The Effect of Pavement Surfaces on Rolling Resistance and Fuel Efficiency

What Was the Need?
Transportation agencies worldwide are increasingly focused on reducing the environmental impacts of automobiles by decreasing congestion, maintaining more fuel-efficient fleets and implementing other measures to lower emissions. One promising method for improving vehicle fuel economy is to optimize pavement surfaces to minimize their rolling resistance. Rolling resistance is the force resisting a vehicle’s tires as they roll across the pavement surface. It is related primarily to the way the shape of a rubber tire changes as it rolls against a pavement surface.

For several years, MnDOT has been exploring the relationship between rolling resistance and pavement surface characteristics. In 2011, the agency invited researchers from the Technical University of Gdańsk, Poland, to make rolling resistance measurements on test cells at MnROAD, Minnesota’s pavement research facility. In a 2013 study and as part of Transportation Pooled Fund study TPF-5(134), researchers used the data from these measurements to explore the relationship between the rolling resistance of pavements and their surface textures.

In the case of concrete pavements, textures are applied to surfaces to provide traction, for instance, by dragging metal prongs, brooms or inverted turf along or across the surfaces before curing or by using diamond-coated saw blades to cut grooves into them after curing. MnROAD test cells include a wide variety of such surface textures as well as concrete and asphalt pavements constructed using various materials and designs.

Further research under the umbrella of TPF-5(134) was needed to conduct follow-up measurements of rolling resistance and evaluate its effect on vehicle fuel consumption.

What Was Our Goal?
The project objective was to evaluate the effect of the rolling resistance of various pavement surface textures on the relative fuel economy of vehicles.

What Did We Do?
MnDOT collaborated with Minnesota State University, Mankato, and the Technical University of Gdańsk to conduct a second round of rolling resistance measurements at MnROAD. Researchers imported an innovative Polish test trailer—the R2 Mk.2, the only device of its kind in the world. While most evaluations of the rolling resistance of tires depend on mathematical models, this device is able to take direct measurements of rolling resistance by using sensors to account for confounding variables such as ride quality and slope.

On MnROAD’s mainline—a 3.5-mile road segment consisting of a working Interstate freeway carrying more than 26,000 vehicles a day—researchers tested three kinds of passenger vehicle tires at speeds of 31, 50 and 68 mph. On its low-volume road—a 2.6-mile closed loop with vehicle weight and traffic volumes simulating rural road conditions—they tested tires only at the two lowest speeds.

Researchers analyzed test data to calculate the coefficients of rolling resistance for each surface and estimate the relative impact by each surface on vehicle fuel consumption.
What Did We Learn?

Researchers found that within the same pavement type, pavement surfaces with higher rolling resistance coefficients and energy consumption were generally those with greater amounts of surface texture, such as porous asphalt, conventional diamond grinding and exposed aggregate. Pavements with lower rolling resistances tended to be asphalt pavements with dense graded aggregates and concrete pavements with broom or turf drag surfaces (textures created by dragging a broom or AstroTurf over curing concrete). Across pavement types, other variables such as texture orientation and texture direction influence comparative rolling resistance.

Researchers found little difference between rolling resistance coefficients for speeds of 31 and 50 mph, but at 68 mph the coefficients increased significantly on all MnROAD mainline surfaces tested. However, as speed increased, the relative effect on energy consumption diminished, as other impacts such as wind resistance were much more prominent.

The final report includes rankings of all 52 test cells by rolling resistance and all surface types by fuel consumption. The surface with the greatest rolling resistance, in a cell with porous hot mix asphalt, had a coefficient of rolling resistance 24 percent greater, and at 50 mph, a fuel consumption 8.4 percent greater, than the surface with the lowest rolling resistance, in a cell with concrete longitudinal turf drag. This amounts to various surfaces having up to a 6.1 percent increase in energy consumption at 50 mph or up to a 2.3 percent decrease relative to the chosen standards of comparison, a 12.5 mm dense graded asphalt surface and a transverse-tined concrete surface (which are roughly equivalent in energy consumption).

What’s Next?

This project will help MnDOT take into account not only friction and ride quality, but rolling resistance when designing pavements and choosing surface textures. MnDOT is also currently working with FuelMiner, Inc, to establish more accurate fuel economy values for various pavement surfaces at MnROAD by using a mechanistic model to translate rolling resistance into fuel consumption. (The current study evaluated only the relative energy consumption of various pavement surfaces.)