# Rough Roads, Increasing Speed and Change in Test Vehicle Motion - Additional Data

*Posting Date: 20-Mar 2015*

In two earlier articles (posted to the Gorski Consulting website on March 6, 2014) we reported on the data obtained from driving our test vehicle over a poor road surface (Sunningdale Road in London, Ontario). Subsequently Gorski Consulting conducted additional testing on April 5, 2014 and on February 27, 2015. The present article reports on the combined results from the three testing sessions.

## Review of Testing Procedure

A 2007 Buick Allure passenger car was equipped with multiple video cameras.

The test vehicle was driven westbound and eastbound along Sunningdale Road in London, Ontario, between the intersections of Clarke Road and Highbury Avenue, as shown in Figure 1.

The distance over which the testing was conducted was approximately 2 kilometres. The speed of the vehicle was increased at 10 km/h intervals from 40 to 90 km/h.

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 2.

An Apple iPhone 4S was used as the instrument that sensed the changes in the test vehicle's lateral and longitudinal motion.

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 then 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 2. At the approximate location of the small bridge (shown in the background of Figure 2) 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 shoulder, the "pause" button was activated on the iPhone and the data file was sent by e-mail to a remote computer. The vehicle was then turned around and another run was performed in an eastbound direction. This process was repeated at travel speeds of 40 through to 90 km/h, at 10 km/h increments.

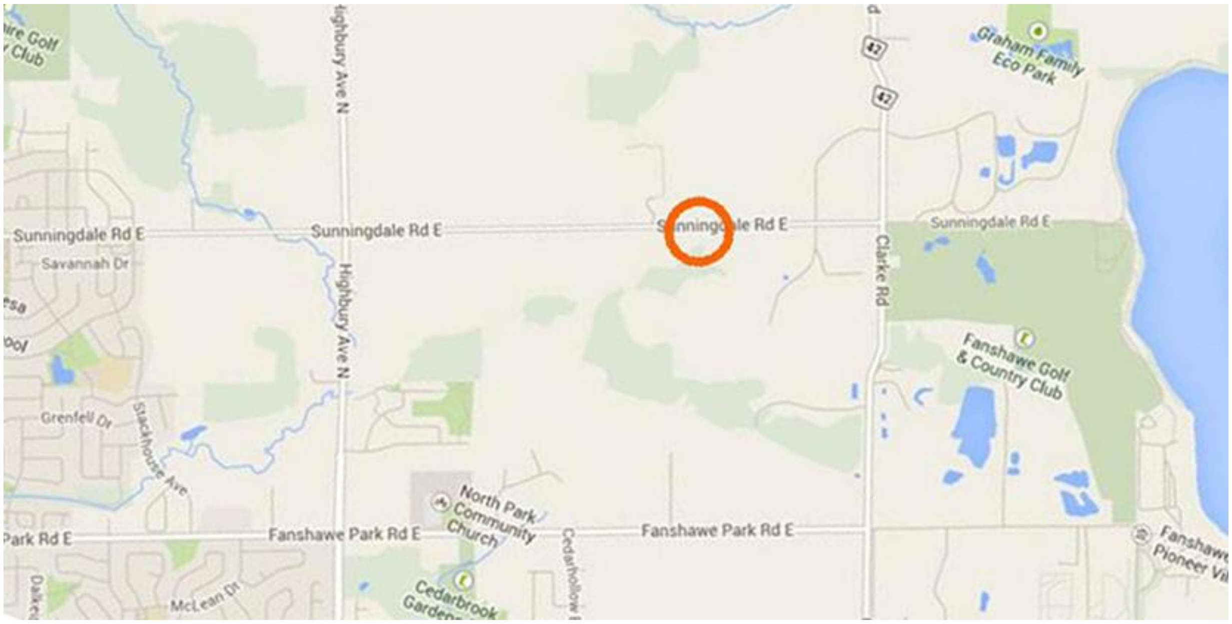


**Figure 1: View of testing location on Sunningdale Road in London, Ontario, Canada, commencing at Clarke Road to the east and terminating near Highbury Avenue to the west.**


**Figure 2: View looking westward along Sunningdale Road from just west of the intersection at Clarke Road. The utility pole on the right side of this view containing the"80 km/h" maximum speed sign, is the precise starting point where the captured data was analyzed.**

Figure 2: View, looking west along Sunningdale Road. Shortly after commencing the data collection a sag is encountered as shown in this view. Commencing at the location of a small bridge the rough road surface was repaved thus a smoother section of pavement was encountered.

Figure 3: View, looking west along Sunningdale Road. The newer (smoother) section of pavement commenced at the west (far) side of this small bridge.

**Figure 4: Upon mounting the upslope of the sag (at small bridge) the roadway entered a long section that was straight and level, as shown in this westward view. The pavement in this area was new and smooth.**


**Figure 5: Near the end of the smooth section of pavement there was a warning sign posted on the right roadside indicating the return of the older and rougher section of road.**

Figure 6: Continuing further westward the end of the newer pavement can be seen the distance background of this westward view along Sunningdale Road.


Figure 7: View, looking west along Sunningdale Road. The end of the newer section of pavement can be seen in the background.

**Figure 8: View, looking west along Sunningdale Road at the point where the newer section of pavement ends and the rougher section of surface returns.**


**Figure 9: View, looking west along Sunningdale Road, along the rough portion of pavement on approach to the intersection with Highbury Avenue.**

Figure 10: View, looking west along Sunningdale Road just east of the intersection with Highbury Avenue. This view shows that the rough segment of pavement ends on the approach to the Highbury intersection.

The point where the rough surface transitioned back into the newer section of pavement (Figure 10) is where the analysis of the gathered data was terminated. Thus each run contained a road segment of rough surface, followed by the smooth surface and then finished off with a segment of rough surface.

## 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 11 is a table providing the results from the three testing dates of March 3, 2014, April 5, 2014 and February 27, 2015. The "Lateral" and "Longitudinal" values being reported in the table are the motion of the test vehicle, in radians per second, displayed as a standard deviation value for the full length of travel of the road, regardless of whether the vehicle is travelling on the rough surface or the smooth surface.

### Test Results From Changing Motion With Increasing Speed

| Testing Date | Direction | Speed | Lateral | Longitudinal |
|---|---|---|---|---|
| | | | | |
| 03-Mar-14 | Westbound | 40 | 0.0357 | 0.0518 |
| | | 50 | 0.0407 | 0.0544 |
| | | 60 | 0.0464 | 0.0517 |
| | | 70 | 0.0497 | 0.0489 |
| | | 80 | 0.0523 | 0.0482 |
| | | 90 | 0.0545 | 0.0523 |
| | | | | |
| | Eastbound | 40 | 0.0336 | 0.0648 |
| | | 50 | 0.0400 | 0.0492 |
| | | 60 | 0.0446 | 0.0446 |
| | | 70 | 0.0491 | 0.0461 |
| | | 80 | 0.0528 | 0.0466 |
| | | 90 | 0.0568 | 0.0469 |
| | | | | |
| 05-Apr-14 | Westbound | 40 | 0.0196 | 0.0299 |
| | | 50 | 0.0219 | 0.0313 |
| | | 60 | 0.0246 | 0.0307 |
| | | 70 | 0.0266 | 0.0288 |
| | | 80 | 0.0286 | 0.0274 |
| | | 90 | 0.0305 | 0.0295 |
| | | | | |
| | Eastbound | 40 | 0.0192 | 0.0283 |
| | | 50 | 0.0224 | 0.0281 |
| | | 60 | 0.0254 | 0.0285 |
| | | 70 | 0.0272 | 0.0266 |
| | | 80 | 0.0300 | 0.0263 |
| | | 90 | 0.0338 | 0.0267 |
| | | | | |
| 27-Feb-15 | Westbound | 40 | 0.0306 | 0.0471 |
| | | 50 | 0.0355 | 0.0426 |
| | | 60 | 0.0404 | 0.0418 |
| | | 70 | 0.0419 | 0.0380 |
| | | 80 | 0.0479 | 0.0379 |
| | | 90 | 0.0518 | 0.0373 |
| | | | | |
| | Eastbound | 40 | 0.0291 | 0.0397 |
| | | 50 | 0.0348 | 0.0400 |
| | | 60 | 0.0426 | 0.0391 |
| | | 70 | 0.0458 | 0.0394 |
| | | 80 | 0.0532 | 0.0348 |
| | | 90 | 0.0577 | 0.0422 |

**Figure 11: Results from 3 testing sessions.**

This data is charted below. In the charts 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 0.0100 to the maximum of 0.0700.

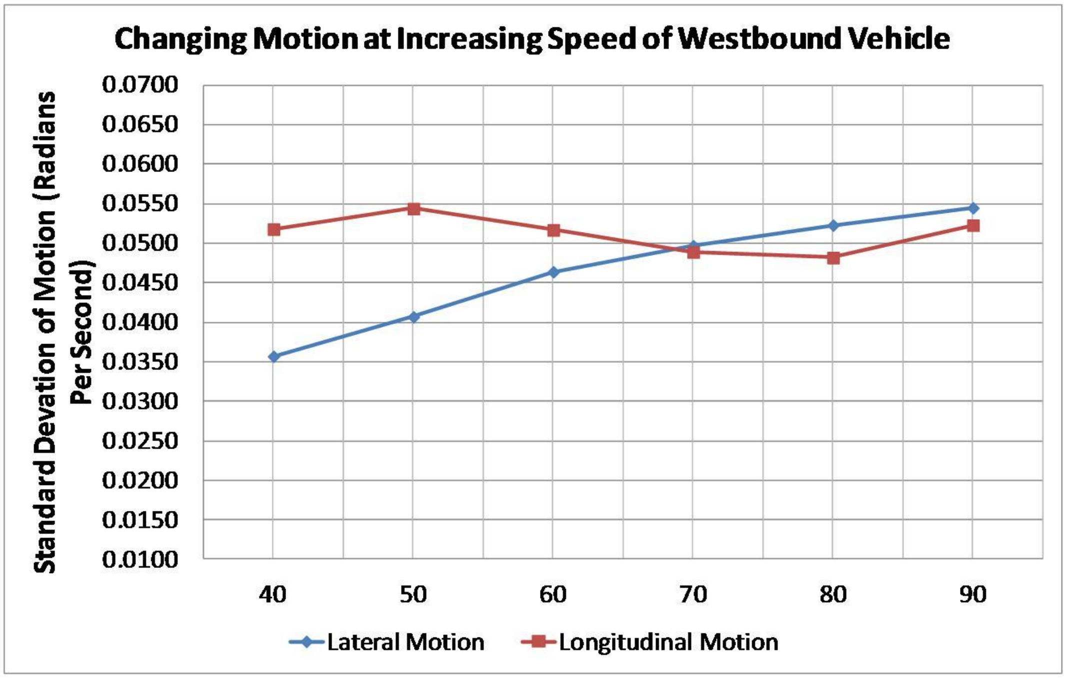


Figure 12: March 3, 2014 - Westbound runs.

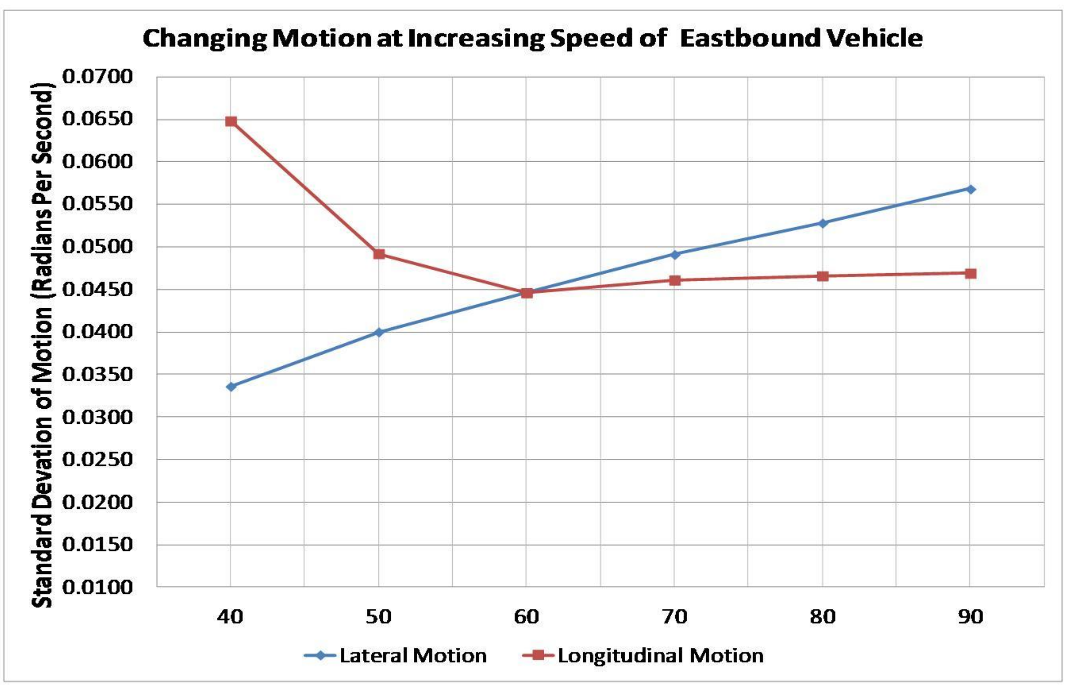


Figure 13: March 3, 2014 - Eastbound runs.

Figures 14 and 15 show the results from our testing April 5, 2014.

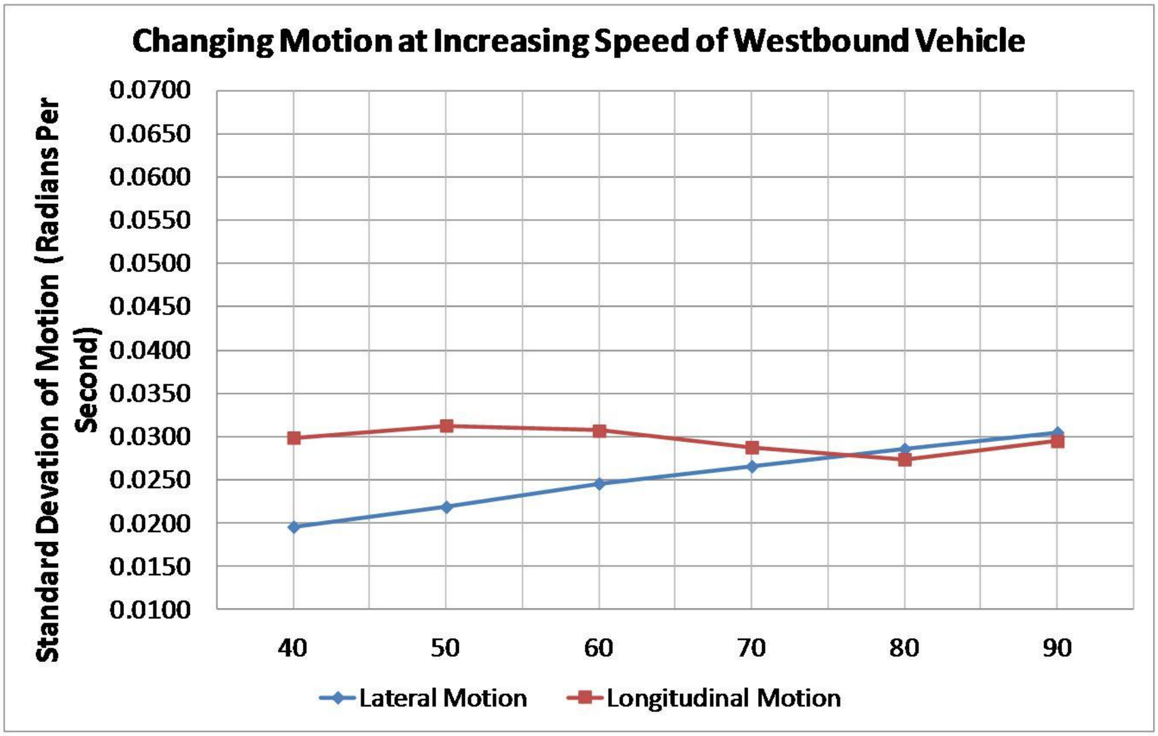


Figure 14: April 5, 2014 - Westbound runs.

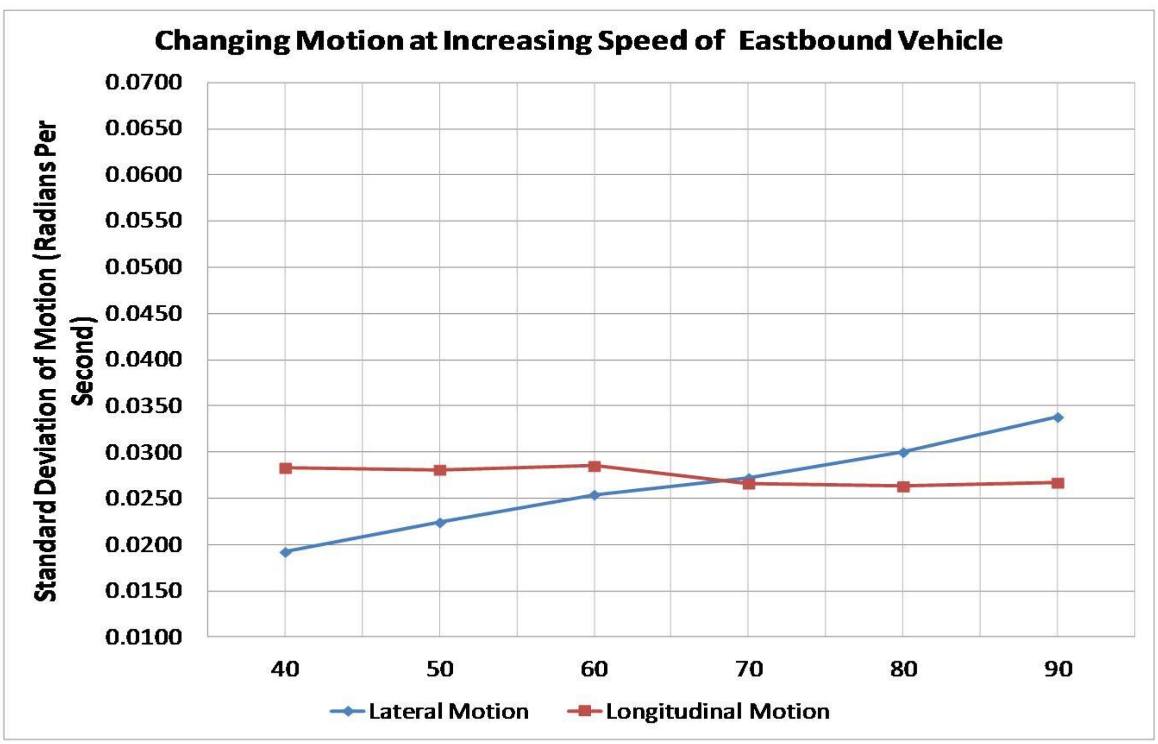


Figure 15: April 5, 2014 - Eastbound runs.

Figures 16 and 17 show the results from our testing February 27, 2015.

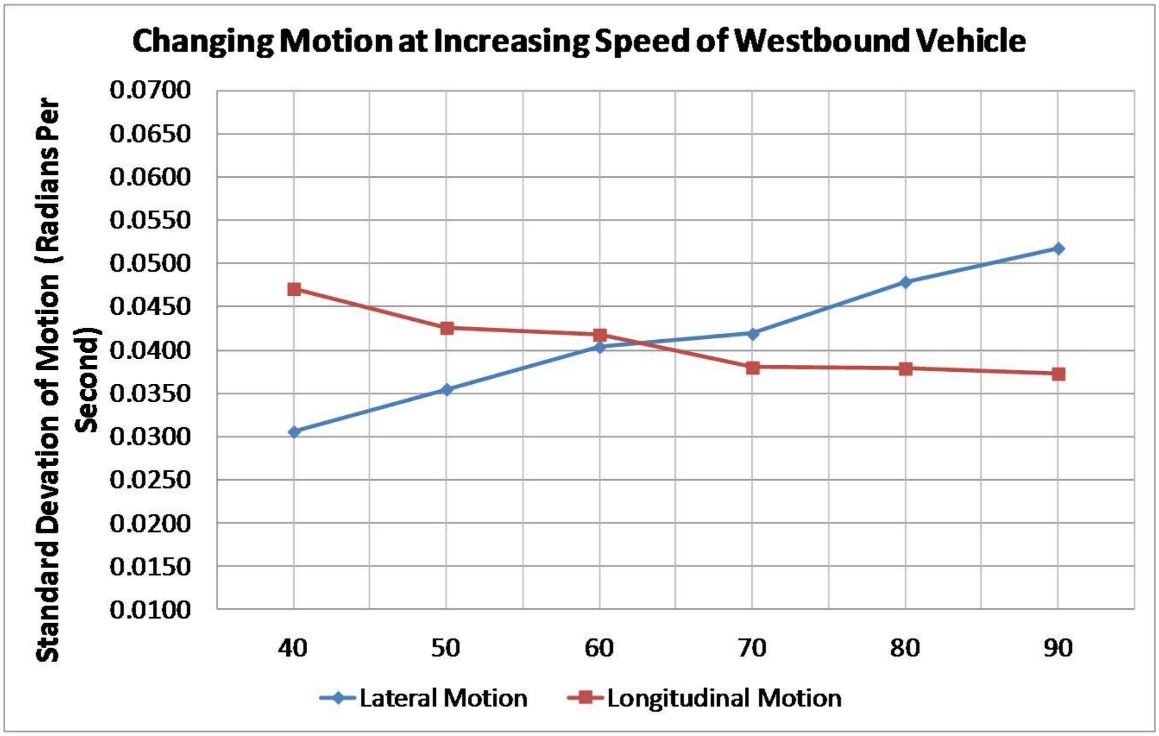


Figure 16: February 27, 2015 - Westbound runs.

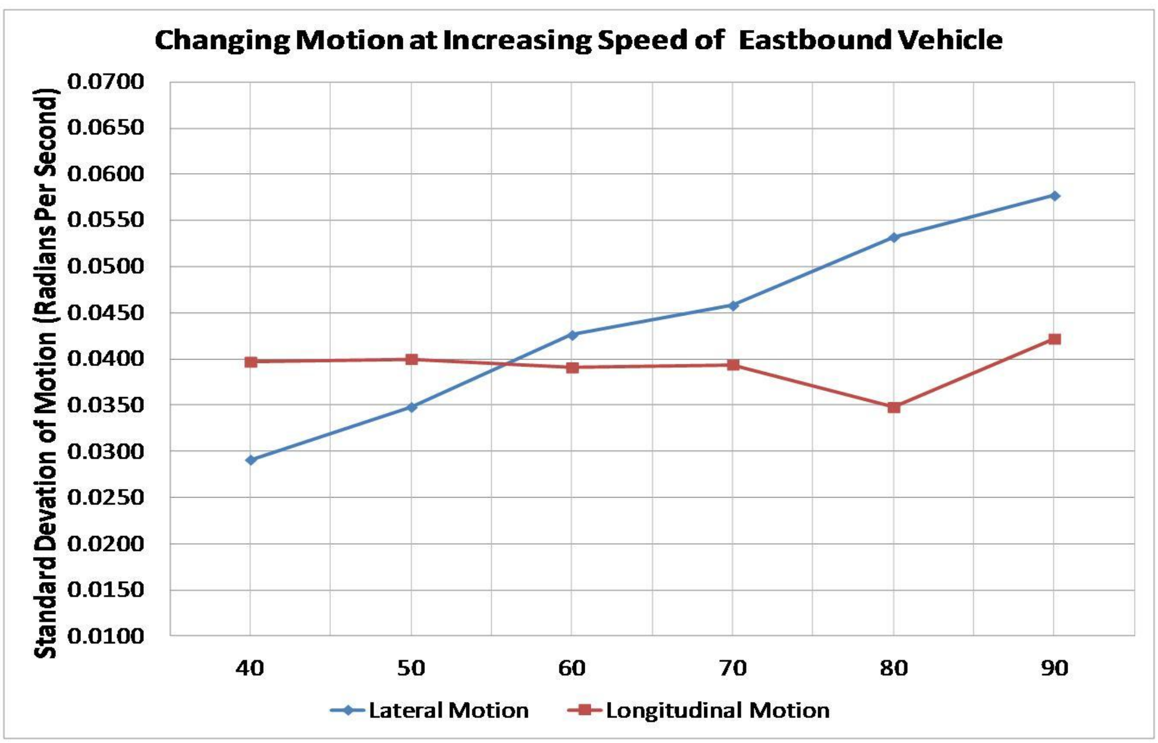


Figure 17: February 27, 2015 - Eastbound runs.

## Discussion

In the area of Sunningdale Road where the testing was conducted the road surface is prone to frost upheaval, usually commencing in mid-January and then receding in late March. Thus on the March 3, 2014 and February 27, 2015 dates the testing was performed when the frost upheaval was present. In contrast, the upheaval had already subsided for the testing on April 5, 2014. The effect of the upheaval of the road surface can be seen in the higher levels of motion displayed in the data for the dates when the upheaval was present. The effect of that upheaval is masked, somewhat, via the inclusion of the smooth segment of road surface within the data of each run. This is so because the newer, smooth section of pavement did not exhibit the frost upheaval, or at least the upheaval in this smooth segment was minimal.

In the earlier articles it was noted that, at the lower speeds of 40-50 km/h the rate-of-change in the longitudinal motion was higher than it was for the lateral motion. However, as the speed was increased, the rate-of-change of the longitudinal motion stayed the same, or perhaps even showed a reducing trend with increasing speed. However, the rate of change in the lateral motion rose significantly as the speed of the test vehicle was increased such that, at the highest speeds (80 and 90 km/h) the lateral motion was higher than the longitudinal motion.

The new data re-affirmed what was indicated in the earlier articles. There appeared to be some choppiness in the longitudinal data as it rose or fell from one speed to another, while generally exhibiting no large increase during increasing speed.

In contrast, the lateral motion data seemed to exhibit a steady, incremental increase that matched very well with the incremental increase in vehicle speed. This pattern was exhibited regardless of the test vehicle's travel direction or the date of the testing, as can be seen in the above charts.

To date, the data has been presented encapsulating the full length of the run regardless of whether the vehicle was travelling on the rough surface or on the newly-paved, smooth surface. It would be of obvious interest to segment the data to separate the effects of the differing surfaces. One option would be to separate the data into three segments along each run since the run includes an initial segment of rough surface, followed by a segment of newly-paved surface and then ending in a final segment of rough surface.

The lengths of these three road segments can be estimated by using one of the 40 km/h tests in which the vehicle would be travelling about 11.11 metres per second.

The first segment of rough surface begins at the "80 km/h" sign and ends at the east edge of the small bridge. From reviewing our videos we noted that it took 63.9 seconds to travel that distance. So it becomes a simple step of multiplying the 63.9 seconds by the average speed of 11.11 metres per second to arrival at an estimated distance of 709.93 metres, or about 710.0 metres for the length of the first of three road segments.

we can remove the length of the small bridge from the analysis and assume that the smooth road surface begins on the west side of the bridge. We can terminate the smooth section of road at the location where the smooth surface returns to the rough surface, as shown in Figure 8. Reviewing the video it can be established that it took our test vehicle 77.87 seconds to traverse this smooth segment. Thus multiplying 77.87 by 11.11 provides an estimated distance of 865.14, or 865.0 metres.

Finally, the termination of the third road segment (or second segment of rough surface) was located in the area shown in Figure 10. Review of the video indicated that it took 45.13 seconds to traverse this final segment and therefore (45.13 x 11.11) this final road segment was about 501.4 metres long.

So, although not equi-distant, each of the three segments represents a substantial length or road and there should be little concern that the differences in lengths should be an issue of concern. The exploration of how these different road segments affect the data will be covered in a future article.

We also hope to conduct a fourth testing date in the summer of 2015 when we can be guaranteed that the road surface is no longer heaved up by the frost. The results from this testing should provide further clarification and solidify the treads that we have observed to date.

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