Brake Calculations

Parameters:-

$$\text{Pedal ratio} = \frac{(\text{Hinge} - \text{brake pedal}) \text{ Length}}{(\text{Hinge} - \text{Master cylinder}) \text{ Length}} = q$$

Friction Coefficient between Brake rotor & disc = 0.4

Friction Coefficient between Ground and wheel = 0.85.

Center of Gravity height from ground = 540 mm

Mass of vehicle = 275 kg.

Mass distribution (Front : Rear) = 40:60

Brake bias (Front : Rear) = 50:50.

Wheelbase (m) = 1530 mm.

Outer Diameter of Tyre = 584.2 mm [23"]

Master Cylinder Bore diameter = 19.05 mm.

Brake Caliper Piston diameter = 28.448 mm.

Number of pistons in each brake caliper = 2.

Brake Rotor radius = 76.2 mm.

To optimize pedal ratio such that the driver applies a force less than 30 kgf for max deceleration, and the pedal ratio is not too large.

Max. deceleration possible through braking:

$\Rightarrow \mu g = 0.85 \times 9.8 = 8.33 \text{ m/s}^2$

$\Rightarrow$ Stopping distance(s) required to decelerate from 40 kmph to 0 kmph:

$$\left(40 \times \frac{5}{18}\right)^2 - 0^2 = 2(8.33)S$$

$\Rightarrow \boxed{S = 7.41 \text{m}}$

Normal Force on each wheel (Static Condition) :-

Normal force on front axle $\Rightarrow (275)(9.8)(0.4)$ N

Normal force on rear axle $\Rightarrow (275)(9.8)(0.6)$ N

$\Rightarrow$ Normal force on each of the front wheels in static condition = 539 N.

$\Rightarrow$ Normal force on each of the rear wheels in static condition = 817.32 N.

Dynamic Load Transfer :-

$$\frac{mah}{\omega_b} = (275)(8.33)\left(\frac{540}{1530}\right) = 808.5 \text{ N}$$

Normal force on the front wheels during deceleration:-

$\Rightarrow$ 539 N (Static) + 404.25 N (Dynamic) = 943.25 N

Normal force on the rear wheels during deceleration:-

$\Rightarrow$ 817.32 N (Static) - 404.25 N (Dynamic) = 413.07 N

Max. friction force on the wheel when all wheels are locked up:-

$\Rightarrow$ friction force on any of the front wheels

$\Rightarrow (943.25)(0.85) = 801.7625$ N.

$\Rightarrow$ friction force required at the rotor $= (801.7625)\left[\frac{292.1}{76.2}\right]$ N

≈ 3073.42 N

Normal force on brake rotor by the brake pad required $= \frac{3073.42}{\mu} = \frac{3073.42}{0.4} = 7683.55$ N

Assuming an approximation where brake piston contact point is at the edge of the rotor.

$\Rightarrow \frac{7683.55N}{2} = 3841.8\ N$ required by each piston.

$\Rightarrow$ Force required at the master cylinder:

$$(3841.8) \times \frac{\text{Master Cylinder Piston Area}}{\text{Brake Piston Area}} = (3841.8) \times \left(\frac{19.05}{28.448}\right)^2$$

$\Rightarrow \boxed{1722.8\ N}$

Force needed at the brake pedal $\Rightarrow \frac{1722.8}{\text{Pedal ratio}} = \frac{1722.8}{q}$

$$\frac{1722.8}{q} < 30\ (9.8)$$

$$\Rightarrow q > \frac{1722.8}{30\ (9.8)}$$

$$\Rightarrow \boxed{q > 5.85}$$

Hence the pedal ratio is chosen as 6.