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Executive Summary Report

Improved Characterization of Truck Traffic Volumes and Axle Loads for Mechanistic-Empirical Pavement Design

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Project Background

Traffic is one of the primary inputs in pavement design. Traditional pavement design procedures account for traffic using the equivalent single axle loads (ESAL's) accumulated during the life of the pavement structure. This procedure is based on converting each individual axle with a specific weight and configuration into an equivalent number of standard 18-kip (80 kN) single axle loads. The equations used in this procedure are based on outdated data obtained from road tests performed over a two year time period in the late 1950's in Ottawa, Illinois. Since these tests were carried out at a single test site, these equations may not be representative of the various environments, materials, and drainage conditions encountered at other locations. Another limitation of these equations is that testing was conducted over a two year time span, which is a relatively short period in terms of pavement design since it does not account for the effect of the environment on the performance of the pavement structure. Furthermore, the size and volume of vehicles have significantly increased over the last six decades, and therefore this procedure is not representative of current vehicle loads and pavement designs. Finally, this procedure introduces a degree of uncertainty that is difficult to quantify because it depends on the pavement type and structure, pavement condition, environmental conditions, and the failure criteria being evaluated. As a result, the use of ESAL's can limit the accuracy of the resulting pavement design.

Recent efforts under the auspices of the National Cooperative Highway Research Program (NCHRP) have resulted in the development of a Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures. The recently developed design guide, referred to thereafter as the mechanistic-empirical pavement design guide (MEPDG), offers unique features that have long been recognized as limitations in the previous American Association of State Highway and Transportation Officials (AASHTO) design guides. Among these features are the introduction of mechanistic-empirical procedures in predicting performance; the accommodation of changes in material properties over time; and the representation of traffic using axle load spectra by axle type. To fully utilize these features, a multitude of project-specific input data need to be defined including the proposed pavement structure, material properties, traffic information, and environmental conditions. Since it is not always practical to obtain this information, the MEPDG assimilates a hierarchal level concept upon which data may be input. Three input levels are suggested in the MEPDG for traffic characterization; the highest input level

(Level 1) requires project-specific traffic data, while the lowest input level (Level 3) relies on national (default) traffic inputs. The selection of the design input level primarily depends on data availability and the importance of the pavement structure under investigation.

To accommodate the transition to the mechanistic-empirical pavement design approach, the MEPDG requires more detailed traffic information, including (a) base-year traffic data such as the initial two-way annual average daily truck traffic (AADTT), (b) traffic volume adjustment factors (directional and lane distribution factors, vehicle class distribution, monthly adjustment factors, hourly truck distribution factors, and traffic growth factors), (c) axle load spectra by truck class (Class 4 to Class 13) and axle type (single, tandem, tridem, and quad), and (d) general traffic inputs (lateral truck traffic wander, number of axles per truck, axle configuration and wheelbase distributions, and tire characteristics and inflation pressure). Accordingly, to advance the implementation of the MEPDG in Ohio, there is an urgent need for an automated tool to assemble traffic volume and axle load information from operational traffic monitoring systems within the state. This tool shall be capable of generating traffic inputs in a format that can be directly imported into the MEPDG. This research is very timely and critical given the fact that several states have already started using the MEPDG in the design of their pavement structures and that the Ohio Department of Transportation (ODOT) is expected to adopt this new design method in the near future.

Study Objectives

The main objectives of this study were to:

- Develop a methodology to obtain the required MEPDG traffic inputs at the various input levels using available traffic monitoring data.
- Implement the developed methodology into user-friendly software that can be used by ODOT engineers to generate the required MEPDG traffic inputs.

Description of Work

This study included a thorough review of literature on topics related to the analysis of traffic data for use in the MEPDG. The hierarchical approach and the various traffic inputs used in the MEPDG were summarized to highlight their importance in pavement design. Additionally, the ESAL approach used by ODOT to characterize traffic for pavement design was summarized to provide a comparison between the MEPDG and the AASHTO design method. Furthermore, the traffic monitoring practices used in Ohio were evaluated to provide insight into the type and quality of data that is obtained by ODOT.

The data set used in this study was provided by ODOT Traffic Monitoring Section. The data was collected using permanent traffic monitoring sites distributed throughout the State of Ohio from 2006 to 2011. The total number of sites was 143 (93 AVC and 50 WIM sites) with the majority of these sites located along roadways classified as FC 1 (rural interstate), FC 2 (rural principal arterial), FC 11 (urban interstate), and FC 12 (urban freeway). Prior to analyzing the traffic data to obtain the required MEPDG traffic inputs, considerable efforts were made to identify and exclude erroneous data. This quality control process was used to detect invalid data entries, outliers, and trends that would otherwise be unrecognizable due to the large amount of data and the variations that occur over the collection period. This process was critical in ensuring that the generated traffic inputs accurately portrayed the traffic characteristics at each AVC and WIM location.

This study also included the development of a VBA code to analyze the traffic monitoring data. VBA is an event-driven programming language that is available in several Microsoft Office applications including Microsoft Excel. The VBA code was used to generate statewide traffic inputs based on functional classification and truck traffic classification. Furthermore, cluster analysis was used to group sites based on the axle load spectra of Class 9 tandem axles in order to obtain the statewide axle load spectra. The analysis was performed based on Class 9 tandem axles because they are the most common types of axles, and their axle load spectra consistently fall within expected weight ranges. The cluster analysis results were incorporated into the VBA code, thus allowing the user to generate Level 1 (site-specific), 2 (statewide averages), and 3 (MEPDG default) traffic inputs. The generated traffic inputs are created in a standard text format that can be directly imported into the MEPDG.

Finally, the sensitivity of the MEPDG to the various traffic inputs was evaluated using two baseline pavement designs, one for a new flexible pavement and one for a new rigid pavement. Site 715 was used to obtain site-specific traffic data (Level 1) for both baseline flexible and rigid pavements. This site is located along interstate 71 between Columbus and Cincinnati. The interstate at that location has two lanes per direction and is classified as a rural interstate (FC 1). The key performance parameters for the flexible pavement included longitudinal (top-down) fatigue cracking, alligator (bottom-up) fatigue cracking, transverse (low-temperature) cracking, rutting (HMA rutting and total rutting), and smoothness expressed using IRI, while the key performance parameters for the rigid pavement included transverse cracking (% slabs cracked), joint faulting, and smoothness expressed using IRI. Each individual traffic input was then varied to determine the impact of using Level 2 (statewide average) or Level 3 (MEPDG default – national average) analysis on pavement performance. This comprehensive sensitivity analysis was used to the influence of each traffic input on pavement design.

Research Findings & Conclusions

The following is a summary of the key findings and conclusions of this study:

- ODOT has an extensive traffic monitoring program that includes more than two hundred continuous (permanent) monitoring sites supplemented with a large number of short-term counts conducted by ODOT personnel on a periodic basis. The locations of these sites are dispersed across the State of Ohio to represent a large number of regions and roadways. ODOT's traffic monitoring program is more comprehensive than most DOT's and state highway agencies.
- To calculate the AADT from short-term counts, ODOT uses a series of seasonal adjustment factors to account for the variations in traffic during the year. All sites within the same functional classification are combined to determine the seasonal adjustment factors for each day of the week and month of the year. However, unlike the AADT, ODOT does not use any adjustment factors to estimate the AADTT from short-term counts. Since short-term counts are typically collected Mondays through Thursday when truck traffic is significantly higher than the rest of the week, this results in an overestimation of the AADTT by approximately 15% to 25% leading to a more conservative pavement design.
- By analyzing the historical traffic data at a large number of sites in Ohio, it was determined that the growth rate for AADT is not necessarily indicative of the growth rate for AADTT. Additionally, the growth rate was found to be significantly influenced by the traffic monitoring period over which the growth rate is estimated. It was also found that a minimum traffic monitoring period of 20 years (with ideally 25 years) was sufficient in predicting the overall truck traffic growth.
- ODOT currently uses the B:C ratio to describe the vehicle (truck) class distribution for different functional classifications. Based on the findings in this study, it was determined that vehicle (truck) class distribution cannot be accurately estimated from the B:C ratio due to a lack of correlation between the B:C ratio and functional classification. The vehicle (truck) class distribution was found to be more accurately determined when short-term counts and seasonal adjustment factors are used for each truck class. The application of these seasonal adjustment factors reduced the difference between the daily truck class distributions and the annual truck class distributions, especially for truck Classes 5, 6, and 11. Additionally, the use of statewide average axle load spectra was found to be more accurate than the MEPDG default values and should be used when site-specific data is not available.
- The sensitivity analysis results revealed that flexible pavements are moderately sensitive to AADTT, growth rate, vehicle class distribution, and axle load spectra; and not sensitive to hourly distribution

factors, monthly adjustment factors, and number of axles per truck. It was also found that rigid pavements are moderately sensitive to AADTT, growth rate, hourly distribution factors, vehicle class distribution, and axle load spectra; and not sensitive to monthly adjustment factors and number of axles per truck.

Implementation Recommendations

The following table presents a summary of recommendations pertaining to the selection of the traffic inputs for mechanistic-empirical pavement design using the MEPDG in Ohio. While Level 1 is expected to provide the most accurate pavement design, these recommendations allow for the use Level 2 or Level 3 analyses for some inputs without compromising the quality or accuracy of the pavement design. These recommendations allow for a seamless transition from the current traffic analysis procedure used by ODOT for pavement design to the new MEPDG.

Traffic Input	Recommendation
AADTT	This traffic input shall be obtained from ODOT Traffic Monitoring Section.
D(%)	Use 50% (current ODOT value) for all roadways.
LF(%)	Level 2 (statewide average). Recommended values: 100% for 2-lane roadways, 95% for 4-lane roadways, 80% for 6-lane roadways, and 70% for 8 or more lane roadways.
Operational Speed	This traffic input shall be obtained from ODOT Traffic Monitoring Section.
MAF	Level 3 (MEPDG default).
VCD	This traffic input shall be estimated from a combination of site-specific short-term counts (Level 1) and seasonal adjustment factors for each truck class. The short-term counts shall be obtained from ODOT Traffic Monitoring Section. Level 2 (statewide average based on functional classification) analysis can be used for locations where site-specific data is not available.
HDF	Level 3 (MEPDG default) for flexible pavements and Level 2 (statewide average based on functional classification) for rigid pavements.
Growth Rate	This traffic input shall be obtained from ODOT Modeling and Forecasting Section (Certified Traffic).
ALS (Single, Tandem, Tridem, and Quad)	Level 2 (statewide average based on information from all sites)
No. of Axles per Truck	Level 2 (statewide average based on information from all sites)
Lateral Wander	Level 3 (MEPDG default)
Axle Configuration	Level 3 (MEPDG default)
Wheelbase Distribution	Level 3 (MEPDG default)