Accuracy evaluation of brake distance measurements

The aim of this study was to determine the accuracy of the VBOX when used to measure the braking distance of a vehicle.

Nowadays, vehicle, tyre and brake manufacturers are putting a huge effort into reducing the braking distance of vehicles with every new model that is released. As a result they are demanding more resolution and higher accuracy from the measurement devices, which is a direct result of the braking distances getting smaller and smaller.

Determining the accuracy of a brake stop measurement is notoriously difficult to achieve, and has required a reliable reference measurement system, which in turn needs to be checked against a known source.

The main difficulty in a brake test is determining when and where the test actually begins. Different brake tests require different starting criteria, some tests start from a given speed, and some start from the point of activation of the brake pedal. In both cases it is very difficult to know the precise point on the track that the test was begun.

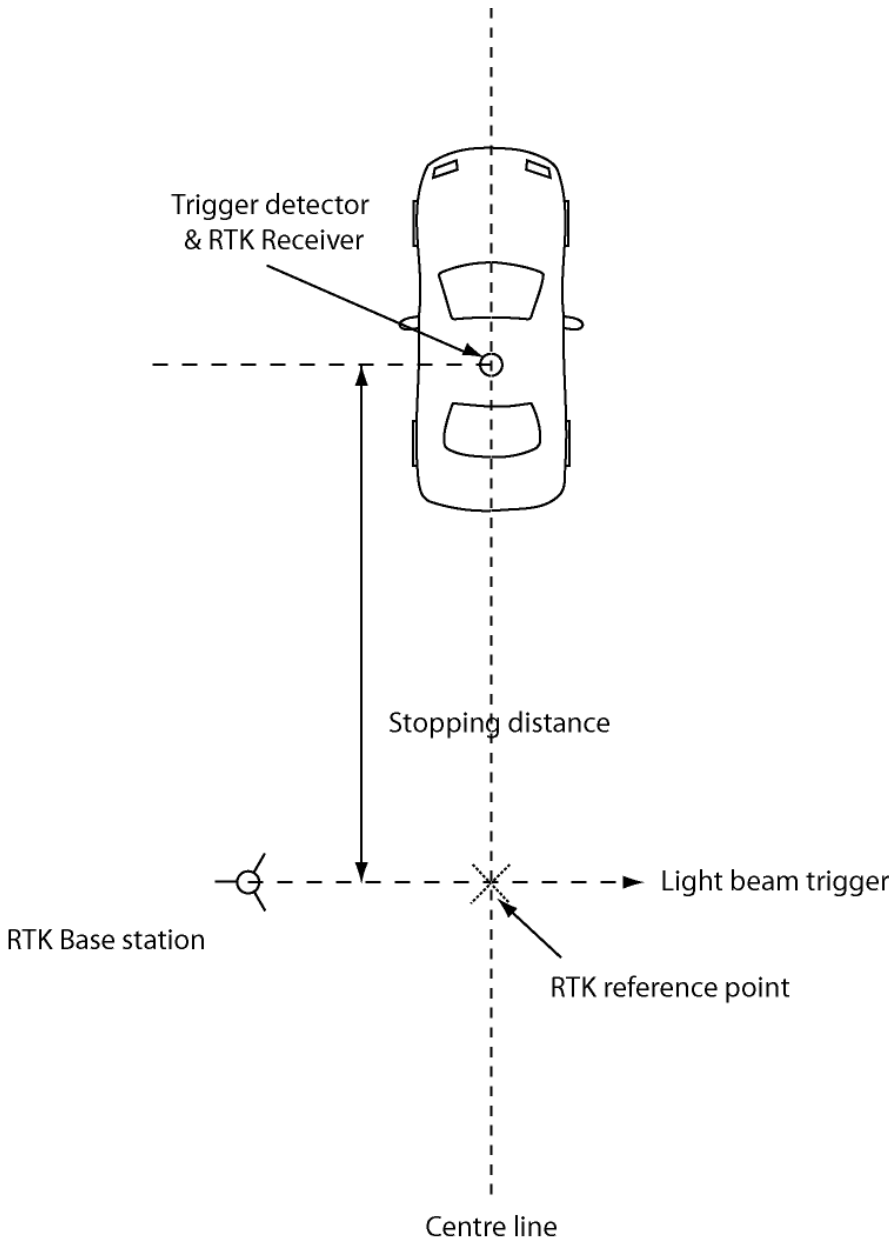
One method that has been used in the past involved the use of a chalk gun, which was activated by a sensor placed on the brake pedal. This fired a chalk shot onto the road surface and was intended to mark the place where the test was started. The main source of error in this method was the variable delay between the electrical application of the gun, and the chalk pellet making impact with the road surface.

RTK GPS

GPS has been used in surveying applications for many years, and modern systems now achieve a 1cm resolution in relative measurement. These systems use a technique called Real Time Kinematic or RTK to achieve these accuracies. This involves the use of a Base Station and a roving receiver, with a radio link between them. Whilst this system is very accurate, you cannot use this in a dynamic situation to measure braking distance, because the question of when and where the test was started still remain.

The best way to use RTK is to have a distance which needs to measured. To do this you place the Base Station at one point, and the Rover at the other, and then you get the co-ordinates of the Rover relative to the Base Station to an accuracy of 1cm.

Simulating a brake test
To accurately determine the starting point of the brake test, a reflective target was placed on a tripod beside the test track in a fixed position. An infrared transceiver was then fixed on the side of the test vehicle so that it would be triggered on passing this target. This would then give a fixed starting line for the distance measurement, and when the vehicle stops, the distance from the starting line to the vehicle could then be measured with relative ease.



(Of course, in a real brake test the trigger would be the pressing of the brake pedal, so this method is only useful for determining accuracy of the measurement system under test, and not the vehicle's actual braking distance.)

To set the base point for the RTK measurement, the vehicle was driven slowly down the centre line until the infrared trigger was activated. The co-ordinates of this location were then averaged for 5 seconds to generate the RTK reference point.

Test setup showing reflector on tripod and RTK base station

To perform a brake test, the vehicle was then driven down the centre line at a set speed, and once the reflector was passed, an ABS assisted brake stop was performed.

Once the vehicle came to a rest, the distance to the RTK reference point was then determined using the RTK system. To verify the accuracy of this method, the first 5 stopping distances were compared using a tape measure, and it was found that they consistently matched the RTK distance to better than 1cm.

Inside the vehicle, the trigger signal was fed into the brake trigger input on the VBOX, and then a number of tests were then carried out with the VBOX recording the information onto a compact flash card.

Results

The VBOX records the Speed, Position, Time, Heading, and Height of the vehicle at 20Hz, and also scans the brake trigger input. From the Speed and Time, the VBOX software calculates the distance travelled by integration. Because the VBOX samples at 20Hz, and the vehicle was travelling at 100kmh, the maximum distance that could be travelled between the trigger point and the next sample point would be over 1 metre. To compensate for this, the VBOX scans the trigger input at 200kHz, and uses this to calculate the extra distance travelled during this period. This is called the “Trigger Event Time”.

In addition to this potential source of error, the GPS calculation of velocity takes a finite time to process. This period is called the GPS Latency, and is in the order of 50ms. As the brake trigger input is external, this latency period has to be taken into account in the measurement of the distance. (The latency of the GPS engine in the VBOX had already been determined by using our Spirent GPS simulator.)

Using these two methods the results from the VBOX were very consistent, and each stop was to within 1% of the RTK distance using our standard software routines.

However, as we now had access to an extremely good reference, the Scan rate and latency algorithms could be further modified to enhance the precision of the VBOX measurements. The end results show a correlation between the RTK distance and the VBOX distance to less than 0.1%.

Results (existing method)

	RTK distance (m)	Trig speed (km/h)	VBOX distance (m) (previous method)	Error (m)
Stop1	41.91	99.9	41.59	**0.32**
Stop2	44.80	103.9	44.49	**0.31**
Stop3	44.32	102.5	43.97	**0.35**
Stop4	45.98	104.6	45.53	**0.45**
Stop5	46.38	107.0	45.91	**0.47**
Stop6	49.75	109.9	49.35	**0.40**
Stop7	50.93	110.4	50.39	**0.54**
Stop8	50.23	107.0	50.03	**0.20**
Stop9	44.60	105.8	44.16	**0.44**
Stop10	54.68	111.6	54.31	**0.37**
Stop11	47.52	107.5	47.14	**0.38**
Stop12	52.56	109.4	52.09	**0.47**
	Average error			**0.39**

Results (new method)

	RTK distance (m)	Trig speed (km/h)	VBOX distance (m) (new method)	Error (m)
Stop1	44.40	98.5	44.36	**0.04**
Stop2	47.91	102.3	47.96	**-0.05**
Stop3	41.87	99.0	41.84	**0.03**
Stop4	43.92	99.9	43.89	**0.03**
Stop5	38.08	94.5	38.07	**0.01**
Stop6	45.81	100.3	45.81	**0**
Stop7	43.22	97.7	43.23	**-0.01**
Stop8	39.14	95.4	39.15	**-0.01**
Stop9	42.14	97.2	42.16	**-0.02**
Stop10	40.82	96.9	40.81	**0.01**
Stop11	42.14	99.7	42.14	**0**
Stop12	38.61	94.3	38.64	**-0.03**
	Average error			**0.00**

Conclusion

Using a fixed reference point with an RTK GPS system is a very precise method of determining the accuracy of distance measurement systems in a dynamic situation simulating a real brake test.

This process was then used to refine the results obtained from the Racelogic VBOX to a level far beyond what is currently required by tyre and vehicle manufacturers, which means that the VBOX can be used with a high level of confidence in such situations.