Stopping Distance: Theory vs Practice

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Mathematical Model

Braking is a dynamic event. A host of factors dictate how, when and where a motorcycle will come to a stop after initiation of braking. Typically, on application of brakes the weight on the rear wheel starts shifting forward. This implies that the centre of gravity (C.G.) will also shift forward. Thus braking effort needs to vary dynamically beginning at the rear and terminating at the front.

In this simple model created to simulate a braking event, we equate the kinetic energy of the vehicle to the braking force applied to obtain an expression for the theoretical stopping distance.

Mathematical Model for Stopping Distance

Mass of vehicle $m_{vehicle} := 100\ kg$

Mass of rider $m_{rider} := 75\ kg$

Total Mass of rider+vehicle $m_{total} := m_{vehicle} + m_{rider} = 175\ kg$

Vehicle Velocity $v_{vehicle} := 50\ \frac{km}{hr}$

Coefficient of Friction $\mu := 0.7$

Reaction at wheel $R_{total} := 175\ kg$

Kinetic Energy $E_{kinetic} := 0.5 \cdot m_{total} \cdot (v_{vehicle})^2 = (1.688 \cdot 10^4)\ J$

Stopping Distance:

$$D_{vehicle} := \frac{E_{kinetic}}{\mu \cdot R_{total} \cdot g} = 14.05\ m$$

The model makes a few assumptions. The coefficient of friction is assumed to remain constant throughout the braking event. The masses of the vehicle and rider are also assumed as standard. The vehicle velocity of 50 km/hr is assumed to be the average riding velocity in city limits. The assumed coefficient of friction of 0.7 is the most prevalent on road conditions in India.

Measuring Practice

The method used by OEM's to measure stopping distances involves the use of GPS and high speed camera tracking. These are unaffordable methods for the average enthusiast. The following is a description of stopping distance testing for a 125 cc motorcycle fitted with Intent Rapid Braking System.

Conditions:

- A flat stretch of Asphalt longer than 1 km.
- 3 Different Riders, 6 Trials Each
- 2 Different Riders, 6 Trials for Rider + Pillion
- Coefficient of Friction, μ = 0.7
- Speed of Vehicle = 50 km/hr

The testing was carried out on the 4th of November 2014 beginning 10:30 AM. The rider profiles of the test riders and stopping distances achieved are documented below.

An average speed of 50 km/hr was maintained by the rider. Braking was initiated upon crossing flags setup at a distance of 200 m from the start point. Measuring flags were setup at intervals of 10 feet and the stopping distance was measured with respect to the rear wheel with measuring tape.

Sl. No	Rider Details		
	Rider 1 – 81 kg , 1.67 m	**Rider 2 – 73 kg , 1.79 m**	**Rider 3 – 55 kg , 1.67 m**
	Stopping Distance (m)		
1	9.15	9.76	10.06
2	9.15	9.76	8.54
3	7.62	9.76	8.54
4	7.62	9.15	9.15
5	9.15	9.15	8.54
6	7.62	9.15	8.84

Table (2) – Rider only Stopping Distances

The test was repeated for Rider + Pillion wherein Rider 1 and Rider 2 tested the motorcycle as both rider and pillion. The results are documented below.

Sl. No	Trial Details	
	Trial 1 – Rider 2 Pillion	**Trial 2 – Rider 1 Pillion**
	Stopping Distance (m)	
1	9.15	9.45
2	8.54	8.54
3	9.15	9.15
4	10.67	9.15
5	8.54	9.15
6	8.84	9.15

Table (3) – Rider + Pillion Stopping Distances

Stopping Distance Index

Serial No.	Speed, v (km/hr)	Coefficient of friction, μ	Stopping distance (m)
1	50	0.1	98.35
		0.2	49.18
		0.3	32.87
		0.4	24.59
		0.5	19.67
		0.6	16.39
		0.7	14.05
2	40	0.1	62.95
		0.2	31.47
		0.3	20.98
		0.4	15.74
		0.5	12.59
		0.6	10.49
		0.7	8.99
3	30	0.1	35.41
		0.2	17.70
		0.3	11.80
		0.4	8.85
		0.5	7.08
		0.6	5.90
		0.7	5.06
4	20	0.1	15.74
		0.2	7.87
		0.3	5.25
		0.4	3.93
		0.5	3.15
		0.6	2.62
		0.7	2.25
5	10	0.1	3.93
		0.2	1.97
		0.3	1.31
		0.4	0.984
		0.5	0.787
		0.6	0.656
		0.7	0.562

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