Nondestructive Testing of Pavements and Backcalculation of Moduli

Harold L. Von Quintas
Albert J. Bush, III
Gilbert Y. Baladi

Editors

ASTM STP 1198
Nondestructive Testing of Pavements and Backcalculation of Moduli: Second Volume

Harold L. Von Quintus, Albert J. Bush, III, and Gilbert Y. Baladi, Editors

ASTM Publication Code Number (PCN)
04-011980-08
Foreword

This publication, *Nondestructive Testing of Pavements and Backcalculation of Moduli (Second Volume)*, contains papers presented at the symposium of the same name held in Atlanta, GA on 23–24 June 1993. The symposium was sponsored by ASTM Committee D18 on Soil and Rock and its Subcommittee D4 on Road and Paving Materials. Albert J. Bush, III, of U.S. Army Corps of Engineers in Vicksburg, MS, Harold L. Von Quintus of Brent Rauhut Engineering in Austin, TX, and Gilbert Y. Baladi of Michigan State University in East Lansing, MI presided as symposium chairmen and are the editors of the resulting publication.
Contents

Overview ix

ANALYTICAL MODELS AND TECHNIQUES

Advanced Backcalculation Techniques—J. UZAN 3

SHRP's Layer Moduli Backcalculation Procedure—G. RADA, C. RICHTER, AND P. JORDAHL 38

Methodology for Identifying Material Properties in Pavements Modeled as Layered Viscoelastic Half Spaces—N. STUBBS, V. TORPUNURI, R. LYTTON, AND A. MAGNUSON 53

Backcalculation of Pavement Layer Moduli, Thicknesses, and Bedrock Depth Using a Modified Newton Method—R. HARRICHANDRAN, T. MAHWOOD, R. RAAD, AND G. BALADI 68

Improved Methods for AC/PCC Pavement Backcalculation and Evaluation—K. HALL AND M. DARTER 83

Concrete Pavement Backcalculation Using ILLI-BACK—A. IOANNIDES 103

Dynamic Analysis of FWD Loading and Pavement Response Using a Three-Dimensional Dynamic Finite-Element Program—S. ZAGHLOU, T. WHITE, V. DRNEVICH, AND B. COREE 125

MEASUREMENT AND CALCULATION TECHNIQUES IN THE FIELD AND LABORATORY

Verification of Pavement Response Models—P. ULLIDTZ, J. KRARUP, AND T. WAHLMAN 143

Field Validation of a Methodology to Identify Material Properties in Pavements Modeled as Layered Viscoelastic Halfspaces—V. S. TORPUNUR, N. STUBBS, R. L. LYTTON, AND A. H. MAGNUSON 159

Comparing Laboratory and Backcalculated Layer Moduli on Instrumented Pavement Sections—T. ACRAM, T. SCULLION, AND R. E. SMITH 170
<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-Situ and Laboratory Characterization of Nonlinear Pavement Layer</td>
<td>K. P. George and W. Uddin</td>
<td>203</td>
</tr>
<tr>
<td>Moduli</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effect of Material Stress Sensitivity on Backcalculated Moduli and</td>
<td>R. N. Stubstad, J. P. Mahoney, and N. F. Coetzee</td>
<td>233</td>
</tr>
<tr>
<td>Pavement Evaluation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problems/Errors Associated With Backcalculation Methods and Design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Misleading Results from Nondestructive Testing—A Case Study—</td>
<td>J. W. Hall, Jr., and P. S. McCaffrey, Jr.</td>
<td>251</td>
</tr>
<tr>
<td>Stochastic Analysis of Errors in Remaining Life Due to Misestimation</td>
<td>K. M. Vennalaganti, C. Ferregut, and S. Nazarian</td>
<td>261</td>
</tr>
<tr>
<td>of Pavement Parameters in NDT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interpretation of Dynamic Survey Measurement on Pavement with Treated</td>
<td>P. Lepert, and P. Caprioli</td>
<td>277</td>
</tr>
<tr>
<td>Roadbase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase LAG Effects on Analysis of FWD Data—</td>
<td>P. E. Sebaaly, and S. Holikatti</td>
<td>291</td>
</tr>
<tr>
<td>The Effect of Annular Load Distributions on the Backcalculated of</td>
<td>J. A. Crovetti, and M. Y. Shahin</td>
<td>309</td>
</tr>
<tr>
<td>Moduli of Asphalt Pavement Layers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effects of Pavement-Falling Weight Deflectometer Interaction on</td>
<td>K. M. Boddapati, and S. Nazarian</td>
<td>326</td>
</tr>
<tr>
<td>Measured Pavement Response</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDT for Other Pavement Uses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Comparison of Laboratory and Field Subgrade Moduli at the Minnesota</td>
<td>D. A. van Deusen, C. A. Lenngren, and D. E. Newcomb</td>
<td>361</td>
</tr>
<tr>
<td>Road Research Project</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detection of Multi-Course Pavement Layers by the SASW Method—</td>
<td>N. Gucunski</td>
<td>380</td>
</tr>
<tr>
<td>Strategies for Application of the Falling Weight Deflectometer to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluate Load Transfer Efficiency at Joints in Jointed Concrete</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pavements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field Testing and Structural Evaluation of Selected Concrete Pavement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sections in Florida</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backcalculation of System Parameters for Jointed Rigid Pavements—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. R. Hiltunen and R. Roque</td>
<td></td>
<td>440</td>
</tr>
</tbody>
</table>
Evaluation of Support Conditions Under Jointed Concrete Pavement Slabs—
J. A. CROVETTI AND M. R. T. CROVETTI 455

Determination of Voids Under Rigid Pavements Using Impulse Method—
S. NAZARIAN, S. REDDY AND M. BAKER 473

Evaluation of NDT Equipment for Measuring Voids Under Concrete Pavements—
W. UDDIN AND W. R. HUDSON 488

PROPOSED STANDARD GUIDE

The Quest for a Standard Guide to NDT Backcalculation—R. W. MAY AND
H. L. VON QUINTUS 505

Author Index 521

Subject Index 523
Overview

In June 1988, the first International Symposium on Nondestructive Testing (NDT) of Pavements and Backcalculation of layer moduli was held. Since then, another symposium on NDT and backcalculation of layer moduli was held in August of 1991 and was sponsored by the Transportation Research Board. Both of these symposia were well attended, and showed that there was a strong interest within the transportation community in the area of NDT and the use of deflection data for evaluating and designing pavement structures. Unfortunately, these two symposia also showed that the industry was divided regarding the adequacy and use of state-of-the-art evaluation procedures for determining structural capacity of pavement structures.

As a result of the first symposium in 1988, ASTM Subcommittees D18.10 and D04.39 have been extensively involved in the preparation of standardized procedures for NDT and the evaluation of deflection data. Standardized procedures have been prepared and approved for collecting deflection data with different devices. These are listed below for reference purposes:

- D 4694 Standard Test Method for Deflections with a Falling-Weight-Type Impulse Load Device
- D 4695 Standard Guide for General Pavement Deflection Measurements

The task of standardizing backcalculation procedures, however, has been more difficult, because of the diversity of opinions and procedures currently in use by the transportation industry. The first draft of a standard guide for backcalculation of layer moduli from deflection measurements was balloted in 1986. The latest draft balloted in 1992 received numerous negative ballots that were found to be persuasive. More recently, there have been numerous research projects completed by individual transportation agencies and as part of the Strategic Highway Research Program (SHRP).

With these recent advancements and the need to develop concurrence within the transportation industry to develop a standardized evaluation procedure, Subcommittees D18.10 and D04.39 suggested to the Executive Committees that ASTM sponsor the second International Symposium on Nondestructive Testing of Pavements and Backcalculation of Moduli. This Second International Symposium was held in Atlanta, Georgia in June, 1993. The attendance at this symposium exceeded 80, representing 12 different countries and 25 states in the United States. An attendance list is included at the end of this publication.

The symposium was divided into four sessions (two sessions per day) and one panel workshop or discussion on issues related to standardization of backcalculation procedures. The papers presented at this Second International Symposium focused in the area of backcalculation of layer moduli techniques and comparisons of material moduli as measured in the laboratory to values calculated from field deflection measurements. Information from these papers and discussion were used to establish whether a backcalculation procedure could be standardized based upon the current state-of-the-art technology. The format of the presentations was divided into four sessions followed by a panel discussion. Each of the sessions were subdivided into two parts as follows:
SESSION 1—Analytical Models and Techniques for Backcalculation of Layer Moduli (5 Papers).

Chairman—Dr. Albert J. Bush III, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Part 1 of Session 1: Recent Developments and Tools to be Used in the Future for Evaluating Pavements Based on Backcalculation Techniques (2 Papers).

Keynote Speaker—Dr. Jacob Uzan, Professor, Israel Institute of Technology (Technion), Israel, "Advanced Backcalculation Techniques."

Part 2 of Session 1: Methods and Procedures Used for Backcalculation of Material and Pavement Properties (4 Papers).

SESSION 2—Measurement and Calculation Techniques in the Field and Laboratory

Chairman—Mr. Harold L. Von Quintus, President, Brent Rauhut Engineering Inc., Austin, TX.

Part 1 of Session 2: Verification of backcalculation techniques and comparisons of laboratory measured values with those calculated from field measurements or deflections (4 papers).

Part 2 of Session 2: Characterization of Pavement Materials and the Effects of Non Linearity on Backcalculation of Layer Moduli (4 papers).

SESSION 3—NDT for Pavement Structural Evaluation, Design and Rehabilitation.

Chairman—Dr. Albert J. Bush III, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Part 1 of Session 3: Problems/errors associated with backcalculation methods in terms of pavement evaluation, and backcalculation of design parameters for concrete pavements (4 papers).

Part 2 of Session 3: Analysis of deflection measurements and effects of load distributions on pavement response (4 papers).

SESSION 4—NDT for Other Pavement Uses: Use of the Results From NDT to Determine Layer Thickness, Joint Efficiency, and Void Detection (5 Papers).

Chairman—Dr. Gilbert Y. Baladi, Professor, Michigan State University, East Lansing, MI.

SESSION 5—Panel Discussion on Backcalculation of Layer Moduli

Chairman—Dr. Gilbert Y. Baladi, Professor, Michigan State University, East Lansing, MI.

Discussion paper presented by Richard May, Asphalt Institute, Lexington, KY and Harold L. Von Quintus, Brent Rauhut Engineering, Austin, TS entitled "The Quest for a Standard Guide to NDT Backcalculation".

Panel participants: Dr. Albert J. Bush III, U.S. Army of Engineers, Waterways Experiment Station, Vicksburg, MS; Dr. Jacob Uzan, Israel Institute of Technology (Technion), Israel; Richter, Federal Highway Administration, Turner Fairbanks, Washington, DC; Dr. Ullditz, Technical University of Denmark, Denmark, and Luckanen, Braun Intertec, Minneapolis, MN.

Papers in this STP are presented on those topics in the four sessions listed previously. These papers include examples of different backcalculation of layer moduli procedures, comparisons x
between laboratory measured and field calculated values, as well as, the more common examples on
the use of deflection testing to evaluate pavement structures. The papers published represent
eight different countries, eleven different states, and thirteen different educational agencies.
It is the hope of the organizers of this symposium that the papers presented will
provide the readers with much of the latest information in the areas of pavement evaluation
using NDT techniques, and application of that data for use in pavement design.

One of the goals and objectives of this symposium was to determine if the industry could
find a common ground to standardize a backcalculation procedure. In specific, this was the
focus of the panel discussion at the end of the symposium. This panel discussion was preceded
by a paper entitled "The Quest for a Standard Guide to NDT Backcalculation" (presented by
Mr. Richard May) and a presentation by Dr. Albert Bush (Symposium Cochairman and D4.39
Subcommittee Chairman) entitled "Where We Go From Here."

From the question and answers during the panel discussion, it was the general consensus
that backcalculation of layer moduli from deflection measurements will definitely be used in
the future for the rehabilitation design and evaluation of pavement structures. The question
however, is still: what is the reliability of these values? Specifically, it was the general consensus
of the panel and attendees that the accuracy of backcalculated moduli is model dependent and
unknown, as well as those values measured in the laboratory because there is a diversity of
opinion on the simulation of field conditions in the laboratory. For example, there is controversy
within the industry on whether backcalculation procedures should be based on a dynamic or
static analysis, and what values actually represent the "truth," both in the laboratory or from
field measurements.

In summary, most participants, concurred that there needs to be a standard "baseline" of
values from which to compare on a project, material, or pavement bases, and that one should
not become paralyzed by the imperfection of the procedures. More importantly, research must
be merged into practice on a consistent basis and one way to accomplish this is through the
standardization process. As such, a procedure needs to be standardized and that procedure
should concentrate on user oriented issues. Thus, the editors, panel, as well as most symposium
participants involved in these discussions, believe that some standardized procedure should be
pursued to ensure that a common set of values can be compared.

The editors wish to thank all those who participated in this symposium and who contributed
to this STP. Special thanks are given to the authors, the reviewers of the papers, ASTM Com-
mitees D18 and D4 for sponsoring the symposium, and to the members of Subcommittees
D18.10 and D04.39 for their valuable input and efforts. Last but not least, the editors would
like to express their deep appreciation to the ASTM staff for their assistance in preparing for
this symposium and in its preparation. The high professional quality of ASTM publications
would not be possible without their dedicated and professional efforts.

Dr. Albert J. Bush III
U.S. Army Corps of Engineers, Waterways
Experiment Station, Vicksburg, MS; symposium cochairman and coeditor.

Mr. Harold L. Von Quintus
President, Brent Rauhut Engineering, Austin, Texas,
symposium cochairman and editor

Dr. Gilbert Y. Baladi
Professor of Civil Engineering, Michigan State
University, East Lansing, Michigan, symposium cochairman and coeditor