MPC-459

April 1, 2014- July 31, 2017

**Project Title:**

Comparison between 1993 AASHTO Pavement Design Guide and Mechanistic-Empirical Pavement Design Guide with North Dakota Case Study.

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**Research Needs:**

The rapid growth of heavy truck traffic in the oil-impacted western counties of North Dakota poses unique challenges to the highway infrastructure of a historically low-volume rural region. Repeated heavy loads, combined with areas of weak subgrade and freeze-thaw cycles, have caused many roads to fail long before their intended design life (Governing, 2011). Oilfield pavement analyses conducted thus far have utilized the empirical design methods outlined in the 1993 AASHTO Guide for Design of Pavement Structures, based on the AASHO Road Test of the late 1950’s. While the AASHTO 1993 Guide has proven an important tool for several decades, its empirical approach limits its effectiveness as a modern pavement design method (NCHRP 2004).

Several studies have claimed that traffic is a controversial parameter in the 1993 AASHTO Guide. The fact that the guide relies on a single value (i.e. ESAL) to represent the overall traffic spectrum is questionable (Schwartz and Carvalho 2007). Zhang et al. (2000) have found that the ESAL, used to quantify damage equivalency in terms of serviceability or even deflections in the 1993 AASHTO Guide, is not enough to represent the complex failure modes of flexible pavements. Today it is widely accepted that load equivalency factor is not a sufficient technique for incorporating mixed traffic into design equations. In addition, the trucks used during the AASHO Road Test were modest in comparison to the trucks utilized in the oil industry today. The models developed and modified from the Road Test relate key pavement properties and traffic to performance but do not consider the range of climatic effects that can also contribute to pavement distress. In addition, the performance index used in the 1993 AASHTO Design Guide relies on an empirical assessment of the overall pavement surface quality. The pavement serviceability index (PSI) is the evaluation users give about the road surface condition, as defined during the AASHO Road Test. PSI cannot be measured and therefore it was correlated to ride quality and other smoothness indices in research done during the period of the mid-1980’s to mid-1990’s. Currently, distresses measured directly on the pavement surface are more accepted as performance measures. They provide a better representation of failure mechanisms and can be modeled directly using site-specific characteristics.

To address some of the limitations of its original design guide, AASHTO in 2004 published the Mechanistic-Empirical Pavement Design Guide (MEPDG). This new design procedure incorporates mechanistic principles, including calculations of pavement stress, strain and deformation responses using site-specific climatic, material, and traffic characteristics. It replaces the 1993 guide’s subjective-based performance index, PSI, with objective distress models for various modes of pavement failure and allows calibration of the distress models in order to allow the design method to represent each region’s unique conditions.

The new guide is a significant departure from traditional pavement design procedures and its implementation requires road agencies to overcome some challenges. However, in the current climate of increasingly urgent infrastructure needs and shrinking funding, it is important for agencies to identify cost effective and structurally adequate pavements that serve stakeholders for their full design life. It is also important for an agency to know, before undertaking a change in design method, whether MEPDG-designed pavements will indeed show performance benefits over their empirically-designed counterparts.

**Research Objectives:**

Fully understanding the performance and reliability of the new design guide is important for agencies wanting to use it. Moreover, understanding the design differences between the current design guide and the newer MEPDG is critical for agencies interested in making the switch.

The primary objective of this project is to provide a critical comparison of performance predictions for pavement designed using the 1993 AASHTO Guide against pavements designed using the new design guide, in order to better assist North Dakota agencies in making the decision whether to switch to MEPDG.

**Literature Review**

Several previous studies have compared the performance of pavements designed using the two major design guides. Schwartz and Carvalho in 2007 demonstrated variability in performance predictions across pavements designed for the same terminal serviceability in 1993 AASHTO – suggesting that the older design method does not adequately account for some factors that are included in the MEPDG distress models. The study found that the 1993 Guide showed increased variability in pavement performance at traffic levels far exceeding the 1 million axle loads that were the limit of the AASHO Road Test. Further, the guide tends to overestimate performance (i.e. underestimate required pavement thickness) for these high traffic pavements. The study also found that, while surface layer thickness in the 1993 method is insensitive to subgrade strength, this assumption is not always correct. Indeed, Schwartz and Carvalho demonstrated high performance variability across AASHTO-designed pavements with different subgrade conditions.

A 2011 study (El-Badawy) supports the assertion that AASHTO 1993 method does not properly account for weak subgrades, finding on 8 pavement sections in Idaho that, at high reliability levels, MEPDG yielded asphalt concrete layers 1-2 inches thicker than the AASHTO 1993 method. The largest differences were on segments with weak subgrades.

Subsequent studies (Li *et al.* 2009; Fick 2010; Gedafa 2011) have indicated that the 1993 method in fact underestimates pavement performance, resulting in thicker, less cost-effective pavements. Li et al. compared high-volume flexible pavements in Washington and found that MEPDG consistently produced thinner asphalt concrete layers that met performance criteria. On five flexible pavement segments in Kansas, Gedafa demonstrated that MEPDG designs resulted in thinner pavements every time.

These studies indicate a number of limitations in the 1993 AASHTO design method, however, none have focused on pavements in the oil-impacted areas of the Upper Great Plains which will be the basis for this study. Moreover, most of previous comparison studies used early versions of MEPDG software. The software has been updated significantly since its earliest beta version. The latest version of the software (AASHTO Pavement ME™), v1.3.29, released July 2013, will be used in this study.

It is important to note that some comparison studies (Fick 2010; El-Badawy 2011) have based their comparisons upon nationally calibrated MEPDG models. Other studies have indicated, however, that local calibration significantly improves distress predictions (Schwartz 2007; AASHTO 2010; Kim *et al.* 2010). Because this local calibration is recommended before an agency-wide MEPDG implementation (AASHTO 2010), it is also an important antecedent to this study. UGPTI is currently undertaking a North Dakota local calibration effort, with the resulting distress coefficients to be used in this study.

**Research Methods:**

The following three potential comparison approaches have been included in the scope of the study:

1. Compare AASHTO 1993 pavement thickness with structurally adequate MEPDG pavement thickness to determine whether AASHTO 93 overestimates or under-estimates performance relative to MEPDG.
2. Design several different pavement segments for a common terminal serviceability using AASHTO 1993 Design Guide, then simulate the resulting designs in MEPDG and determine the extent of variation in distress predictions despite a constant terminal serviceability.
3. Simulate existing pavement structures (designed by AASHTO 1993) in MEPDG and compare measured (i.e. actual) field performance with predicted performance from AASHTO 1993 and MEPDG

The first two comparisons will address the key differences between the two procedures. They will allow for a quantification of these differences and evaluate whether they are significant for the flexible pavements in the Upper Great Plains region. The third comparison is the most important. It will provide a means of verifying the accuracy of both procedures. In addition, the third comparison will provide important data to investigate the need for local calibration of MEPDG models.

The following major steps have been included in the scope of the study:

Step 1: Literature Review: A national and state literature review pertaining to comparison of pavement performance between MEPDG and AASHTO 1993.

Step 2: Data Collection: the primary inputs required to run MEPDG include:

* Site selection, including several test sites with a focus on western North Dakota
* General site information, such as design life, construction factors, and design reliability
* Analysis parameters, such as pavement conditions, pavement key distresses and smoothness
* Pavement structure, such as pavement foundation/subgrade, layer thickness, and paving materials (design and as-built)
* Environmental factors such as temperature and moisture
* Traffic characterizations, baseline volume, vehicle distribution, axle load spectra
* Locally calibrated (for North Dakota) pavement distress parameters  
    
  UGPTI is currently preparing data inputs for North Dakota MEPDG analysis on all three input levels as part of a separate local calibration project. This data will include selected Level 1 traffic and materials data as well as Level 3 data.

Step 3: Analysis and Evaluation:

* AASHTO 1993 20-year design with traffic growth based on recent counts for general comparison
* AASHTO 1993 analysis using original design period for comparison number 3
* Build AASHTO 93 design in locally calibrated (for ND) MEPDG software
* Run 20-year analysis to check if AASHTO 93 design meet MEPDG performance thresholds
* Design the same segments again in MEPDG to meet performance thresholds
* Compare design thicknesses to review differences in design

Step 4: Final Report: A final report will summarize all the tasks and findings including: (1) summary of input, (2) summary of methods, (3) summary of findings, and (4) recommendations.

**Expected Outcomes:**

In North Dakota, state agencies face the challenge that heavy truck traffic in oil-impacted regions has and will likely continue to increase dramatically. Currently, many roads impacted by oil-related traffic fail long before their intended design life (Governing, 2011). In these regions, then, pavement analysis with a robust design method which incorporates a more complete understanding of modern truck configurations is needed. Further, understanding the differences and potential benefits of shifting the design method from the current AASHTO 1993 practice to MEPDG is critical.

The project will explore the use and comparison of 1993 AASHTO pavement design guide and MEPDG. It will evaluate and compare the 1993 AASHTO and MEPDG pavement design and pavement performance. Moreover, the project will review how different pavement design guides incorporate oil-related traffic issues and how different given pavements will perform under the two different design methods.

The project will directly provide a critical comparison of performance predictions of pavement designed using the 1993 AASHTO Guide against pavements designed using MEPDG, in order to better assist North Dakota agencies to make the decision to switch to the MEPDG.

There is no doubt that the research project findings and contributions will advance the implementation of the MEPDG and promote the application of MEPDG among NDDOT agencies.

**Relevance to Strategic Goals:**

The research project and its potential outcomes directly related to State of Good Repair and Livable Communities. The project directly focuses on evaluating a sophisticated pavement design guide to provide a better lasting pavement and better prediction of pavement performance which in turn will provide livable communities and assist a better state of good repair decisions.

**Educational Benefits:**

Students who are interested in learning pavement design, pavement performance, and pavement preservation decision making can be involved in the project on various levels by studying differences between 1993 AASHTO design guide and MEPDG.

**Work Plan:**

All the project tasks will be completed from October 1, 2013 to September 30, 2015. The last one and half months of the project will be dedicated to reviewing and finalizing the final report.

**Project Cost:**

Total Project Costs: $150,000

MPC Funds Requested: $75,000

Matching Funds: $ 75,000 Source of Matching Funds: NDSU

**TRB Keywords:** Asphalt Pavement; Highway Design; Pavement; Pavement Design; Industrial Trucks;

**References:**

American Association of State Highway and Transportation Officials (AASHTO). (1993). *AASHTO Guide for Design of Pavement Structures,* Amer Assn of State HWY (June 1993), Washington, D.C. U.S.A., ISBN-10: 1-56051-055-2, 640 pp.

American Association of State Highway and Transportation Officials (AASHTO). (2008). *Mechanistic-Empirical Pavement Design Guide*. AASHTO Designation: MEPDG-1. Washington, D.C.

AASHTO. (2010). Guide for the Local Calibration of the Mechanistic-Empirical Pavement Design Guide. American Association of State Highway and Transportation Officials, Washington, D.C.

Applied Research Associates Inc. *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures (NCHRP 1-37A report).* ERES Consultants Division, Urbana Champion, IL, 2004.

Governing, North Dakota’s Oil Boom is a Blessing and a Curse. <http://www.governing.com/topics/energy-env/north-dakotas-oil-boom-blessing-curse.html>. Accessed at Aug. 2013.

El-Badawy, S.M., F.M. Bayomy, M. Santi, and C.W. Clawson. (2011). Comparison of Idaho Pavement Design Procedure with AASHTO 1993 and MEPDG Methods. American Society of Civil Engineers, Reston, VA.

Fick, S. (2010). Evaluation of the AASHTO Empirical and Mechanistic-Empirical Pavement Design Procedures Using the AASHTO Road Test. University of Maryland, College Park, MD.

Gedafa, D., J. Mulandi, M. Hossain, G. Schieber. (2011). Comparison of Pavement Design Using AASHTO 1993 and NCHRP Mechanistic-Empirical Pavement Design Guides. American Society of Civil Engineers, Reston, VA.

Kim, S., H. Ceylan, K. Copalakrishnan, O. Smadi, C. Brakke, and F. Behnami. (2010). Verification of Mechanistic-Empirical Pavement Design Guide (MEPDG) Performance Predictions Using Pavement Management Information System (PMIS). Transportation Research Board 2010 Annual Meeting, TRB Paper 10-2395, Washington, D.C.

Schwartz, C. W. (2007). *Implementation of the NCHRP 1-37A Design Guide Final Report Volume 1: Summary of Findings and Implementation Plan*. MDSHA Project No. SP0077B41, Maryland State Highway Administration, Lutherville, MD.

Schwartz, C.W. and Carvalho, R.L. (2007). *Implementation of the NCHRP 1-37A Design Guide Final Report Volume 2: Evaluation of Mechanistic-Empirical Design Procedure*. MDSHA Project No. SP0077B41, Maryland State Highway Administration, Lutherville, MD.

Zhang, Z., J.P. Leidy, I. Kawa, and W.R. Hudson. (2000). *Impact of changing Traffic Characteristics and Environmental Conditions on Flexible Pavement*. Transportation Research Record 1730, Washington, D.C., pp. 125-131