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Item 1

Ride Specification Review for the Montana Department of Transportation

MONTANA DEPARTMENT OF TRANSPORTATION

FHWA/MT-06-004/8179 • 2006

This report covers the activities that were performed to enhance the current Montana Department of Transportation (MDT) ride specification for flexible pavements. The project team reviewed the MDT ride specification for flexible pavements and compared it with current literature and state of practice. An extensive state-of-practice survey of other Departments of Transportation (DOT's) was conducted and the results were utilized to provide recommendations to MDT for improving its ride specification. This report provides detailed information on the review of MDT current ride specification, literature review, state-of-the practice survey, and recommendations for improvements. The recommendations cover the proposed improvements to the current ride specification, tolerances, project classification levels, analysis tools and indices, and methods of acceptance. As part of the recommendations, a series of new documents (i.e., Profiler Operations Manual, QC/QA Plan) have been developed to enhance future profile data collection and analysis. Based on the findings of this project, the project team have revised the document entitled Method of Sampling and Testing (MT-422) and the document MDT Ride Specification For Flexible Pavement. An implementation plan has been developed and presented in this report to provide MDT with a road map for implementing the findings of this project.

Full-text PDF of this report is available for free download at

http://www.mdt.mt.gov/research/docs/research_proj/ride_review/final_report.pdf

Item 2

Contraflow Transportation Network Reconfiguration for Evacuation Route Planning

MINNESOTA DEPARTMENT OF TRANSPORTATION

MN/RC-2006-21 • 2006

Given a transportation network having source nodes with evacuees and destination nodes, we want to find a contraflow network configuration, i.e., ideal direction for each edge, to minimize evacuation time. Contraflow is considered a potential remedy to reduce congestion during evacuations in the context of homeland security and natural disasters (e.g., hurricanes). This problem is computationally challenging because of the very large search space and the expensive calculation of evacuation time on a given network. To our knowledge, this paper presents the first macroscopic approaches for the solution of contraflow network reconfiguration incorporating road capacity constraints, multiple sources, congestion factor, and scalability. We formally define the contraflow problem based on graph theory and provide a framework of computational structure to classify our approaches. A Greedy heuristic is designed to produce high quality solutions with significant performance. A Bottleneck Relief heuristic is developed to deal with large numbers of evacuees. We evaluate the proposed approaches both analytically and experimentally using real world datasets. Experimental results show that our contraflow approaches can reduce evacuation time by 40% or more.

Full-text of this report is available for viewing at

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Item 3

Intersection Decision Support: Evaluation of a Violation Warning System to Mitigate Straight Crossing Path Collisions

**VIRGINIA TRANSPORTATION RESEARCH COUNCIL
VTRC 06-CR10 • 2006**

This project entailed the design, development, testing, and evaluation of intersection decision support (IDS) systems to address straight crossing path (SCP) intersection crashes. This type of intersection crash is responsible for more than 100,000 crashes and thousands of fatalities each year. In developing these IDS systems for both signalized and stop-controlled intersections, a top-down systems approach was used that determined the necessary system functions and evaluated the capability of different technologies to perform those functions. Human factors tests were also conducted that evaluated the effectiveness of warning algorithms and infrastructure-based driver-infrastructure interfaces in eliciting a stopping response from drivers about to be involved in an SCP intersection crash. Results indicated that further technological development is needed for the sensing and intersection state IDS functions. Furthermore, infrastructure-based warning interfaces tested were greatly outperformed by previously-tested in-vehicle warnings. Thus, future research on IDS systems should focus on their infrastructure-cooperative configuration, where the system supports an in-vehicle warning.

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<http://www.virginia.gov/vtrc/main/online%5Freports/pdf/06-cr10.pdf>

Item 4

Impact of a smoothness incentive/disincentive on hot-mix asphalt maintenance-resurfacing costs

**VIRGINIA TRANSPORTATION RESEARCH CENTER
VTRC 06-R28 • 2006**

Smoothness, the absence of bumps and dips in the riding surface of a pavement, improves the quality of the ride and is believed to prolong the life of the pavement. This research addressed the impact of potential pay adjustments for smoothness on maintenance contract prices for hot-mix asphalt. In addition to the construction costs associated with potential incentives/disincentives for smoothness, the research examined the financial value of the resulting product (presumably smoother pavements). The analysis included maintenance cost savings for the owner/agency, as well as any reduction in delay and operating costs for the motoring public. A detailed statistical analysis of 5 years of Virginia's plant mix resurfacing schedules found no statistically definitive impact on bid price as a result of the Virginia Department of Transportation's (VDOT) special provision for rideability for asphalt pavements. A similar analysis on a more focused data set, however, did document a lifetime reduction in the International Roughness Index (IRI) of almost 9 in/mi. This reduction in roughness (increase in smoothness) implies an increase in pavement service life, which translates into reduced annual maintenance costs. Although the analysis supports as much as 7 years in additional functional life, an example calculation demonstrates that just a 2-year life extension will supply approximately \$1,295 (about 6% of material costs) in owner/agency savings for every lane-mile of highway that is resurfaced under the special provision for rideability. If VDOT continues to employ the special provision with the frequency it has averaged over the past 4 years (1,033 lane-miles per year), using the special provision will save on the order of \$1.3 million per year. The lifetime decrease in roughness can lead to even more dramatic user cost savings. One real example provided in the report demonstrates a fuel cost savings (for trucks alone) of \$160,000 over a 10-year period for each lane mile of highway that is resurfaced under the special provision for rideability. Full-text PDF of this report is available for free download from

<http://www.virginia.gov/vtrc/main/online%5Freports/pdf/06-r28.pdf>



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Item 5

Best practices for the rehabilitation and moving of historic metal truss bridges

VIRGINIA TRANSPORTATION RESEARCH COUNCIL

VTRC 06-R31 • 2006

The Virginia Department of Transportation and the Department of Historic Resources are responsible for the management of about 30 historic truss bridges. All too often, these structures do not meet today's traffic demands or safety standards. Their general deterioration requires disassembly and relocation, rehabilitation and re-erection, or storage. The technology and materials used to build them are no longer in use, and many of the people with practical experience are no longer working. Little information is readily available on safely and effectively identifying and performing necessary operations. VDOT's Knowledge Management Division and the Virginia Transportation Research Council interviewed active and retired engineers, consultants, field personnel, environmental specialists, and architectural historians to collect best practices related to pin-connected and riveted truss bridges. The report is organized using the process followed for the recent rehabilitation of a historic truss in Goshen, Virginia, and discusses the issues faced by those moving and rehabilitating historic metal truss bridges.

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Item 6

Determination of the In-Place Hot-Mix Asphalt Layer Modulus for Rehabilitation Projects

Using a Mechanistic-Empirical Procedure

VIRGINIA TRANSPORTATION RESEARCH COUNCIL

VTRC 07-CR1 • 2006

This project evaluated the procedures proposed by the Mechanistic-Empirical Pavement Design Guide (MEPDG) to characterize existing hot-mix asphalt (HMA) layers for rehabilitation purposes. Thirty-three cores were extracted from nine sites in Virginia to measure their dynamic moduli in the lab. Falling-weight deflectometer (FWD) testing was performed at the sites because the back-calculated moduli are needed for the Level 1 procedure. The resilient modulus was also measured in the lab because it is needed for the Level 2 procedure. A visual pavement rating was performed based on pavement condition because it is needed for the Level 3 procedure. The selected cores were tested for their bulk densities (Gmb) using the AASHTO T166 procedure and then for their dynamic modulus in accordance with the AASHTO TP62-03 standard test method. Then the cores were broken down and tested for their maximum theoretical specific gravity (Gmm) using the AASHTO T-209 procedure. Finally an ignition test was performed to find the percentage of binder and to reclaim the aggregate for gradation analysis. Volumetric properties were then calculated and used as input for the Witczak dynamic modulus prediction equations to find what the MEPDG calls the undamaged master curve of the HMA layer. The FWD data, resilient modulus data, and pavement rating were used to find the damaged master curve of the HMA layer as suggested for input Levels 1, 2, and 3, respectively. It was found that the resilient modulus data needed for a Level 2 type of analysis do not represent the entire HMA layer thickness, and therefore it was recommended that this analysis should not be performed by VDOT when implementing the design guide. The use of Level 1 data is recommended because FWD testing appears to be the only procedure investigated that can measure the overall condition of the entire HMA layer.

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Item 7

Comparison of Virginia's Multimodal Transportation Corridors Using Cost and Demographic Analyses

VIRGINIA TRANSPORTATION RESEARCH COUNCIL

VTRC 07-CR3 • 2006

This effort was performed in support of VTrans2025, Virginia's long-range multimodal transportation plan, and the VTrans2025 Multimodal Advisory Committee. The effort develops a preliminary approach to evaluating multimodal and highway-only corridor plans and policies when the projects comprising the plans and policies are not yet clearly defined. The effort compares Virginia's eleven multimodal transportation corridors using two sources of data: (1) cost, and (2) demographic. With the cost analysis, the report seeks to compare the corridors using capital cost estimates from four readily available sources of data: multimodal agency plans, a highway needs assessment, a statewide highway plan, and MPO/PDC long-range transportation plans. The cost analysis highlights the challenges of preparing and comparing cost estimations, including the non-uniformity of assumptions about constituent projects and overlapping or noncontiguous jurisdictions. The results of the cost analyses suggest needs for the consideration of operations and maintenance costs in comparing corridors, and a consideration of whether the benefits of particular multimodal initiatives in corridors might be equivalent to those of particular highway-only initiatives. With the demographic analysis, population density studies within each of the corridors suggest several corridors have densities that might readily support non-automobile modes. The results of the demographic analyses suggest extending the approach to study accessibility metrics by mode and addressing which spatial scales--local, regional, and statewide--are appropriate for various questions of investment policy. The recommendations identify opportunities for improving coordination among government and stakeholder organizations that are engaged in cost and benefits analyses for long-range multimodal transportation planning. Cost-benefit analysis of major transportation projects is required by the recent Transportation Act of the Commonwealth of Virginia.

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Item 8

Benefits Estimates of Highway Capital Improvements with Uncertain Parameters

VIRGINIA TRANSPORTATION RESEARCH COUNCIL

VTRC 07-CR4 • 2006

This report warrants consideration in the development of goals, performance measures, and standard cost-benefit methodology required of transportation agencies by the Virginia 2006 Appropriations Act. The Virginia Department of Transportation has begun to implement a quantitative methodology as an aid to prioritizing highway construction projects in four categories: interstate, primary, urban, and rural. The methodology adopts fifteen quantitative metrics including level of service (LOS), volume-to-capacity ratio, traffic flow, intermodal access, crash rate, emergency route access, heavy truck usage, unemployment rate, environmental issues, right-of-way use, use of alternative transportation modes, bridge sufficiency rating, and cost-effectiveness. The results of the methodology are used by executive review teams to negotiate, interpret, and support decisions regarding the selection of construction projects for funding in a \$1.8 billion construction program. This report describes an effort to extend the current prioritization methodology via modeling and uncertainty analysis of the risk reductions, benefits, and costs that are expected of candidate construction projects. The report (1) develops monetized estimates of benefits in several categories including crashes avoided, travel time saved, fuel uses avoided, and emissions avoided; (2) compares the estimates of benefits to the estimates of project costs, representing the uncertainty of the results as numerical intervals; and (3) compares the results to the results of the prioritization methodology that is currently in use. The major contribution of the report is the assembly of existing and new methods of benefits assessment via an interval analysis of uncertainty that enables a prioritization to proceed with sparse data on a large number of potential projects. With the interval analysis of uncertainty, a decision maker is provided with a sound basis to recommend that more data are needed or that existing available data are sufficient to distinguish among the potential projects. The developed methodology is demonstrated with project data from VDOT's Northern Virginia District using a database of performance criteria of 53 candidate projects ranging in cost from \$2 million to \$130 million. A prototype of a prioritization software was developed along with the report for the support of future analyses.

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Item 9

Use of the Digital Surface Roughness Meter in Virginia

VIRGINIA TRANSPORTATION RESEARCH COUNCIL

VTRC 07-R4 • 2006

Pavement surface texture is measured in a variety of ways in Virginia. Two methods commonly used are ASTM E 965, Standard Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique, known as the "sand patch" test, and ASTM E 2157, Standard Test Method for Measuring Pavement Macrotexture Properties Using the Circular Track (CT) Meter. In September 2005, staff from the Virginia Transportation Research Council inquired about using the Digital Surface Roughness Meter (DSRM®) to measure the surface texture of several concrete and asphalt surfaces. Measurements were taken on concrete and asphalt surfaces using the DSRM®, CT meter, and sand patch test, and the results were compared. From the data obtained, there appears to be a good correlation among the results of the three methods. The DSRM® and sand patch tests appear to be more accurate on surfaces that are not uniform. However, this may be because the center of the rotating arm of the CT meter may have missed particular non-uniform areas on the testing surface. The use of the DSRM® and CT meter devices also reduces the probability of human error. The sand patch test is exposed to a greater probability of human error; it is a test that cannot be performed quickly without comprising accuracy. The DSRM® is a better device to use under a time constraint.

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Item 10

Using Fiber-Optic Sensor Technology to Measure Strains Under the Asphalt Layer of a Flexible Pavement Structure

VIRGINIA TRANSPORTATION RESEARCH COUNCIL

VTRC 07-R5 • 2006

In this study, a flexible pavement system was instrumented using fiber-optic strain sensors (FOSS). The purpose of this study was to demonstrate the feasibility of a FOSS installation, monitor the long-term strains under repeated traffic loading, and compare the measured strains with the calculated ones from multi-layer elastic (MLE) analysis. MLE analysis was performed before and after FOSS installation to monitor strains during and after construction. In-situ strains during construction under the hot-mix asphalt (HMA) delivery truck, paver operations, and roller operations were compared to the results of theoretical MLE analysis. In addition, in-situ strains after construction under dump truck and falling weight deflectometer (FWD) loadings at multiple load levels were compared to the results of theoretical and in-situ MLE analysis. The in-situ strain under construction was at least 50 fold that obtained with MLE analysis. The FOSS were sensitive enough to collect strain measurements during construction at very high construction temperatures and moisture conditions. Further, the MLE analysis results were very close to the measured deflection under dump truck and FWD loadings. The results show that MLE analysis can be used to validate and calculate the strains in asphalt pavement sections. Long-term performance monitoring is continuing, and the study will be repeated after FOSS placement in new HMA pavement sections. Understanding the behavior of asphalt pavement under repeated traffic loads can result in an optimized design, thus reducing the rehabilitation costs associated with premature failures or the higher costs associated with conservative asphalt pavement designs. The in-situ strains can be used to calibrate mechanistic-empirical pavement design guide (MEPDG) performance models for local conditions so that measurements can better predict the life of pavement layers and the layers that will need replacement. The installation of FOSS at selected pavement sites that represent the typical pavement designs across the state would allow for the development of accurate statewide mechanistic-empirical performance models, which would lead to more cost-effective pavement rehabilitation decisions.

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Item 11

An Evaluation of the Performance of Concretes Containing Fly Ash and Ground Slag in Bridge Decks

VIRGINIA TRANSPORTATION RESEARCH COUNCIL

VTRC 07-R7 • 2006

Cores from 36 bridge decks were evaluated to assess the condition and quality of the concrete by petrographic methods and direct and indirect measures of the transport properties. Transport properties were measured by a rate of absorption test (ASTM C 1585) and by electrical conductance using the rapid chloride permeability apparatus (ASTM C 1202). The decks were distributed across Virginia to reflect the varied geographic and climatic regions. Two bridge age groups, each constructed under different specifications, were represented: (1) from 1968 through 1971, where portland cement concrete with a maximum specified water-cementitious material ratio (W/C) of 0.47 was used with uncoated reinforcing steel; and (2) from 1984 through 1991, where the specification required a maximum W/CM of 0.45, required epoxy-coated reinforcement, and allowed the use of fly ash or ground slag as supplementary cementitious materials. The older group included 10 decks, and the younger included 26. In the younger group, 8 were identified as containing fly ash and 7 were identified as containing slag. Five of the concretes exhibited excessively high spacing factors, suggesting susceptibility to freezing and thawing damage, although only two showed signs of such damage. Four of the decks exhibited excessively small spacing factors that could significantly affect strength. Signs of poor paste quality attributable to excessive water were noted in approximately one-third of the concretes. Cracking was of significance in 12 decks but was limited to paste cracking in 6; of these, 5 contained either fly ash or slag. Four showed signs of damage related to alkali-aggregate reactions, including 3 with carbonate rocks, 1 of which contained slag. A general assessment based on petrographic observations showed a fairly even distribution of good, fair, and poor ratings. Fly ash and slag concretes tended to have initial rates of absorption in the lower third, often despite their petrographic rating, suggesting they are providing beneficial reductions in transport properties in field concretes. The secondary (longer term) rate of absorption related better with the petrographic ratings, and the fly ash and slag concretes again tended to have lower rates. Of the fly ash and slag concretes exhibiting paste cracking, only one consistently had high absorption rates. In contrast to the rate of absorption results, the electrical conductivity results suggested little differences between the concretes, raising questions about its usefulness in evaluating mature field concretes. This study demonstrates the beneficial contributions that fly ash and ground slag as supplementary cementitious materials provide to concrete durability, and they should continue to be used as an integral part of efforts to increase the service life of concrete structures.

ASTM C 1585 provides a direct measure of the transport properties of concrete and should be incorporated into both the concrete materials acceptance and asset evaluation and management programs.

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