Summary Report 1184-S
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MEASURING THE EFFECTS OF TRUCK TIRE TYPE, SPEED, INFLATION PRESSURE, AND AXLE LOAD ON PAVEMENTS

DEPARTMENTAL INFORMATION EXCHANGE

TEXAS TRANSPORTATION INSTITUTE

In cooperation with
Texas Department of Transportation
and the FHWA

Summary Report

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PROBLEM STATEMENT

In recent years, replacing dual tires with wide-base single tires on heavy trucks has generated concern that the single tires, along with higher tire pressures and new axle configurations, may cause more highway deterioration. However, proponents of these "super singles" claim that using them on truck tractors and trailers improves fuel consumption, ride, handling, and braking, while reducing tire cost and increasing payload. The debate is heated, and the question has not been conclusively answered—Do wide-base "super-single" tires damage the pavement?

Along with this issue is the growing need for the Texas Department of Transportation (TxDOT) to more reliably predict pavement performance. To establish general damage rate relationships for functional and structural pavement deterioration, a technique has been developed which determines the critical stresses or strains in individual materials of the pavement structure with a device called the multidepth deflectometer (MDD). Also, the measured depth deflections under the falling weight deflectometer (FWD) and truck loadings can be used to verify modulus backcalculation techniques. How well do these instruments perform? Basically, TxDOT needs a field testing framework to better answer these questions and to continue evaluating the effects of tire configuration, load, speed, and tire inflation pressure on the pavements.

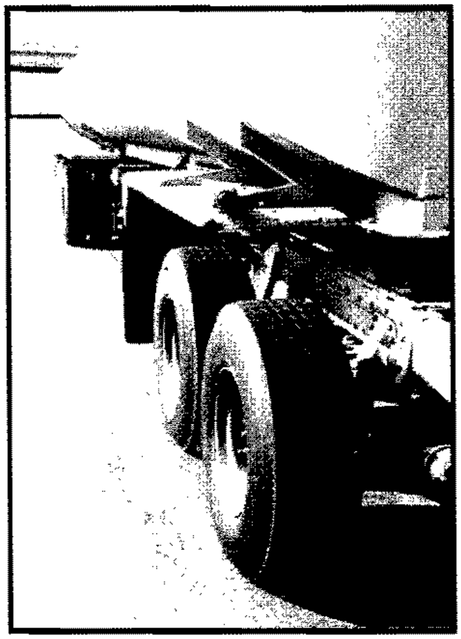
OBJECTIVES

The Texas Transportation Institute (TTI) conducted study 1184, *Using the Multidepth Deflectometer to Study Tire Pressure and Dynamic Load Effects on Pavements*, in cooperation with TxDOT and the Federal Highway Administration (FHWA) to determine the impact of truck tire type, tire inflation pressure, speed, and axle load on flexible pavement response. Researchers addressed the following questions in the course of the study:

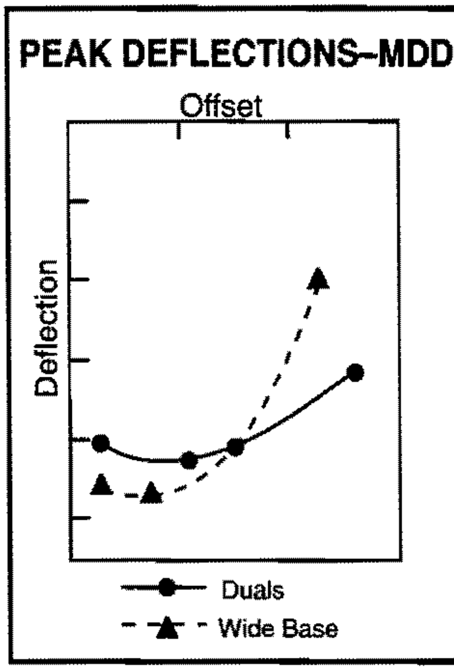
1) How do wide-base single truck tires compare with conventional dual tires in terms of pavement damage?
2) How reliable are FWD moduli when used to predict pavement responses under truck loads?
3) How well does the MDD perform in measuring vertical strains

and deflections in the pavement structure under actual truck loading in field tests?

The study was conducted on two in-service test sites (one thick and one thin) of Hot Mix Asphalt Concrete (HMAC) over a crushed limestone base course and a sandy clay subgrade. The test vehicle was an 18-wheel water tanker converted to a 14-wheeler by replacing the dual wheels on one set of tandem axles with wide-base single tires. Using the MDD, depth deflections were measured for various combinations of two load levels, three tire pressures, four speeds, and the two tire types. Surface and depth deflection data were collected under FWD and actual truck loadings. The moduli calculated from the FWD loads were used to predict pavement response under known truck loads. These predictions were compared to the actual measured responses to determine the accuracy of the estimations.



Truck used to test single tires (front) and dual tires (rear)



The results reflected in this graph show that the single tire leaves a deeper impression in pavement than the dual base tires.

FINDINGS

Dual Vs. Wide Base Single Tires

Researchers found that maximum deflection under the wide-base single tires generally occurs under the tire centerline, whereas, the maximum deflection under dual tires occurs under either of the two tires. The measured pavement deflections in all the layers, under both dual and wide-base single tires, decreased with increase in speed. Under similar test conditions, wide-base singles produced higher deflections than duals.

The multidepth deflectometer data on both test sections (thick and thin asphalt concrete) under truck loadings was converted into vertical compressive strains at the top of the subgrade layer. Regression equations were developed to predict the relationships between subgrade strains and tire type, axle load, speed, tire inflation pressure and asphalt layer temperature. The measured subgrade strains, as predicted by regression equations, were used to estimate pavement performance under dual and wide-base single tires using a subgrade strain prediction model. *Under similar conditions, the strains were always found to be greater under wide-base single tires than under dual tires.*

The subgrade strains decreased with an increase in truck speed and increased with an increase in axle load and asphalt layer temperature. Axle load was the most significant factor affecting the subgrade strain. For this portion of the study, tire inflation pressure was not a significant factor in the measured subgrade strains. *Pavement performance under identical conditions—33 kips tandem axle loading, 77 degree F asphalt concrete temperature, and 55 mph truck speed—showed* *the wide-base single tires to be approximately 4 times more damaging on the thin section of pavement and 3 times more damaging on the thick section.*

In estimating the rutting potential of wide as opposed to dual tires (in terms of vertical strains), a first order analysis was made of the impact of tire type on surface cracking. Surface Curvature Index values were greater under wide-base singles than under dual tires and were also greater on the thin section compared to the thick. Analysis of the data implies that because the load is spread over a smaller area with a wide-base single, larger shear strains are generated at the edge of the tire. This should contribute to significantly more surface cracking under wide-base tires. Again, the effect of load was more significant than other factors. Overall, the wide-base single tires cause more deflection, higher vertical compressive strains, and sharper curvature of the deflection bowl, resulting in larger shear strains at the tire edge.

Pavement Responses Under FWD and Truck Loads

This segment of the study addressed the basic question—"Given a set of moduli values obtained from FWD testing, how accurate are they in predicting what a truck load will do to the pavement?" Researchers found that the FWD moduli values slightly underpredict strains induced by known truck loads by about 14 to 18%. Correction factors of this magnitude should be considered for mechanistic design procedures.

Measurement of Tire Footprint Pressures

When measurements were taken at deeper depths, researchers did not find that increased tire pressure caused significant pavement damage; however, there was still the question of what effect increased pressure would have on the top of the pavement surface. Therefore, a final phase of the research measured tire-pavement pressure distributions, commonly called footprint pressures. The final report, 1184-3F "Measurement of Tire Footprint Pressures," reveals the testing and evaluation of TTI's newly purchased load pin array, which measures tire-pavement shear pressures with a triaxial load pin. The load pin signal responds to dynamic tire contact pressure.

Replacing the eight dual tires on a tandem axle with four wide-base tires, under the same loading conditions, is likely to cause substantially more highway damage.

Footprint pressure measurements were made on three different tires: 1) a conventional radial truck tire, used either as a single or a dual, 2) a single wide base tire that is a possible replacement for a dual tire set, and 3) a conventional truck tire made with patternless tread for research purposes. Measurements were taken with varied inflation pressures and load weights.

Footprint pressure distributions varied considerably due to tread wear and tire non uniformity. The contact pressures for the conventional truck tire were not symmetric about the tire plane of symmetry. Researchers propose that this is due in part to the fact that conventional truck tires are mounted on a wheel with an offset flange. This effectively cantilevers the tire thus possibly contributing to the slight dip in the contact pressure at about +1.5 inches from the tread center. This effect has not been noticed in previous studies.

Unlike the conventional tire, the wide base tire mounted on a center flange wheel showed virtually the same footprint pressures along the transverse median (the center tread); however increasing inflation pressure from 95 psi to 120 psi had a significant effect when the tire load was held constant at 6000 lbs. and 9000 lbs. Research Report 1184-3F details recommended improvements to the equipment and the data acquisition methods. Future research of tangential tire-pavement pressures is also suggested.

CONCLUSIONS

Wide-base "super-single" tires are at least twice as damaging as regular dual tires. Replacing the eight dual tires on a tandem axle with four wide-base tires under the same loading conditions is likely to cause substantially more highway damage. Further work is necessary to determine where these wide-base tires can be used—perhaps with triple axle configurations.

The multidepth deflectometer is an excellent tool for measuring vertical strains and deflections in the pavement structure under actual truck loading. The information in this study can be used to demonstrate to tire manufacturers, legislatures and others the damaging effects of wide-base super-single tires. The information in the reports also provides TxDOT with a field testing framework to make quantitative decisions about the impact of truck/tire configurations on typical pavement structures.

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The information in this summary is detailed in the following TTI Research Reports:

1184-1, "Estimating Damage Effects of Dual Vs. Wide Base Tires with Multidepth Deflectometers," Tayyeb Akram and Tom Scullion, April 1992.
1184-2 Vol. 1, "Comparing Pavement Responses Under FWD and Truck Loadings," Tayyeb Akram, Tom Scullion, and Roger Smith, July 1993.
1184-2 Vol. 2, "Using the Multidepth Deflectometer to Study Tire Pressure, Tire Type, and Load Effects on Pavements," Tayyeb Akram, Tom Scullion, and Roger Smith, September 1992.
1184-3F, "Measurement of Tire Footprint Pressures," John T. Tielking and Moises A. Abraham, September 1992.