

Smoothness Still Matters

The Asphalt Industry Responds to Concrete Industry-sponsored Studies
Of Fuel Efficiency Including
Effect of Pavement Type on Fuel Consumption and Emissions in City Driving

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Many factors influence a vehicle's rate of fuel consumption. Among them are engine efficiency, speed, aerodynamics, and rolling resistance. When it comes to the influence that pavement characteristics have on fuel consumption, one of the major contributors is surface roughness which impacts rolling resistance; more energy is required to propel a vehicle over a rough surface than over a smooth surface.

Improving pavement smoothness over a typical roadway network can have dramatic effects on the overall fuel consumption of the vehicles within that network. A maintenance program that slightly increases pavement smoothness has been estimated to be able to reduce annual vehicle fuel consumption by about 7 billion gallons annually, equivalent to taking over 10 million vehicles off the road every year. Pretty dramatic effects for something so simple – placing smooth pavements and keeping them smooth. An obvious collateral consequence of smoother roads would be a significant drop in vehicle greenhouse gas emissions. In the interest of conserving fuel and reducing emissions, it would be prudent to focus on building smooth pavements and keeping them smooth.

For a review of how pavement smoothness affects vehicle fuel economy, consult the Asphalt Pavement Alliance brochure "Smoothness Matters"
<http://www.asphaltroads.org/documents/Asphalt_Smoothness_Matters_Downloadable.pdf>.

The concrete industry has sponsored a number of studies investigating the effect of pavement type (asphalt or concrete) on vehicle fuel economy. Many of the shortcomings of these studies are discussed in a 2009 HMAT magazine article <http://www.hotmix.org/images/stories/Smoothness_Matters.pdf>. In order to

accurately quantify the impact of pavement characteristics on vehicle fuel economy, there are numerous factors that need to be highly controlled. Other than pavement smoothness, factors such as road grade, weather conditions including wind speed and direction, and a host of pavement, fuel, and vehicle factors, would need to be accounted for and controlled. Even something as simple as properly inflated tires, or keeping vehicles tuned, can improve fuel economy by up to 7 percent (US DOE <http://www.fueleconomy.gov/feg/maintain.shtml>). All these factors need to be considered when reviewing results from any study which suggests that pavement type affects vehicle fuel consumption.

NRMCA's most recent study on pavement type impacting vehicle fuel economy: A recent study sponsored by the National Ready Mixed Concrete Association Research & Education Foundation is *Effect of Pavement Type on Fuel Consumption and Emissions in City Driving* by S. Ardekani and P. Sumitsawan. In this study, researchers from University of Texas at Arlington concluded that driving on concrete pavements is more fuel-efficient than driving on asphalt pavements. This simply is not the case. This study, similar to previous studies sponsored by the concrete industry, does not adequately address pavement characteristics that are known to influence vehicle fuel economy, such as smoothness and roadway grade or slope, and exogenous factors such as temperature, wind speed, and humidity.

Examining the study's findings, it is apparent that the two pavement types investigated (concrete and asphalt) were not comparable in terms of pavement design, pavement grade, and smoothness, all of which are known factors that influence vehicle fuel economy, and could contribute to the study's findings. Furthermore, it is possible that the functional classifications of the roads were not the same, which would have influenced both design and construction.

The study's authors themselves also conclude that factors other than pavement type have a large influence on vehicle fuel economy. The authors' point out a few specific factors that should be controlled in future studies:

- Broadening the variety of materials and structures investigated;
- Better control of weather factors such as wind, temperature, and humidity even to the point of suggesting that it might be necessary to conduct such tests indoors.

In the end, the study's authors state that conclusively proving that one type of pavement leads to better fuel efficiency could only be accomplished through careful control of a wide variety of factors and by increasing the number of pavement sections in the experiment.

However, one pavement characteristic continues to remain determinant in vehicle fuel economy – and that is smoothness. As over 30 years of research confirm, pavement smoothness, regardless of whether it is a concrete or asphalt surface, is one of the major pavement determinants of vehicle fuel economy.

Aside from the factors that the study's authors point out above, a few additional crucial issues are identified below and a more in-depth discussion follows:

- The statistical analysis was based on a technique that would allow differences that may not be significant to appear significant.
- Pavement design characteristics are dissimilar when comparing some roads and road functionality (e.g., 10-inch concrete composite pavement vs. 7-inch asphalt pavement), including a higher roughness reading on the asphalt pavement (Abram St. vs. Pecandale Dr. test sections).
- Road grade or slopes are dissimilar when comparing some roads (e.g., +0.6 percent on the asphalt pavement (Randol Mill Rd.) vs. +0.4 percent on the concrete pavement (Six Flags St.).

Statistics

The researchers observed a wide range of fuel economy differences when comparing asphalt to concrete pavements – from less than 0.005 percent to almost 20 percent. This is a very wide range – the upper bounds have not generally been previously reported in the literature. According to the statistical analysis performed on the data, each of these pavement impact differences was found to be statistically significant. From a lay perspective, it would be difficult to statistically distinguish differences of less than 0.005 percent in vehicle fuel economy using less than the 30 trials conducted in the study – otherwise, the data would be considered incredibly similar or consistent. This is highly unlikely.

One of the statistical tools employed in the data's analysis was to look at the level of significance at the 90th percent confidence interval. This is not necessarily a standard practice because it may lead to a conclusion that a difference exists when it actually does not. Most statistical analysis occurs at a 95th or 99th percent level, which offers greater precision in identifying differences between data sets. Those changes in fuel economy identified in the study, using the less stringent measure at the 90th percent level, may in fact be non-existent if the data were analyzed at the more standard 95th or 99th percent level.

Roadway Design

There are other pavement-related factors that may also have influenced the results. It should be noted that this area of Texas has very expansive clay soils, known to affect the roughness of all pavements, and that any difference in the treatment or cross section of the pavement could lead to drastic differences in not only the roughness but the wavelength of the roughness, and that could have a compounding effect on the fuel consumption. The two test sites used in this study are discussed below.

The first test site (Abram St. and Pecandale Dr.) compared a concrete to an asphalt pavement. The grade of the roadway appears similar as does the IRI value (approximately 175 in/mi).

However, the types of roadway used in the comparison and the actual pavement design appear to be drastically different. For example, the concrete pavement was 8 inches thick over a 2-inch asphalt pavement with an 8-inch stabilized subgrade. Pictures of the concrete pavement section show it to be a four-lane roadway. Compare this with the street paved with asphalt, which was only 7 inches thick on thinner stabilized subgrade. A review of the pictures provided in the report and an observation made through Google Earth show that the asphalt-paved street appears to be a two-lane low-volume surface street without any centerline division. It is likely that the higher functional classification of the concrete roadway (Abram St.) receives greater attention in terms of maintenance, has fewer at-grade intersections and driveways, and does not have on-street parking as does the asphalt pavement (Pecandale Dr.). All of these factors could influence driver behavior, which could certainly influence fuel consumption.

The only other pair of streets compared were both of similar pavement depth; however, the grade of the road was greater for the asphalt pavement than the concrete pavement. That is, vehicle travel on the asphalt pavement was uphill as compared to the concrete pavement. Therefore, the resulting fuel consumption values could also be interpreted to show that as the grade of the road increases so does vehicle fuel consumption – a well-known tenet. In addition, IRI readings were very high (approximately 300 in/mi or 4.7 m/km), which is typical for highly distressed older pavements. Because of their roughness, these roads do not appear to be good candidates for investigation of fuel economy.

(See

http://training.ce.washington.edu/wsdot/Modules/09_pavement_evaluation/09-2_body.htm).

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Smoothness and grade play a large role in vehicle fuel economy. Unless these and other potential confounding variables are exactly matched or controlled along with a host of other influences, the comparison of fuel economy based on pavement types is tenuous. However, as over 30 years of research findings support, smoothness is the major pavement determinant of vehicle fuel economy. In the real world, concrete pavements start off rougher and become even rougher with time. Asphalt is smoother, and a well maintained asphalt pavement is as good as new throughout its service life.