# Results From iPhone 4S Gyro Testing On A Freshly-Graded Gravel Shoulder To Evaluate It's Safety

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In a July 18, 2013 article posted on the Gorski Consulting website ("Publicity Given To Fortunate Result in Rollover But Nothing Said About Freshly Graded Soft Shoulder That Might Have Caused Crash") we described the evidence left on a freshly graded gravel shoulder where a Kia SUV rolled on Perth County Road 23 south of Mitchell, Ontario. In that article we described how we set-up number of video-cameras on our test vehicle and, using the Gyro app of our iPhone 4S, we conducted testing to evaluate the reaction of our vehicle to the soft gravel.

The present article is a continuation of that description. We developed a video project in Adobe Premiere where we synchronized the videos and displayed them on a single computer screen. We then manually input the values displayed by the Gyro app into an Excel spreadsheet and summarized the data.

The purpose of our testing was to compare the reaction of our test vehicle as it entered onto the freshly graded gravel shoulder to its motion while travelling within its lane.

It can be recalled from the earlier article, the iPhone Gyro app provides a real-time display of the motion of the test vehicle along its three axes. The X axis value identifies the "pitch-pole" action of the vehicle in that it identifies whether the front end may be dipping down toward the pavement or the rear end may be lifting.

The value on the Y axis describes any lateral rolling motion of the vehicle. So it would identify whether the vehicle was tilting to the left or right for example.

The value on the Z axis describes the yawing action of the vehicle. In other words, whether the vehicle is attempting to "fish-tail" or rotate about this vertical axis.

Not only does the Gyro app display a value of the real time angle of the vehicle with respect to these three axes, it also provides separate values of how quickly those angles are changing in degrees per second. It is this second set of values that we focus on in the present article.

Figure 1 on Page 3 shows a screenshot of our computer screen showing the Premiere project opened up at the beginning of Test #1 where we can see synchronized views from the seven video cameras.

We need to identify what is shown in each camera in Figure 1. At the upper left is a view of the test vehicle's speedometer and tachometer. Just below that is a view from the camera mounted from the bike rack, extended from a lateral pole to a position behind the left rear of the vehicle, and pointing forward to show the left side of the vehicle. In the bottom left corner is a view from the left, showing driver's left leg and brake pedal. The view at in the upper middle shows a rearward view of the left front wheel. The view in the centre of the screenshot is from a camera mounted from the dash of the vehicle and pointing forward through the windshield. In the upper right corner of the screenshot is a forward view of the right front wheel. The view at the bottom right is of the face of the iPhone displaying the Gyro app.

In the camera displaying the Gyro app it can be seen that the rates of change in angle (in degrees per second) are displayed along the top row. So the "-0.4" indicates that, at the present time, the angle of the vehicle along the X axis is changing at a rate of -0.4 degrees per second, or that the front end of the vehicle is diving toward the ground slightly. Similarly, the "-0.1" value in the middle of the top row indicates that the angle of the vehicle along the Y axis is changing at the very small rate of -0.1 degrees per second, or that there is almost no lateral rolling of the vehicle. And finally, at the right end of the top row the value of "-0.1" indicates that there is minimal movement of the vehicle's angle with respect to its fish-tailing or yawing about its vertical (Z) axis.

Of course, we explained in the previous article that the second row of values contains the current angle of the vehicle with respect to the three axes.

So, in considering how we should proceed with our testing, we decided that we wanted to obtain an indication of the total motion of the vehicle with respect to its three axes. That is, how quickly was the angle of the vehicle changing with respect to these three axes as the vehicle passed through the site at highway speed. One way this could be done was to simply add up the three values (-0.4, -0.1 and 0.1) in the top row of the Gyro display and obtain a value of -0.4. However doing so would mean that the negative values would cancel out the positive values and we might never detect that something large was occurring to the vehicle. So we decided to sum the absolute values of those three values in the top row. So now the values of 0.4 + 0.1 + 0.1 = 0.6 and this gives us some indication of the extent to which the vehicle is being moved about along these three axes. So these are the values that we inputted into our Excel spreadsheet.

First we decided to obtain some control data by driving northbound in the middle of the northbound lane at 80 km/h with minimal steering. We reasoned that the relatively good road surface condition would provide relatively mild rotations of the vehicle with respect to its three axes. We could then follow up this control testing by driving onto the east gravel shoulder at various speeds, and along various paths, to explore what would happen to the vehicle.

If the descriptions from our previous article can be recalled, we placed four cones on the east gravel shoulder at 50 metre intervals. The first cone was at the precise point where the tire marks from the rollover vehicle exited the paved road surface. Then the remaining three cones were placed at 50 metres intervals back from this location.

For those tests where we had to enter the east gravel shoulder we decided to do so precisely when we could see the top of the 200 metre cone over the slight hillcrest of the road. While viewing that action in the Premiere video project we observed that this exit onto the gravel shoulder occurred when the last tree on the east roadside was exiting the view of our windshield video camera. That tree, and that position can be seen in Figure 1 on Page 3 at the extreme right edge of the camera view in the centre of the screenshot. So in commencing our documentations in the Excel spreadsheet we started that documentation when that tree was disappearing from the right edge of the camera view.


**Figure 1: Screenshot At Timecode 00;07;28;15 of Test #1, of July 18, 2013 Testing With iPhone 4S**

Figure 2 shows the view from our Test #1 when our test vehicle is approaching the 200 metre cone which can be seen near the right edge of the view of the camera pointing through our windshield. Similarly Figure 3 shows the view when our test vehicle is passing the 100 metre cone, and Figure 4 shows the view when our test vehicle is approaching the location where the tire marks of the accident-involved vehicle exited the paved road surface. You can note in Figure 4 that there is an warning sign visible on the east shoulder indicating the symbol for an intersection ahead. When this sign was exiting the right edge of the camera view we terminated the documentation of the data in our Excel spreadsheets.


**Figure 2: Screenshot At Timecode 00;07;36;27 of Test #1, of July 18, 2013 Testing With iPhone 4S Gyro App**


**Figure 3: Screenshot At Timecode 00;07;39;09 of Test #1, of July 18, 2013 Testing With iPhone 4S Gyro App**

Figure 4: Screenshot At Timecode 00;07;43;27 of Test #1, of July 18, 2013 Testing With iPhone 4S Gyro App

For Test #1 our documentations of the data were made between timecode 00;07;28;15 and 00;07;45;21. For those not familiar with timecode, it is just a time clock with the last two digits displaying the number of frames (in the 30 frames of one second). So, for example, the starting time of our documentations began at 00 hours, 7 minutes, 28 seconds and 15 frames of the video project and it ended at 00 hours, 7 minutes, 45 seconds and 21 frames of the project. So the documentations were taken over a period of just over 17 seconds. Because the cruise control on our test vehicle was set at 80 km/h, and because  this translates to a speed of about 22.2 metres per second, it can be said that the documentations occurred over a distance of (22.2 x 17 = 377.4) just over 377 metres.

Recall that Test #1 was supposed to be our control in which we expected to obtain rather benign values. Upon averaging the values of the rates of change in the x, y and z axes contained in our spreadsheet we obtained the following for the 17 seconds of data:

X axis average rate of change in angle  = 0.512 degrees per second

Y axis average rate of change in angle = 0.513 degrees per second

Z axis average rate of change in angle = 0.316 degrees per second

Average rate of change in angle summed across all three axes = 1.341 degrees per second.

Just as a point of clarification, the value of "1.341" degrees per second is just the sum of the previous three values. So it can be looked upon as the value expressing the "overall disturbance of  the vehicle" as the vehicle moves along in the middle of the northbound lane. It combines the effects from all three axes.

So these are the rather benign values that are to be the controls for comparison to the values obtained when the vehicle is driven off the paved surface and onto the loose gravel.

Following Test #1 we conducted 14 other tests, varying our speed and varying the extent to which our vehicle entered onto the loose gravel shoulder. It would be too time consuming to go into the details of all these tests so we have selected two additional tests (Tests 5 and 6) to provide you with an appreciation of how the testing unfolded.

In Test #5 we drove our test vehicle at 80 km/h along northbound in the same portion of the highway as in Test #1 except that we steered our vehicle into a position where the right side tires were in the vicinity of the asphalt edge, but mostly off that asphalt edge. So this would be similar to the many tests conducted by many previous researchers who expressed the opinion that drivers lost directional control of their vehicles when they attempted to steer their vehicles over the hump of the edge drop off between the pavement edge and the lower surface of the gravel shoulder.

Figure 5 on Page 7 shows a screen shot taken of our test vehicle during Test #5 at timecode 00;12;56;27. Our documentations of this test commenced at timecode 00;12;55;09 so it can be seen that this time is about 1.5 seconds into the documentations or shortly after the test vehicle was steered into its test position. The view from the camera shown in the upper right corner of the screenshot is a view looking forward along the right side of the test vehicle and pointing at the right front wheel. Looking past that wheel one might be able to detect the edge of the asphalt and therefore appreciate that the tire is travelling very close to that asphalt edge. In attempting to stay near that asphalt edge the right front tire sometimes mounted the edge and then dropped back into the gravel shoulder. Upon averaging the values of the rates of change in the x, y and z axes contained in our spreadsheet we obtained the following for the 17 seconds of data:

X axis average rate of change in angle  = 0.619 degrees per second

Y axis average rate of change in angle = 1.129 degrees per second

Z axis average rate of change in angle = 0.429 degrees per second

Average rate of change in angle summed across all three axes = 2.151 degrees per second.

These values can be compared to the control values of Test #1 where we simply travelled straight ahead on the relatively smooth pavement of the asphalt surface.


**Figure 5: Screenshot At Timecode 00;12;56;27 of Test #5, of July 18, 2013 Testing With iPhone 4S Gyro App**

When comparing the results from the two tests it can be agreed that there are slightly higher rates of change in angle for the x and z axes but those are relatively small when compared to the larger difference in the values of the y axis. Recall in Test #1 that the average rate of change in angle of the y axis value was 0.513 degrees per second, whereas in Test #5 the value is 1.129 degrees per second.

In a nutshell, the test vehicle appears to be rolling left and right more when it is on the loose gravel shoulder than when it is travelling on the pavement and not much else appears to be different. In fact, when we drove along in the test vehicle the experience we felt was that the vehicle was being pulled left and right, as evidenced by our commentary which was captured by the video cameras as we progressed through the test. But otherwise we were not particularly alarmed by the resultant effects. However it was a different story in Test #6 when we drove half of our vehicle into the loose gravel shoulder.

Figure 6 is a screenshot from our video project at timecode 00;18;42;07. We started documenting this data at 00;18;41;19 or less than a second prior to what is visible in this screenshot. It became clear shortly after entering half of our vehicle onto the loose gravel that the experience was quite different and more hazardous than simply riding near the asphalt edge as in Test 5. So much so that by timecode 00;18;45;01 we can be seen gradually applying the brake pedal in a decision to abort the run. Thus that decision was made after only riding onto the shoulder for less than 4 seconds. After gentle brake application and applying minimal steering we reduced our speed to about

65 km/h at timecode 00;18;49;18 or about 8 seconds after entering the gravel and this is the point where we decided to end our data documentation as the speed of the test vehicle was significantly less than what we had intended.


**Figure 6: Screenshot At Timecode 00;18;42;07 of Test #5, of July 18, 2013 Testing With iPhone 4S Gyro App**

So what was so alarming that we decided to terminate our test? One consideration was the amount of opposing traffic in the vicinity as can be observed in Figure 6. We recognized that any significant instability of the test vehicle could send it into opposing traffic and it was not worth the risk. But also, the effect on the vehicle was also alarming to us. We truly sensed that there was sufficient lack of contact between the tires and a solid surface that the vehicle might enter a state of loss of control. So what did the Gyro data tell us?

Upon averaging the values of the rates of change in the x, y and z axes contained in our spreadsheet we obtained the following for the less than 4 seconds of travel on the shoulder before we applied the brake:

X axis average rate of change in angle = 0.794 degrees per second

Y axis average rate of change in angle = 2.218 degrees per second

Z axis average rate of change in angle = 0.624 degrees per second

Average rate of change in angle summed across all three axes = 3.635 degrees per second.

Again, the rates of change in angle of the X and  Z axis data were larger than in Test 5 but still not as large as the rate of change in the Y axis data. Between Test 5 and 6 the data for the Y axis rose in value from 1.129 to 2.218 degrees per second, or by over one degree. And the "overall disturbance of  the vehicle" value (where we sum the averages from all three axes) rose from 2.151 in Test 5 to 3.635 in Test 6.

It is difficult to objectively quantify what these increases in value mean without examining their value when a test vehicle actually does enter into a loss-of-control. However there were obvious repercussions for allowing that to occur at the present site. However we performed additional tests which are not discussed in this article and this additional testing determined that a speed of no greater than 60 km/h could be acceptable on a loose gravel shoulder of this type. In fact this observation coincides with previous testing we conducted a number of years earlier on roads where a fresh layer of gravel was laid.

The use of the iPhone gyro function in motor vehicle accident reconstruction is a new activity and we have not found any previous research that discusses any test results. For now, until further testing is conducted, the present results have provided a data point where we have not observed any other research, about what vehicle motions and speeds may not be safe when roadside shoulders are freshly graded. It confirms the wisdom of previous research that, when the shoulder of a rural highway is freshly graded it would be dangerous not to place a warning sign to alert drivers that entering the loose gravel at highway speed presents an unacceptable risk of entering into a state of loss of control and eventually resulting in a dangerous collision.

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