Adhesion is the grip or force of attachment, produced by friction between the wheels and rails. Adhesion is required to keep the wheels from slipping. It depends on various factors and it applies a maximum limit on the useful Tractive Effort (TE) for a given axle-load.

Coefficient of Adhesion

\[ \mu = \frac{T_{\text{max}}}{W} \]
Coefficient of Adhesion

- Coefficient of adhesion ($\mu$) is the ratio of "maximum value of tractive effort ($T_{\text{max}}$) which can be transmitted to the wheel" divided by the "effective value of load (W) on the driving axle".

$$T_{\text{max}} \propto W \text{ or } T_{\text{max}} = \mu W, \text{ if } T > T_{\text{max}} \text{ wheel-slip starts.}$$

$$\mu = \frac{T_{\text{max}}}{W}$$

- Max. Value of $\mu$ for steel on steel = 0.44 = 44% in most ideal case.
Therefore, if $T_{\text{max}}$ is to be increased, weight on driving-wheel has to be increased, but track has the limitation of maximum axle-load, therefore number of axles has to be increased.
Wheel slip in traction

Wheel slide in braking

1. Wheel slip may lead to stalling, damage to rail and wheel.

2. Slip-stick oscillations create stress on components of axle wheel assembly e.g. bearings, gear, pinion, axle, armature shaft, commutator, carbon brushes.

3. Wheel slide eventually makes the wheel tread flat which, if retained in service, hammer the rails. So immediate tyre turning is required (loco is taken out of service)
The Wheel Slip Phenomenon

Maximum tractive or braking effort is obtained if each powered wheel of the vehicle is rotting at such an angular velocity that its actual peripheral speed is slightly higher (motoring) or slightly lower (braking) than the true vehicle speed.

i.e. the linear speed at which the vehicle is traveling, usually referred to as “ground speed” or “track speed”. The difference between wheel speed and track (or “ground”) speed is referred to as “slip speed” or Creep.

\[ \text{Slip} = \left( \frac{\delta V}{V} \right) \times 100\% \]
Bad Effects of Wheel Slip / Slide

- Damaged Gears.
- Damaged gear profiles lead to other modes of oscillations.
- Damaged bearings.
- Cracks in bogie frames, supports and fixtures.
- Excessive wheel wear and rail-burns.
Rail Burn
Damaged Wheel
Damaged Rail Head
FACTORS AFFECTING ADHESION
1. **Effect of speed on adhesion** :- As friction is maximum at start and then reduces with speed, similarly adhesion is maximum at start and then reduces with speed.

2. **Rail condition and weather condition** :-

   - Dry leaves and coal dust also reduces adhesion.
   - Wet rails reduce adhesion.
   - Oily rails drastically reduce adhesion.
   - A thin film of dust, etc. gets stuck to wheel-rim and reduces adhesion-value of steel on steel.
• Moderate to heavy rain is better than drizzle for adhesion.

• Sanding helps, but the sand should be fine, dry and should fall on rail-head.

• Unevenness of rail-wheel contact,

• Due to worn-out rail or wheel,

• Loose track packing,

• Warp in wheel-rim,

• Difference in wheel-dia,
• irregular wheel tread profile,
• variations in track-levels,
• less contact area between rail & wheel at points & crossings, and curves,

**Reduction of Adhesion on Curves**

• The angle subtended between the wheel flange and the gauge face of the rail is called “angle of attack”.

• Increase in this angle by 1 deg. as on curves, reduces the adhesion by half.
• Wheels mounted in a conventional rigid bogie cannot conform to curves. Their flanges bite into the gauge face of the rail, wearing metal from both surfaces.

• The radial bogie reduces the angle of attack, and literally steers through curves, keeping wheels parallel to the direction of the track. This type of bogie improves adhesion.
3. Mechanical Factors

3.1 Effect Of Weight Transfer :-

When the loco is standstill on level gradient, its weight is equally shared by all axles, but this condition is disturbed when the loco or train is in a condition of run or start/brake, due to turning moments.
<table>
<thead>
<tr>
<th>SN</th>
<th>Component</th>
<th>Important Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body Reaction</td>
<td>1. Height of drawbar &amp; centre-Pivot.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Gap between loading points on front &amp; rear bogie.</td>
</tr>
<tr>
<td>2</td>
<td>Bogie Reaction</td>
<td>1. Direction of TM noses.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Height of centre pivot.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Primary suspension.</td>
</tr>
<tr>
<td>3</td>
<td>TM Nose Reaction</td>
<td>1. Diameter of wheel.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Gap between TM nose and axle-centre.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Direction of noses.</td>
</tr>
</tbody>
</table>
3.1a.  **Effect of Truck Draw Bar Pull** :-

This results in reduction of load on leading bogie, and corresponding increase in load for trailing bogie, as explained on next slide.

![Diagram showing effect of truck draw bar pull]
3.1b. Effect of Traction Motor Nose:

If the direction of nose is towards the direction of motion of loco, the nose presses upward on bogie and equal pressure acts downwards on axle bearing, increasing pressure on axle. If the nose points opposite the loco-motion, the load on the axle decreases.

TM Nose Force = \( N = \frac{1092}{2} \cdot \frac{6}{800} = 4.1 \, t \)
Weight transfer due to torque exerted by traction motor

If the direction of motion is from left to right and

\[ D = \text{Diameter of driving wheel.} \]
\[ d = \text{diameter of the gear wheel.} \]
\[ S = \text{distance between the axle and the nose.} \]
\[ T = \text{Tractive effort at the rails.} \]
The force at the gear teeth $= \frac{TD}{d}$ and its direction is downwards on the gear wheel and its reaction on the pinion of the motor is upwards.

As a result of this, motor nose exerts an upward force $F$ on the bogie truck.

When the vehicle is moving in the direction towards which the nose is pointing, the motor nose presses upwards on the bogie truck and axle bearing presses downwards on the axle, thus increasing effective axle-load. These forces are reversed when the vehicle is moving in opposite direction to that in which the nose is pointing.
In WAM-4 and WAG-5, both nose-reaction and truck-reaction are subtractive from the weight on leading axle, hence there will be tendency of lifting or wheel slipping.
In high-adhesion bogies of WAG-7, nose-reaction is adding to the weight of leading axle, so better adhesion and less chances of slipping occurs.
Weight Transfer

- Type of body-bogie connection
- Heights of draw-bar and centre-pivot
- Distance between loading points of front and rear bogies
- Primary and secondary suspensions
- Mounting of traction motors
- Direction of noses and distance between axle & armature shaft and wheel diameter for “Axle hung and nose suspended arrangement.”
3.2. **Effect of Vertical Shocks**:  

- The contact between rail & wheel gets detached, under the effect of instantaneous vertical shocks. The extent of this detachment depends on elastic reaction of suspension.

- Provision of better elastic suspension and damping arrangement in a bogie, reduces the chances and duration of such a loss of rail-wheel contact, thus giving better adhesion.
WAG7 vs WAG5

- Primary Suspension of WAG-7, has sets of equalizers hung directly on end axle boxes, and supported on middle axle box through a link & compensating beam arrangement. This ensures equal distribution of vertical load on all 3 axles.

- WAG-5 has two different sets of equalizer beams, one each between either end-axles and middle axle. These distribute the load transmitted by springs supported on respective equalizers.
Secondary Suspension of WAG-7 has 4 nos. of side bearers on each bogie, and are located such that they share full vertical load leaving nil for centre pivot.

In WAG-5, centre pivot takes 60% of vertical load, and 40% shared by 2 nos. of side bearers, arranged in triangular fashion.

WAG5 does not have the side bearers for shock absorption.
4. Electrical Factors

4.1. Effect of performance characteristics of TMs:

- The steepness of the TE vs. Speed characteristics of TM, decides the time taken for arresting the wheel-slip and better adhesion. Normally TE at any speed should be lower than the maximum adhesive limit, but if the maximum adhesive limit decreases due to factors like dew or oil on rails, the wheels start slipping, and speed increases, causing TE to fall.
If this instantaneous fall in TE is too rapid, it may become lower than the new adhesive limit and slipping may be arrested, otherwise for a less steep curve the slipping will continue a longer.
4.2 Effect of TM combination in series or in parallel :-

- Wheel-slipping of one axle causes the speed of that TM to increase, in turn increasing the back-emf, thus reducing the current.

- Now, if TM groups are in series, the current-reduction in slipping TM will also cause current-reduction in other TM in series with it, so developing slipping in additional TM.

- Whereas TMs in parallel will not be affected by slipping of one TM.

- Hence 6-P combination of TMs give better adhesion than 2S-3P combination.
4.3. **Method of traction control** :-

- Method of control of TM is by rheostatic in DC locos and tap-changer method as in AC locos, sudden large variation in TE in discrete steps and the average value of TE becomes much less than the maximum permitted by adhesive limit.

- Increased number of steps reduce the variation in TE and hence the average value of TE rises and becomes closer to maximum.

- Continuous step-less control, as provided in 3-phase locos achieve better adhesion.
Traction Motor Current

Traction Motor Voltage

Tractive Effort (TE)

Speed (v)

Ripples in TE due to DC series motor in conventional loco

Voltage and Current in TM is increased in steps in DC series motor. It is smooth in Induction Motor (vvvf control).
5. **Enginemanship**: 

- The driver’s skill or enginemanship also affects the adhesion while in motion.
- Sudden increase in TE may result in a value higher than permitted by kinematic coefficient of adhesion and may result in slipping and auto regression.
- Negotiating a gradient with necessary attacking speed and timely use of sanders helps in maintaining proper adhesion.
When a locomotive is standing on a track, its weight is normally shared by each driving axle.

This weight share is disturbed and weight transfer takes place from axles to others in locomotive due to the turning moments.

Turning moments may be produced by the traction motors themselves as in the case of nose suspended motors or by the draw-pull.
• Development of tractive-effort (TE) by locomotives causes some wheels to offload while overloading others. In other words weight transfer (or shift) takes place from some wheels of the locomotive to the rest of them.

• The magnitude and pattern of such weight transfer depend on the geometrical features of locomotive particularly its bogies.

• It is obvious that bogie weight transfer can never be eliminated as long as mechanism of torque transmission is through gear wheels.
Weight Transfer Due To Torque Exerted By Traction Motor
If the direction of motion is from left to right and

\[ D = \text{Diameter of driving wheel.} \]

\[ d = \text{diameter of the gear wheel} \]

\[ S = \text{distance between the axle and the nose} \]

\[ T = \text{tractive effort at the rails.} \]

- then the force at the gear teeth=TD/d and its direction is downwards on the gear wheel and its reaction on the pinion of the motor is upwards. As a result of this motor nose exerts an upward force F on the bogie truck.
• When the vehicle is moving in the direction towards which the nose is pointing, the motor nose presses upwards on the bogie truck and axle bearing presses downwards on the axle.

• These forces are reversed when the vehicle is moving in opposite direction to that in which the nose is pointing.
Calculation Of Weight Transfer

\[ M = \] Mass of locomotive at the centre of gravity.
\[ T = \] Tractive effort exerted by the motor at each driving axle.
\[ L = \] Bogie centre distance.
\[ I = \] Bogie wheel centre distance.
\[ H = \] Height of drawbar coupling above rail level.
\[ h = \] Height at which tractive effort is exerted by the bogie on the locomotive body.
Final weight distribution due to weight transfer between bogies and between axles of the bogie is as follows:

Leading axle of leading bogie

\[
\begin{align*}
\text{Leading axle of leading bogie} & = \frac{M}{4} - \frac{2T(H-h)}{L} - \frac{2Th}{l} \\
\text{Trailing axle of leading bogie} & = \frac{M}{4} - \frac{2T(H-h)}{L} + \frac{2Th}{l} \\
\text{Leading axle of trailing bogie} & = \frac{M}{4} + \frac{2T(H-h)}{L} - \frac{2Th}{l} \\
\text{Trailing axle of trailing bogie} & = \frac{M}{4} + \frac{2T(H-h)}{L} + \frac{2Th}{l}
\end{align*}
\]

Thus the maximum weight transfer

\[
\pm \left[ \frac{2T(H-h)}{L} + \frac{2Th}{l} \right]
\]
The weight transfer effect is reduced with the increase in the bogie wheel centre distance. Due to safety considerations of negotiating curves, points and crossings, wheel centre distance of bogie ‘l can be adjusted only to a limited extent. In the bogie employing nose suspended motors, wheel centre distance is fixed by the diameter of driving wheels and traction motor dimensions.
While reducing the value of h’ will have desirable effect on the weight transfer between the two axles of the bogie, it will on the other hand increase the weight transfer effect between the bogies. Weight transfer between the axles of the bogie of conventional design is of the order of 15 to 20% of the adhesive weight of locomotive and weight transfer effect between the bogies is only 1 to 3%. Thus the overall effect due to the reduction in the value of ‘h’ is to decrease the weight transfer considerably.
Methods Of Reducing The Weight Transfer.

- The weight transfers in the case of trailing axle of leading bogie and leading axle of trailing bogie are just opposite to each other. Thus by effecting vertical coupling between bogies by resilient component vertical reactions due to weight transfer are made to cancel each other.
By means of low traction bars the point of application of tractive effort by bogie on the locomotive body is virtually brought down i.e. the value of ‘h’ is reduced. This design feature is incorporated in the manufacture of bogies of WAM1, WAG1 and WAG4 locomotives of Indian Railways.
The torque developed by traction motor (TM) is proportional to the product of field flux and armature current. A part of the TMs field is diverted through a shunting resistor. Therefore torque produced by motor and, consequently, TE at the corresponding wheels will be lower. In this way, fields of TMs on off-loaded axles are weakened while those of TMs on over-loaded axles are working to their full strength.
Thereby total TE of locomotive is so distributed among axles that ratio of TE to weight is more or less equal for all axles. This provides relief to offloaded axles that would otherwise have this ratio unduly strained - heightening the probability of wheel-slip. For same level of limiting adhesion utilization (µ), higher TE can be obtained from the locomotive.
A spring-loaded switch named 'ZQWC' is provided on the driver's desk. The driver is expected to use it by pressing it until the train starts rolling while starting the train on up gradients. This switch operates a relay 'QWC', which in turn operates the shunting contactors to achieve shunting of fields of desired TMs depending upon the direction of motion.
It may be noted that the driver is supposed to leave the switch the moment locomotive has begun to roll. Therefore this circuit is relevant only before the moment in which back emf gets established.

Both magnitude and pattern of weight transfer are significantly different in the two cases. In WAG-5 axles 1, 2 & 4 are offloaded while in WAG-7 axles 1, 2 & 3 are off-loaded. WAM-4 has almost identical pattern and quantum of weight-transfer, as WAG-5 except its static weight is lower by 1.0 t per axle.
Weight transfer in WAG5 and WAG7 locomotives

- Dynamic load is directly proportional to the TE.

<table>
<thead>
<tr>
<th></th>
<th>Axle No. →</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic Load</td>
<td></td>
<td>-3.29</td>
<td>-2.12</td>
<td>+5.26</td>
<td>-5.26</td>
<td>+2.12</td>
<td>+3.29</td>
</tr>
<tr>
<td>WAG5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static Load</td>
<td></td>
<td>20.5</td>
<td>20.5</td>
<td>20.5</td>
<td>20.5</td>
<td>20.5</td>
<td>20.5</td>
</tr>
<tr>
<td>Dynamic Load</td>
<td></td>
<td>-1.34</td>
<td>-1.34</td>
<td>-1.34</td>
<td>+1.34</td>
<td>+1.34</td>
<td>+1.34</td>
</tr>
<tr>
<td>Net Load</td>
<td></td>
<td>19.16</td>
<td>19.16</td>
<td>19.16</td>
<td>21.84</td>
<td>21.84</td>
<td>21.84</td>
</tr>
<tr>
<td>WAG7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Major differences between WAG-5 and WAG-7 in respect of features having a bearing on the weight transfer are:

1. Traction motors (TM) are axle hung and nose suspended in both bogies. But WAG-7 bogie has unidirectional noses against two forward/one reverse combination (and vice-versa on second bogie) of WAG-5.

2. Primary suspension of WAG-7 consists of sets of equalisers hung directly on end axles boxes and supported on middle axle-box through a link and compensating beam arrangement. This Special mechanism redistributes the loads equally on all the three axles.
WAG-5 has two sets of equaliser beams: one each between either end axle and middle axle. These distribute the loads transmitted by spring supported on the respective equaliser between the two axle boxes to which they are connected.

3. Unlike WAG-5, WAG-7 is provided with secondary suspension comprising 8 side bearers-4 on each bogie. These are designed to distribute the vertical load such that the two closer to centre-pivot and the two away from it share the vertical load in the ratio of 60:40.

4. The center pivot does not carry any vertical load. In WAG-5 two center pivot carry 60% of the vertical load and the rest is shared by the four side-bearers equally.
TRACTIVE EFFORT & TRAIN - RESISTANCE
1. **Force:-**

The application of force to a mass will cause it to accelerate as governed by one of Newton's laws of motion. The relationship is that the force necessary, is the product of the mass and acceleration.

\[ \text{Force} = \text{Mass} \times \text{Acceleration} \]

(Tractive effort is a type of force, causing a loco or train to move)
2. **Energy**: The energy consumed in moving an object over a distance is the product of the force required and the distance.

\[ \text{Energy} = \text{Force} \times \text{Distance} \]

3. **Power**: Power is the rate of energy usage, or energy per unit time.

\[ \text{Power} = \frac{\text{Energy}}{\text{Time}} = \frac{(\text{Force} \times \text{Distance})}{\text{Time}} = \text{Force} \times \left(\frac{\text{Distance}}{\text{Time}}\right) = \text{Force} \times \text{Speed} \]

or \[ \text{HP} = \text{TE} \times \text{Speed} \]
Tractive Effort (TE) is the force applied to the rail by the wheel of the train to cause movement. The size of this force is determined by the characteristic of the power equipment installed on the train, and how the driver uses it. Tractive Effort (TE) is a function of speed for a particular setting of control.
• By necessity, this tractive effort is not constant throughout the speed range, and most traction units have a characteristic that looks Fig 1.

**Fig.1 – Tractive Effort versus Speed Curve**
In the T-N characteristic shown in fig. 1, the TE is constant up to 20 mph, therefore in this speed range, from relationship of $F = ma$, as TE (or Force) is constant, the acceleration will be constant. As a result of this, speed will build up uniformly with time as shown below in fig-2.

![Fig 2- Speed versus Time](image-url)
This is the region of **Maximum Tractive Effort**, limited by adhesion as shown on T-N Curve. Above this speed, TE falls, and in consequence, the acceleration will start to fall and speed will not build up so quickly. The plot of speed with time, now starts to curve as shown next slide in Fig 3.
Fig. 3 - Speed versus Time Graph
So, in the example given, the maximum TE of the unit is 100kN, and hence the maximum power may be calculated as follows:

Speed in m/s = \{(\text{speed in mph}) / 2.2\} = 20/2.2 = 9.1 \text{ m/s}

Power = \text{Force} \times \text{Speed} = 100\text{kN} \times 9.1 \text{ m/s} = 910\text{ kW}

As this is the power needed to actually move the train, it is strictly referred to as the *Maximum Power at Rail* as shown below in Fig.4.
Fig. 4 – Power – vs. –Speed Curve
In reality, the total power drawn from the supply will be greater than 910 kW, due to the need for additional auxiliary loads and due to losses in the conversion process.

It is highly unlikely that the equipment is capable of running at this power level continuously, and for all types of services. Again, for reasons of rating, the characteristic of the equipment will not follow the curve of maximum power at top speed, as indicated by the dip from 70mph onwards in Figs 1 & 4. Consequently a continuous power rating will often also be quoted.
**Continuous Power** rating may be derived from a number of factors based around the equipment characteristic and will include assumptions of proportion of time, coasting is done at a lower tractive effort demand by driver (driver's controller).
Types Of Tractive Effort:

As, \( TE = \text{loco weight} \times \text{adhesion} \). It may be noted that horsepower isn’t part of the calculation for TE.

1. **Starting Tractive Effort** - is the amount of tractive effort that must be produced by the motive power to start moving a train from a dead stop without slipping the wheels.

2. **Continuous Tractive Effort** - is the amount of tractive effort required to keep a train in motion continuously for long term without slipping the wheels or overheating the traction motors & transmission.
3. Short Term Tractive Effort for X minutes - is the amount of tractive effort required, for short term (for prescribed X minutes), say to climb a grade. This will generally not exceed 120% of the continuous TE for the prescribed short period of time. It is limited by overheating of the traction motors, of other power & transmission equipment on the locomotive.
As the DC motor starts to turn, the interaction of the magnetic fields inside it causes it to generate a voltage internally. This "back emf" opposes the applied voltage and the current that flows is governed by the difference between the two.

So, as the motor speeds up, and the internally generated voltage rises, the effective voltage falls, less current is forced through the motor and thus the torque falls.
In order to continue accelerating the train, notches are further increased, each notch increases the effective voltage and thus increasing the current and torque for a little bit longer until the motor again catches up. This can be felt by a jerk of acceleration as the torque suddenly increases in response to the new surge of current.

The motor naturally stops accelerating at any notch-position, when the drag or Resistance of the train (increasing with speed) matches the torque produced by the motors. This is called the “Balancing Condition”.
Balancing Speed is the maximum speed for the given load, on that gradient & curvature, and is the speed at the intersection-point of TE-speed curve & Train Resistance-speed curve.

It is 95 mph on level, but 75mph on 1:100 gradient. Force available to accelerate the train is the difference between TE and train resistance.

Intersection of TE-vs-Speed Curve, with Train Resistance Curve
Train Resistance

- It is the resistance offered to start or run a train of given load at a given speed and on a given gradient. Train Resistance during run is normally given by:

\[ R = a + bv + cv^2, \quad \text{where} \ v = \text{speed} \]

- The factors \( a, b \) and \( c \) characterize the particular train, with "\( a \)" being the static friction, "\( b \)" is due to mechanical considerations, and "\( c \)" is air resistance.
Fig.6- Train Resistance v/s Speed Curve
It is normally expressed as the Specific Resistance in kg/ton, which is the force or TE required to start or run a loco or train, per ton weight of loco or train.

Types of train-resistances are :-

1. Resistance to start (a loco or loco+train) on straight level track.
2. Resistance to run at a given speed on straight level track.
3. Resistance due to gradient.
4. Resistance due to track-curvature.
SPEED TIME GRAPH
Physically there are three types of train services which in traction system has to be looked after i.e.

- Urban System,
- Suburban System and
- Main Line System.

While the distance in urban & suburban system is comparatively smaller, but this requires frequent starting and stopping.

On main line the distance between stations are longer.
A typical speed time curve of a main line train is depicted in the diagram as below:-
1. 0a: This is notching up period and during this period, the train is accelerated from the start. The average tractive effort during this period remains the same and there is no significant rise in the train resistance. Hence acceleration remains constant.

2. ab: During this period, the difference of tractive effort and train resistance accelerates the train depending upon the torque speed characteristic of the traction Motor. The speed of the train will continue to increase till the balancing speed is achieved when tractive effort becomes equal to train resistance and thereafter the train will continue to run at the maximum speed.
3. bc : During this period the trains run at constant speed with constant torque.

4. cd : This is called coasting period and during this period the power supply is cut off to traction motor and train is allowed to run under its momentum. The speed of the train gradually falls due to train resistance.

5. de : This is called braking period and at the end of coasting, brakes are applied to bring the train to a halt.
The speed-time curve is different for different types of services by way of acceleration and retardation, maximum speed attained, the period of free running and coasting.

Following table shows typical values of these parameters for some representative services.
## Typical Values for Different Parameters of Speed – Time Curve

<table>
<thead>
<tr>
<th>Type of Service</th>
<th>Sub Urban (Passenger)</th>
<th>Main Line (Passenger)</th>
<th>Main Line (Goods/Passenger)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acceleration</strong> (kmph/sec)</td>
<td>1 to 4</td>
<td>0.5 to 1</td>
<td>0.2 to 0.4</td>
</tr>
<tr>
<td><strong>Retardation</strong> (kmph/sec)</td>
<td>3 to 4</td>
<td>1.5 to 2</td>
<td>0.3 to 0.5</td>
</tr>
<tr>
<td><strong>Max. Speed</strong> (kmph)</td>
<td>60 to 80</td>
<td>100 to 160</td>
<td>60 to 100</td>
</tr>
<tr>
<td>Type of Service</td>
<td>Sub Urban (Passenger)</td>
<td>Main Line (Passenger)</td>
<td>Main Line (Goods/Passenger)</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------</td>
<td>-----------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Distance between stoppages (kms)</td>
<td>1 to 3</td>
<td>10 to 15 kms for pass. &amp; 100 kms or more for Exp.</td>
<td>50 to 100</td>
</tr>
<tr>
<td>Special Features</td>
<td>Free running period is small &amp; some times absent.</td>
<td>Free running is large or very large.</td>
<td>Free running period is very large</td>
</tr>
</tbody>
</table>
Reference Documents:

1. Traction Rolling Stock Maintenance
2. Traction Rolling Stock Operation

Phase II - Module No. STC-TRS-CON-03(Supp.)
Patience is power

“जब तक किसी काम को किया नहीं जाता तब तक वह असंभव लगता है”