Vehicle Characteristics

Braking Distance

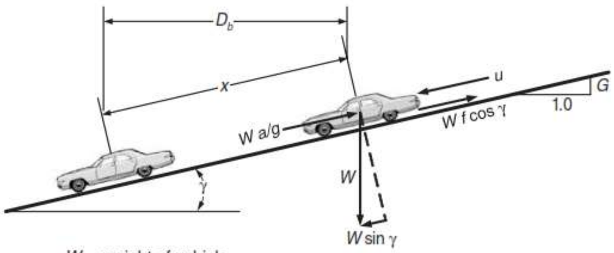
- The action of the forces on a moving vehicle play an important part in determining the distance required by the vehicle to stop.

- Factors of importance include
  - the deceleration rate,
  - the coefficient of friction between the tires and the road pavement

Vehicle Characteristics-Roads …

Braking Distance, Road Vehicles

FIGURE 3.7
Forces acting on a vehicle braking on a downgrade.



W = weight of vehicle
f = coefficient of friction
g = acceleration of gravity
a = vehicle deceleration
u = speed when brakes applied
D_b = braking distance
γ = angle of incline
G = tan γ (% grade/100)
x = distance traveled by the vehicle along the road during braking

Vehicle Characteristics-Roads …

Braking Distance, Road Vehicles

Frictional force on the vehicle $= Wf \cos \gamma$

Force acting on the vehicle due to acceleration $= W \frac{a}{g}$ (3.11)

where

g = acceleration due to gravity
a = deceleration that brings the vehicle to a stationary position

If u is the initial velocity, then $a = -\frac{u^2}{2x}$ (assuming uniform deceleration), where x = distance traveled along the plane of the grade during braking. The component of the weight of the vehicle $= W \sin \gamma$.

Substituting into $\sum F = ma$, we obtain

$$W \sin \gamma - Wf \cos \gamma = W\frac{a}{g} \quad (3.12)$$

Substituting for a in Equation 3.12, we obtain

$$W \sin \gamma - Wf \cos \gamma = W\frac{u^2}{2gx} \quad (3.13)$$

However, $D_b = x \cos \gamma$.

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Vehicle Characteristics-Roads …

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Substituting for x in Equation 3.13, we obtain

$$W\frac{u^2}{2gD_b} \cos \gamma = Wf \cos \gamma - W \sin \gamma$$

which gives

$$\frac{u^2}{2gD_b} = f - \tan \gamma \quad (3.14)$$

and

$$D_b = \frac{u^2}{2g(f - \tan \gamma)} \quad (3.15)$$

Note, however, that $\tan \gamma$ is the grade G of the incline (that is, percent of grade/100) as shown in Figure 3.7.
Equation 3.15 can therefore be written as

$$D_b = \frac{u^2}{2g(f - G)}$$

If g is taken as 9.81 m/s^2 and u is expressed in km/h, Equation 3.15 becomes

$$D_b = \frac{u^2}{254.3(f - G)} \quad (3.16)$$

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and D_b is given in meters. Also, the friction coefficient f can be represented as a/g, where a is the deceleration rate in m/s^2. AASHTO recommends that a deceleration rate (a) of 3.41 m/s^2 be used as this is a comfortable deceleration rate for drivers. Equation 3.16 then becomes

$$D_b = \frac{u^2}{254.3(0.35 - G)} \quad (3.17)$$

Note that Equation 3.17 is for when the vehicle is traveling down a grade. When the vehicle is traveling up a grade, the equation is

$$D_b = \frac{u^2}{254.3(0.35 + G)} \quad (3.18)$$

A general equation for the braking distance can therefore be written as

$$D_b = \frac{u^2}{254.3(0.35 \pm G)} \quad (3.19)$$

The plus sign is for vehicles traveling uphill, the minus sign is for vehicles traveling downhill, and G is the absolute value of tan γ.

Also, the distance traveled while reducing the speed of an automobile from u_1 to u_2 in km/h is given as

$$D_b = \frac{u_1^2 - u_2^2}{254.3(0.35 \pm G)} \quad (3.20)$$

Vehicle Characteristics-Roads …

Stopping Sight Distance, Road Vehicles

It should also be noted that the distance traveled between the time the driver observes an object in the vehicle's path and the time the vehicle comes to rest is longer than the braking distance computed from Equation 3.19. The additional distance accounts for the distance traveled during the perception reaction time. The total distance traveled during a braking maneuver is referred to as *the stopping distance* and is given as

$$S(in\ m) = 0.28ut + \frac{u^2}{254.3(0.35 \pm G)} \quad (3.21)$$

The first term of Equation 3.21 computes the distance traveled during the perception reaction time t (s), and u is the velocity in km/h at which the vehicle was traveling when the brakes were applied.