EFFECTS OF TRUCK TIRE PRESSURES ON PAVEMENTS

Research Study 372/386

by

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EXECUTIVE SUMMARY REPORT

On

EFFECTS OF TIRE PRESSURES ON PAVEMENTS

This report summarizes the results of cooperative research projects carried out both at Texas Transportation Institute (TTI) at Texas A&M University and at the Center for Transportation Research (CTR) at the University of Texas at Austin. The work on the projects was divided as follows. TTI conducted a survey of the truck tire inflation pressures that are currently being used on Texas highways, calculated tire contact pressure distributions using a finite element layered shell computer program that was developed at Texas A&M, and predicted the effects of increasing tire inflation pressures on stresses, strains, rutting, cracking, and Present Serviceability Index for a variety of flexible pavements in the four different climatic zones that are found in Texas. For its part, CTR measured the vertical contact pressure distributions of a variety of tires using pressure sensitive film, and calculated the useful life of both flexible and jointed concrete pavements under a variety of wheel loads and tire inflation pressures using layered elastic and three-dimensional finite element computer programs. Figure 1 shows the cross section of a typical truck tire.

Tire Pressure Survey

The tire inflation pressure survey was conducted at 12 different locations scattered throughout the State of 1486 trucks carrying 18

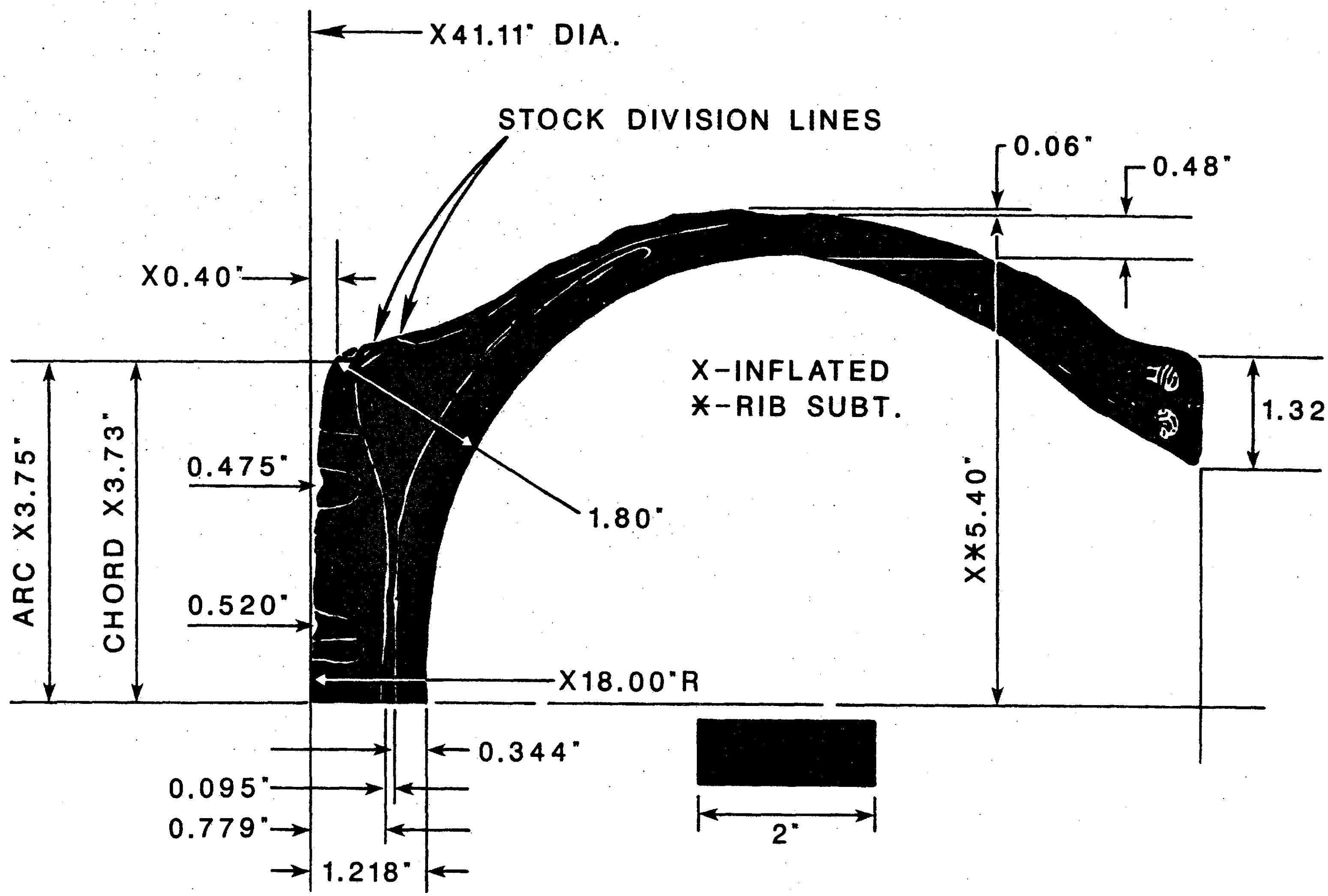

Figure 1. Details of a 10.00-20 truck tire carcass.

different commodities. About 70 percent of the trucks were of the 3S2 AASHTO class. All inflation pressures were measured on tires that had been running and were therefore heated. Inflation pressures on bias ply tires ranged between 10 and 130 psi whereas radial tires were inflated to between 28 and 153 psi. The mean pressures varied with the commodity carried: between 95 and 106 psi for radial tires to between 79 and 90 psi for bias ply tires with the difference between averages ranging from 12 to 20 psi. Figure 2 shows a typical plot of the cumulative distribution of tire inflation pressures, this one found on non-front axles of 3S2 trucks. The percent of radials on all of the 3S2 trucks is 72 percent.

Comparison with AASHO Road Test Results

No tire pressure surveys could be found other than the data from the AASHO Road Test. This is valuable information mainly because, although it was not a survey of tire pressures actually being applied to highways, it represents what was judged to be the common practice at that time. The rated cold tire pressures were 75 psi on all but Loop 6 where the heaviest loads were applied, and where the cold inflation pressure was 80 psi. Increases in tire pressures after 6 hours of running were between 8 and 37 percent, with the higher increases on the heavier loads. Since the time of the AASHO Road Test, the cold tire inflation pressures have been used commonly as a basis for the design of both flexible and rigid pavements.

Tire Contact Pressure Distributions

A unique method of measuring the static vertical tire contact pressure distributions was developed using pressure sensitive film and

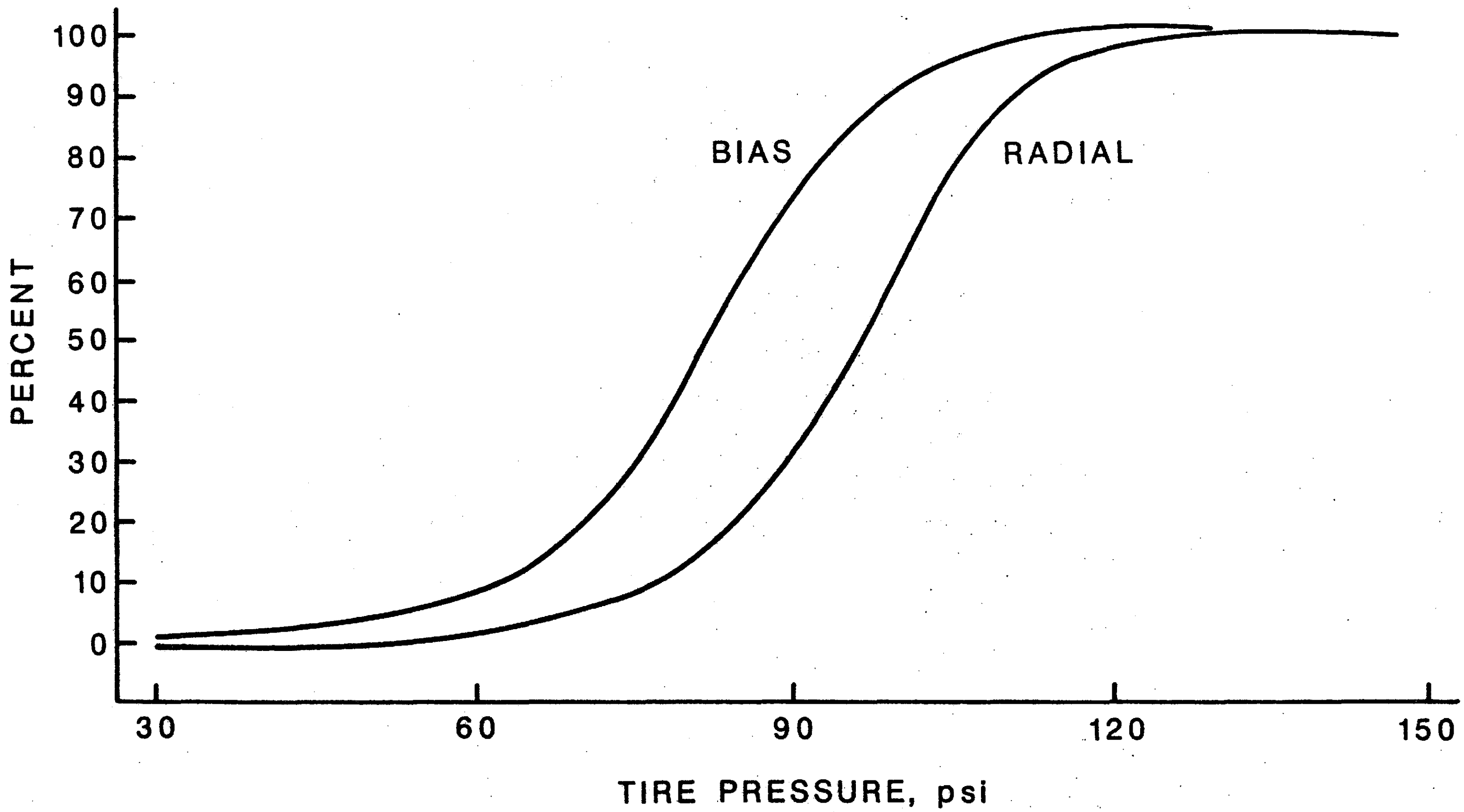

Figure 2. Cumulative distribution of tire pressures for non-front axles of 3-2S trucks.

a "densitometer", an optical device which is capable of distinguishing between fine gradations of color intensity and thus to convert the shades of color on the pressure sensitive film to units of pressure. Experiments were made with bias ply tires, with and without tread, and at different levels of load and tire inflation pressure, all of which were found to produce different tire contact pressure distributions. Figure 3 shows a typical result of these measurements. The tread separates areas of distinctively different tire pressures, and a ridge of high pressure is found beneath the tire shoulders.

Tire pressures were also calculated using a finite-element layered toroidal shell computer program. The program computed both vertical and horizontal contact stress distributions, but could not account for the effect of the tread. However, because the calculated horizontal stresses could not be measured with the pressure sensitive film, the use of the program was the only way to determine what they are. Calculated vertical contact pressure distributions for a bias ply tire at different inflation pressures are shown in Figure 4.

The calculated and measured vertical tire contact pressure distributions agree reasonably well with the exception of the localized pressure ridges at the edges of the tire treads.

Effects on Design Life of Flexible Pavements

A variety of computer programs were used to compute the expected life of flexible pavements at different levels of tire pressure. TTI used a finite element program in cylindrical coordinates which had been modified to take multiple tire loads and vertical and horizontal contact pressure distributions, and to have the ability to predict

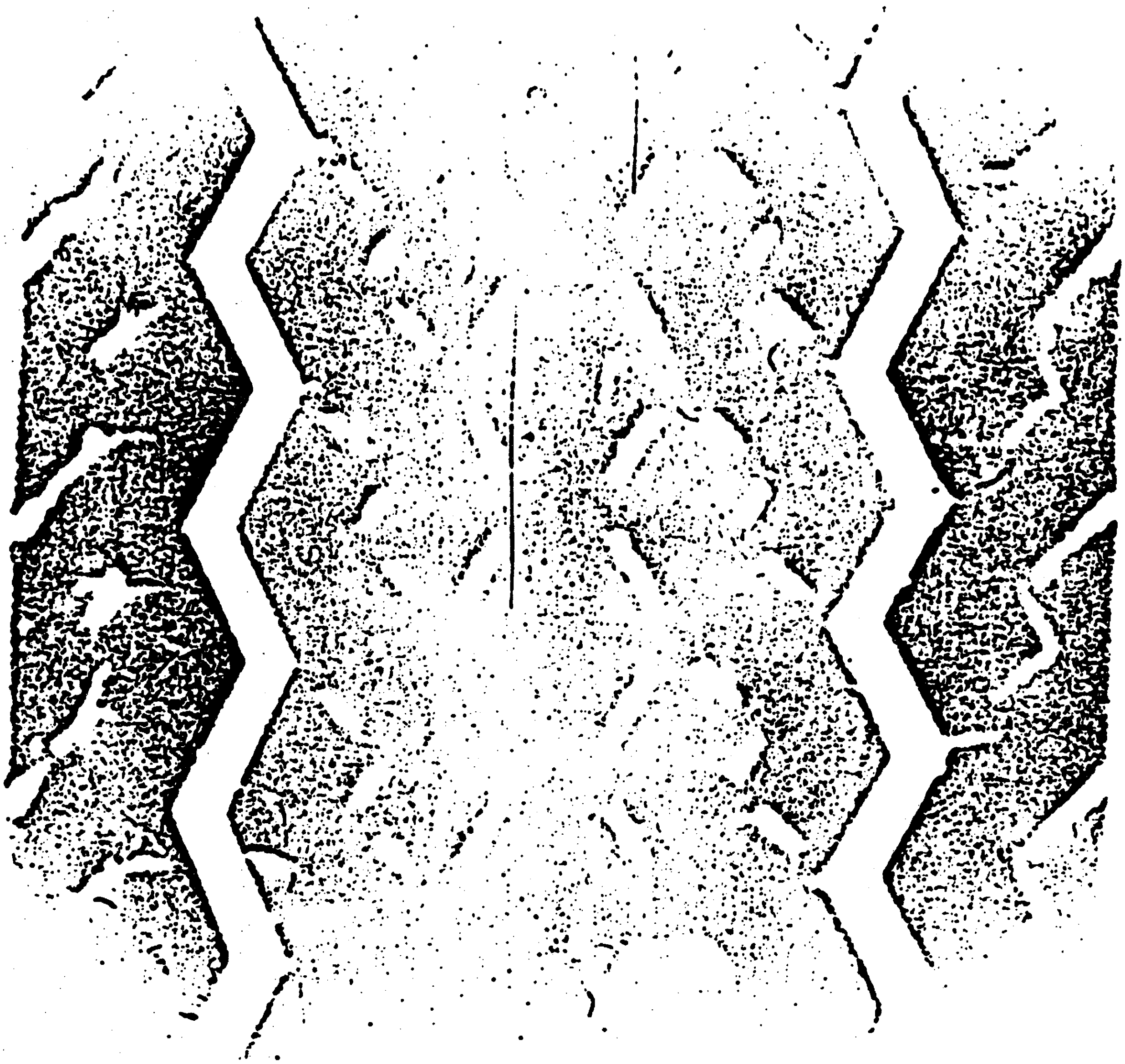

Fig 3. A typical print of contact pressure distribution using pressure sensitive film and treaded tire 10 x 20 (bias-ply).

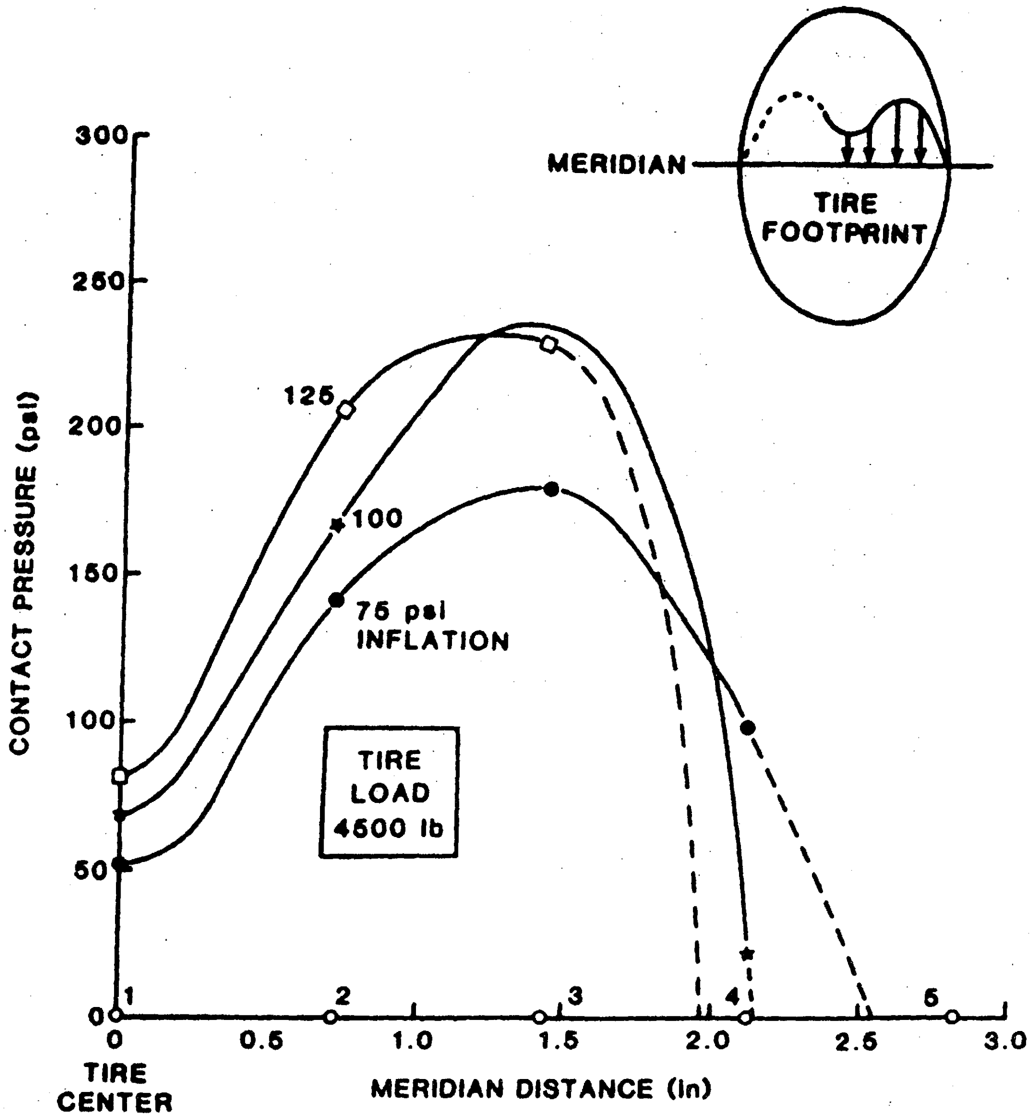

Figure 4. Effect of inflation pressure on contact pressure calculated for a 10.00-20 truck tire with a 4500 lb. load.

rutting, fatigue cracking, and Present Serviceability Index. CTR compared the calculated results of three programs: the layered elastic programs BISAR and ELSYM5 and the three-dimensional finite element program TEXGAP-3D. The first two of these programs apply a circular uniform load to the pavement, and BISAR can apply annular regions of uniform vertical pressure on multiple tires and thus can represent vertical tire pressure distributions. The TEXGAP-3D program applies rectangular patches of uniform vertical pressure within a rectangular pattern which is closer to the actual shape of the tire footprint than the circular loaded areas.

Increasing tire pressures while holding the load the same in all studies showed more strain in critical locations and a lower service life in fatigue, rutting, and serviceability index. A typical result comparing 75 psi and 125 psi inflation pressures is illustrated in Figure 5, which shows the numbers of 18-kip single axle loads that are required to fatigue flexible pavements with different surface thicknesses and moduli resting a moderately stiff 8-inch thick base course layer. All of the studies showed that increasing the tire inflation pressure while holding the load the same produces more rapid fatigue cracking particularly when the surface course thickness is between 1 and 3 inches thick. The rate of increase of rutting is doubled when the tire inflation pressure is increased from 75 to 125 psi. The time required to reduce the Present Serviceability Index to an unacceptable level is reduced by a factor of three or more in pavements with a surface thickness between 1 and 3 inches but pavements more than 4 inches thick are affected much less markedly when the tire pressure is increased from 75 to 125 psi.

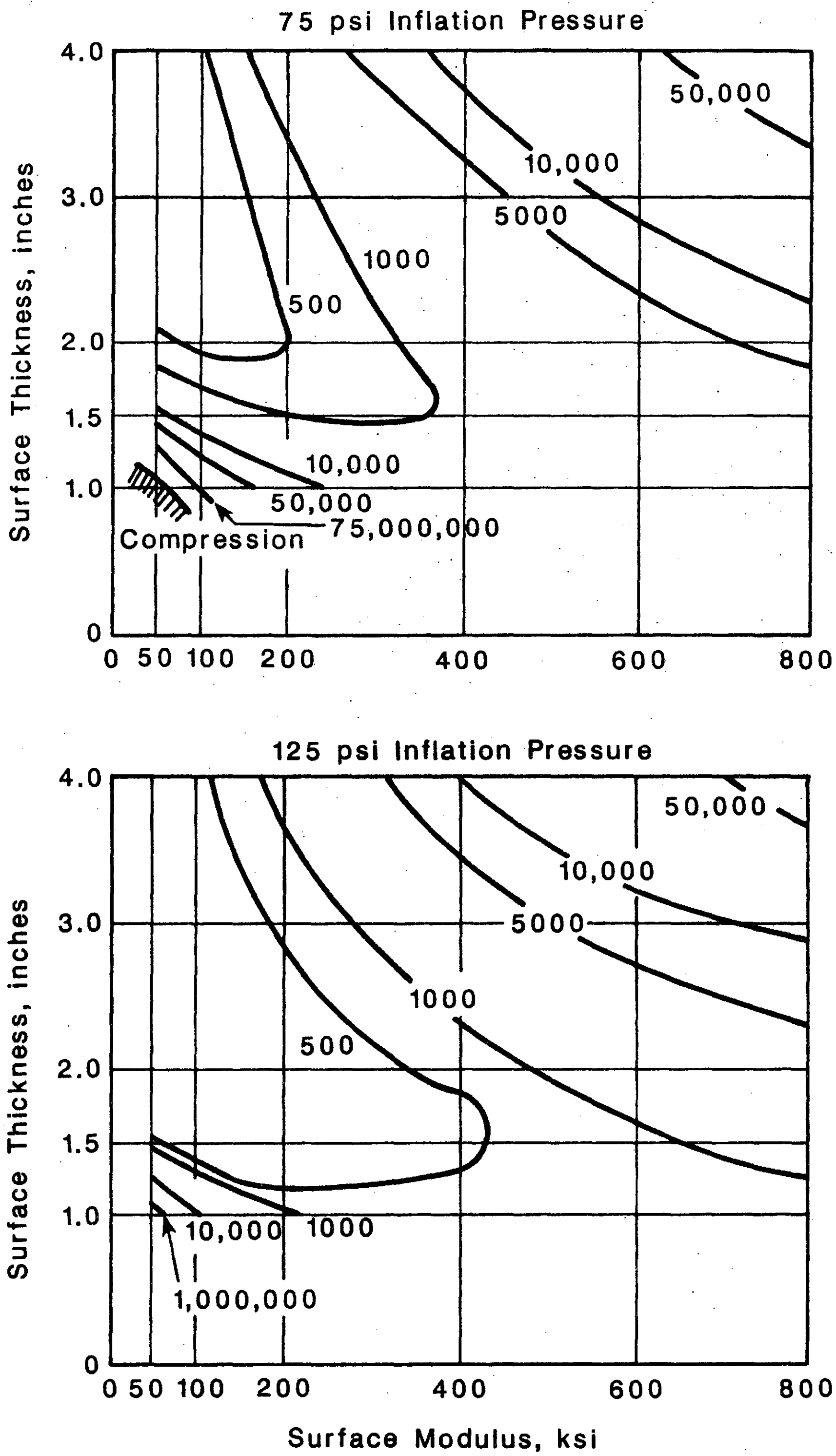

Figure 5. ESAL contours as a function of the tensile strength at the bottom of the surface for a 7000 $\theta^{0.325}$ base modulus and 8-inch base.

Effects on the Design Life of Concrete Pavements

The computer program used by CTR to study the effect of tire pressures on the design life of jointed concrete pavements was JSLAB which represents a jointed slab on a base course layer resting on a subgrade. It was found that an increase of tire inflation pressure while holding the load the same does not increase the tensile stress at the bottom of the slab. Calculations also showed that there was virtually no difference between the results with a uniform vertical pressure and a realistic distribution of vertical pressure. Thus, it is expected that increasing tire pressures will have little effect on reducing the service life of concrete pavements.

Conclusions

The following conclusions came from the two studies:

1. There is a need for a periodic survey of truck tire pressures and tire construction to monitor how they are changing.
2. Increasing tire pressures will reduce the useful life of flexible pavements; increasing load will reduce the life of both flexible and rigid pavements.
3. There is a need to incorporate actual tire contact pressures in the design of flexible pavements and no such need in rigid pavements.
4. There is a need to study the effect of radial tires to compare with the results of the bias ply tires used in the two studies.

5. There is a need to study the implications on load equivalence factors of changes in tire pressures and tire construction.

6. There is a need to determine the benefits and costs which are related to changes in tire pressures and tire construction.

References

"Effect of Tire Pressure on Flexible Pavements", F.L. Roberts, J.T. Tielking, D. Middleton, R. L. Lytton, and K. H. Tseng., TTI Research Report 372-1F.

"Experimental Investigation of Truck Tire Inflation Pressure on Pavement-Tire Contact Area and Pressure Distribution", K. M. Marshek, W. R. Hudson, R. B. Connell, H. H. Chen, and C. L. Saraf., UT Research Report 386-1.

"Effect of Truck Tire Inflation Pressure and Axle Load on Pavement Performance", K. M. Marshek, W. R. Hudson, H. H. Chen, C. L. Saraf, R. B. Connell. CTR Research Report 386-2F