



Transportation Engineering II: Highway Design & Railways

Lecture 9

GEOMETRIC DESIGN-II

Dr. Charisma Choudhury

May 2011

Terms related to Gradient Design



- Ruling gradient
 - Steepest gradient in a rail section
 - Should be adequate to haul the maximum load at maximum permissible speed given the hauling power of the engine
 - Determines the maximum gradient that is compatible with the hauling power of the engine
- Pusher/ helper gradient
 - Gradient so steep that requires extra engine to push the train up

Terms related to Gradient Design



- Momentum gradient
 - Steeper than the ruling gradient, but fine due to momentum gathered
- Gradients in stations/yards
 - Flatter (e.g. 1 in 1000)
 - To avoid rolling and moving away of vehicles
 - To reduce additional resistive forces required to start the train

Factors affecting Critical Gradient

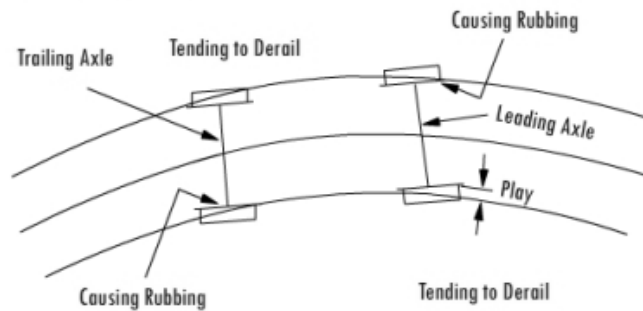


- Hauling power of the engine
- Position of the gradient

5. Resistance due to Curves



- Rubbing action
- Centrifugal action
- Super elevation



Charisma Choudhury, BUET

5

5. Resistance due to Curves



Curve resistance for B.G. $(R_5) = 0.0004 \times W \times D$
Curve resistance for M.G. $(R_5) = 0.0003 \times W \times D$
Curve resistance for N.G. $(R_5) = 0.0002 \times W \times D$

Where W = Weight of train; D = Degree of curve

Charisma Choudhury, BUET

6

Grade Compensation on Curves



- Curves provide extra resistance to the movements of trains
 - Reduces allowable gradient (grade compensation on curves)

Gauge	Compensation
BG	Minimum(0.04% per degree of curve , $70/R$)
MG	Minimum(0.03% per degree of curve , $52.5/R$)
NG	Minimum(0.02% per degree of curve , $35/R$)

Charisma Choudhury, BUET

7

Summary of Track Resistance



Type of Resistance	Value
1. Resistance due to friction (R1)	$0.0016W$
2. Resistance due to wave action (R2)	$0.00008WV$
3. Resistance due to wind (R3)	$0.0000006WV^2$
4. Resistance due to gradient (R4)	$W * 1/\text{Rate of slope}$
5. Curve resistance (R5)	$0.0004WD$ (BG) $0.0003WD$ (MG)

Charisma Choudhury, BUET

8

Hauling Power of Engine



- Hauling power
= (number of pairs of driving wheel) x (axle load) x (coefficient of friction)
- Alternate formula: Hauling power
= (total number of driving wheels) x (weight exerted on each wheel) x (coefficient of friction)
- Factors affecting coefficient of friction:
 - Speed of locomotive
 - Condition of rail surface
 - Wet, dry
 - Smooth, rough

Problem 1



What will be the compensated gradient of a B.G. track which having 2° curvature on a rising gradient of 1 in 200 ?

Ans:
0.41% or 1 in 238

Problem 2



Calculate the maximum permissible load that a B.G. locomotive with 3 pairs of driving wheels with axle load of 22 tonnes each on a straight level track at a speed of 80 kmph. Also calculate the reduction in speed if the train has to run on a rising gradient of 1 in 200.

What would be the further reduction in speed if the train has to negotiate a 4° curve on the rising gradient? Assume coefficient of friction as 0.2.

Ans:

- 13.2 tonne
- 1115 tonne
- (80-48) kmph=32 kmph
- (48-44) kmph =4 kmph

Problem 3



Compute the steepest gradient that a train of 20 wagons with a locomotive can travel with the following data :

- | | | |
|--------------------------------------|-----|--------------|
| (a) Weight of each wagon | ... | 20 tonnes |
| (b) Weight of Locomotive | ... | 150 tonnes |
| (c) Tractive effort of Locomotive | ... | 15 tonnes |
| (d) Rolling resistance of Locomotive | ... | 3 kg/tonne |
| (e) Rolling resistance of wagon | ... | 2.5 kg/tonne |
| (f) Speed of the train | ... | 60 kmph |

Ans:

1 in 56

Problem 4



- Calculate the maximum permissible train load that can be pulled by a locomotive with four pairs of driving wheels with an axle load of 28.42t each on a BG track with a ruling gradient of 1 in 200 and a maximum curvature of 3 degrees, travelling at a speed of 48.3 km/h. Take the coefficient of friction to be 0.2.

Ans:
1740 t