A METHOD OF ESTIMATING TENSILE PROPERTIES OF MATERIALS TESTED IN INDIRECT TENSION

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Foreword

Research Report 98-7 summarizes the results of a study to develop and evaluate equations for estimating modulus of elasticity, Poisson's ratio, and failure strains for materials tested by indirect tension. It is the seventh report in a series which describes work done on Project 3-8-66-98, "Evaluation of Tensile Properties of Subbases for Use in New Rigid Pavement Design."

Introduction

The increased use of stabilized subbases as a part of the rigid pavement structure has stimulated interest in the tensile properties of such subbase materials. Since at present no standard test or procedure seems to provide an adequate estimate of material properties of stabilized subbases, there is a need for a method of evaluating such tensile properties as modulus of elasticity and Poisson's ratio for the subbase materials in use. When these material properties are known, layered system theory can be used to evaluate stabilized subbases.

The indirect tensile test is based on a well-defined theory, and it appears to have the greatest potential of all currently available tests for the evaluation of tensile properties of stabilized materials. Although previous studies have evaluated only the tensile strength of different materials, the indirect tensile test can also be used to estimate material properties such as modulus of elasticity, Poisson's ratio, and failure strains.

The objectives of the study reported in Research Report 98-7 were to develop and verify formulations for determining modulus of elasticity and Poisson's ratio based upon equations derived by G. Hondros for materials tested in the indirect tensile test.

Development of Formulations

The indirect tensile test involves the loading of a circular element with compressive loads acting along two opposite generators. The equipment used at The University of Texas at Austin for testing specimens in indirect tension can be used to measure the load-deformation characteristics of a circular specimen along the principal stress planes. The deformation data, however, consist of the overall vertical and horizontal deformations rather than strain information and cannot be substituted directly into theoretical equations relating stress and strain. In order to obtain the required estimates of the material properties, it is necessary to develop relationships based upon the total horizontal and vertical deformations experienced by a circular specimen during indirect tensile testing.

Hondros developed equations for stresses created in a circular element subjected to short strip loading, assuming that body forces are negligible. With these equations, the stress distributions along the horizontal and vertical axes of the specimen were obtained and converted to strain distributions utilizing the theory of elasticity. The total deformation in either the vertical or horizontal direction was then set equal to the integration of the strains of all the individual elements along the diameter and was expressed as a function of modulus of elasticity and Poisson's ratio. This resulted in two equations which can be solved simultaneously to obtain values for the modulus of elasticity and Poisson's ratio.

Experimental Evaluation

Experimental studies were conducted to verify the theoretical equations by testing a material which behaved somewhat elastically and to determine the effects produced by changes in loading rate and width of the curved loading strip.

A study was undertaken to verify the theoretical relationships for modulus of elasticity and Poisson's ratio. To substantiate the equations, a specimen made from aluminum, which exhibits a high degree of elasticity, was tested. The measured output data were center strains and total deformations along the major axes. The equations were verified by comparing the values for Poisson's ratio and modulus of elasticity which were calculated from measured center strains with those which were calculated from measured total deformations. The values for measured center strains were considered to be the best estimate of modulus of elasticity and Poisson's ratio because the recorded strain output which is measured in micro units should be more accurate than the total deformation values. The resulting modulus of elasticity E and Poisson's ratio ν were also compared with the generally accepted values of modulus of elasticity and range of Poisson's ratio for aluminum of 10×10^6 psi and 0.33 through 0.35, respectively.

Additional tests were included in the study to evaluate the effect of width of the curved loading strip used in the indirect tensile test and to evaluate the effect of loading rate. The strip widths under consideration were ½ inch and 1 inch. The 1-inch strip had been used in previous studies; however, it was thought that the smaller, ½-inch, strip might provide better results since it approximates a point load more closely. In addition, it was felt that using the smaller strip would reduce the possible confining effect caused by the curved strip. The loading rates used in the study were 0.05, 0.5, and 1.0 inch/minute. Total deformations were obtained from these latter tests.

Conclusions

Based on the results of this study the following conclusions were made:

(1) The elastic properties E and ν can be obtained from total overall deformation in the x and y-directions of a specimen tested in indirect tension through theoretical development.

(2) Center strains created in a specimen during the indirect tensile test can be estimated from known total horizontal and vertical deformation by theoretical development based upon Hondros' equations.

(3) The width of the curved loading strip used (½ inch or 1 inch) had no significant effect on center strains created in the specimen.

(4) The width of the curved loading strip used (½ inch or 1 inch) had a highly significant effect on modulus of elasticity and Poisson's ratio values obtained from total deformation values. For best results the ½-inch loading strip should be used when calculating E and ν from total deformation information.

(5) From an engineering standpoint the loading rate used in the indirect tensile test had no practical significant effect on modulus values obtained from total deformation information.

(6) The loading rate had a significant effect upon the Poisson's ratio of the material. The mean value obtained at static testing was 0.363 while the mean values for loading rates of 0.05, 0.5, and 1.0 inch were 0.249, 0.288, and 0.281, respectively. The two higher rates compare better with the static test results. At the higher loading rates ν may be underestimated, which would result in lower values of E.

(7) The indirect tensile theory is valid when testing involves elastic materials with loads applied through a short curved loading strip.

(8) The estimated center strain values remain fairly constant over the middle inch of a 4-inch-diameter specimen and are approximately equal to one-half of the total horizontal deformation.

Applications

The equations developed in Research Report 98-7 cannot be directly applied in the field but can be used in subsequent studies of stabilized materials to estimate values of modulus of elasticity, Poisson's ratio, and tensile strain for a variety of highway construction materials.

The ability to estimate values of elastic properties is a major step in the development of a design procedure for stabilized subbases and can lead to evaluation of the pavement structure as a layered system.

Since the results of this study indicate that center tensile strain created in a circular specimen tested in indirect tension approximately equals one-half of its total horizontal deformation, the tensile strains at failure for stabilized materials evaluated in previous studies (Refs 1-3) can be estimated.

The full text of Research Report 98-7 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

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KEY WORDS: indirect tensile test, modulus of elasticity, Poisson's ratio, tensile strain, loading rate, loading strip, total deformation, center strains, aluminum.