Rough Roads, Increasing Speed and Change in Test Vehicle Motion

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What happens when a vehicle is driven at increasing speed over a road surface that is in poor condition? Knowing the answer to this question might help to resolve many issues of the public's safety as well as providing better guidance to those who must maintain roads and those in the justice system who must make decisions about a driver's level of negligence or liability for a motor vehicle collision.

Gorski Consulting has been conducting field testing in recent years to document the interaction between the driver, vehicle and the travelled roadway. A variety of testing has been performed on a specific roadway, Sunningdale Road, in the north-eastern area of the City of London, Ontario, Canada, where the roadway was found to be in poor condition. Several articles have been uploaded to the Gorski Consulting website (www.gorskiconsulting.com) that present the results of that testing.

On March 3, 2014 testing was conducted on Sunningdale Road to explore the motion of a test vehicle as its speed was increased incrementally from 40 to 90 km/h. The present article will review the test procedure and summarize the test results.

Review of Testing Procedure

A 2007 Buick Allure passenger car was equipped with multiple video cameras at the following locations:

1. Mounted to centre dash and pointing forward through the windshield.
2. Mounted in front of instrument cluster and documenting the status of the Speedometer, Tachometer and other instruments.
3. Mounted to the driver's sunvisor and pointing rearward at the driver's head.
4. Mounted to the centre console and pointing downward upon the face of an iPhone displaying the sensed values of lateral and longitudinal motion of the centre-of-gravity of the test vehicle.
5. Mounted underneath the left end of the front bumper and pointing forward to display a close-up view of the road surface.
6. Mounted to the right end of a lateral bar that was anchored to a bicycle rack at the rear of the vehicle. This camera was pointed forward and documented the right side and taillights of the test vehicle.

The test vehicle was driven westbound along Sunningdale Road in London, Ontario, from, commencing from the intersection of Clarke Road and terminating near the intersection of Highbury Avenue, as shown in Figure 1.

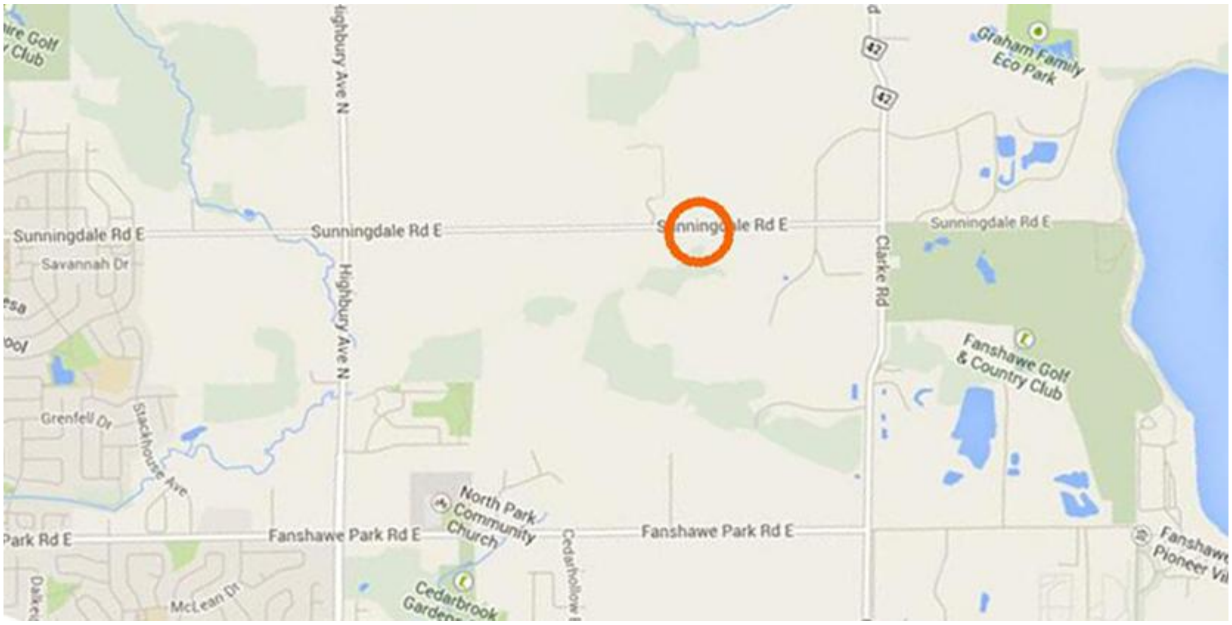

Figure 1: View of testing location on Sunningdale Road in London, Ontario, Canada, commencing at Clarke Raod to the east and terminating near Highbury Avenue to the west.

The distance over which the testing was conducted was about 2 kilometres.

Over the years Sunningdale Road had experienced a variety of road surface problems. It is believed that the water table in the vicinity of the road is high and, over winter months the freezing of the ground caused an upheaval of the road surface.

Figure 2 shows an example of a localized depression in the road surface that was documented in the winter of 2011. The charpenter's level shown in the Figure is 8 feet long and it can be seen that the depression spans the full length of the level. Thus it is possible to note that this depression was not just an insignificant feature. Depressions like these existed throughout the most of the length of Sunningdale between Clarke and Highbury. In the fall of 2011 the City of London re-paved the worst portion of the problems in the middle two-thirds of the road segment. However, portions of the poor surface still remained to the east and west of the ends of the re-paved segment.

By the winter of 2013-14 the portions of Sunningdale Road to the east and west of the re-paved area became more uneven as various depressions and ruptures in the surface were clearly visible. These features became an obvious opportunity to study how these conditions would affect a vehicle travelling over them and this is why the site was selected for this testing.

Figure 2: View, looking west along Sunningdale Road, at one of numerous depressions that existed in the road surface in 2011. The surface was subsequently re-paved though some portions of poor surface still remained.

Sunningdale Road was generally straight and level except for a small sag located near its east end. There was a small bridge at the bottom of this sag as shown in the westward view of Figure 3.

An Apple iPhone 4S was used as the instrument that sensed the changes in the test vehicle's lateral and longitudinal motion.It might seem unusual to use a "cell" phone to document the motions of a vehicle however modern smart phones are not just cell phones. Previous testing of the accelerometer and gyro of the iPhone 4S had demonstrated that it reliably captured a variety of motions.

The "app" used to store the sensed data was able to store data a the rate of 32 Hertz. Not an impressive rate, but more than sufficient. At 32 Hertz a vehicle travelling at 40 km/h (11.11 metres per second) would allow data points to stored every 37 centimetres along the road length. At 90 km/h (25 metres per second) data points would be captured every 83 centimetres, which is still a reasonable extent of detail for most roadway evaluations.

Figure 3: View, looking west along Sunningdale Road, near the location where data collection was commenced. In the background is a sag and small bridge which is the only significant elevation change in the road segment.

The testing was begun at the intersection at Clarke Road where the test vehicle was at a stopped position. The "record" button on the iPhone was activated and they the vehicle was accelerated to the desired speed. While travelling westbound the vehicle passed over the old pavement, some of which is shown in Figure 3. At the approximate location of the small bridge (shown in the background of Figure 3) the section of new pavement was encountered. As the vehicle progressed further westward the new pavement terminated and the vehicle began travelling on the old pavement. Shortly afterward, on approach to the intersection of Highbury Avenue, the vehicle was stopped on the north shouler, the "pause" button was activated on the iPhone and the data file was sent by e-mail to a remote computer. This process was repeated at travel speeds of 40 through to 90 km/h, at 10 km/h increments. Although not discussed here, the test vehicle was also run eastbound, using the same procedure. The results of those runs may be reported in a future article.

Review of Test Results

When the e-mailed data file was retrieved at the office, it was converted into an Excel spreadsheet. Part of the data file reported the rate-of-change of the lateral and longitudinal motion of the vehicle and these two parameters were selected for further review. This rate-of-change in the angle of the vehicle was reported in radians per second. There are 57.3 degrees in one radian. As a measure of the dispersion and differentiation of the data it was decided to take the standard deviation of the of the data points. This would provide a simple way of showing how quickly the vehicle moved away from its "mean", level position. Figure 4 summarizes the results of this testing.

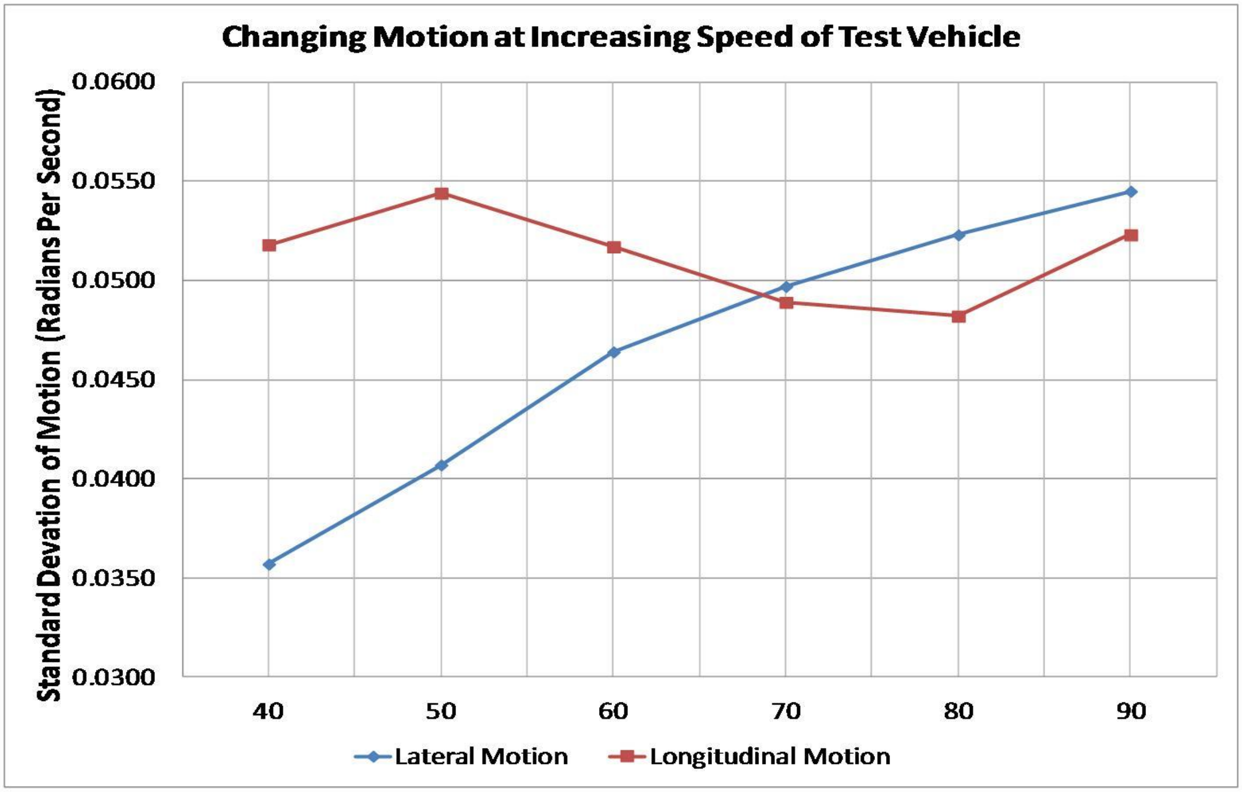

Figure 4.

In the chart of Figure 4 the blue line indicates the lateral motion while the red line indicates the longitudinal motion of the test vehicle. The axis along the bottom of the chart indicates the increasing speed of the test vehicle, from 40 to 90 km/h. The vertical axis is expressed in radians per second, from the minimum of 0.0300 to the maximum of 0.0600.

At the low speed of 40 km/h the rate-of-change in the longitudinal motion was much higher than it was for the lateral motion. However, as the speed was increased, the rate-of-change of the longitudinal motion stayed relatively the same, or perhaps the data might suggest that the rate was being reduced as speed was increased. However, the rate of rate-change in the lateral motion rose significantly as the speed of the test vehicle was increased such that, in the last three highest speeds the lateral motion was higher than the longitudinal motion.

In simple terms, as the vehicle was travelling relatively slowly over the rough road the front and rear ends of the vehicle were being lifted up or dropped toward the pavement, while there was little side-to-side motion. The front and rear end motion was large and was experienced as such by the test driver. As the vehicle's speed was increased, the test driver's perception was that the vehicle's overall motion was increased, and the data supports that perception. However it is the manner in which that overall motion was increased that is interesting to observe. The increase in the overall motion of the vehicle, as the vehicle speed increased, was achieved via an increase in the lateral, side-to-side, motion, while the longitudinal, front to back, motion either remained the same or might have been reduced slightly.

As the test vehicle was also run in an eastward direction the data from those tests will also be reported, in a future article, and compared to the present data.

Gorski Consulting
London, Ontario, Canada