cement-treated, and lime-treated materials subjected to repeated applications of tensile stress.

(2) There was significant random variation associated with the fatigue life data for all three basic types of materials studied.

Asphalt-Treated Materials

(1) The relationship between tensile stress and the logarithm of fatigue life was essentially linear, as previously reported from studies utilizing other test configurations. Fatigue failures occurred at indirect tensile stresses ranging from 8 to 40 psi, which were approximately 6 to 30 percent of the static indirect tensile strengths.

(2) Significant random variation in fatigue life occurred. It was found that the standard deviation of fatigue life varied linearly with the mean of fatigue life and that the variation was aggregate dependent. The variation of fatigue life for the asphalt-gravel mixtures was much larger than for the limestone-asphalt mixtures. The coefficient of variation for the limestone was 30 percent while the coefficient of variation for the gravel was more than 75 percent.

(3) The tensile fatigue life characteristics were found to be affected by the type of asphalt cement, asphalt content, compaction temperature, and mixing temperature. Within the range tested, it was found that fatigue life was increased by using a more viscous asphalt cement, higher compaction temperatures, and higher mixing temperatures. It was also concluded that there is an optimum asphalt content for maximum fatigue life.

(4) A simple predictive equation developed from the results of this study adequately described the observed fatigue lives observed in the study. However, additional information should be included in the equation to make it applicable to other types of asphalt-treated materials and to define better the effects produced by varying asphalt content.

(5) As in previous studies, fatigue life was found to correlate with stiffness, initial tensile strain, and stress-strength ratio. Fatigue life increased with
   (a) increased stiffness,
   (b) decreased initial tensile strains, and
   (c) decreased stress-strength ratios.

   Each of these correlations was associated with a large amount of scatter, as expected, since fatigue life involves a great deal of inherent variation. For the variety of mixtures tested in this study, it was concluded that there was no general relationship between laboratory fatigue life and air void content, although a correlation might exist for a given mixture.

(6) The correlation between fatigue life and stress-strength ratio suggested that tensile stress should be less than 10 percent of the static indirect tensile strength and the correlation between fatigue life and initial tensile strain indicated that the initial strain should be less than about 50 micro units, in order to obtain a satisfactory fatigue life, i.e., a relatively long fatigue life.

Cement-Treated and Lime-Treated Materials

(1) For both cement-treated and lime-treated materials, the relationship between tensile stress and the logarithm of fatigue life appeared to exhibit a critical stress level above which the fatigue life was very short and below which the fatigue life was long.

(2) For the lime-treated materials cured at 125° F and subected to a tensile stress of 36 psi,
   (a) specimens compacted at a water content of 10.5 percent had a longer fatigue life than specimens compacted at a water content of 15.5 percent, and
   (b) specimens containing 62.5 percent clay had a longer fatigue life than specimens containing 37.5 percent clay.

(3) Difficulties associated with the fatigue testing of both materials make it necessary to conduct additional tests before definite conclusions can be made.

Recommendations

This is the only report concerned with the fatigue properties of stabilized subbase materials programmed within this research project. Although preliminary in nature, the conclusions reached on the basis of the analysis of the fatigue data collected clearly illustrate the need for conducting additional research within this area. Additional information on the fatigue characteristics of cement-treated and lime-treated materials is critically needed, and special emphasis should be placed on further investigation of what appeared to be critical stress levels. Other areas which need further research include the effects of frequency; environmental variables, i.e., those found under field conditions; controlled strain loading; and compound loading.

Because (1) information on the fatigue characteristics of stabilized materials is urgently needed to develop and improve rational design procedures, and (2) fatigue testing is time-consuming and expensive and a well-planned research effort requires a significant period of time, it is further recommended that additional tensile testing of stabilized materials be initiated immediately.

Utilization of Results

This study is part of an overall program to provide a better understanding of the behavior and performance of stabilized materials used as elements in a pavement structure. One notable finding in this study, the apparent effect of compaction temperature on the fatigue life of asphalt-treated mixtures, supplements previously obtained information reported by this project (Refs 1, 2, and 3) concerning the effect of compaction temperature on the tensile strength, modulus of elasticity, Poisson's ratio, and critical failure strains of asphalt-treated materials. Since all of these tensile properties improve as the temperature of compaction increases, it is recommended that specifications which control the compaction temperature of asphalt-treated materials in the field be reviewed. The findings of this study will also assist in the development of a subbase design procedure which considers the fatigue characteristics of stabilized subbase materials.

The full text of Research Report 98-12 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).

References

1. Hadley, William O., W. Ronald Hudson, and Thomas W. Kennedy, "An Evaluation of Factors Affecting the Tensile Properties of Asphalt-Treated Materials," Research Report 98-2, Center for Highway Research, The University of Texas at Austin, March 1969.
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KEY WORDS: repeated loading, tensile properties, subbases, lime stabilization, cement stabilization, asphalt stabilization, fatigue.