



C E N T E R F O R  
**PORTLAND CEMENT CONCRETE  
PAVEMENT TECHNOLOGY**

Fly Ash Soil Stabilization for  
Non-Uniform Subgrade Soils, Volume II:  
Influence of Subgrade Non-Uniformity  
on PCC Pavement Performance

Final Report  
April 2005

IOWA STATE UNIVERSITY

Sponsored by  
the Iowa Highway Research Board (Project TR-461),  
Federal Highway Administration (Project 4), and  
Iowa Department of Transportation (CTRE Project 01-90)

### **Disclaimer Notice**

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Iowa Department of Transportation, the Iowa Highway Research Board, and the Federal Highway Administration. The sponsors assume no liability for the contents or use of the information contained in this document. This report does not constitute a standard, specification, or regulation. The sponsors do not endorse products or manufacturers.

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for the contents or use of the information contained in this document. This report does not constitute a standard, specification, or regulation.

The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers' names appear in this report only because they are considered essential to the objective of the document.

### **About the PCC Center/CTRE**

The Center for Portland Cement Concrete Pavement Technology (PCC Center) is housed at the Center for Transportation Research and Education (CTRE) at Iowa State University. The mission of the PCC Center is to advance the state of the art of portland cement concrete pavement technology. The center focuses on improving design, materials science, construction, and maintenance in order to produce a durable, cost-effective, sustainable pavement.

**Technical Report Documentation Page**

<b>1. Report No.</b> IHRB Project TR-461; FHWA Project 4	<b>2. Government Accession No.</b>	<b>3. Recipient's Catalog No.</b>	
<b>4. Title and Subtitle</b> Fly Ash Soil Stabilization for Non-Uniform Subgrade Soils, Volume II: Influence of Subgrade Non-Uniformity on PCC Pavement Performance	<b>5. Report Date</b> April 2005	<b>6. Performing Organization Code</b> CTRE Project 01-90	
	<b>7. Author(s)</b> David J. White, Dale Harrington, Halil Ceylan, and Tyson Rupnow	<b>8. Performing Organization Report No.</b>	
<b>9. Performing Organization Name and Address</b> Center for Transportation Research and Education Iowa State University 2901 South Loop Drive, Suite 3100 Ames, IA 50010-8634	<b>10. Work Unit No. (TRAIS)</b>	<b>11. Contract or Grant No.</b>	
	<b>12. Sponsoring Organization Names and Addresses</b> Iowa Highway Research Board      Federal Highway Administration Iowa Department of Transportation      U.S. Department of Transportation 800 Lincoln Way      400 7th Street SW, HIPT-20 Ames, IA 50010      Washington, DC 20590	<b>13. Type of Report and Period Covered</b> Final Report	<b>14. Sponsoring Agency Code</b>
<b>15. Supplementary Notes</b> Visit <a href="http://www.ctre.iastate.edu">www.ctre.iastate.edu</a> for color PDF files of this and other research reports.			
<b>16. Abstract</b>  <p>To provide insight into subgrade non-uniformity and its effects on pavement performance, this study investigated the influence of non-uniform subgrade support on pavement responses (stress and deflection) that affect pavement performance.</p> <p>Several reconstructed PCC pavement projects in Iowa were studied to document and evaluate the influence of subgrade/subbase non-uniformity on pavement performance. In situ field tests were performed at 12 sites to determine the subgrade/subbase engineering properties and develop a database of engineering parameter values for statistical and numerical analysis. Results of stiffness, moisture and density, strength, and soil classification were used to determine the spatial variability of a given property. Natural subgrade soils, fly ash-stabilized subgrade, reclaimed hydrated fly ash subbase, and granular subbase were studied. The influence of the spatial variability of subgrade/subbase on pavement performance was then evaluated by modeling the elastic properties of the pavement and subgrade using the ISLAB2000 finite element analysis program.</p> <p>A major conclusion from this study is that non-uniform subgrade/subbase stiffness increases localized deflections and causes principal stress concentrations in the pavement, which can lead to fatigue cracking and other types of pavement distresses. Field data show that hydrated fly ash, self-cementing fly ash-stabilized subgrade, and granular subbases exhibit lower variability than natural subgrade soils. Pavement life should be increased through the use of more uniform subgrade support. Subgrade/subbase construction in the future should consider uniformity as a key to long-term pavement performance.</p>			
<b>17. Key Words</b> fly ash—long-term pavement performance—non-uniformity—stress and deflection responses—subgrade/subbase		<b>18. Distribution Statement</b> No restrictions.	
<b>19. Security Classification (of this report)</b> Unclassified.	<b>20. Security Classification (of this page)</b> Unclassified.	<b>21. No. of Pages</b> 46 plus appendix	<b>22. Price</b> NA

# **FLY ASH SOIL STABILIZATION FOR NON-UNIFORM SUBGRADE SOILS, VOLUME II**

## **INFLUENCE OF SUBGRADE NON-UNIFORMITY ON PCC PAVEMENT PERFORMANCE**

**Final Report**  
**April 2005**

**Principal Investigators**

David J. White

Department of Civil and Construction Engineering, Iowa State University

Dale S. Harrington

Center for Transportation Research and Education, Iowa State University

**Technical Contributor**

Halil Ceylan

Department of Civil and Construction Engineering, Iowa State University

**Research Assistant**

Tyson Rupnow

Sponsored by  
the Iowa Highway Research Board  
(IHRB Project TR-461)

Preparation of this report was financed in part through funds provided by the Iowa Department of Transportation through its research management agreement with the Center for Transportation Research and Education, CTRE Project 01-90

A report from  
**Center for Transportation Research and Education**

**Iowa State University**

2901 South Loop Drive, Suite 3100

Ames, IA 50010-8632

Phone: 515-294-8103

Fax: 515-294-0467

[www.ctre.iastate.edu](http://www.ctre.iastate.edu)

## TABLE OF CONTENTS

EXECUTIVE SUMMARY .....	XI
INTRODUCTION .....	1
BACKGROUND .....	3
Pavement Distress .....	3
Spatial Variation of Soil Stiffness .....	3
Support under PCC Pavements .....	4
Case Study: Ohio SHRP Test Road, U.S. Rt. 23, Delaware, Ohio .....	4
Subgrade Models for Numerical Analysis .....	5
Dense Liquid Model .....	5
Elastic Solid Model .....	6
METHODS .....	7
Collection of Field Data .....	7
Task 1: Project Selection .....	7
Task 2: Grid Pavement and Document Pavement Quality .....	13
Task 3: DCP Testing .....	13
Task 4: Clegg Impact Hammer Testing .....	14
Task 5: GeoGauge Stiffness Testing .....	14
Task 6: Nuclear Density Gauge Testing .....	16
Task 7: Determine Subgrade/Subbase Index Properties .....	17
Finite Element Modeling to Evaluate Pavement Response .....	17
Task 1: Estimate Modulus of Subgrade Reaction .....	18
Task 2: Select Pavement Engineering Properties and Loading Conditions .....	18
Task 4: Evaluate Pavement Responses .....	19
Task 5: Estimate Pavement Life from Numerical Analysis Output .....	20
Statistical Analysis of Field and Numerical Results .....	20
Task 1: Determine the Mean, Standard Deviation, and COV Values for In-Situ Tests .....	20
Task 2: Perform SAS Analysis of ISLAB2000 Results .....	20
MATERIALS .....	21
In Situ Test Results .....	21
Nuclear Density Gauge .....	21
GeoGauge Stiffness .....	21
Dynamic Cone Penetrometer .....	21
Clegg Impact Hammer .....	21
Subgrade/Subbase Index Properties .....	21

RESULTS .....	27
Pavement Modeling .....	27
ISLAB2000 Results .....	27
Pavement Life Results .....	38
Statistical Analysis.....	40
Field Data Statistical Analysis .....	41
DISCUSSION .....	43
ISLAB2000 Pavement Modeling.....	43
Statistical Analysis.....	44
Field Data Statistical Analysis .....	44
ISLAB2000 Statistical Analysis .....	44
SUMMARY AND CONCLUSIONS .....	45
REFERENCES .....	47
APPENDIX – IN SITU TESTING RESULTS.....	48

## LIST OF FIGURES

Figure 1. CBR data indicating non-uniform subgrade, US 61, Muscatine, IA.....	2
Figure 2. Project 1: Highway 63 in Eddyville, Iowa .....	8
Figure 3. Project 2: Highway 330 northeast of Bondurant, Iowa .....	8
Figure 4. Location for projects 3 and 4: Knapp Street, Ames, Iowa .....	10
Figure 5. Location for projects 5 and 6: I-235 West Des Moines, Iowa .....	10
Figure 6. Location for project 7: Highway 34 east of Fairfield, Iowa.....	11
Figure 7. Location of project 8: U.S. Highway 218, Henry County.....	11
Figure 8. Location of project 9: Interstate 35 north of Highway 20.....	12
Figure 9. Location for projects 10 and 11: Ames, Iowa .....	12
Figure 10. Location for project 12: University and Guthrie Aves, Des Moines, Iowa .....	13
Figure 11. DCP testing on westbound entrance ramp of I-235 at 35th Street in West Des Moines, Iowa.....	15
Figure 12. Clegg Impact Hammer .....	15
Figure 13. GeoGauge .....	16
Figure 14. Nuclear Density Gauge .....	16
Figure 15. Winkler spring foundation to simulate non-uniform subgrade/subbase stiffness .....	17



























































































































































