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Modulus of Elasticity as a Mechanistic Input

Prepared for
WHRP Rigid Pavements
Technical Oversight Committee

Prepared by
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WisDOT Research & Library Unit

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Transportation Literature Searches are prepared for WisDOT staff and investigators to identify completed research and other authoritative information in an area of interest. The citations below are representative, rather than exhaustive, of available English-language studies on the topic. Primary online resources for the literature searches are OCLC's WorldCat and TLCat, U.S. DOT's TRIS Online, the National Transportation Library (NTL), TRB's Research in Progress (RiP) database, and other academic, engineering and scientific databases as appropriate.

To request a literature search, contact the WisDOT Library at library@dot.state.wi.us or (608) 264-8142, or WisDOT Research at research@dot.state.wi.us or (608) 261-8198.

Topic/Problem Statement: Document literature from 2000 to the present relevant to use of modulus of elasticity as an input parameter for the AASHTO Mechanistic Empirical Pavement Design Guide protocol. This information will be used to supplement the FFY08 Wisconsin research project, WHRP 0092-08-08, "Reduction of Minimum Required Weight of Cementitious Materials in Concrete Mixes" (see the project Web page at http://www.whrp.org/Research/Rigid/rigid_0092-08-08/index.htm). This Transportation Literature Search will supplement the one prepared for the RFP for 0092-08-08.

Keywords: Modulus, elasticity, modulus of elasticity, mechanistic, input.

Summary

Modulus of elasticity as a mechanistic-empirical design input was the subject of two published articles and two studies currently in progress that we found in our search.

The two journal articles, one from 2006 and the other from 2003, treat modulus of elasticity in terms of hydrating cement paste and shrinkage in high-performance cement, respectively. The two studies in progress include a Florida study of creep and shrinkage, in its second phase, and a Mississippi study of eight MEPDG inputs for portland cement concrete pavements, including modulus of elasticity.

Citations

Results are listed chronologically, with the most recent citations shown first. Links to online copies of cited literature are provided when available. Contact the WisDOT Library to obtain hard copies of citations.

Title: Microstructure-based micromechanical prediction of elastic properties in hydrating cement paste
Author(s): Vit Smilauer, Zdenek Bittnar
Date: September 2006
Source/URL: *Cement and Concrete Research*, Vol. 36 (9), September 2006: 1708-1718.
Description: 11 pp.

Contents: Elastic properties of hydrating cement paste can be successfully predicted by combination of the hydration model, percolation theory, and micromechanical analysis. Reconstruction of hydrating microstructure is based on the 3D digital NIST model of cement hydration, enhanced for the prediction of 2 C–S–H types. Chemical phases in a percolated microstructure served as an input in a 2-level analytical or 1-level 3D FEM or FFT elastic homogenization. Special mesh generation for the percolated microstructure is discussed as well as its numerical implementation. Good results from FEM and FFT were found for the size of the representative volume element of 50 × 50 × 50 μm, considering water-to-cement ratio in the range 0.25-0.5. While good predictions in well-hydrated cement pastes were obtained for analytical and numerical approaches, numerical homogenization was found more accurate and versatile for the whole hydration time.

Title: Autogenous shrinkage in high-performance cement paste: An evaluation of basic mechanisms
Author(s): Pietro Lura, Ole Mejlhede Jensen, Klaas van Breugel
Date: February 2003
Source/URL: *Cement and Concrete Research*, Vol. 33 (2), February 2003: 223-232.
Description: 10 pp.
Contents: In this paper, various mechanisms suspected to cause autogenous shrinkage are presented. The mechanisms are evaluated based on their soundness and applicability to quantitative modeling of autogenous shrinkage. The capillary tension approach is useful, as it has a sound mechanical and thermodynamical basis. Also, this mechanism is easily applicable in a numerical model when dealing with a continuously changing microstructure. In order to test the numerical model, autogenous deformation and internal relative humidity (RH) of a Portland cement paste were measured during the first week of hardening. The isothermal heat evolution was also recorded to monitor the progress of hydration and the elastic modulus in compression was measured. RH change, degree of hydration, and elastic modulus were used as input data for the calculation of autogenous deformation based on the capillary tension approach. Because a part of the RH drop in the cement paste is due to dissolved salts in the pore solution, a method is given to separate this effect from self-desiccation and calculate actual stress in pore fluid associated with menisci formation.

Research in Progress

Results are listed chronologically, with the most recent citations shown first. Links to research project Web sites or TRB Research in Progress listings are provided when available.

Title: Modulus of Elasticity, Creep and Shrinkage of Concrete – Phase II
Principal Investigator(s): Mang Tia, University of Florida-Gainesville, (352) 392-6784 or tia@ce.ufl.edu
Start Date: 2/10/2006
RIP URL: http://rip.trb.org/browse/dproject.asp?n=11480
Sponsor Organization: Florida Department of Transportation
Contents: The main objectives of this project are to: (1) set up a concrete creep testing laboratory at the University of Florida with a minimum of 24 creep testing apparatuses; (2) conduct an extension laboratory testing program to determine the compressive strength, indirect tensile strength, modulus of elasticity, creep and shrinkage of typical Class II, IV, V and VI concrete mixes made with normal-weight and lightweight aggregates used in Florida; (3) determine the effects of aggregate properties, w/c, cement content, fly ash content, ground blast furnace slag content and curing time on the compressive strength, indirect tensile strength, modulus of elasticity, creep and shrinkage properties of Florida Class II (Bridge Deck), IV, V and VI concretes, and to determine the inter-relationships between these properties; (4)recommend values of modulus of elasticity, creep and shrinkage properties for typical Florida Class II (Bridge Deck), IV, V and VI concrete mixes to be used in structural designs; (5)conduct a laboratory study on low modulus concrete for use in concrete pavement; and (6)develop a framework for improved specifications for pavement concrete in which modulus of elasticity, along with other important properties such as flexural strength and coefficient of thermal expansion of concrete would be specified for optimal expected pavement performance.

Title: Inputs of Portland Cement Concrete Parameters Needed for the Design of New and Rehabilitated Pavements in Mississippi
Principal Investigator(s): Ahmed Al-Ostaz, University of Mississippi, (662) 915-5364 or alostaz@olemiss.edu
Start Date: 1/10/2004
RIP URL: http://rip.trb.org/browse/dproject.asp?n=10002
Sponsor Organization: Mississippi Department of Transportation
Contents: Mississippi Department of Transportation MDOT is implementing the mechanistic-empirical pavement design methodology developed under NCHRP 1-37A. This pavement design method characterizes the pavement materials by fundamental properties such as modulus and Poisson's Ratio. For rigid pavement design the Portland

Cement Concrete (PCC) is characterized by: (1) modulus of rupture; (2) compressive strength; (3) modulus of elasticity; (4) tensile strength; (5) coefficient of thermal expansion; (6) concrete shrinkage; (7) unit weight; and (8) Poisson's ratio. In this study PCC mixes encompassing a range of aggregate types with various blends of Type I cement, Class F or C fly ash and slag that are typically encountered in Mississippi will be evaluated for these parameters.