RESEARCH & DEVELOPMENT NEWS

March 2015 Vol. 1, no. 2

Moving Forward:
The FY 2017 Research Work Program

Welcome to the second issue of the NCDOT Research and Development Unit's newsletter, *Research and Development News.* We are excited that we've managed to produce two consecutive issues. Two or three more and we will have a trend!

The biggest news for this quarter is the approval of the annual Research Program by the Research Executive Committee. The REC met on February 9, 2015 and approved twenty projects in wide ranging areas from Pavement and Materials to Wetland Modeling to Pedestrian Safety, to Performance and Asset Management issues to multiple Mobility and Safety topics. Each of these projects has a few simple goals:

⇒ Make our business processes, designs and policies more efficient, more robust and more cost effective

⇒ Advance Departmental goals relating to safety, economic development, stewardship and quality

⇒ Evaluate new techniques and technology and the potential benefit to NCDOT

Over the next few months, keep an eye on our Connect Page. You will see a more robust website with easier to access ongoing research information, final research reports, and several updated forms and policies.

We hope you enjoy this newsletter, and if you have ideas for articles or questions about the Research Program, please give us a call or drop us an email.

Neil Mastin
Research & Development Unit Manager

Table of Contents

Structures/Geotechnical/Construction Research Projects

Subgrade Stabilization Alternatives to Lime and Cement

Ernest Morrison, PE

This project involved four distinct research activities, (1) determine the influence of temperature on lime-stabilized soils, (2) determine the influence of temperature on cement-stabilized soils (3) temperature modeling of stabilized subgrade and (4) use of calcium chloride (CaCl2) to accelerate strength gain of cement-stabilized soils.

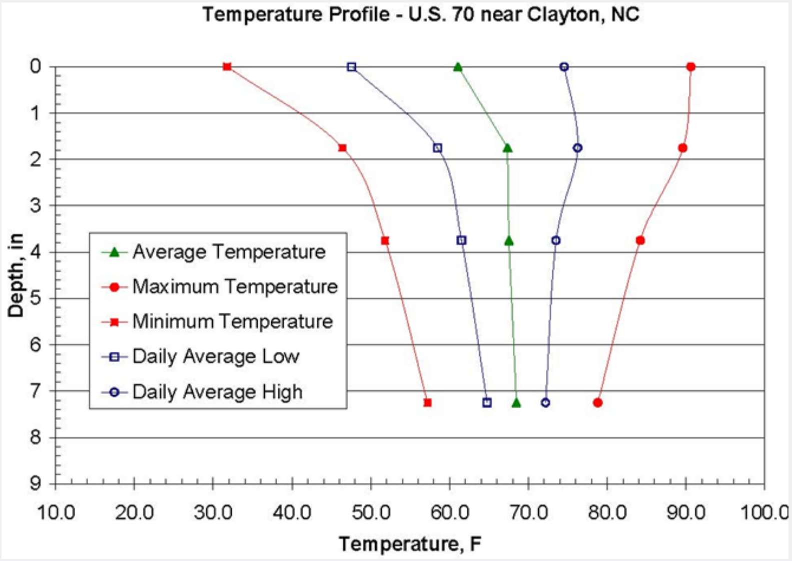
Significant conclusions from the lime-focused research include that the minimum lime content of a soil increases as temperature decreases. Increased curing duration leads to decreases in pore fluid pH. However, this reduction in pH is less at lower temperatures, indicating that little reactivity occurs below 50°F. Exposure to freeze-thaw cycles or initial curing at 35°F resulted in significant reductions in strength gain for a given curing duration. However, once the freeze-thaw cycles or temperature reduction was removed, strength gain resumed at approximately the same rate. Overall, these results suggest that current specifications may be modified to allow lime stabilization to proceed in cooler temperatures, provided a corresponding increase in curing time and/or thermal protection is provided prior to loading.

The soil cement data indicate that curing soil-cement at lower temperatures will result in lower strengths. For example, the 7 day strength for samples cured at 25°F was less than the strength of samples cured at 50°F or 70°F by a factor ranging from 2-6. Likewise, the 7 day strength for samples cured at 35°F was less than the strength of samples cured at 50°F or 70°F by approximately 20-25%. Additionally, on the basis of 15 repeat tests for 3 and 7 day curing periods, for three different soils, results indicate that the mean strength at 3 days is 84-93% of that for 7 days, in support of a potential change in current subgrade evaluation practice predicated on the longer duration.

Specifications for stabilization work have often been based on air temperature measurements, however the performance of lime or cement treated soil is expected to be more closely related to the in situ temperature. This research has found that the thermal diffusivity of both lime and cement-stabilized subgrades varies from 3.8 x 10-7 m^2/s (2.14 $in^2/hr.$) to 9.8 x 10-7 m^2/s (5.46 $in^2/hr.$). These data were incorporated into a model that relates air and soil temperatures. A computer application was developed to use the model to make predictions of subgrade temperatures and cured strength.

The overall body of research presented in this report suggests that CaCl2 modification of soil-cement is not a mature enough approach to serve as a method for mitigating the effects of low temperatures on strength gain. Additional data are required to probe the sensitivity of temperature, mixing method and soil type.

This research provides the NCDOT data which can result in more efficient and expanded time frame cold weather road construction operations. This research could result in quicker completion of road construction projects and reduced construction costs. The investigators were J. Brian Anderson, Ph.D., John L. Daniels, D.Eng., P.E., and Rajaram Janardhanam Ph.D., P.E. of UNC-Charlotte). The full report for RP2007-11 can be found at the NCDOT Research Project Information Page.



List of other active projects being managed by Ernest Morrison:

2011-05 Field Verification of Undercut Criteria and Alternatives for Subgrade Stabilization in the Piedmont Area

2013-07 Design of Temporary Slopes and Excavations in NC Residual Soils

2014-11 Evaluation of Life Cycle Impacts of Intersection Control

2014-12 Incident Management Assistance Patrols – Assessment of Benefits/Costs, Route Selection, and Prioritization

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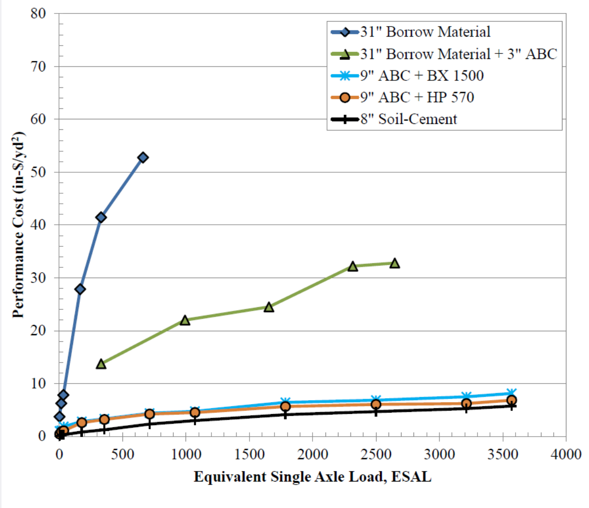
Field Verification of Undercut Criteria and Alternatives for Subgrade Stabilization – Coastal Plain

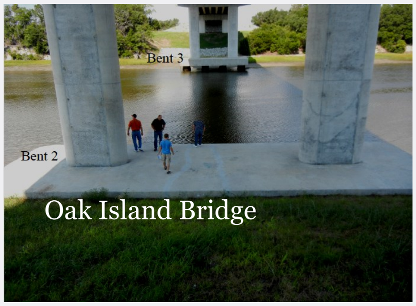
F. Rasay Abadilla, Jr., PE

The NCDOT is progressing toward developing quantitative and systematic criteria that address the implementation of undercutting as a subgrade stabilization measure. As part of this effort, NCDOT has conducted a research project focused on performing full-scale testing in the field on instrumented unpaved roadway sections to collect data for the validation of guidelines developed from the laboratory and modeling study. Full-scale testing in the field was performed on four 16 feet wide by 50 feet long instrumented unpaved roadway sections built on poor subgrade soils encountered in the Coastal Plain region of North Carolina. One test section encompassed undercutting and replacement with select material (Class II), the second and third test sections included reinforcement using a geogrid and geotextile, respectively, in conjunction with undercutting and replacement with ABC (Class IV), and a fourth test section included cement treatment of the soft subgrade soil. Dynamic cone penetrometer (DCP), soil stiffness gauge (SSG), and falling weight deflectometer (FWD) tests were performed on the test pad at various stages of the project to obtain strength and stiffness data in situ for both the subgrade and base layer materials. Full-scale testing was conducted on the test pad by applying 1000 consecutive truck passes using a fully loaded tandem-axle dump truck over a period of four days. During this time visual observations were noted and measurements were collected regarding rut depth, vertical stress increase at the base/subgrade interface, and subgrade moisture content with truck passes. Once the traffic loading was completed, the test pad was re-graded and proof roll testing was performed to look for signs of pumping and rutting.



Average performance cost of stabilization measures based on unit costs from R-3403

Based on the field results, the proposed undercut criteria are evaluated in regard to the ability to discern the need for undercutting as well as predict the performance of the stabilized test sections. Finally, a performance cost analysis was conducted to illustrate the relative cost of each stabilization measure in relation to the measured performance (rutting) such that an informed decision on cost-effective subgrade stabilization can be made. ***Soil-cement stabilization*** was the most economical alternative because of the low initial construction cost as well as low cumulative rutting. However, certain factors such as time, ambient air temperature, expected construction traffic, and the costs associated with repair should be considered prior to implementing soil-cement mixing as a stabilization measure. ***Geosynthetic reinforcement*** tends to have the highest initial construction cost due to the high price of ABC. However, the performance of the geosynthetically reinforced sections outweighs its high initial costs leading to a performance cost that is comparable to soil-cement stabilization. ***Deep undercut (31 inches) and backfill with select material*** has a moderate initial construction cost and performs poorly due to excessive rutting at low truck passes. However, by placing an additional three inch layer of ABC on top of the select material, the vertical confinement curtails the rate of rutting leading to a reduction in performance cost by more than 50%. The principal investigators were Mohammed A. Gabr, Ph.D. and Roy H. Borden, Ph. D., P.E., both of NC State University). [The Final Report for RP2008-13 is available at the NCDOT Research Project Information Page.]



Crack Free Mass Concrete Footings on Bridges in Coastal Environments

F. Rasay Abadilla, P.E.

Large volumes of concrete have the potential to experience temperature gradients because of heat released during curing that can lead to cracking. Cracking of mass concrete in coastal structures is of special concern because of its exposure to saltwater with its corrosive effects on steel reinforcement. The NCDOT identified several mass concrete footings in bridges along the coastal region of North Carolina with cracking problems that needed to be assessed for cracking in light of the current North Carolina mass concrete specifications.

A finite element model was developed to predict the temperature rise and temperature distributions arising from early age concrete hydration, as well as the stresses induced by the resulting temperature gradients. The model was validated by a laboratory experiment and used to analyze several mass concrete footings in bridges in the coastal region of North Carolina for their early age thermal cracking potential. Reasonably sized mass concrete structures that followed the typical NCDOT control plans did not have a high likelihood of significant cracking from thermal stresses, while large mass concrete footings, such as the Wilmington Bypass footing, have a much higher risk of significant cracking, even when the typical NCDOT control plans are followed.

Based on the findings of this research and the evaluation of North Carolina's current mass concrete specifications, additions and revisions to current NCDOT mass concrete specifications were recommended. Research recommendations have been split into two categories: "typical" mass concrete and special cases, referred to as "massive" mass concrete structures. This "massive" mass concrete should currently be defined as a structure with a minimum dimension of 14 feet, based on this research, until future research provides a better definition.

Some of the typical mass concrete recommendations are summarized as follows:

1. A maximum allowable temperature after placement of 158 °F should be specified.
2. Concrete should remain covered and monitored until the difference between the internal concrete temperature and the average daily ambient temperature is below 35 °F, but in no case should the concrete be cured and protected for less than 7 days after placement.
3. Early formwork removal may be allowed based on evidence from match-cured cylinders.
4. Consider material specifications allowing the use of granulated slag replacement of cement by 50 – 70% and/or a ternary mix of granulated slag, fly ash, and Portland cement, where there is at least 20% fly ash by weight and 40% Portland cement by weight. The use of fly ash replacement of cement by 30% is also allowed.
5. Require temperature sensors at the surface nearest to the concrete's center of mass as well as at the farthest surface from the center and at the center of mass itself.
6. Require the Contractor to provide an analysis (preferably using Schmidt's Method with the measured adiabatic temperature curves from a semi-adiabatic calorimetry test) of the anticipated range of peak temperatures, maximum temperature gradients, time to peak temperature, as well as the time it takes to cool to the allowable temperature differential in the mass concrete elements using his proposed mix design, casting procedures, and materials.

The special case recommendations would require more in depth calculations, analysis, and/or monitoring to highlight the special attention these "massive" mass concrete structures require. Additional information for RP2012-09 can be found on the Project Information Site. The report is available by request. Investigators were: Christopher Bobko, Ph.D., Rudolf Seracino, Ph.D. and Paul Zia, Ph.D., all of NC State University

Other Active Research Projects being managed by F. Rasay Abadilla include:

2014-07 Determination of Bridge Deterioration Models and Bridge User Costs for NCDOT Bridge Management System

2014-08 Determination of Vertical Resistance for Sheet Pile Abutments

2014-09 CFRP Strands in Prestressed Cored Slab Units

2014-10 Retaining Wall Inventory and Assessment System

2014-35 Assessment of Deteriorated Cored Slabs: Bridge Nos. 150035 and 150039

New Publications from TRB

Design Guide for Addressing Nonrecurrent Congestion (SHRP 2) Report S2-L07-RR-2

This report catalogs highway design treatments that can be used to reduce nonrecurring congestion and improve the reliability of urban and rural freeways .

Development and Calibration of AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals: National Cooperative Highway Research Program (NCHRP) Report 796

Specifications for structural supports of highway signs, luminaires, and traffic signals for consideration and inclusion in the American Association of State Highway and Transportation Officials (AASHTO) load and resistance factor design (LRFD) methodology are provided in this report.

Highway Design 2014,Volume 1: Transportation Research Record (TRR) No. 2436*

This TRR consists of 16 papers that examine crossover roundabouts; safety effects of using short left-turn lanes at unsignalized median openings; horizontal clearance offsets to objects higher than sight lines; effects of geometric and traffic variables on double left-turn lane operations; and stopping sight distance and horizontal sight line offsets at horizontal curves.

***Please contact NCDOT Research Librarian for access to this publication.**

Roadway Safety Data Interoperability Between Local and State Agencies: National Cooperative Highway Research Program (NCHRP) Synthesis 458

This synthesis provides an overview of the state of the practice regarding the interoperability between state and local safety data. The report also highlights agency practices that supporta data-driven safety program on all public roads.

Thin Asphalt Concrete Overlays: National Cooperative Highway Research Program (NCHRP) Synthesis 464

This synthesis documents the current state of the practice as well as research efforts on the use of thin asphalt concrete overlays for pavement maintenance, rehabilitation, and preservation.

Many more publication links can be found on NCDOT's TRB News Feed

Calendar 0f Events 2015

March 2015

- **NC DOT Board of Transportation Meeting, March 4-5, 2015**
- **NCDOT Centennial Celebration, March 5, 2015**

April 2015

- **NC DOT Board of Transportation Meeting, April 1-2, 2015**
- **National Library Week, April 12-18, 2015**

Librarian's Corner

By Lamara W. Jones with Chris Mulder

In this issue, we want to focus on the *Our State Digital Collection.*

The *Our State Digital Collection* is a collaborative project of the State Library of North Carolina, Our State Magazine, the North Carolina Digital Heritage Center, East Carolina University's Joyner Library, and Caswell County Public Library.

Visit this web site to begin exploring this wonderful new, FREE resource:

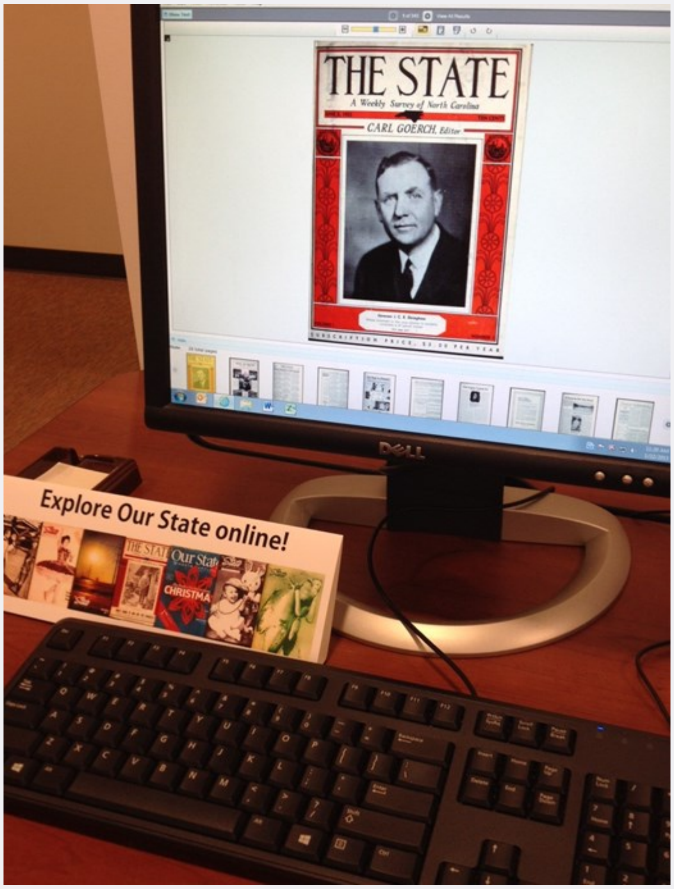
http://digital.ncdcr.gov/cdm/home/ourstate.

You can search, browse and read issues of *The State* and *Our State* from 1933-2011. We found various articles by searching with terms such as: "highway", and "north carolina department of transportation". When you try your own terms you may find yourself venturing off into other paths—there's a wealth of material here! North Carolina has a fascinating history, and these periodicals (The State, and Our State) have been chronicling it for over 80 years.

Here are two interesting article snippets about the history of transportation in North Carolina:

- ***Planning a Superhighway: Charlotte to Greensboro*** Plans for promoting a "master highway" to connect Charlotte and Greensboro were revealed Monday by C. O. Kuester, Chamber of Commerce Manager. The proposed route would extend through Guildford, Randolph, Davidson, Rowan Cabarrus, and Mecklenburg counties … May 20, 1939. (You can read the entire article online.)

- ***North Carolina's First Director of Highways*** Action of the recent General Assembly has changed even the name of North Carolina's Highway Commission eliminating the words "and Public Works." Biggest change is the creation of the new office of Director of Highways, to be filled by William Farrington Babcock, who will have the job of carrying out policies of the new seven-man commission and policy-making body. July 27, 1957. (You can read the entire article online.)



NCDOT Research and Development Unit General Information

How to find us:

We are located at 104 Fayetteville Street, Raleigh, in the Transportation Technology Center (formerly The Raney Building).

The Research & Development web page contains more information about the Unit and what we do.

The Research Library's catalog is also available on the web.

NCDOT RESEARCH AND DEVELOPMENT

The Research & Development Unit oversees transportation-related research that investigates materials, operations, planning, traffic and safety, structures, human environments, natural environments, and more. Please contact one of our engineers listed on this page if you have questions.

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