National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

Mechanistic Comparison of Wide-Base Single Versus Dual-Tire Configuration

RESEARCH SYNOPSIS–NCAT REPORT 05-03

Problem Statement

In an effort to increase trucking efficiency, the commercial tire industry has produced wide-base single tires that can replace the standard dual-tire configuration. Although wide-base tires can offer benefits like increased fuel economy and cargo capacity, previous studies have shown that they may cause premature highway distress. Many agencies have restricted the use of wide-base single tires to preserve the integrity of their highway infrastructure.

Objective

The National Center for Asphalt Technology (NCAT) conducted a study of standard dual-tire and wide-base single-tire configurations with the following goals:

1. Model the two tire configurations, and predict the pavement response and effect of the wide-base tire using a layered elastic computer model.
2. Measure and compare the field dynamic pavement response of the two tire configurations.
3. Evaluate the effectiveness of the computer model in predicting the pavement response for both tire configurations.

Figure 1 A standard dual-tire configuration (left) and a wide-base single tire (right).

Description of Study

To accomplish these objectives, measured and predicted pavement responses were determined for the NCAT Pavement Test Track trucks with the standard dual (275/80R22.5) tires and newly developed single wide-base tires (445/50R22.5). Field testing was conducted on one test section on the test track over two days.

Prior to field testing, simulations were conducted using a linear layered elastic program to predict the strain and stress in the pavement structure under load. The results from this analysis indicated what could be expected in the field, and the results were compared to the field analysis to indicate the accuracy of the theoretical models.

Theoretical Analysis

At the time of this study, linear layered elastic models were the state-of-the-practice for pavement analysis and design and, therefore, were an appropriate model to evaluate. WESLEA for Windows was the analysis program used to predict the pavement response and corresponding predicted performance under the two loading conditions. This program uses linear layered elastic theory to calculate stress and strain at specified locations within the pavement structure under circular tire loads. In this study, the program was used to calculate the response at three critical locations in the pavement structure corresponding to gauge locations in the actual test section. The predicted responses were then compared to the measured field responses to determine how accurately the program evaluated the effect of wide-base tires on pavement response.

The cross-section and material properties of the test section were first modeled in WESLEA. The most recent, accurate information was used, including the as-built surveyed pavement thickness and the unbound material properties from the backcalculated falling weight deflectometer (FWD) data. Because hot-mix layer properties are dependent on temperature, the modulus was taken from the temperature-moduli relationship established from months of backcalculated data based on the mid-depth asphalt temperature during testing. The applied load in WESLEA was characterized by the tire configuration, load per tire and tire-inflation pressure, obtained through measurements of the test vehicle. These inputs were then used to define a circular-loaded area of uniform pressure in the specified load configuration.

In all WESLEA simulations, the theoretically-calculated stress or strain significantly increased under the wide-base tire compared to the dual configuration.

Key Findings from Theoretical Analysis

Horizontal tensile strain at the bottom of the asphalt layer and vertical pressure at the top of the base are the two pavement responses considered most critical to asphalt pavement performance. In all WESLEA simulations, the theoretically calculated stress or strain significantly increased under the wide-base tire compared to the dual configuration.

Horizontal tensile strain was most severely affected, with a predicted strain increase of 46 percent. Additionally, the vertical stress on the base and subgrade layers also increased by 25 and 11 percent, respectively, which could lead to increased deformation in those layers.

Using the calculated strain from WESLEA and performance equations developed at the Minnesota Research Project (Mn/ROAD), it appeared that the single-tire configuration would reduce the asphalt pavement life. Theory predicts that the fatigue life under the wide-base single tire would be 69 percent less than the conventional dual-tire configuration under the same axle load.

Field Testing

Field testing was conducted over two days in October 2004 on Section N5 at the test track. Section N5 is a seven-inch HMA pavement over six inches of aggregate base over the soil. The HMA was PG 76-22 in all three lifts. Dynamic pavement response under the two loading conditions was measured via asphalt strain gauges and earth pressure cells. The data were collected from multiple truck passes of each loading configuration in order to compare pavement responses and investigate the accuracy of the layered elastic analysis.

To ensure that the only experimental variable was the tire configuration, the same test vehicle was used to guarantee identical axle-load magnitude and distribution. Additionally, the same driver was used for both tests. The driver was instructed to maintain a speed of 45 mph and to drive so that the vehicle aligned with the gauges in the outside wheel path of the lane. Fifteen truck passes were recorded for each of the loading configurations to help guarantee a direct hit on the gauges. The tests were also run at similar pavement and air temperatures to provide comparable strain and pressure readings.

Once confidence was established in the testing scheme, the responses under the two tire configurations were compared. The maximum recorded value among the strain gauge array was determined for each of the 15 truck passes. (The maximum recorded value is considered to correspond with a best hit of the load on a gauge.) Then, the average and maximum values of the 15 passes were calculated.

Key Findings from Field Testing

Results showed little to no difference in the measured pavement responses under both the standard dual- and wide-base single-tire configurations. The measured horizontal strain response at the bottom of the asphalt layer was nearly equal for both configurations, differing by only one microstrain. Both the measured base and subgrade stress increased under the wide-base single by only 2.8 percent. In addition to comparisons of response magnitude, the dynamic strain traces from both tire configurations were investigated. The behavior of both traces was nearly identical.

Conclusions

The following can be concluded regarding the layered elastic theory analysis and its comparison to the field data:

1) The predicted responses using linear layered elastic theory for the standard dual-tire assembly agreed reasonably well with the field-measured responses.
2) The theoretical model overestimated the horizontal tensile strain in the asphalt layer when compared to the field-collected data for the wide-base single tire. This was likely due to the inaccurate assumption that the tire load is distributed evenly in a circular footprint calculated from the tire load and inflation pressure.

The following can be concluded regarding the field-measured methodology and pavement responses of the two tire configurations:

1) The test method of collecting 15 passes of each tire configuration over two testing dates at equal pavement temperatures was effective in creating two equal testing conditions.
2) The field-measured horizontal strain at the bottom of the asphalt layer was indistinguishable between the standard dual- and wide-base single-tire configurations. This indicates that the predicted fatigue life is equivalent for the two tire configurations for the given testing conditions and pavement cross-section.

Suggested Further Research

1) The tire footprint under load for both tire assemblies should be measured to compare the actual and calculated load area used in the theoretical model.
2) Using varying pavement cross-sections, additional wide-base single tires of various sizes and inflation pressures should be evaluated in a similar manner as in this study.
3) The effect of wide-base single tires on other pavement responses, like surface shear stress, that could cause top-down cracking or surface rutting should be investigated.
4) Field performance testing should be conducted to investigate the long-term effects of wide-base single tires on pavement performance.

Acknowledgements and Disclaimer

The research reported herein was performed by the National Center for Asphalt Technology, Auburn University. This research synopsis provides a brief summary of the study's final publication. This document is for general guidance and reference purposes only. NCAT, Auburn University and the listed sponsoring agencies assume no liability for the contents or their use.