SIMRET makes Heavy Vehicle Brake Testing easy!

The traditional way to measure brake performance of a vehicle has been to its measure stopping distance. In other words, the distance travelled between applying the brakes and coming to rest. Unfortunately to determine brake performance in this way requires an accurate knowledge of the speed. In fact, double the speed means four times the stopping distance with the same brakes! Even a 20% error in speed means nearly 50% error in brake performance, and what if the speedometer is faulty? Did the driver accurately judge his brake application point? At 32 km/h his truck travels 9 metres in a second, and that’s two thirds of the permitted maximum stopping distance from that speed! On sloping ground things get even worse, and the gradient of the test track needs to be known accurately.

Fortunately there is an easy way, use SIMRET. Then you can forget about having to know the speed, or the track gradient, or worry about the driver’s reaction time, and there are no tedious calculations to do. It even produces a printout of the results complete with time and date of the test and the identity of the truck.

SIMRET was specifically designed by the Research Division of the UK Health and Safety Executive to test heavy off-road vehicle brakes and to automatically compensate for any variation in gradient when doing so. Other brake testers are available but these were first and foremost designed for testing normal road going vehicles on good level surfaces, consequently any variation in gradient could lead to significant and potentially dangerous errors in their measurement.

Guidelines for the minimum brake performance of rubber-tyred machines can be found in the Internation Standard BS EN ISO 3450:1996 The table overleaf reproduces its recommendations in terms of SIMRET brake efficiency readings.

Minimum Brake Performance

Minimum brake performance for rubber-tyred machines. Derived from BS EN ISO 3450:1996 in terms of SIMRET brake efficiency		
	Service	*Secondary*
Machines tested without payload - see ISO 3450:1996 Table 2	**28 %**	**14 %**
Machines tested with payload except rigid frame or articulated dumpers with a machine mass over 32 tonnes - see ISO 3450:1996 Table 3	**17 %**	**12 %**
Rigid frame and articulated steer dump trucks with a machine mass over 32 tonnes and tested with payload - see ISO 3450:1996 Table 4	**19 %**	**14 %**
All tests to be carried out with a fully loaded machine (except where stated), on any safe down-slope, and from the maximum safe machine speed subject to a maximum of 32 kph. Figures have been rounded up to nearest %.		

Brakes should normally be tested with the machine fully laden, this ensures that they are capable of generating sufficient work to stop the machine to the required standard in all circumstances.

A Pedal Force Transducer is also available for SIMRET. This measures the brake pedal force in Newtons applied by the driver during the brake test and records it on the SIMRET printout. Maximum force levels are stipulated in Table 1 of ISO 3450:1996

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Brake Testing and EN ISO 3450:1996

Applying the brakes generates a force on the brake drums which is transmitted to the road surface through the wheels and tyres. When a force acts on anything it causes a change in velocity, in other words it causes an acceleration or deceleration. This is just Newton's Second Law, **Force** = **Mass** times **Acceleration**. When brakes are applied the force is opposing the motion and the velocity decreases with time, a deceleration.

Braking Force equals **Mass** times **Deceleration**

When fully applied, the braking system for a particular vehicle will normally generate a roughly constant **Braking Force**. As the brakes deteriorate the braking force will get less. When this force is written as a fraction of the vehicle weight it is called the **Brake Ratio** (or the **Brake Effort** if expressed as a percentage).

Brake Ratio equals **Braking Force** divided by **Weight**

The vehicle **Weight** is just the downward force of the vehicle caused by gravity acting on the **Mass** of the vehicle.

If an object is allowed to fall freely under the force of gravity its velocity increases at a constant rate of 9.81 metres per second per second. That is, in each second its speed increases by 9.81 metres per second. This acceleration is always the same regardless of the object. For shorthand, this constant acceleration due to gravity is called **g**.

Therefore

Weight equals **Mass** times **g**

and

Brake Ratio equals **Deceleration** divided by **g**

The above is true for <u>level ground only</u>, we will look at the effect of slopes later.

It is usual to express vehicle deceleration as a percentage or fraction of **g**. For example, a deceleration of 20% **g** is equal to a deceleration of 0.2 times 9.81 or 1.9 metres per second per second.

Simple mathematics allows us to calculate the **Stopping Distance** for vehicles braking under constant deceleration.

Stopping Distance equals **Speed** squared divided by twice the **Deceleration**

or in shorthand, stopping distance in metres= $\frac{V^2}{2 \times A}$ where A is the deceleration (in metres/second/second) and V the speed in metres per second.

Suppose a vehicle is travelling at 25 km/h and its brakes decelerate it at 25% **g**, what will be its stopping distance? Well 25 km/h is 6.94 metres/sec and 25% g is 2.45 metre/sec/sec so the distance is (6.94 x 6.94)/(2 x 2.45) or 9.8 metres.

How about if the speedometer was wrong and it was actually travelling at 30 km/h (in other words a 20% speedo error)? The answer would be 14.2 metres which is quite a difference. In fact it is 44% more than the test done from the correct speed. This might be the difference between pass and fail! Generally speaking the distance error will be about twice the speedo error

Some brake performance tests have to be done on steep down slopes. This makes sure the brakes have to do a lot of work to stop the vehicle. Now, on a down slope, gravity is trying to push the vehicle down the slope. On a 10% slope a freewheeling vehicle would accelerate down the slope at 10% **g**. It follows that the **Braking Force** has to counteract this accelerating force before starting to stop the vehicle. So if the brakes gave 25% **g** on the flat, they would only give 25% - 10% = 15% **g** deceleration on a 10% downslope. This corresponds to an increase in stopping distance. From the same 25 km/h speed, on this 10% slope the stopping distance would be 16.4 metres instead of 9.8 metres.

Deceleration (in % **g**) equals **Brake Effort** minus **Slope**

It should be clear that speed and slope variations are great sources of error when trying to check brake performance by measuring stopping distance. For example, how many operators have access to the correct test slope?

And just how accurately can the exact point where the brakes are applied be determined? At 32 km/h the vehicle travels 9 metres in every second, so just half a second error changes the stopping distance by over 4 metres, or about a third of minimum required stopping distance for an un-laden machine from that speed.

Looking back on the above, the only constant which determines how a particular vehicle will stop is the **Brake Effort**. Regardless of the slope or the speed it remains constant. If we could measure this, the only thing that would need to be remembered is that the vehicle must be travelling fast enough or going down a steep incline so that the brakes have to do a realistic amount of work. But otherwise we could do the test anywhere!

The SIMRET 3000 instrument measures **Brake Effort** and gives a printout of the average **Brake Effort** and, to show the test was realistic, the vehicle **Speed** and ground **Slope** too.

The average or mean **Brake Effort** measured while the vehicle is decelerating is called the **Brake Efficiency**.

Of course, brakes (especially heavy vehicle brakes) do not operate instantaneously. There will always be a delay or reaction time which adds to the stopping distance. During the **Delay Time** the vehicle will have travelled an extra distance equal to its **Speed** times the **Delay Time**.

SIMRET measures the **Delay Time** too! From the discussion above

$$\textbf{Stopping Distance} = \frac{V^2}{2 \times \text{Deceleration}} + V \times \text{Delay Time}$$

Or expressed in percentage g deceleration and speeds in km/h the stopping distance in metres is

$$\textbf{Stopping Distance} = \frac{V_{kph}{}^2}{2.6 \times \text{Deceleration}(\%)} + 0.28 \times \text{Delay}(\text{sec}) \times V_{kph}$$

The **Deceleration** depends on **Slope** whereas the **Brake Effort** does not! For example, on a nominal 10% **Slope** with 25% **Brake Effort**, each 1% change in the slope causes an 8% change in the **Stopping Distance**.

Substituting into the equation gives, stopping distance in metres =

$$\frac{V_{kph}{}^2}{2.6 \times \text{Brake Efficiency}(\%) - 2.6 \times \text{Slope}(\%)} + 0.28 \times \text{Delay}(\text{sec}) \times V_{kph}$$

The similarity of the above equation and those in Tables 2, 3 and 4 of EN ISO 3450:1996 is obvious and below we give a table of the SIMRET Brake Efficiency readings which are equivalent to the maximum permitted stopping distances.

By inspection we can see that for a given brake performance, the SIMRET Brake Efficiency is independent of the speed of the truck or the slope of the test course. In other words, just a single number characterises the brake performance independently of speed or slope. Remember that with SIMRET brake performance tests can be done anywhere, on any slope and from any speed. The only proviso is that the vehicle should be going fast enough for the **Brake Effort** to fully develop and the brakes to work as hard as recommended in the standard test.

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