



Project Summary Report O-4184-S

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Project O-4184: Characterize the Effects of Permitted Overweight Loads on SH4/48 at the Port of Brownsville

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## Investigation of the Effects of Routine Overweight Truck Traffic on SH4/48

The 75th and 76th Texas Legislatures passed bills allowing trucks of gross vehicle weights (GVW) up to 125,000 lb to routinely use a route in south Texas along the Mexican border. The Texas Department of Transportation (TxDOT) is concerned about the impact of overweight truck traffic on highways. There is a need to establish the potential impact of overweight truck traffic on Texas roads and evaluate structural requirements for pavements that carry axle loads above legal limits on a routine basis.

In this project, researchers investigated the effects of overweight truck traffic on a permitted truck route in the city of Brownsville. This route proceeds from the border checkpoint at the terminus of US77 to the Port of Brownsville via US77, SH4 and SH48. According to the Brownsville Navigation District, 95 percent of the truck traffic originates from the Port of Brownsville and continues south to the border checkpoint at the end of US77.

The payloads carried by permitted trucks are mostly coiled metal sheets, oil, and powder mineral (fluorite), which are transported from the Port of Brownsville to Mexico and vice versa. The route was established in response to the need expressed by truckers to haul cargo at their trucks' operating capacities to improve operational efficiency. This need meant hauling in excess of legal load limits, thus requiring permits to be issued.

On average, about 2700 permitted overweight trucks use the route per month. Considering that the route was not designed to sustain routine overweight truck traffic, the potential for accelerated pavement deterioration exists. Since it is likely that requests for similar permitted routes will be made, TxDOT funded this project to study the effects of routine overweight loads on SH4/48 and to develop guidelines for evaluating and/or designing routine overweight truck routes.

### What We Did...

To achieve the objectives of this project, researchers carried out a comprehensive test program to characterize the pavement sections along the southbound (K6 and K7) lanes, which carry about 95 percent of the permitted truck traffic on SH4/48. As part of this program, researchers conducted tests with TxDOT's ground penetrating radar (GPR) systems to estimate pavement layer thicknesses and to subdivide the route into uniform subsections based on the layering information determined from analyses of GPR data. From this initial work, researchers established uniform subsections where falling weight deflectometer (FWD) tests were conducted at various times to monitor the loading response over time.

In addition, researchers took cores at various locations to verify the GPR predictions and to characterize asphalt concrete material properties in the laboratory for the purpose of assessing

the potential pavement damage due to routine overweight truck traffic. To monitor the performance of pavement sections along the K6 and K7 lanes, profile, rut bar and visual distress measurements were collected at different times during the project. In addition, researchers instrumented two locations along the route with multi-depth deflectometers (MDDs) to estimate damage potential due to overweight truck traffic through comparisons of measured pavement deflections under permitted and non-permitted trucks.

The test data and results from the analyses are presented in a companion report (O-4184-1). In addition to characterizing the effects of overweight loads on SH4/48, researchers developed a methodology for evaluating the suitability of using an existing route for routine overweight truck use. This methodology includes procedures to estimate overlay thickness requirements for upgrading a route to accommodate projected overweight truck traffic. A documentation of this methodology is presented in two companion documents (O-4184-P2 and O-4184-P3).

### What We Found...

Based on the research conducted, the following findings are noted:

- For static backcalculation, a three-layer model provided the best fit to measured FWD peak displacements and reasonable estimates of layer moduli.



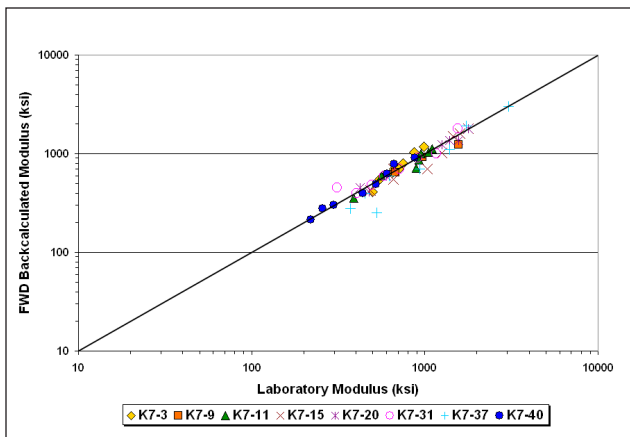


Figure 1. Comparison of Backcalculated Modulus from Static Analysis with Laboratory Test Modulus (K7 FWD Stations).

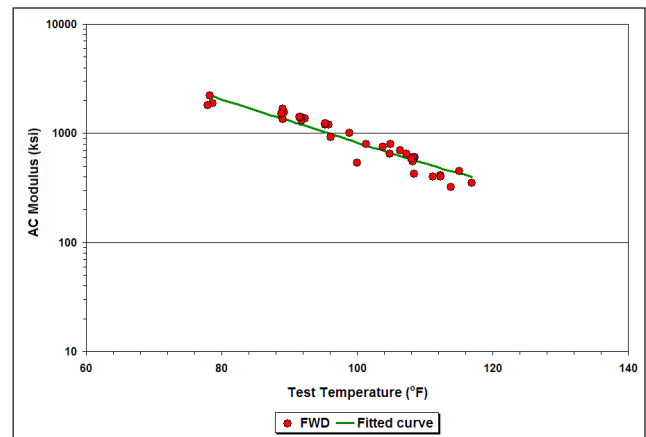


Figure 2. Relationship between Backcalculated AC Modulus and Pavement Temperature (FWD Stations in Subsection 3 of K7 Lane).

- From analyses of test data on cores taken from SH4/48, researchers found a good correlation between the backcalculated asphalt concrete (AC) modulus and the dynamic modulus from laboratory testing, particularly on the inside (K7) lane as shown in Figure 1.
- While the correlation between laboratory and backcalculated AC moduli from the tests conducted in this project is generally good, this agreement is not always observed in practice. For example, on the outside (K6) lane, there was one station where the backcalculated AC moduli are much lower than the values determined from laboratory tests. Researchers note that the laboratory data are specific to the core tested and that district personnel had problems getting intact cores along SH4 in the downtown area of Brownsville. Because of these considerations, researchers are of the opinion that the FWD test results are probably more indicative of the pavement condition along the K6 lane of SH4 in the downtown area.
- Researchers also determined the AC moduli corresponding to the FWD test frequency of 16.7 Hz based on the creep compliance parameters backcalculated from dynamic analyses of full-time FWD displacement histories. A good correlation was observed between the AC moduli from dynamic and static analyses, providing further verification of the FWD test results.
- Using FWD data collected at different times during this project, researchers evaluated relationships between backcalculated asphalt concrete modulus and pavement temperature for the different uniform subsections established on the K6 and K7 lanes. The Witczak-Fonseca model provided an adequate fit to the backcalculated moduli at different temperatures. An example for one subsection is illustrated in Figure 2. The relationships determined based on this model were found to be statistically significant.
- The modulus-temperature relationships for FWD groups on the K6 lane are generally lower than those determined for corresponding groups on the K7 lane. Since K6 and K7 are adjacent lanes, it is not likely that different asphalt concrete mixtures would have been placed on these lanes, particularly for FWD stations that are within adjacent subsections. In the researchers' opinion, the observed differences reflect the effect of higher cumulative truck loading on the outside (K6) lane.
- Researchers further verified the effect of truck loading by comparing the backcalculated AC moduli between lanes after correcting the values to a reference temperature of 75 °F. This comparison also showed that the corrected AC moduli are lower on the K6 lane than on the K7 lane. Moreover, researchers observed that the corrected moduli show a decreasing trend over the duration of the project, particularly for FWD groups on the K6 lane.
- Another corroboration of the effect of truck loading was made when researchers estimated the cumulative 18-kip ESALs from traffic data provided by TxDOT. Researchers evaluated the relationships between the corrected AC moduli and cumulative 18-kip ESALs for the different uniform subsections along the route. It was found that a sigmoidal model fits the data quite adequately as illustrated in Figure 3 and that the fitted curves have strong statistical significance. In the opinion of the researchers, the relationships from this analysis clearly demonstrate that the higher cumulative 18-kip ESALs is associated with lower corrected AC moduli on the K6 lane.
- Researchers also compared the pavement condition survey data collected along the K6 and K7 lanes during this project. This comparison showed a higher level of observed pavement distress on the K6 lane compared to the K7 lane in terms of rutting, roughness, and cracking.

Researchers also used the MDDs to compare overweight versus non-permitted trucks on the basis of damage estimates made from the measured MDD deflections. This task required the evaluation and application of models to predict pavement response



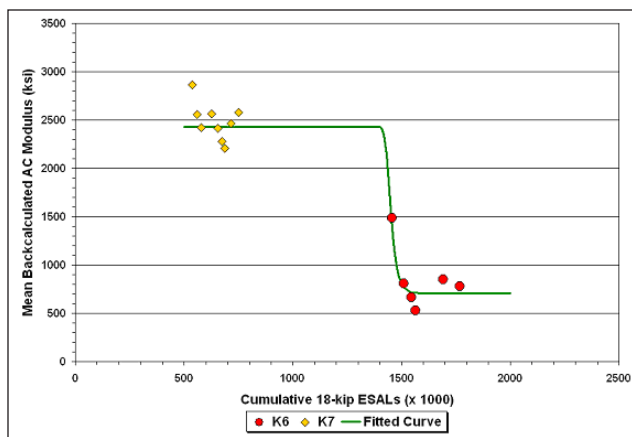


Figure 3. Plot of the Average Corrected AC Moduli versus Cumulative 18-kip ESALs for FWD Stations within Subsection 5.

and performance. The findings from this task are summarized as follows:

- A nonlinear anisotropic (NA) model gave the closest predictions to measured MDD peak displacements relative to the other models evaluated by researchers, specifically, nonlinear isotropic (NI), linear anisotropic (LA), and linear isotropic (LI) models. The accuracy of the predictions diminished in the order: NA → NI → LA → LI. This order suggests the importance of modeling the stress-dependency of base and subgrade materials to predict pavement response for assessing the potential pavement damage due to routine overweight truck loads.
- Researchers found that the MDD displacements are highly correlated with pavement response parameters that are predictors of fatigue cracking and rutting, and that the displacements adequately account for differences in layer moduli and wheel loads.
- Researchers used MDD data taken under permitted and non-permitted trucks at close to the same time to assess the pavement damage potential of permitted overweight trucks relative to legal or non-permitted trucks. For each truck pair, researchers determined the ratio of the service life consumed from one pass of the permitted truck to the corresponding service life consumed due to passage of the non-permitted truck. This analysis showed all ratios to be greater than

one, indicating greater potential for accelerated pavement deterioration on the route due to permitted overweight truck use. The averages of the service life consumption ratios based on rutting and fatigue cracking criteria were determined to be about 5.3 and 4.0, respectively, on the K6 MDD station. The corresponding averages on the K7 MDD station are about 3.4 and 2.4, respectively.

In summary, the characterization of the effects of overweight truck traffic on SH4/48 showed that accelerated pavement deterioration can be expected due to the higher rate of accumulation of 18-kip ESALs, and the fact that routine overweight truck use was not considered in the original pavement design for this route. The higher loading rate is a consequence of the additional overweight trucks that the route now serves, and the higher allowable axle loads on these trucks that produce more pavement damage per application relative to legal or non-permitted trucks.

## The Researchers Recommend...

Based on the project findings, researchers offer the following recommendations for TxDOT's consideration:

- The good correlation observed between the AC moduli backcalculated from static and dynamic analyses is encouraging since dynamic analysis provides additional properties that are not determined from static backcalculation based

on FWD peak deflections. In particular, the slope  $m$  of the creep compliance curve has been shown (from theoretical considerations) to be a predictor of material parameters that govern the development of fatigue cracking and permanent deformation in flexible pavements. TxDOT should renew efforts to implement this pavement evaluation tool, which was developed in research projects conducted for the department in the late 1980s to early 1990s. Initial implementation could target forensic investigations.

- The evaluation of pavement response models suggests the need for considering the anisotropic behavior of pavement materials in predicting pavement response under load. To address this need, further research is recommended to:
  - review pavement evaluation and design procedures to assess the impact of implementing an NA model and establish a staged plan for revising existing procedures to consider the effects of material anisotropy;
  - characterize anisotropic properties and evaluate the factors that affect these properties;
  - revise methodologies presently used for pavement evaluation and design to model, where appropriate, the anisotropic behavior of pavement materials; and
  - develop a standard test method for characterizing material anisotropy that specifies the test equipment and procedure to be used, and associated data acquisition and reduction programs.

As an interim methodology, a nonlinear isotropic approach should be used for evaluating routes proposed for routine overweight truck use.

- Support should be provided to continue the monitoring and evaluation of the overweight truck route investigated in this project. In view of the maintenance work that has been done on various segments of this route during the course of the project, the monitoring effort should focus on the segment of SH48 between FM511 and FM802, which has not received



maintenance treatments during the project. As a minimum, inertial profile and rut bar data should be collected at three-month intervals, and FWD and visual surveys at six-month intervals. These measurements should be made on both the K6 and K7 lanes to track the pavement condition over time and provide further verification of the findings from this project.

- Enforcement of permitted axle loads is important to minimize the likelihood of non-permitted but overweight vehicles blending in with the permitted truck traffic. The use of visible or electronic tags can help differentiate permitted from non-permitted trucks, without the need to stop vehicles to view the permit papers. For axle load measurements, the existing weigh-

in-motion (WIM) site along SH48 can be used. However, piezoelectric WIM sensors, while relatively cheap, are not as accurate as the load cells or bending plates used on high-end WIM installations. Thus, studies directed at developing or identifying alternative methods for WIM measurement on routine overweight truck routes would be useful.

## For More Details...

The research is documented in Report 0-4184-1, *Characterizing the Effects of Routine Overweight Truck Traffic on SH4/48*. In addition, guidelines for evaluating proposed routes for routine overweight truck use are presented in Product 0-4184-P2, and a computer program for overweight truck route analysis is described in Product 0-4184-P3.

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## Disclaimer

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