CIVIL ENGINEERING

For

UPSC Engineering Services Examination, GATE,

State Engineering Service Examination & Public Sector Examination.

(BHEL, NTPC, NHPC, DRDO, SAIL, HAL, BSNL, BPCL, NPCL, etc.)

RAILWAY, AIRPORT, PORT AND HARBOUR & TUNNELING

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RAILWAY

CHAPTER 1

Rails, Railway and Rail Joints

Rails :

- The rails on the track can be considered as steel girders for the purpose of carrying axle load.
- Rails transfer Axle load to the subgrade through sleepers and ballast.
- Rails convert the moving wheel loads of train into point load, which acts on the sleepers.
- Rails are made up of high carbon steel, to resist wear and tear.
- On points and crossing rails of medium carbon and high manganese steel is used.
- In India rails are manufactured by open hearth or duplex process.

Requirement of Rails :

- Vertical stiffeners should be high enough to transmit the vertical load, for that height of the rail should be adequate.
- Rails should be capable of withstanding lateral forces, large width of head and foot will result into larger lateral stiffness.
- To allow adequate margin of vertical wear, head of the rail must be sufficiently deep, max. wear of head allowed is 10 mm.
- Minimum tensile strength of rail should be 72 kg/m^2.
- In India rails are tested by falling weight test or tup test.

Types of Rails :

1. Double headed rails (D.H. rails)

- These rails were used in the beginning

2. Bull Headed rails (B.H. rails)

- In B.H. rails the head was made a little thicker and stronger than the lower part.

3. Flat footed rails (F.F. rails)

- F.F. rails are also called Vignole's rails after the name of the inventor.
- Bearing plates are used between the sleeper and rail at rail joints.
- These rails are designated by wt of rail per unit length.
- 52 kg/m or 52 MR and 60 kg/m or 60 MR F.F. rails are used in India.
- 52 kg rail is suitable upto speed of 130 kmph and 60 kg rail is suitable upto sped of 160 kmph.

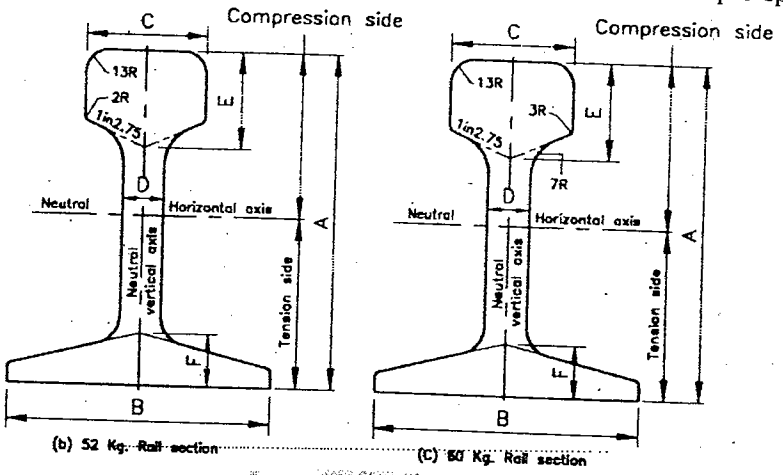


Fig. 52 MR Rail

Comparison b/w Flat footed rails and Bull haded rails

Point of Comparison	Flat Footed Rails	Bull Headed Rails or Double Headed rails
1. Strength and Stiffness	These have more strength hand stiffness for same wt.	Having lesser stiffness and strength.
2. Laying and Relaying	Fitting is simpler so, can be easily laid or relaid.	Laying or relaying is difficult.
3. Initial cast	Fastenings are lesser and	

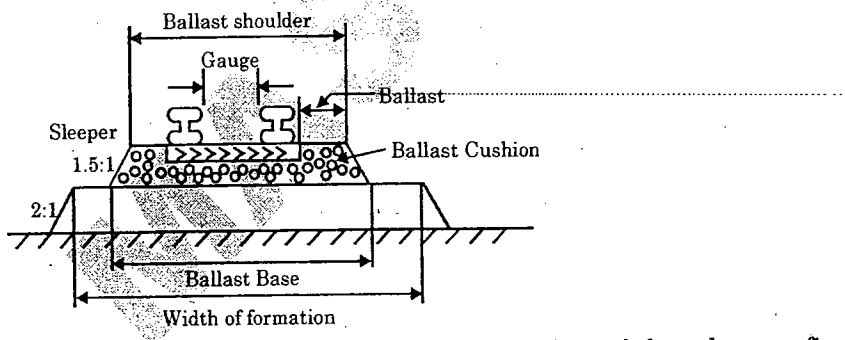
- Rail's length is restricted due to transportation limitations and due to more gap required for expansion joints.
- Rail length of 12.8 m (say 13 m) for BG tracks and rail length of 11.89 m (say 12 m) for MG tracks are used by Indian railways.

Some Other Important Points :

- Ratio of wt. of rails to wt of locomotive (axle load) is 1 : 510.
- When wear of head exceeds 5% of total wt., the rail must be replaced.
- On the curves, check rails parallel to inner rail can be introduced to control wear.
- Check rail prevent the wear of outer rail.
- Check rail, is used if curves (degree of curves) is more than 8° for BG and more than 14° for M.G.

Permanent Way or Railway Track :

- Combination of rails, fitted on sleepers and resting on ballast and subgrade is called the railway track or permanent way.
- Some time temporary tracks are also laid for the transportation of the material. So to distinguish final alignment with the temporary tracks, the term permanent track is used.
- On the curve super elevation is maintained by the ballast and formation is levelled.

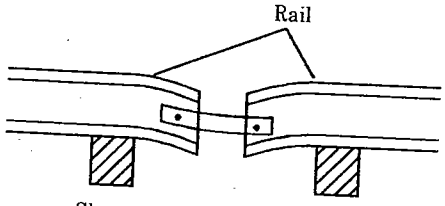


- In a permanent way the rails are joined in series by fish plates and bolts and then they are fixed to sleepers by different types of fastenings.
- The sleeper properly spaced and resting on the ballast are suitably packed with the ballast.
- The permanent way is regarded as semi-elastic in nature due to packing of ballast cushion.

Defects on Rails :

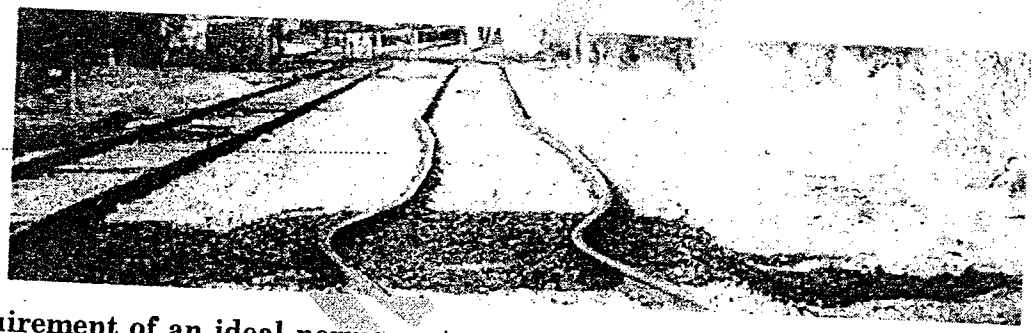
- These occurs due to loose packing of ballast or loose fish plates at the joints.

Kinks in Rail [Top View of rail]



4. Buckling of rail :

- During summer due to rise in temperature , the expansion of the rail occurs, to allow this expansion there must be certain gap in between two rails at the end joints.
- These joints are known as expansion joints.
- If sufficient gap / expansion joint is not available, the thermal expansion would not be accommodated within the expansion joint which will create thermal stresses in the rail and rail will buckle.
- Buckling also occurs if fish plates are bolted so tightly that the rails are not allowed to slip or expand.



Requirement of an ideal permanent way :

1. The gauge should be correct and uniform.
2. The permanent way should be resilient and elastic in order to absorb shocks and vibrations of running track.
3. The track should have enough lateral strength.
4. Drainage system should be perfect.
5. Joints should be properly designed and maintained.

Advantages of B.G. over MG. and N.G.

1. Stability of Train Movements :

On B.G. gauge the stability of train operations is more than on M.G. and N.G.

2. Speed of the Train :

The speed of train allowed on B.G. track is more than the speed on the M.G. and N.G.

- The speed more than 100 kmph is allowed only on B.G. track.

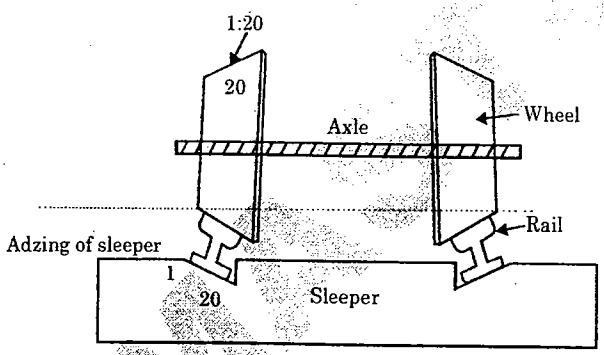
3. Axle Load :

Greater axle load is permitted on B.G. track.

4. Economy of B.G. track :

Operations and control of train movement on the B.G. track is economical as compare to M.G. and N.G.

Coning of the Wheel :



- The wheels of the train are made at a slope of 1:20, this is known as coning of the wheel.

Purposes :

1. On a straight track :

- It keeps the train just in central position during movement so that the distance travelled by two wheels are always same.
- If the train moves side way in any direction, the diameter of wheel on that direction increases and on other rail in decreases so distance travelled by two wheel becomes unequal, it directs

- When train moves on curved track, the distance of the outer rail is more than the inner rail.
- On curves due to centrifugal force, the train is forced to move outward direction, thus the diameter of wheel on the outer rail become more than dia of wheel on the inner rail so distance travelled by outer wheel is more than inner wheel.
- So more length of outer rail is partly adjusted due to coning of wheel, remaining length is adjusted due to skid of outer wheel and slip of inner wheel.
- The slip or skid distance is 0.029 m per 1° of central angle.

Adzing of Sleepers :

- For the effective use of coning of wheels, the rails are not laid horizontal, these are laid at a slope of 1 in 20 on the sleepers. Thus is known as adzing of sleepers or tilting of rails.
- On the curves, advantage of coning of wheel is not effectively utilized.
- If may exceed the pressure on outer rail.

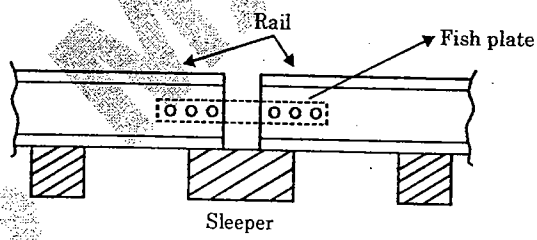
Rail Joints :

- Rail joints are necessary to hold together the adjoining ends of the rails in the correct position both in horizontal and vertical.
- Rails joints from the weaket part of the track, its strength is only 50% of the strength of rail.

Types of Rail Joints :

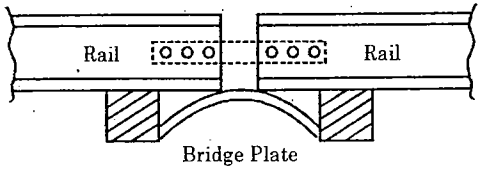
1. Supported rail joint :

- When the rail ends rest on a single sleeper called a "Joint Sleeper", the joint is termed as supported joint.



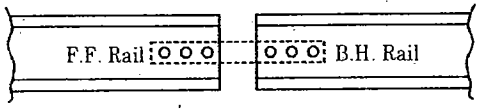
2. Suspended Rail Joints :

When rail ends are projected beyond sleepers called "Shoulder Sleepers", the joint is termed as suspended rail joint.



4. Compromise Joint :

Where two different rail sections are jointed by fish plate, the joint is termed as compromise joint.



5. Expansion Joint :

- To allow the thermal expansion at the end joints of rail so gap is provided, thus type of joint is termed as expansion joint.
- The gap of 2.2 cm in case of mitered rail and 7.2 cm in case of halved joint is provided.

6. Welded Joints :

- Welded joints are considered as the most perfect and strongest type of joints.

Purpose of Welding of Rail or Advantages of Welded Rail :

1. To increase the length of the rail by joining two or more rails and thus to reduce the number of joints and requirement of costly fasteners like fish plats etc. Thus leads to economy and strength of the track.
2. Some rails at the beginning and at end of track are welded in order to ommit the requirement of expansion joint
3. To reduce the creep of rail in order to maintain proper gauge and alignment.
4. To increase the life of the railway track and to reduce maintenance cost of the track.

Concept of Welded Rail :

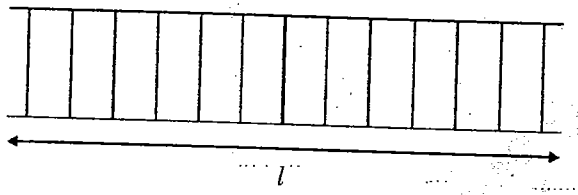
- In non welding rails the sufficient amount of resistance is available due to sleeper fasteners to resist the thermal stresses, but at the rail ends no sufficient restraining force is available so non welded rail may buckle.
- The idea behind using the welding rail is to provide sufficient restraint at the ends of rail and better degree of fixity of rail to the sleeper so that the stresses [thermal and Creep] produced

- LWR is one whose central part does not undergo any longitudinal movement and only end portions are effected due to temperature variation.
- The maximum LWR length allowed is 1000 m.

3. Continuous Welded Rail :

- The welded rail longer than 1 km and extending from 1 station to other with switch expansion joint are called CWR.

Length of Welded Rail :



l = length of rai

α = coefficient of thermal expansion

t = rise in temp,

E = modulus of elasticity

Increase in length of rail due to temp. rise

$$\Delta l = l\alpha T$$

Strain in rails

$$\varepsilon = \frac{\Delta l}{l} = \alpha T$$

Thermal stress produced, if this exp. is not allowed

$$\sigma_T = \alpha T E_S$$

The for developed in rail

$$F_S = \alpha T E_S A_S \qquad [A_S = \text{Cross section of rail}]$$

- The internal force F_S has to be resisted by sleepers, let resisting force per sleeper is R.
- No. of sleepers req. $\quad n = \dfrac{\alpha T E_S A_S}{R}$

- In case of LWR, the minimum length of rail, required to be welded at the end of track, so the portion of rail between welded rail does not undergo only thermal expansion or contraction, is known as breathing length.

  Breathing length at the both ends = (n – 1)S

  Total breathing length = 2(n –1)S

Q. Theoretical length of LWR beyond which control portion of 52 kg rail would not be subjected to any longitudinal movement due to 30°C temperature increase.

Given Data :

$$As = 66.15 \text{ cm}^2$$
$$\alpha = 11.5 \times 10^{-6}$$
$$E_S = 21\times10^6 \text{ kg/cm}^2$$
$$\text{Spacings} = 60 \text{ cm}$$
$$\text{Resistance (R)} = 300 \text{ kg}$$
$$t = 30°C$$

The Internal force developed due to rise in temperature

$$Fs = \alpha t E_S A_S$$
$$Fs = 11.5\times10^{-6}\times30\times21\times10^6\times66.15$$
$$Fs = 47925.6 \text{ kg.}$$

No. of steeper 8 required

$$n = Fs/R$$
$$n = \frac{47925.6}{300} = 159.7$$
$$S = 160 \text{ cm}$$

LwR at an end

$$= (n-1)S$$
$$= (160 - 1) \times 60$$
$$= 95.4 \text{ m}$$

Breathing length required $= 2 \times 95.4$

$$= 190.8 \text{ m}$$

2. Foot should not be wide enough so that resistance against overturning is kept high.
3. Minimum tensile strength of rail should be 72 kg/m^2
4. Rail specimen are testes by falling wt test.

(a) Statement 1 and 2 are correct (b) Only 1 is correct
(c) 1, 3 and 4 are correct (d) all are correct

4. Consider the following statements.
   1. F.F. rails are also known as Vignole's rail.
   2. On BG 52 kg/m and 62 kg/m F.F. rails are used
   3. 60 MR rails are used for the speed more than 130 kmph.

   Which of the statements is/are correct ?

   (a) only 1 (b) 1 and 2 (c) 1 and 3 (d) all are correct

5. The ratio of wt of rail to the locomotive axle load is

   (a) 1 in 720 (b) 1 in 870 (c) 1 in 510 (d) 1 in 675

6. Maximum permissible wear on the top of rail is:

   (a) 2% of the wt of rail (b) 3% of the wt of rail
   (c) 4% of wt of rail (d) 5% of the wt of rail

7. Consider the following statements :
   1. Corrugation are created at the place where train accelerates or retard
   2. Hogging rail defect is produced due to battering action of wheel
   3. Kinks are formed where either breaks are applied or train starts.

   Which of the statements is / are correct ?

   (a) only 3 (b) 1 and 2 (c) only 2 (d) All are correct

8. Buckling of rail may occur

   (a) Due to inadequate expansion joint (b) Due to excessive creep
   (c) Due to both (a) and (b) (d) N.O.T.

9. Consider the following statement
   1. Welded rails satisfies the condition of a perfect joint and hence increases the life of the rail.
   2. Welded rail also reduces creep

C. If statement 1 is correct and 2 is wrong.

D. If statement 2 is correct and 1 is wrong.

11. State 1 : While laying the railway track some time temporary track is also laid for transporting the material.

State 2 : To distinguish temporary track and final alignment, the final alignment is said to be permanent track.

(a) A (b) B (c) C (d) D

12. State 1 : On the curve rail are laid at a slope of 1 in 20 m the sleepers.

State 2 : This process is known as Adzing

(a) A (b) B (c) C (d) D

13. State 1 : On the curves check rails parallel to inner rail are introduced.

State 2 : Check rail prevents the wear of inner rail.

(a) A (b) B (c) C (d) D

14. State 1 : Coning of wheels in railway does not cause wear tear of the wheels.

State 2 : The rails are tilted at angle of 1 in 20 to reduce the wear and tear on the rails as well as on the tread of the wheel.

(a) A (b) B (c) C (d) D

15. Breathing length LWR is the

(a) End portion which gets affected by temperature variation

(b) End portion which does not get affected by temperature. variation.

(c) Central portion which gets affected by temperature variation

(d) Central portion which does not get affected by temperature variation.

16. Vertical wear on tongue rail should not exceed.

(a) 6 mm (b) 10 mm (c) 12 mm (d) 15 mm

17. Metal sleepers produce minimum creep because of

(a) Performance of the fasteners is high.

(b) Metal sleeper are light in weight.

State 2 : In welded joints the length of rail is measured so the requirement of costly fasteners is reduced which leads to low initial and low maintenance cost.

(a) Only statement 1 is correct

(b) Only state 2 is correct

(c) Both are correct and 2 is correct explanation of 1 .

(d) Both are incorrect.

20. Find out the breathing length required for a BG track for the data given

$A = 60\ cm^2$, $\alpha = 2.0 \times 10^{-5}$ per °C, $E = 20 \times 10^5\ kg/cm^2$

and r in temperature. = 30°C, Assume = 720 kg/km as resistance to track.

(a) 100 km (b) 150 km (c) 200 km (d) 250 km

21. Success of welded rails depends upon

1. Better degree of fixity of rails with the sleepers
2. Use of proper ballast material
3. Proper packing of ballast
4. Better measure against the buckling of rail
5. Regular maintenance.

(a) 1, 2, 3 (b) 1, 1, 4, 5 (c) 1, 2, 3, 4 (d) 1, 2, 3, 4, 5

22. State 1 : Coning of wheel acts as automatic handle of the train on the straight track.

State 2 : Once the train moves left or right from centre part line of track, the dia. of wheel on the wheel increase and another decreases, if produces restoring force and train comes on centre line.

(a) Only state 1 is correct (b) only 2 is correct

(c) Both are correct (d) Both are correct and 2 is correct exp. for 1.

23. Kinks on rail forms due to

(a) Battering action of wheels (b) Due to loose packing of joints at end.

(c) Due to improper ballast material (d) Use of fish plats at joints.

EXPLANATIONS

9. (c) In case of welded rail the length of rail gets increased and the performance of welded joint is also high so creap gets reduced in welded rails.

Expansion Joints are not required in case of welded rails.

11.(a) For transporting eath work and materials, during laying track, some temporary tracks are also laid and to distinguished final alignment from temp. track the term permanent way is given to final alignment.

12.(b) State (2) : is telling the name of method, it is not explaining the purpose of tilting rails.

14.(a) On curves due to centrifugal the outer wheels are pushed outwards, the flange of wheel may start touching the rail which would have resulted in wear and tear of rail, to prevent this rails are tilted at slope of 1 in 20 on curve, this process is known as adzing.

20.(c) Internal force developed

$$DF \propto TEA$$

$$F = 2\times10^{-5}\times30\times20\times10^{5}\times60$$

$$F = 72000 \text{ kg}$$

Resistance of track

$$= 720 \text{ kg/m}$$

Length to resist at one end

$$= \frac{72000}{720} \text{ km}$$

$$= 100 \text{ km}$$

total breathing length required

$$= 200 \text{ km}$$

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CHAPTER 2

Sleepers and Track Fasteners

Sleepers :

- Sleepers are the members which support the rail and are laid transverse to the rail.
- Sleepers rest on the ballast cushion and transfer the axle load to subgrade through ballast.

Functions of Sleeper :

- To hold the rail to correct gauge.
- It also facilitates adzing of the rails.
- To act as elastic medium in between ballast and rail, to absorb the shocks and vibrations.
- To provide longitudinal and lateral stability to the track.
- To distribute load from rail to ballast.

Classification of the sleepers :

- Classification is based on the material used. Different types of sleepers as follows.
  1. Wooden sleepers
  2. Metal Sleepers
     a) Cast Iron Sleepers
     b) Steel sleepers
  3. Concrete sleepers
     a) Reinforced concrete sleepers

- Sal and teak are most commonly timbers used for sleepers.
- Boxed heart or Ekka wood must be used for the construction of sleepers.
- Wooden sleepers are easily subjected to wear, decay, attack of white ants thus the life of the sleepers is minimum (12 to 15 year).
- Creosting and Burnettising (application of $ZnCl_2$ solution) are done to increase life of wooden sleepers.

Composite Sleeper Index (C.S.I.)

C.S.I., measures the mechanical strength of timber, derived from its composite properties of strength and hardness.

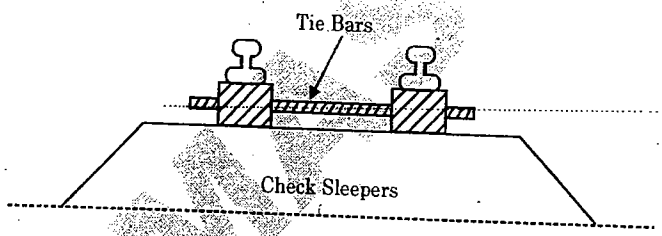
$$\text{C.S.I.} = \frac{S+10H}{20}$$

S = Strength Index at 12% moisture content

H = Hardness Index at 12% moisture content.

Check Sleepers :

- Serviceable portion of spiked killed sleepers is cut and used with tie bars in station yards.
- They are not used on a track having running traffic.



2. Metal Slippers :

- Metal sleepe is a inverted channel with folded ends. The folded ends and edges form a bulb, which resist the damage caused by the packing of ballast.
- Two types of metal sleepers are used :
  1. Cast Iron (C.I.) Sleeper
  2. Steel Sleeper
- C.I. Sleepers are in greater use than steel sleeper because these are less prone to corrosion.
- Metal sleepers are uniform in strength durability

Disadvantages of C.I. Sleepers :

1. Their initial cost is high, because they require fasteners large number of fasteners.
2. They do not provide elastic bed in between ballast and rail.
3. Not suitable for track circuiting.

Type of C.I. Sleepers :

a) Pot or Bowl Sleepers

b) Plate Sleeper

c) Box Sleeper

d) CST 9 Sleeper

CST-9 Sleeper :

- It has triangular inverted pot on either side of the rail section and a plate with the projecting rib and a box on the top of the plate.
- The various pieces are connected across the track by means of a rod.
- A rail seat or a chair is provided to hold the F.F. rail with 1 in 20 cant.

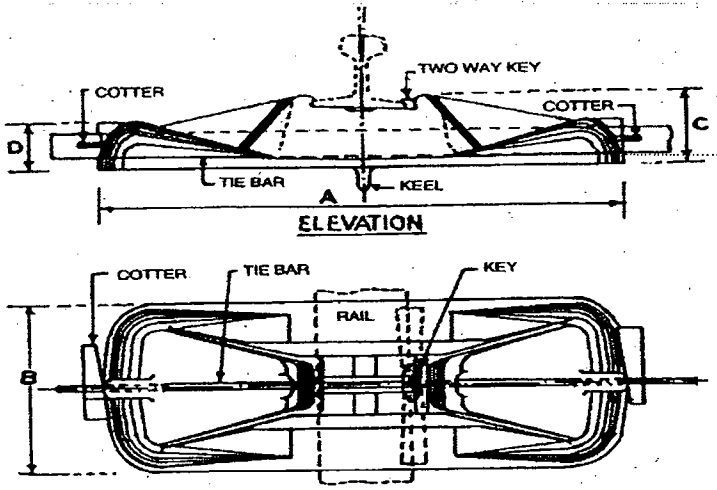


Fig. CST-9 Sleeper

b) Steel Sleeper :

Advantages and disadvantages of steel sleepers

Steel Trough Sleeper

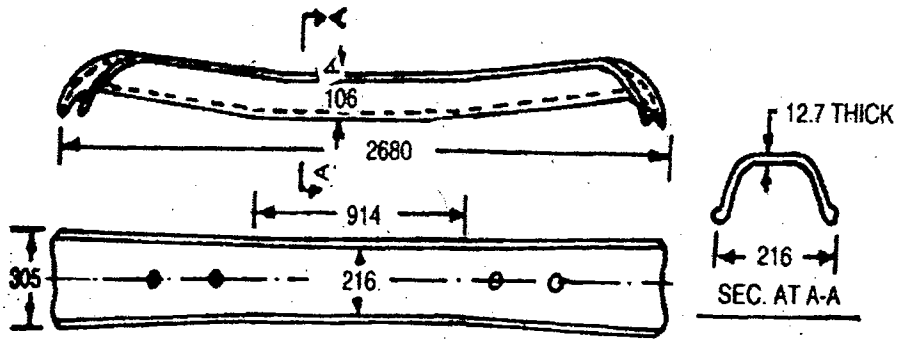


Fig. Steel Sleeper

Concrete Sleepers :

- Due to chronic shortage of timber for wooden sleeper, the concrete sleepers came into picture.
- Later it was investigated that these sleeper are very much useful for Indian railways for developing High Speed tracks.

Advantages of Concrete Sleepers :

1. These sleepers are free from Natural decay and attacks by vermin, insects etc.
2. There is no difficulty in the track circuiting required for electrifying the track.
3. These sleepers have higher track modulus so can with stand the stresses induced by fast and heavy traffic.
4. Concrete sleepers in the elastic fastenings offers an Ideal track in respect of gauge and alignment.

Disadvantages of Concrete Sleepers :

1. The weight of concrete sleepers is 2 to 3 times of cost of wooden sleepers, so that their transportation is difficult.
2. The damage the bottom edges during the packing.
3. They have very poor scrap valve.

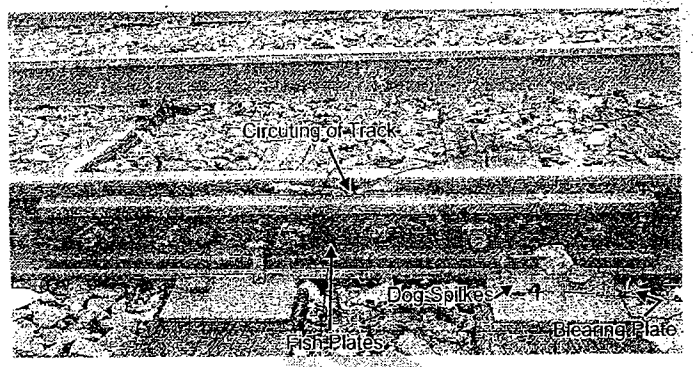
- Concrete sleepers are of two types :
  a) Reinforced concrete sleepers
  b) Prestressed concrete sleepers.

Track Fasteners :

1. Fish plate
2. Spikes
3. Chair
4. Bolts
5. Keys
6. Plates.

1. Fish Plates :

- Fish plats are used at rail joints in order to maintain continuity of rail joints.
- It also allows thermal contraction and thermal expansion.



2. Spikes

- It is used to hold rail on wooden sleepers.
- For holding Flat footed rails on wooden sleepers dog spikes are used.
- Screw spikes have double the holding power to that of dog spikes.

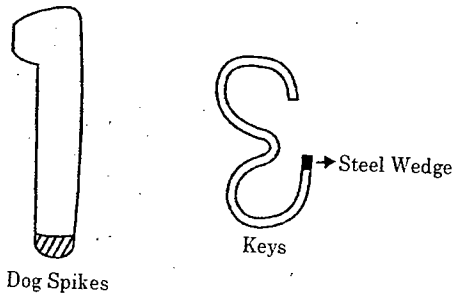
3. Chair :

- C.I. chairs are used to support bull headed rails on the sleepers.
- Slide chairs are used to hold stock rail and tongue rail.

4. Bolts :

- Bolts are used where sleepers directly rest over the steel girders.

- No adzing of sleepers is required because bearing plates are counted at 1 in 20.



Sleeper Density :

- No of sleepers per rail length is termed as sleeper density.
- In India sleeper density is represented by (M+x) where M is rail length and x is no which varies from 3 to 7.
- For B.G. track sleeper density is represented by (M+5).

Squaring of Sleeper :

- Squaring of sleepers may be defined as process of adjusting ballast under the sleepers to space them parallel to each other.
- In through packing the sleepers are squared and brought to specified spacing at straight length and on the curves i.e. the ballast under the sleepers is adjusted to space them parallel to each other.

Q. Using sleeper density M + 5 find out the number of slepers required for constructing a railway pack 40 m long (B.G. track).

Length of rail on B.G. track = 12.8 m

$$\text{Total no. of rails req.} = \frac{640}{12.8} \simeq 50 \text{ rail}$$

no. of sleepers per rail = 12.8 ≃ 18

Total no. of sleepers req. = 50 × 18

n = 900 sleepers

(a) only 1 (b) only 2 (c) 2 and 3 (d) all

3. Composite sleepers index (C.S.I.) used to measure mechanical strength of timber is defined to moisture content of

(a) 12% (b) 13% (c) 14% (d) 15%

4. Consider the following statements

1. Cast iron sleeper is most commonly used because it is corrosion resistant.
2. In metal sleeper the performance of fitting is better so less creep occurs.
3. Metal sleepers have poor scrap value.
4. Gauge can't be easily adjusted and maintained in metal sleepers.

Which of the above statements are correct.

(a) 1 and 4 (b) 1 and 2 (c) 1, 2, 3 (d) 1, 3, 4

5. Consider the following statements :

1. Metal sleepers requires more ballast than other type sleepers
2. Metal sleepers are unsuitable for bridges and level crossings.
3. They interfere with track circuiting

(a) 1 only (b) only 3 (c) 1 and 2 (d) all the above

6. State 1 : CST-9 sleeper is extensively used in India in place of other metal sleepers.

State 2 : CST-9 sleepers has triangular inverted pot on the either side of the rail.

(a) only state 1 is correct (b) only state 2 is correct

(c) both are correct (d) both are incorrect

7. CST-9 sleeper is used upto sleep of

(a) 110 kmph (b) 120 kmph (c) 130 kmph (d) 145 kmph

8. Consider the following statements :

1. Concrete sleepers have maximum life 40 to 60 years
2. There is no difficulty in track circuiting
3. The sleepers have higher elastic modulus, so high speed can be permitted.
4. The have very poor scrap value.

11. Consider the following statements
    1. For holding D.H. rail and B.H. ail the C.I. chairs are used.
    2. Blocks are inserted to maintain spacing in between closely spaced rails.
    3. keys are used to fix the rail to chair on metal sleepers
    4. Bearing plats are used to distribute the load of metal sleeper

    Which of the statements is are correct ?

    (a) 1, 2 (b) 2, 4 (c) 1, 3, 4 (d) 1, 2, 3

12. Consider the following statements
    1. Ballast imparts same degree of elasticity to the railway track.
    2. Ballast cannot prevent lateral movement of sleepers
    3. Ballast converts line load of the sleepers into UDL.
    4. Super elevation is maintained through ballast.

    Which the above statements is / are correct. :

    (a) only 1 (b) 1 and 2 (c) 1, 2 and 3 (d) 1, 3, 4

13. The loose layer of ballast above the packed layer, which surrounds sleeper is called

    (a) Adzing (b) Ramming (c) Ballast crib (d) Boxing

14. For packing pot sleepers which of ballast materials is used

    (a) Broken stone (b) Sand (c) Ashes (d) River pebbles

15. Sand ballast is covered by stone layer, to

    (a) prevent blowing off sand (b) to strengthen the sand ballast
    (c) to provide proper drainage (d) N.O.T.

16. Consider the following statements about concrete sleepers.
    1. They improve the pack modulus
    2. They have good scrap value
    3. They render transportation easy
    4. They maintain the gauge quite satisfactory

    (a) 1 and 2 are correct (b) 2 and 3 are correct
    (c) 3 and 4 are correct (d) 1 and 4

19. Consider statements about C.I. sleepers
    1. They can't be used for every type of ballast
    2. They provide better lateral and longitudinal stability
    3. They require less no. of fastners, so initial cost is less
    4. Track circuiting can be easily done

    (a) only 1 is correct (b) only 2 is correct
    (c) 1, 3, 4 are correct (d) 1, 2 and 4 are correct

20. Which of the following are types of C.I. sleepers
    1. Plate sleepers
    2. Dot or bowl sleepers
    3. Box sleepers
    4. Through sleepers
    5. Duplex sleepers

    (a) 1, 2, 3 (b) 1, 3, 5 (c) 1, 2, 3, 5 (d) all

ANSWER

1. (b)	**2.** (c)	**3.** (a)	**4.** (b)	**5.** (d)
6. (c)	**7.** (c)	**8.** (a)	**9.** (a)	**10.** (a)
11. (d)	**12.** (d)	**13.** (d)	**14.** (b)	**15.** (a)
16. (d)	**17.** (b)	**18.** (d)	**19.** (b)	**20.** (c)

EXPLANATIONS

6. (c) CST-9 sleepers have inverted pot on the either side of the rail which are used to hold fastness and the performance of

$= 51 \times 18$

$= 918$

CHAPTER 3

Ballast and Soil Subgrade & Survey Work

Ballast :

Ballast is the granular material usually broken stone or brick, kankar gravel and sand, which is placed and packed below and surrounding to the sleeper such that it transmit the load from sleepers to subgrade and at the same time it provides good drainage.

Functions of Ballast :

- It transfer the load from sleepers to the subgrade and then distributes it uniformly over a larger area of the formation.
- It holds the sleepers in position and prevent the longitudinal and lateral movements of the sleepers.
- It imparts some degree of elasticity to the track.
- It also provides good drainage medium to the track.
- On the curved track super elevation is maintained by ballast cushion and formation is levelled.

Requirements of Good Ballast :

- It should be abled to get packed properly without any disintegration.
- It should make proper drainage medium and soak minimum water.
- It should offer good resistance to wear and tear.
- It should be chemically inert or does not react with rail or metal sleeper.
- The size of stone ballast should be 5 cm for wooden sleepers 4 cm for metal sleepers and 2.5 cm for turnouts and crossovers.

Types of Ballast :

2. Gravel or River Pebbles :

- River Pebbles or Gravels are broken before use.
- These are smooth and round so packing or interlocking will not be proper.

3. Sand :

- It provides good drainage, if free from earth and vegetation.
- It produces silent track and used for packing pot sleepers.
- The main draw back of sand is, it blows off due to vibration
- To encounter this problem the sand ballast can be covered by stone or brick ballast.

4. Ashes or Ginders :

- Ashes has excellent drainage property.
- It is very soft and gets reduced to powder under wheel load.
- It makes the track very dusty, so always used in sidings.
- It is excellent ballast material for station yard, because does not retain water so track is not slippery in rainy season.

Size and Section of Ballast :

- The size of ballast varies in between 1.9 cm to 5.1cm.
- The packing or interlocking is better for this grading.
- For different type sleeper, different size of ballast is used such as :

For wooden sleepers = 5.1 cm

For steel sleepers = 3.8 cm

For switch ad crossing = 2.64 cm.

Depth of Ballast Section :

- The depth of ballast layer has important role on bearing capacity and distribution of load on subgrade.
- Greater the depth of ballast, greater will be load bearing capacity.
- Width of ballast layer beyond the ends of sleepers effect lateral stability of the track.
- In India this width is kept in between 38 cm to 43 cm.
- Load distribution below the sleepers is assumed to be 45° to the vertical, so minimum depth is calculated as follows.
- Let spacing of sleepers [illegible]

Minimum depth of ballast layer, D_{min},

$$D_{min} = \frac{S-W}{2}$$

Note :

- The process of ramming the ballast underneath the sleeper is known as packing.
- The ballast above the packed layer is loose filled, known as boxing
- The quantity of stone ballast required per meter tangent length is 1.036 m^3 for B.G.; 0.071 m^3 for M.G. and 0.53 m^3 for N.G.

Subgrade :

- It is naturally occurring soil, which is prepared to receive ballast, sleepers, rails for constructing railway track.
- Width of formation is the width of the prepared surface to receive ballast.

Function of the Subgrade or formation :

- It bears all the moving loads transmitted to it through ballast.
- It should prevent the ballast from puncturing into it.
- It should provide good drainage.
- It should be stable.

Subgrade Material and its Improvement :

- The ideal material for subgrade is soil containing gravel, sand clay and silt in equal proportion with the moisture content slightly above the plastic limit.
- Non cohesive soils as subgrade satisfies all requirement.
- Heavy clay, peaty soil and loamy soil must be avoided.

Subgrade can be Improved by following Methods :

1. Ad mixture of different soils like sand, clay silt.
2. Blanket - The blanket of non cohesive soil is provided above poor cohesive soil and below ballast.
3. Cement Grauting - The cement sand mixture (1:1 to 1:2) is injected to subgrade under pressure in order to stabilize it.
4. Concrete mats are also provided to stabilize poor subgrade.

- It considers the future potential of both passengers and good traffic.

2. Reconnaissance Survey (or Recce) :

- This is rough and rapid inspection both visual and instrumental of various physical characteristics of the area.
- It is done to find various suitable alignment.
- It collects ecological information like nature of soil, hill or pond, dip of existing rock etc.

3. Preliminary Survey :

- Detailed analysis of all suitable routes.
- To find the best suitable route.
- Theodolite, tachometer, dumpy level etc. are used.

4. Detailed Survey or Location Survey :

- Detailed study of final route is done.

OBJECTIVE QUESTIONS

1. Consider the following surveys
   1. Reconnaissance survey
   2. Preliminary Survey
   3. Traffic survey
   4. Location survey

   The correct order of survey work for constructing a railway track is

   (a) 1, 3, 2, 4 (b) 1, 3, 4, 2 (c) 3, 1, 4, 2 (d) 3, 1, 2, 4

2. Match **List-I** and **List-II**, using the code given below :

List-I	**List-II**
A. Rails	1. Connect one section of rail to next
B. Sleepers	2. Convert line load into U.D.L.
C. Ballast	3. Convert point load into uniformly distributed load
D. Fish plates	4. Convert railing load into point loads.

	A	B	C	D
a)	4	3	2	1

6. Consider the following statements.

State 1 : Sand ballast is sometimes covered with layer of stone or brick to prevent heavy wear.

State 2 : De to vibration sand gets blow off and gets into moving port.

(a) only 1 is correct

(b) Only 2 is correct

(c) Both are correct and 2 is correct explanation for ⊥

(d) Both are correct but 2 is not correct explanation for ⊥

7. The best suitable grading for ballast material is

(a) 2.1 cm to 6.2 cm (b) 1.5 cm to 6.11 cm

(c) 1.9 cm to 5.1 cm (d) 2.5 cm to 5.8 cm

8. Spacing of the sleeper is 1.2 m and the width of the sleeper is 30 cm. Find minimum depth of ballast cushion.

(a) 0.45 m (b) 0.60 m (c) 0.50 m (d) 0.70 m

9. Minimum quantity of ballast require to make 1 m B.G. track is

(a) 1.23 m^3 (b) 2.15 m^3 (c) 1.025 m^3 (d) 1.036 m^3

10. Width of formation is

(a) the width of land acquired along the alignment of Railway track

(b) the width of track which receives ballast

(c) the width equal to length of sleeper

(d) the width of track levelled.

ANSWER

1. (d)	**2.** (c)	**3.** (d)	**4.** (c)	**5.** (a)
6. (c)	**7.** (c)	**8.** (a)	**9.** (d)	**10.** (b)

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CHAPTER 4

Stresses on Railway Track & Creep of Rail

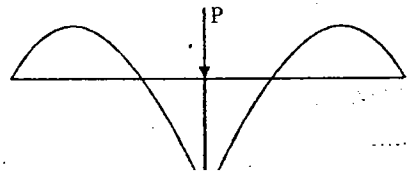
- Unlike other civil engineering structure, railway track isn't firmly embedded on the ground, it is floating on the ground.
- Analysis of stresses on railway track is governed by theory of elasticity.
- Overall elastic property of track is represented by track modulus.

Track Modulus (μ) :

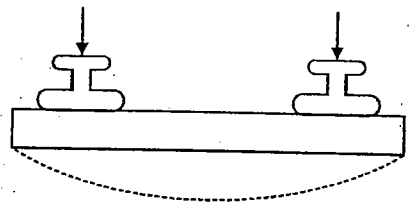
- Track modulus is index for stiffness or resistance to deformation of the permanent way, it is defined as load per unit length of the rail required to produce unit deformation / depression in the track.
- Track modulus depends upon the gauge, the type of rails, the type and density of sleepers, the type and section of ballast and subgrade.
- For computation of track modulus initial load is 4 tones for BG track and 3 tones for MG track.

Stresses on the Rail :

- Rails act as continuous beams carried on to the sleepers which provides elastic support.
- Rails converts rolling loads of wheels into point load.
- B.M.D. of rail under single wheel load.

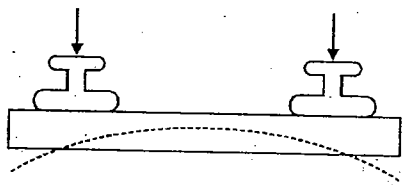


- Under newly constructed sleepers, the deflection takes place. like :



[end bound sleepers]

- Repeated action of loads causes depression at the ends thus is known as centre bound sleepers.



Stresses in the Ballast :

- The transmission of the pressure from the sleepers to the ballast depends upon the elastic properties of the sleepers, degree of compaction of ballast.
- Ballast converts line load into the uniformly distributed load.

Stress Formulae :

- Assuming single wheel load acting on rail, the formula to calculate is

1. $$M_{max} = \frac{w}{\sqrt[4]{4.5\mu}}\sqrt{EI} \text{ cm. tonnes}$$

or

$$M_{max} = 0.318 \text{ w.x. cm. tonnes}$$

2. $$x = 42.34\sqrt[4]{\frac{I}{\mu}}$$

$$f = \frac{M_{max}}{Z} \text{ kg/cm}^2$$

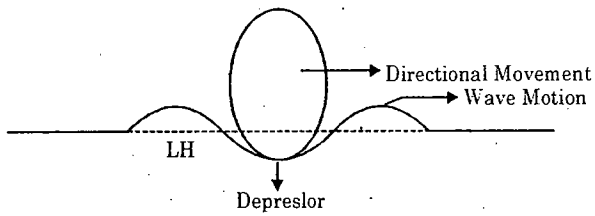
where w = Isolated wheel load on tonnes

μ_{max} = Max. B.M. in cm. tonnes

μ = track modulus

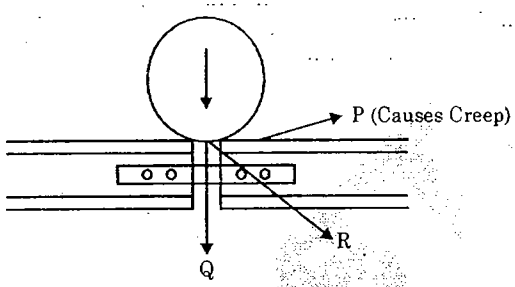
I = Modulus of Inertia (cm⁴)

- Vertical reverse curve is formed in rails, resulting the longitudinal movement of rail in the traffic direction.



2. Precursion Theory :

- This theory states that the creep is due to impact of wheels at the rail end ahead at joints.
- The horizontal component of resultant force R causes creep.



3. Drag theory :

It states that backward thrust on driving wheels of the locomotive of train has got a tendency to push the rail off the track backward while the other wheels of the locomotive and wagons push the rail in the direction of travel as explained in the wave theory.

Effects of Creep :

- Sleepers are disturbed from their position. So gauge may change.
- Joints are opened out of their limit, it also causes stress in the fish plate
- Most serious effect is buckling of the rails, which may cause derailment.

Measurement o Creep :

- Creep indicators are used to measure creep.
- As per I.R. practice, the creep should be measured at on interval of about 3 months.
- Maximum permitted creep on BG track is 150 mm.

3. Type of rails :

The old rails have creep more than new rails.

4. Direction of heaviest traffic :

Creep will be more in the direction of heaviest traffic.

OBJECTIVE QUESTIONS

1. Which one of the following is not related to theories of creep of rails ?
   (a) wave theory (b) percussion theory
   (c) drag theory (d) reversal theory

2. The track modulus is in an index of measure of which of the following ?
   (a) Resistance to friction (b) Resistance to shear
   (c) Resistance to deformation (d) Resistance to rolling

3. Which of the following factors help in ensuring track modulus in a railway track ?
   (a) Gauge and formation width (b) Track material and sleeper density
   (c) Degree of curvature and S.E. (d) Length of rail and flange width

4. Consider following statements
   State 1 : On concrete sleeper higher speed can be permitted.
   State 2 : Track modulus of concrete sleeper sleepers is very high which represent greater stiffness of concrete sleepers
   (a) only 1 correct
   (b) only 2 is correct
   (c) Both are correct and 2 is correct explanation for ↓
   (d) Both are correct but 2 is not correct exp. for ↓

5. Initial track modulus is defined for the load of
   (a) 4 tones (b) 5 tones (c) 6 tones (d) 7 tones

6. Which of the theory defines track modulus.
   (a) Plastic theory (b) Elastic theory
   (c) Elasto plastic theory (d) Brittle theory

9. Consider the following statements
   1. Creep is defined as lateral movement of rails with respect to sleepers
   2. Opening of successive expansion joints along the traffic direction is indicator of creep.
   3. Creep causes buckling of the rails.

   Which of the following statements is / are correct

   (a) 1 and 2 (b) only 2 (c) only 3 (d) all are correct

10. Which of the following theory is/are used to explain creep of rails ?

    (a) wave theory (b) percussion theory (c) both a and b (d) none of these

11. Which of the following theory states that creep of the rail is due to impact of wheels at the rail end.

    (a) wave theory (b) percussion theory (c) drag theory (d) N.O.T.

12. Max. crep allowed on the B.G. track is

    (a) 150 mm (b) 200 mm (c) 250 mm (d) 300 mm

13. Consider the following factors :
    1. Maintenance of track
    2. Alignment of track
    3. Grade of track
    4. Type of rail
    5. Packing of joints

    Which of the above factors govern magnitude of creep.

    (a) 1, 2 and 5 (b) 2, 3 and 5 (c) 1, 2, 3, 4 (d) 1, 2, 3, 4 and 5

14. Which of the statements is true regarding drag theory of creep
    (a) The creep is caused due to drag of locomotive
    (b) Creep is caused due to drag of only driving wheels of locomotive
    (c) Dag of driving wheels of locomotive have opposite effect with respect to direction of creep
    (d) Locomotive's driving wheel and wagon's wheel combinally produces drag, which causes creep of the rail

ANSWER

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CHAPTER 5

Geometric Design of the Track

- Visible features of railway track and its alignment are known as geometric design of the track. These parameters includes :-
  1. Gradients and grade compensation
  2. speed of the train
  3. Radius or degree of the curve
  4. Cant or super-elevation
  5. Curves
  6. Widening of Gaues on curves.
- Most of the train derailment is due to :
  1. Track defects; 2. Vehicular defects; 3. Operational defects.
- There can be following track defects.
  1. Defective cross levels;
  2. Defective alignment
  3. Defective Gauge
  4. Improper super elevation
  5. Improper radius of curve
  6. Improper assembly of crossing.

Gradients and Grade Compensation

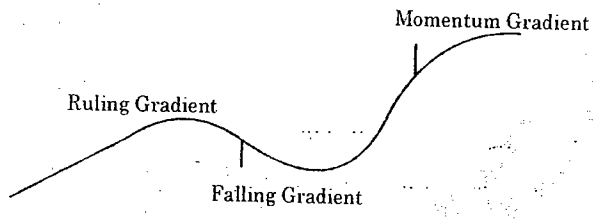
A. Gradient :

In plain terrain - 1 in 150 to 1 in 200 [0.50% to 0.67%]

In hilly regions - 1 in 100 to 1 in 150 [0.67% to 1%]

2. Momentum Gradient :

- If rising gradient is followed by the falling gradient, the train while coming down in a falling gradient acquires sufficient momentum, this momentum gives additional kinetic energy to the train. This would enable the train to overcome a steeper rising gradient than the ruling gradient.
- This rising gradient is called as momentum gradient and in such case the steeper grade than the ruling grade on the adopted.



3. Pusher or Helper Gradient :

- If sever ruling gradient is in longer length of the track, there must be unused power of locomotive to carry the load on the plain track or train load.
- But if this gradient is concentrated in a certain specific section such as monotonous section, instead of limiting train load, the train is run on that section by assistant engine or helper engine.
- Such sever gradient where pusher or helper engine in provided at the end of the train is known as pusher gradient.
- On B.G. tracks of Western Ghats pusher gradient is of 1 in 37.
- In general for gradient of 1 in 75 and above pusher engine is used.

4. Gradients in station yards :

- Gradients in the station yards is provided to drain off the water used for cleaning rains.
- It should be sufficiently low. Reasons are :
  a) To prevent the movement of standing vehicle.
  b) To prevent additional resistance at the start of vehicle.
- Maximum gradient permitted on station yards is 1 in 400 though minimum is 1 in 1000.

Q. If ruling gradient is 1 in 150 on a particular section of broad gauge and at the same time a curve of 4 degree is situated on this ruling gradient, what should be allowable ruling gradient ?

Sol. Prevailing gradient - 1 in 150 = 0.667%

The compensation of grade on BG curve

= 0.04% per 1 D°

Total compensation = 0.04 × 4 = 0.16%

The allowable raling gradient = 0.507%

= 1 in 197.

The allowable ruling gradient would be = 1 in 197

Speed of the Train :

- The speed of train depends upon the strength of the track and the power of the locomotive.
- Safe speed on a railway track should be minimum of the following :
  1) Safe speed on curves (as per Martins formula).
  2) Speed calculated as per cant formula allowing cant deficiency.
  3) Max speed as per length of transition curve.
  4) Maximum specified speed as per railway board.

1. Safe Speed as per Martin's Formula :

- If radius of the curve is R meters

A. For low speed (< 100 kmph)

a) On a transitioned curve

1. $V_{max} = 4.35\sqrt{R-67}$ for BG and MG

2. $V_{max} = 3.6\sqrt{R-6.1}$ for N.G.

b) On Non transitioned curve :

80% of the speed allowed on transitioned curve.

B. For High Speed (> 100kmph)

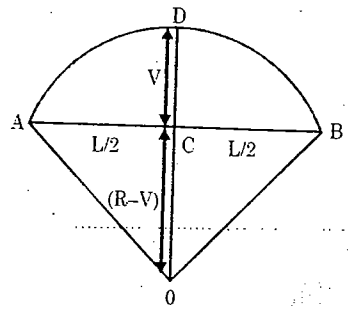
$V_{max} = 4.58\sqrt{R}$ for BG only

Radius of curve/ Degree of Curve

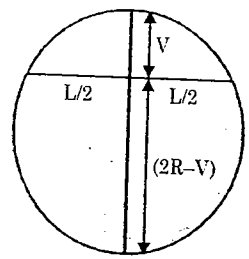
- Maximum degree of curve or minimum Radii for Indian railways are as follows :

for B.G.	10°	175 m
for M.G.	16°	109 m
for N.G.	40°	44 m

Versine of the Curve :



- It is used to check the accuracy of the curvature.
- For a chord AB, CD is known as Versine of the curve.
- Let length of chord is L radius of the curve is R and V cosine is V.



By using the property of circle

$$\left(\frac{L}{2}\right)\times\left(\frac{L}{2}\right) = (2R-V) * V$$

$$\text{Versine} = V = \frac{L^2}{8R}$$ [where V is in cm and L and R are in meters]

Q. If a length of chord of a circular curve is used on BG track is 200 m and its radius is 400 m, what would be safe speed as per martins formula and versine of the curve.

Sol. Safe speed as per Martin's formula.

Case-I : For low speed (speed < 100 kmph)

$$V_{safe} = 4.35\sqrt{400-67}$$

$$V_{safe} = 79.38$$

$$V_{safe} = 79 \text{ kmph}$$

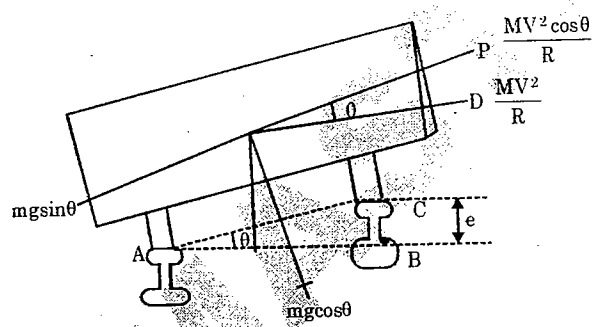
Calculated speed is less than 100 kmph, that why

Super Elevation or Cant

- When train negotiates on a horizontal curve. It is subjected to centrifugal force, which acts or pushes the train away from the centre of the curve.
- Which results increase of the pressure on the outer rail.
- To encounter the effect of centrifugal force the level of the outer rail is raised above the inner rail by certain amount.
- This raised elevation of outer rail is known as super elevation.
- Superelevation is denoted by e.

Objects of providing superelevation :

- To encounter the effect of centrifugal force, this will result in the faster movement of trains on curves.
- To provide equal distribution of wheel loads on two rail, so that there is no tendency of track to move out of position due to more load on outer rail.
- To provide an even and smooth running track to ensure comfortable ride to passengers and safe movement of goods.



- Force acting on the train are
  a) Weight of the vehicle
  b) centrifugal force.
- Friction force is not considered on deriving eqn. For minimum cant

$$mg\sin\theta = \frac{mv^2}{R}\cos\theta$$

$$\tan\theta = \frac{V^2}{gR}$$

Maximum Limit of Superelevation :

Track	Speed < 120 kmph	Speed > 120 kmph
BG	16.50 cm	18.50 cm
MG	10 cm	×
NG	7.6 cm	×

- Maximum valve of superelevation is 1/10 of the gauge.
- When loads or pressure on the both rail is equal the cant provided is known as equilibrium cont.

Equilibrium Speed and Equilibrium Cant

- On a same railway track trains like passenger train (the lowest speed) and Rajdhani, Shatabdi trains (the fastest speed) move. The cant provided for the passenger train will not suit the Rajdhani trains and vice versa. So actual cant should be provided for an average speed (also called equilibrium speed) so that all trains with different velocities can be allowed.
- The trains running faster than average speed will be able to pass the curve with certain cont deficiency.

Equilibrium Speed :

a) When sanction speed > 50 kmph

1. $V_{eq} = \frac{3}{4} V_{max} = 0.75 V_{max}$
2. Safe speed as per martins formula

} lesser of both is adopted

b) When sanctioned speed is < 50 kmph

1. $V_{eq} = 50$ kmph
2. Safe speed from martins formula

} lesser of both is adopted

c) Weighted avg. speed can also be calculated

No. of trains	Speed	Weighted avg. speed
n_1	V_1	
n_2	V_2	
n_3	V_3	$V_{avg} = \frac{\Sigma nV}{\Sigma n}$

- This shortage of cant is known as cant deficiency.
- Cant deficiency is the difference between the equilibrium cant necessary for the maximum permissible speed on a curve and the actual cant provided.

Limits of Cant Deficiency

- Cant deficiency is limited because
  1. Higher cant deficiency gives much discomfort to passengers
  2. Extra pressure and lateral force on outer rail.

Limit of - cant Defficiency

Gaurge	Speed < 100 kmph	Speed > 100 kmph
BG	7.6 cm	10.00 cm
MG	5.1	×
NG	3.8 cm	×

Q. On a 2° curve for a BG track a actual cant is provided for a speed of 80 kmph, what is cant deficiency for a train with speed 120 kmph. It exceeds permissible limit find safe speed.

$$\text{Radius of the curve, } D^\circ = \frac{1720}{R} \quad \text{[for 30 m chain]}$$

$$R = 860 \text{ m}$$

$$\text{equilibrium speed} = 80 \text{ kmph}$$

$$\text{actual cant provided} = e = \frac{GV^2}{127R}$$

$$e = \frac{1.676 \times (80)^2}{127 \times 860}$$

$$e_{act} = 98.20 \text{ mm}$$

Theoretical cant required for speed 120 kmph

$$e_{th} = \frac{GV^2}{127R}$$

$$e_{th} = \frac{1.676 \times (120)^2}{127 \times 860} = 22.09 \text{ cm}$$

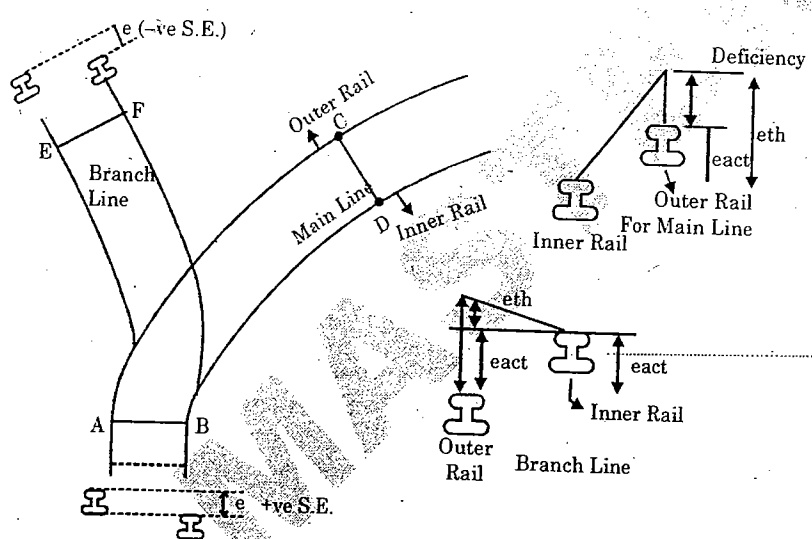
$$0.1982 = \frac{1.676\ V_{max}^{2}}{127 \times 860}$$

$$V_{max} = 113.7 \text{ kmph}$$

Maximum speed allowed is = 113.7 kmph

Negative Super Elevation :

- If the level of outer rail is above the level of inner rail, super elevation is known as +ve super elevation.
- If the level of outer rail is below the level of inner rail. This is known as –vc super elevation.
- When a main line on a curve has a turnout of opposite curvature leading to a branch line, then the level of outer rail in branch line is always kept lower than level of inner rail. This leads to –VC super elevation for branch line.



- In above figure at section AB branch line and main line arc getting separated. AC is outer rail for main line so AC should be at higher level than BD. Means A should be at higher level than B.
- BF is outer rail for branch line so level of BF should bc higher than level of AE, means B should be at higher level.
- The above two conditions be met at the some time so we provide –Ve S.E. for branch line.

Q. If branch [illegible]

Theoretical cont req. for main line

$$e_{th} = \frac{GV^2}{127R} = \frac{1.676 \times (9.5)^2}{127 \times 349}$$

$$e_{th} = 7.768 \simeq 7.7 \text{ cm}$$

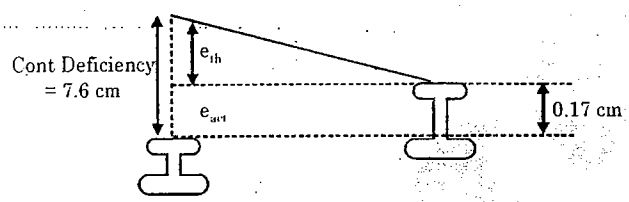
Max cont deficiency for BG for speed of 4s kmph

$$= 7.6 \text{ cm}$$

Actual cont for main track $= 7.77 \text{ cm} - 7.6 \text{ cm}$

$$e_{out} = 0.17 \text{ cm}$$

Branch Line :



–ve S.E. for branch line $= -0.17$ cm

Theoretical super elevation for branch line

$$e_{th} = 7.60 - 0.17$$

$$e_{th} = 7.43 \text{ cm}$$

Max permissible speed on branch line

$$e_{th} = \frac{GV^2}{127R} = V_{max}^2 = \frac{0.0743 \times 127 \times 215}{1.076}$$

$$V_{max} = 34.7 \text{ kmph}$$

Maximum speed on branch line $= 34.7$ kmph

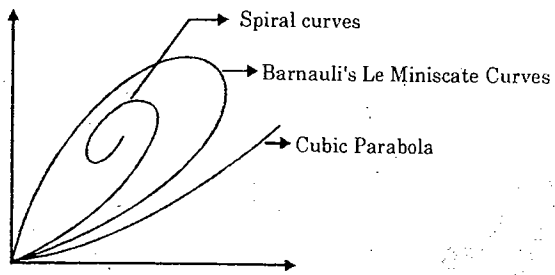
Curves :

- The use of curves becomes absolutely necessary for a change in the alignment through horizontal curves and change in the gradient through vertical curves.
- The use of the curves is necessary in the following conditions

Transition Cures :

- This is the curve which is introduced in between the circular portion of track and strait tack at both ends.
- Radius of the transition curve uniformly decreases from infinity near the start portion of the track to the minimum at the junction point with the circular curve.

Types of Transition Curves :



- Spiral curve is used in the highways because the curvature of the curve deflection is more and spiral curves allows deflection more than 9°.
- Cubic parabola is used for railways because deflection allowed in tracks are below 9° and within this limit cubic parabola traces spiral curve and setting out the parabola is also easy.
- Lemniscate satisfies the requirement of transition curves upto deflection angle of 30°.

Functions of Transition Curves :

- To decrease the radius of curve gradually in order to reduce the effect of sudden jerk due to centrifugal force.
- To provide the gradual super elevation within the length of the transition curve.
- To provide gradual extra widening of the rail.

Properties/Requirements of the Idea transition curve :

- The transition curve should be perfectly tangential at two junction points. It means at straight junction its radius should be infinite and at the curve junction its radius must be equal to radius of the curve.
- The rate of change of curvature should be same as rate of change of super elevation. So that fall super elevation can be provided within the length of transition curve.

Transition Curve for Railway :

- Cubic parabola is used in Indian railway, it can be easily set out by offsets and

General Eqn. of cubic parabola :

$$y = ax^3 + bx^2 + cx + d$$

at x = 0, y = 0

$$0 = a(0)^3 + b(0)^2 + c(0) + d \quad [d = 0]$$

at x = 0, $\frac{dy}{dx} = 0$.

$$\frac{dy}{dx} = 3ax^2 + 2bx + c$$

at x = 0, $\frac{d^2y}{dx^2} = 0$ (curvature)

$$\frac{d^2y}{dx^2} = 6ax + 2b \quad [\text{curvature} = 1/R]$$

$$b = 0$$

at x = L, radius of curve = Radius of circular curve.

$$\frac{d^2y}{dx^2} = \frac{1}{R}$$

$$\frac{1}{R} = 6aL + (2b = 0)$$

$$a = \frac{1}{6RL}$$

Eqn. of deflection :

$$y = \frac{1}{6RL}x^3$$

$$\text{Slope } \tan\phi = \frac{dy}{dx} = \frac{3x^2}{6RL} = \left(\frac{x^2}{2RL}\right)$$

$$\tan\phi_{max} \Rightarrow \text{at } x = L$$

$$\tan\phi_{max} = \frac{L}{2R}$$

Spiral Angle (ϕ) :

Length of the transition curve :

- Length of the transition curve is length along the centre line of the track from its meeting point with the straight to that of circular curve.
- There are two approaches where L is length of transition curve in meter.

1. 1st approach :

a) L = 7.2e
b) L = 0.03 e Vmax
c) L = 0.073 D Vmax

} Maximum of these

where e = S.E.om cm, Vmax = max speed allowed in kmph, D = cont deficiency in cm.

2. 2nd approach

a) Railway board formula :

$$L = 4.4\sqrt{R}$$

L = Length of transition curve in m; R = Radius of curve in m.

b) Based on change of radial acceleration :

$$L = \frac{3.28\,V^3}{R}(m)$$

v = Speed in m/sec.

R = Radius in m

C = rate of change of acc. in m/sec^3

c) As per rate of change of super elevation.

L = 3.6 e; L = D Length in M; e = 1 S.E. in cm.

Max. speed based on length of transition wave (L)

a) for normal speed < 100 kmph

$$V_{max} = \frac{134L}{e} \text{ or } \frac{134L}{D}$$

b) For speed > 100 kmph

$$V_{max} = \frac{198L}{e} = \frac{198L}{D}$$

where L = length of transition cure M

Sol. Radius of the curve $R = \frac{1720}{D^\circ}$ [for 30 m chain)

$$R = \frac{1720}{4} = 430 \text{ m}$$

- Using Martin's formula, max speed allowed on BG curved back.

$$V_{max} = 4.35\sqrt{R-67}$$

$$V_{max} = 4.35\sqrt{430-67} = 82.87 \text{ kmph}$$

$$V_{max} = 83 \text{ kmph}$$

For this speed theoretical cant required

$$e_{th} = \frac{GV^2}{127R}$$

$$e_{th} = \frac{1.676 * (83)^2}{127 \times 430} = 0.2114 \text{ m}$$

$$e_{th} = 21.11 \text{ cm.}$$

For speed of 83 kmph on BG track max cant allowed

$$= 16.5 \text{ cm}$$

Cant deficiency $= 21.11 - 16.5$ cm

$D = 4.61$ {which is less than max i.e. 7.5 cm)

Equivalent cont provided

$$ea_{oct} = e_{th} - D_{max}$$

$$e_{act} = 21.11 - 7.6$$

act cont. provided $= 13.51$ cm

Length of transition curve, from 2nd approach

1. $L = 4.4\sqrt{R}$

$L = 91.24 \text{ m} \simeq 91 \text{ m}$

2. $L = 3.60 \times e = 3.60 \times 13.51$

$= 48.63 \text{ m} \simeq 48.50 \text{ m}$

Calculate : 1. Radii in meters, 2. Maximum speed allowed, 3. The cont cant actually be provided.

Sol. 0.76 cm, R = radius of curve in m

Let max. speed is V_{max} and equilibrium speed is V_{avj} and max. speed as per cont formula is Ve.

$$D = e_{th} - e_{act}$$

e_{th} = D req. cont for max speed for cont format

e_{act} = D actual cont provided for equilibrium speed

$$\Rightarrow \quad 0.075 = -\frac{1.676\ V_{avg}^2}{127r} + \frac{1.676 \times Ve^2}{127R}$$

$$Ve^2 - V_{avg}^2 = \frac{7.6 \times R}{1.315}$$

$$V_e^2 - V_{avg}^2 = 5.78\ R \quad .....(i)$$

$$V_{avg} = 60 \text{ kmph}$$

$$V_{max} = 1.25\ Ve$$

$$V_{max} = 4.35\sqrt{R-67}$$

$$V_{max}^2 = 18.92\ (R - 67)$$

$$V_{max}^2 = 1.5625 V_e^2 = 18.92(R-67)$$

$$V_e^2 = 12.10\ (R - 67)$$

From eqn. (i)

$$12.10\ (R - 67) - 60^2 = 5.78R$$

$$6.32R = 3600 + 810.7$$

$$R = 697.89$$

$$R = 698 \text{ m}$$

ii) Max. speed allowed will be as per cant formula.

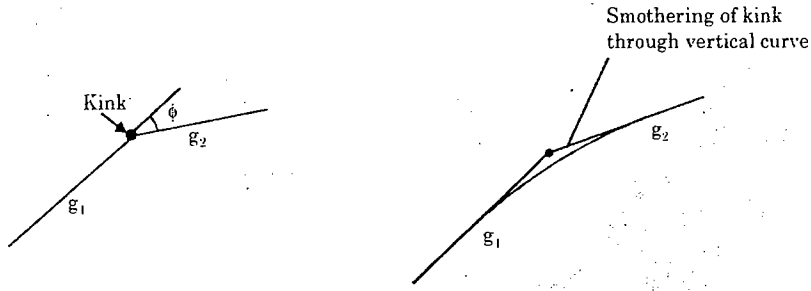
$$V_{allowed} = \frac{4}{5} \times \left(4.35\sqrt{R-67}\right) \quad [V_{amx} = 1.25\ V_e]$$

Vertical Curves :

Two types of vertical curves are used

(i) Vertical summit curves (ii) Vertical say or valley curves.

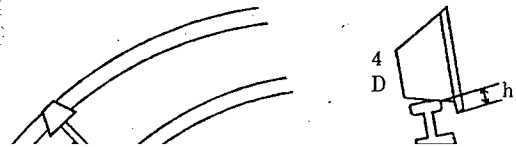
- Whenever there is change in the gradient of the track, an angle if formed at the junction of the gradients.
- Thus vertical kink formed at the junction is smoothened by the use of curve so that lurching is not experienced.



- When train passes over the summit of the curve, acceleration begins to act, speed of the train increases, draw the bar pull increases behind each wagons, which result increase in tension in the coupling.
- When train passes over the vertical valley curve, the front of the train ascends on upgrade while rear wagons tend to compress the couplings.
- The parabolic curve is also provided with the vertical curves.
- Length of vertical curves depends upon algebraic sum of the grades.
- The curves are set out by string line method.
- Slew or shift of the curve is

$$S = \frac{Ls^2}{24R}$$

Widening of Gauge on the curves :



B = Rigid wheel base in meter

B = 6 m – BG

4.88 mm – MG

L = Lap of flange in m

$L = \sqrt{h^2 + Dh}$

h = depth of flange below top of the rail in cm.

D = Dia. of wheel in m

R = radius of curves in m.

d = extra widenging in cm.

Q. Find out the extra widening of Gauge on a BG track of circular curve of radius 450 m, using the following data.

i) Length of rigid wheel base = 6 m

ii) Depth of flange below top of the rail = 4 cm

iii) Diameter of wheel = 1.3 m

Sol. B = 6m; h = 4 cm; D = 1.3 m

$$\text{Lap length, } L = \sqrt{h^2 + Dh}$$

$$L = \sqrt{(4)^2 + 1.3 \times 4}$$

$$L = 4.6 \text{ m}$$

$$\text{Extra widening (d)} = \frac{13(B+L)^2}{R}$$

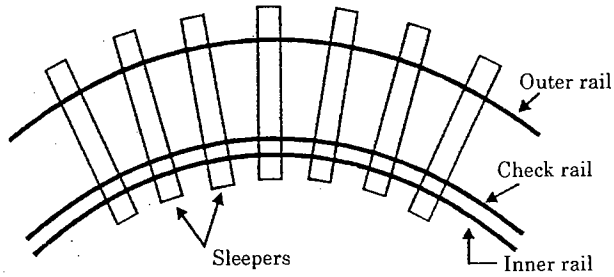
$$d = \frac{13(6+4.6)^2}{450}$$

$$d = 3.24 \text{ cm.}$$

Extra widening of gauge on curve = 3.24 cm.

Shift :

whenever a transition curve is fitted in between the straight and circular track, original curve is to be shifted inwards by certain distance, this distance from circular curve is known as shift.



Q. Determine the length of transition curve and offsets at every 15 m for a B.G. track having 4° curvature and conf. of 12 cm. The maximum permissible sped is 85 kmph.

Sol. Radius of the curve $\rightarrow R = \frac{1720}{D}$ [for 30 m chain]

$$R = \frac{17200}{4} = 430 \text{ m}$$

Actual emf provided $e_{oct} = 12$ cm

$V_{max} = 85$ kmph

- Max. speed allowed on the curve as per Martin's formula :

$$(V_{max}) = 4.35\sqrt{R-67}$$

$$= 4.35\sqrt{430-67}$$

$$V_{max} = 82.88 \simeq 83 \text{ kmph}$$

- Max speed allowed as per cent. formula :

$$e_{th} = e_{act} + D = 12 + 7.6 = 19.6 \text{ cm} \quad [D = 7.6 \text{ for B.G.}]$$

$$e_{th} = \frac{GV_{max}^2}{127R}$$

$$V_{max}^2 = \frac{0.196 \times 127 \times 430}{1.676}$$

$$(V_{max})C = 79.01 \text{ kmph} \simeq 79 \text{ kmph.}$$

Safe speed of the track = minimum of the above

Setting out the curve :

Eqn. of cubic parabola, transition curve,

$$y = \frac{x^3}{6RL}$$

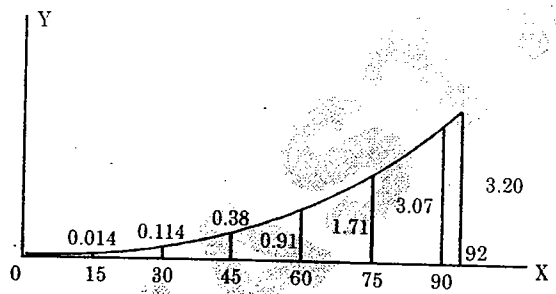
$$y = \frac{x^3}{6 \times 430 \times y2} = \frac{x^3}{237360}$$

For every offset of 15 m (x = 0, 15, 30, ...)

x	0	15	30	45	60	75	90	92
y	0	0.014	0.114	0.38	0.91	1.78	3.0	3.28

when x = 0; y = 0

when x = 15 m; $y = \frac{15^3}{237360} = 0.014$ m



OBJECTIVE QUESTIONS

1. If cure of 4° accompanied by the rulling gradient of 1 in 150 on BG track the permissible gradient would be

   (a) 1 in 150 (b) 1 in 175 (c) 1 in 185 (d) 1 in 200

2. Grade compensation for curvature per degree on BG tack is

   (a) 0.02% (b) 0.03% (c) 0.04% (d) 0.05%

3. Safe sped of the railway track is calculated by using ?

   (a) using martins formula (b) using cant formula

   (c) using length of transition curve

3. Max value of S.E. is 1/10 of the gauge.

Which of the following statements is/are correct

(a) only 1 (b) 1 and 2 (c) only 3 (d) all are correct

7. Consider the following statements

1. Equilibrium speed is the average speed for the all trains passing in the track.
2. Actual cant. provided is based on the maximum speed of the trains passing through that pack.
3. Cant. deficiency is not allowed for the train running more than 100 kmph

Which of the following statements is/are correct ?

(a) only 1 is correct (b) 2 and 3 (c) 1 and 3 (d) 1, 2 and 3

8. Match the following

Column I	Column II
A. Buckling of rail	1. Wooden sleepers
B. Dog spikes	2. C.I. chair
C. Creep of rail	3. Steel sleeper
D. Morgan key	4. Thermal expansion

Which of the following is correctly matched.

	A	B	C	D
a)	4	1	3	2
b)	3	1	2	4
c)	4	2	3	1
d)	3	4	1	2

9. Match the following :

List I (Components)	List-2 (Function
A. Ballast	1. Strengthen steel sleepers
B. Sleepers	2. Maintain gauge
C. Fishplates	3. Provides some elasticity to tack
D. Saddle plate	4. To connect to rails at ends

Which of the following is correctly matched ?

A B C D

3. Cubic parabola is not used in Indian railway because setting out it is difficult.

Which of the following statement is/are correct ?

(a) only 1 (b) only 3 (c) 1 and 3 (d) all

12. Consider the following statements

1. Ruling gradient is the gradient allowed so that engine can haul the load with its maximum capacity.
2. On the plain ruling gradient is 1 in 200 to 1 in 300
3. When extra momentum is given by the another engine at the end of the train, gradient is known as momentum gradient

Which of the statements is / are correct.

(a) only 1 (b) only 2 (c) 1 and (d) 1, 2 and 3

13. For B.G. track helper per engine / pusher is provided if gradient is steeper than

(a) 1 in 25 (b) 1 in 32 (c) 1 in 37 (d) 1 in 50

14. The Grade compensation of 4° curve on a Bread gauge railway track is

(a) 0.20% (b) 0.16% (c) 0.12% (d) 0.08%

15. In a BG track, the specified ruling gradient is 1 in 250. The horizontal cure of 3° on a gradient of 1 in 250 will have the permissible compensated gradient of

(a) 1 in 257 (b) 1 in 357 (c) 1 in 457 (d) 1 in 512

16. Which of the following is correct expression of version of a curve.

(a) $h = \frac{l^2}{r}$ (b) $h = \frac{l^2}{2r}$ (c) $\frac{l^2}{8r}$ (d) $h = \frac{l^2}{4r}$

17. The ruling gradient on B.G. section of railway is 1 in 150 and a 4° curve is also there on it. What is the allowable ruling gradient.

(a) 1 in 146 (b) 1 in 154

(c) 1 in 196 (d) 1 in 232

18. In India the minimum gradient provided on the station yards to drain out off water is

(a) 1 in 400 (b) 1 in 600 (c) 1 in 800 (d) 1 in 1000

19. Maximum degree of curvature on B.G. track is

(a) 4° (b) 6° (c) 8° (d) 10°

20. On the curves railway tracks are realign by

Reason (R) : Restricting the gradient to the ruling gradient in hilly terrains would mean increasing the length of track resulting considerably in heavy excavation.

22. **Assertion (A)**: Super elevation provided on the track is less than the maximum cant required (equilibrium cant.)

Reason (R) : Subject to maximum value depending upon speed and gauge cant deficiency is allowed, therefore actual cant provided is less than the equilibrium cant.

23. **Assertion (A)**: Cubic parabola is used as a transition curve in Indian railways, unlike spiral curve in road ways.

Reason (R) : Upto deflection angle of 9° cubic parabola traces same path as by spiral curve and setting out cubic parabola is easier by offset method.

24. **Assertion (A)**: Transition curve's length should be such that curvature of transition curve may decrease at the same rate as the super elevation is increasing.

Reason (R) : This is necessary to attain the full super elevation at the junction of transition and circular curve.

25. **Assertion (A)**: The smallest radius and largest degree of a railway track curve is limited.

Reason (R) : Sharper curve leads to huge wear and tear of wheels and rails and may also lead subsequent derailment.

26. Bernoulli is lemniscate curves losses its transition property after the deflection angle of

(a) 20° (b) 25° (c) 30° (d) 35°

27. Slope of tangent at any point on the transition curve is known as

(a) spiral angle (b) deflection angle

(c) transition angle (d) N.O.T.

28. Consider the following statements.

State-I : When a train climbs a certain upgrade at a uniform speed and passes over the summit of the curve, tension in the coupling increases.

State-II : The downward acceleration on locomotive starts to occur which increases draw bar pull behind each wagon.

(a) only statement 1 is correct

ANSWER

1. (d)	2. (c)	3. (d)	4. (b)	5. (b)
6. (b)	7. (c)	8. (a)	9. (d)	10. (b)
11. (a)	12. (a)	13. (c)	14. (b)	15. (b)
16. (c)	17. (c)	18. (d)	19. (d)	20. (b)
21. (a)	22. (a)	23. (a)	24. (d)	25. (a)
26. (c)	27. (a)	28. (c)	29. (b)	30. (d)
31. (d)				

EXPLANATIONS

1.(d) and 14 (b)

Grade compensation for B.G. track is

= 0.04% per degree of curve

For 4° curve the Grade compensation

= 0.16%

Current Railing gradient

= 1 in 150

= 0.6666 = 0.67

The allowable gradient

= 0.61 – 0.16 = 0.51

l..c 1 in 200

4.(b) Degree of curve is angle subjected by 1 chain length at the centre of curve.

For $2\pi R = 360°$

$$20 \text{ m} = \frac{360}{2\pi R} \times 20$$

Ruling gradient

= 0.4%

Allowable gradient on curve

= 0.4 – 0.12

0.28

l.c. 1 in 357

17.(c) Grade compensation of BG

= 0.04% per degree of curve

For B.G. curve of 4°

= 0.16%

Railing gradient

= 1 in 150 = 0.67%

Allowable gradient

= 0.67

= 0.51%

Allowable gradient 1 in 196

CHAPTER 6

Points and Crossings

Points and crossings are special arrangements which are used to move trains from one track to another track

Uses :

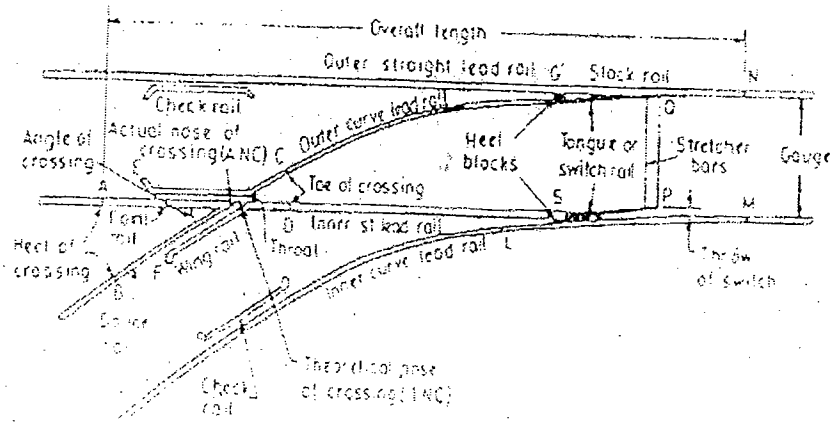
- Points and crossings provide flexibility of movement by connecting one line to another according to requirements.
- They also help for imposing restrictions over turnouts which necessarily retards the speed of operation of trains.

Turn out :

Turnout is the simplest combination of points and crossing which enables a track either branch line or siding to take off from main track. High magnese steel are used to make material (steel) for point and crossing.

Parts of the turn outs

- 2 points or switches
- 2 (a pair) of stock rails
- a pair of check rail
- a V crossing or acute angle crossing
- 4 lead rail
- a pair of stock rail



Working principle of turnout :

- One turnout provides facilities for turning vehicles from one direction only and not from both the directions of straight path.
- Turn out works with combination of points and crossings.
- Points consist of stock rail (part of outer straight lead rail) and tongue rail (part of out curved lead rail).
- Tongue rail is tapered having toe at one end and heal at the another end.
- If there is a gap in between outer straight lead and toe of the tongue rail, the train will pas through straight track.
- If toe of tongue rail touches the outer straight lead rail the train will be diverted on curved track.
- Check rails are provided on the opposite side of the crossings for guiding one wheel of the vehicle and thus to check the tendency of other wheel to climb over the crossing.
- Tongue rail is kept 6 mm higher than stock rail, so vertical wear of tongue rail should not exceed 6 mm.

Important Points of Switch :

1. Heel Divergence :

It is distance between running faces of stock rail and tongue rail at the heel of the switch.

2. Flange way clearance :

Distance between adjacent faces of tongue rail and stock rail at heel of the switch.

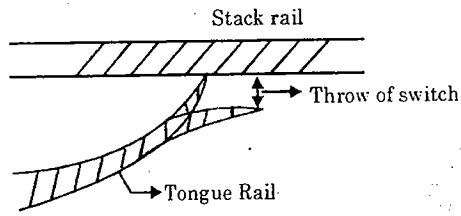
For 1 in 12 crossing = 6.30 cm

for 1 in 8½ crossing = 6.6 cm

3. Flange way depth :

Vertical distance between top of rail it heel block.

4. Throw of switch :

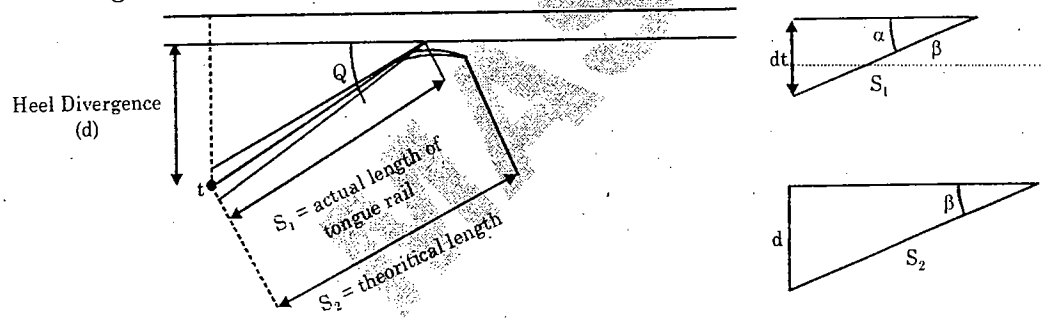


The maximum distance by which the toe of tongue rail moves side way is called throw of switch.

For BG = 9.5 cm

For MG/NG = 8.9 cm

5. Switch Angle :



This is angle between the running faces of stack rail and tongue rail when tongue rail touches the stack rail.

Important Points of Crossing :

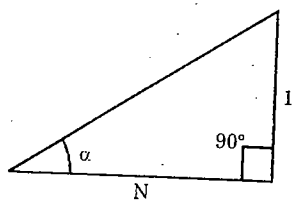
1. Crossing Angle :

Acute angle crossing are designated by either the angle that the gauge faces makes with each

Different Methods to represent crossing angle

1. Cole's method - (Right angle triangle method):

This method is used in Indian railway.

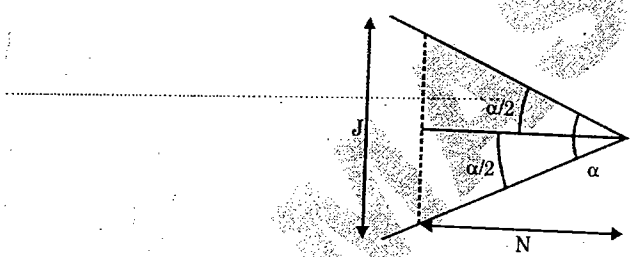


[α = Crossing Angle]

$$\tan\alpha = \frac{1}{N} \qquad \alpha = \cot^{-1}(N)$$

Crossing No.	Angle of Crossing	Used in
1 in 6	9°27′44″	In symmetrical split.
1 in 8½	6°42′35″	In station yard where space is limited
1 in 12	4°45′44″	Station yards of main line.
1 in 16	3°34′35″	High speed turnouts on BG and MG track.

2. Centre line method :



$$\tan\left(\frac{\alpha}{2}\right) = \frac{\frac{1}{2}}{N}$$

$$\text{Crossing angle} = 2\cot^{-1}(2N)$$

3. Isoscles triangle method :

α = crossing angle

N = Crossing No.

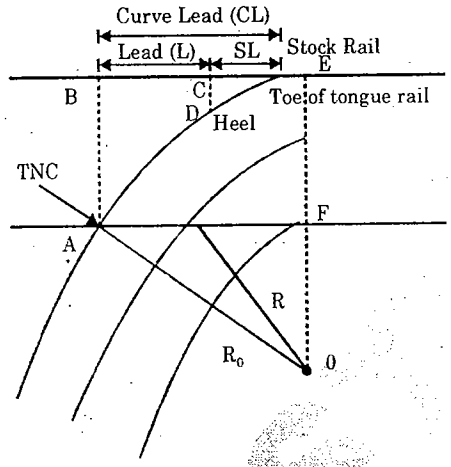
Design Calculations of a Turnout :

1. Curve lead :

It is the distance measured along stock rail between toe of switch and TNC.

2. Switch lead :

Distance between heel of the switch and toe of the switch, measured on stock rail.



3. Lead (L)

Distance between heel and TNC measured along stack rail.

4. Outer radius = R_0 = 0A or OE

5. Central radius = $R = R_0 - G/2$

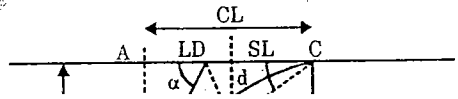
6. Heal Divergence = d

7. Switch angle = β

8. Crossing angle = α

Case-1 :

When curve is starting from toe of switch and ends at TNC (full portion is curved)



$$CL = G\tan\left(\frac{\alpha}{2}\right)$$

2.

$$CL = SL + L$$

$$CL = AD + CD$$

$$CL = G\cot\alpha + G\operatorname{cosec}\alpha$$

$$CL = GN + G\sqrt{1+\cos^2\alpha}$$

$$CL = GN + G\sqrt{1+N^2}$$

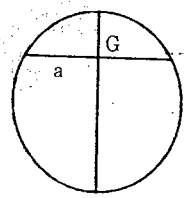
$$CL = 2GN$$

3. Using properties of circle :

$$CL^2 = G(2R_0 - G)$$

$$CL^2 = 2R_0G - G^2$$

$$CL = \sqrt{2R_0L}\ G^2 <<< 2Rds$$



4. Radius RO

$$R = OC = CE + OE$$

$$= G + CL\cot\alpha$$

$$R_0 = G + 2GN.N$$

$$R_0 = 2GN^2 + G$$

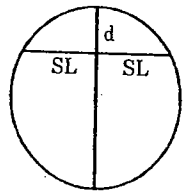
but as per Indian railway

$$R_0 = 1.5G + 2GN^2$$

5. Switch lead :

$$SL^2 = 2(2R_0 - d)$$

$$SL = \sqrt{2R_0d} \quad [\because d^2 <<< 2Rod]$$



6.

$$\text{Lead} = CL - SL$$

7.

$$\text{Central radius} = R = R_0 - \frac{G}{2}$$

Q. Elements whole setting out a turnout on BG track are

1. Curve lead (CL)

$$CL = 2\ GN = 2 \times 1.676 \times 12$$
$$CL = 40.224\ m$$

2. Outer radius

$$R_0 = 1.5\ G + 2\ GN^2$$
$$R_0 = 1.5 \times 1.676 + 2 \times 1.676 \times 12^2$$
$$R_0 = 485.202\ m$$

3.
$$SL = \sqrt{2Rod}$$
$$SL = \sqrt{2 \times 485.202 \times 0.12}$$
$$SL = 10.8\ m$$

4.
$$\text{Lead (L)} = CL - SL$$
$$= 40.224 - 10.8$$
$$L = 29.424\ m$$

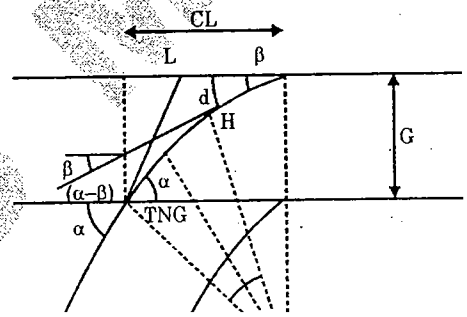
5. Central Radius :

$$R = R_0 - \frac{G}{2} \qquad R = 481.364\ m$$

Case-2 :

In this case the curve is starting from the heel of the switch and ends at the TNC portion of tongue rail is straight.

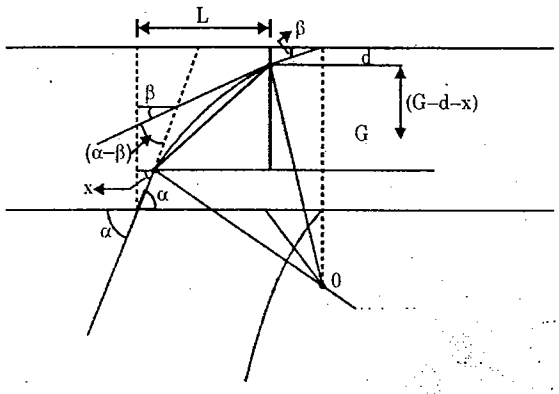
We have to find 1. Lead, 2. Outer radius, 3. Central Radius



Case-3 :

In this case, the curve is starting from the heel of the switch and ends at starting point of straight portion provided just before TNC. Only lead and Ro are calculated.

This method is used in Indian Railway.



$$\text{Lead (L)} = (G - d - x\sin\alpha)\cot\left(\frac{\alpha+\beta}{2}\right) + x\cos\alpha$$

$$\text{Radius } R_0 = \frac{G - d - x\sin\alpha}{\cos\beta - \cos\alpha}$$

$$\text{Central radius} = R = R_0 - \frac{G}{2}$$

Q. On a straight B.G. track, a form out takes off at one angle of 6°42′35″, design the turn out when it is given angle of switch = 1°34′27″ the length of switch rail is 4.73 m heel divergence i.e. d = 11.43 cm and straight arm x) = 0.85 m.

$\alpha = 6°42'35''$, $\beta = 1°34'27''$

d = 0.1143 m G = 1.640 m x = 0.85 m

Lead (L)

$$L = (G - d - x\sin\alpha)\cot\left(\frac{\alpha+\beta}{2}\right) + x\cos\alpha$$

$$= (1.676 * -0.1143 - 0.85\sin 6°42'35'')$$

$$R_0 = \frac{1.676 - 0.1143 - 0.858 \times \sin(6°42'35'')}{(\cos 1°34'27'' - \cos 6°42'35'')}$$

$$R_0 = \frac{1.4625}{0.0064} = 229\,\text{m}$$

$$R_0 = 229 \text{ m}$$

Types of Switches :

1. Stab Switch :

In this type of switch, no separate tongue rail is provided and some portion of the track is moved from side to side.

2. Split Switch :

In this type of switch tongue rail is combined with the stock rail. Split switches are classified follows

a) Louse heel type :

In this tongue rail is joined to lead rail by means of fish plate.

b) Fixed heel type :

It is improvement over loose heel type and used with long tongue rails only.

Wingrail and check rail at points and crossing :

- Check rails are provided on the opposite sides of the crossings for guiding one wheel of the train and thus to check the tendency of other wheel to climb over the crossing.
- While changing the route, wing rails help in channelizing the wheels in their proper route.

OBJECTIVE QUESTIONS

1. The functions of points and crossings are
   1. They enables to connect different routes either parallel or diverging.
   2. They offer the means to move train from one route to another.
   3. Help for marshalling and shunting work in station yards.
   4. Act as a control system for the train movement.

   Which of the above are correct ?

(b) to provide desired super elevation

(c) to prevent wear and tear of rail

(d) to channelize wheel in their proper routes.

4. Which of the following pairs are correctly matched -

1. Distance between adjoining face of running rail and check rail - flange way clearance
2. Distance through which the tongue rail moves laterally at the toe of switch for the movement of train - Heel divergence
3. Distance between gauge faces of stock rail and tongue rail at the heel - throw of switch
4. Angle between the gauge face of stock rail and tongue rail - Switch angle and tongue rail

(a) 1 and 4 (b) 2 and 4 (c) 3 and 4 (d) all

5. What will be curve lead for a 1 in 8½ turnout taping off from a straight broad gauge track.

(a) 28.49 m (b) 21.04 m (c) 14.24 m (d) 7.45 m

6. If A is the angle formed by two gauge faces, the crossing number will be

(a) tanA (b) cotA (c) sec A (d) cosec A

7. The distance between the running faces on the stock rail and gauge face of tongue rail measured at the heal of switch Flange way clearance is known as

(a) Flange of clearance (b) Throw of switch

(c) Heel Divergence (d) Flare

8. If the curve lead of B.G. track turnout is 16.76 m. The angle of crossing will be given by

(a) $\tan^{-1}10$ (b) $\tan^{-1}5$ (c) $\tan^{-1}\frac{1}{10}$ (d) $\tan^{-1}\frac{1}{5}$

9. A rail which is tapered from toe to heel is known as

(a) stock rail (b) tongue rail (c) wing rail (d) lead rail

10. The minimum length of tongue rail is given by ?

(a) $S = R\tan\left(\frac{\alpha}{2}\right)$ (b) $S = R\cot\left(\frac{\alpha}{2}\right)$ (c) $S = R\sec\left(\frac{\alpha}{2}\right)$ (d) $S = R\,\mathrm{cosec}\left(\frac{\alpha}{2}\right)$

11. Consider the following statements :

1. Through sleepers have advantages of maintaining the two tracks on the same level
2. Trough sleepers are longer in length

14. Throw of switch is defined at
    (a) Heel of the switch
    (b) At crossing
    (c) at toe of tongue rail
    (d) N.O.T.

15. Heel divergence for BG track in India is
    (a) 9.8 cm
    (b) 10.5 cm
    (c) 12.5 cm
    (d) 13.5 cm

16. Consider the following statements :
    1. Crossing no is defined as ratio of length of crossing at T.N.C. to the spread of leg of crossing.
    2. Check-rails are provided on the opposite sides of the crossing for guiding one wheel of the vehicle thus to check the running of vehicles.
    3. At a single turnout one point and one crossing is required.

    Which of the following statement is/are correct.
    (a) only 1
    (b) only 2
    (c) only 3
    (d) 1 and 3

17. For 1 in 12 crossing on BG track permissible speed is
    (a) 16 kmph
    (b) 18 kmph
    (c) 20 kmph
    (d) 24 kmph

18. For crossing angle of 6° the crossing number would be
    (a) 1 in 10
    (b) 1 in 12
    (c) 1 in 16
    (d) 1 in 20

19.

List-I (Crossing No.)	List-II (Use)
A. 1 in 6	1. In symmetrically split
B. 1 in 8½	2. In stations yard
C. 1 in 12	3. In station yards of main line
D. 1 in 16	4. High speed turnouts.

	A	B	C	D
a)	1	2	3	4
b)	4	3	2	1
c)	3	2	1	4
d)	2	3	4	1

3. Centre line method
4. Isosceles triangle method

Select the answer using code given below :

(a) 1, 2 and 3 (b) 2, 3 and 4 (c) 1, 3 and 4 (d) all of these

ANSWER

1. (b)	**2.** (c)	**3.** (d)	**4.** (a)	**5.** (a)
6. (b)	**7.** (c)	**8.** (d)	**9.** (b)	**10.** (a)
11. (d)	**12.** (c)	**13.** (d)	**14.** (c)	**15.** (d)
16. (b)	**17.** (d)	**18.** (a)	**19.** (a)	**20.** (d)
21. (a)	**22.** (c)			

EXPLANATIONS

2.(c). High carbon steel is used to prevent wear and tear of rail but not at the points and crossing.

One turnout provides facility for turning in one direction only. [Only 3 is correct]

5.(a)

Curve lead (CL)

$= 2$ GN

$$\alpha = \tan^{-1}\left(\frac{1}{5}\right)$$

12.(c) Level of tongue rail is kept 6 mm higher than stock rail so maximum wear of tongue rail allowed as 6 mm.

18.(a)

Crossing Number

CHAPTER 7

Track Junctions

Track Junctions :

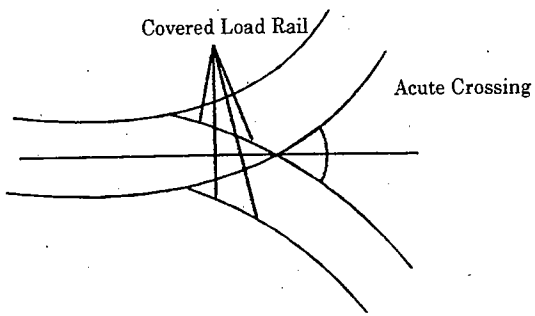
The different types of track junctions are formed by combinations of points and crossings, with curves and straights, to transfer trains from one track to another.

Important Types of Track Junctions :

1. Turnouts - Discussed in earlier chapter.

2. Symmetrical split or equivalent turnout.

- When a straight track is split up in two different directions with equal radii, it is known as symmetrical split.



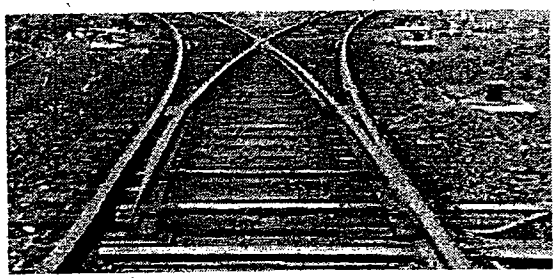
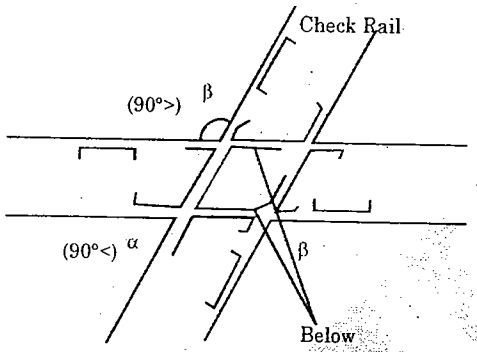


Fig. Symmetrical Turout

- Crossing number used in this case is 1 in 6.
- It consists of 4 curved lead rails, 2 check rails and 1 acute crossing.

4. Diamond crossing

- When straight tracks or curved tracks cross each other at an angle less than 90°, a diamond shape is formed this is called diamond crossing.
- It consists of 2 acute angle crossing and 2 obtuse angle crossings and four check rails.
- Indian railway specify flattest diamond to be 1 in 10 for BG and 1 in 8½ for other gauges.
- Diamond crossing is avoided on curves.



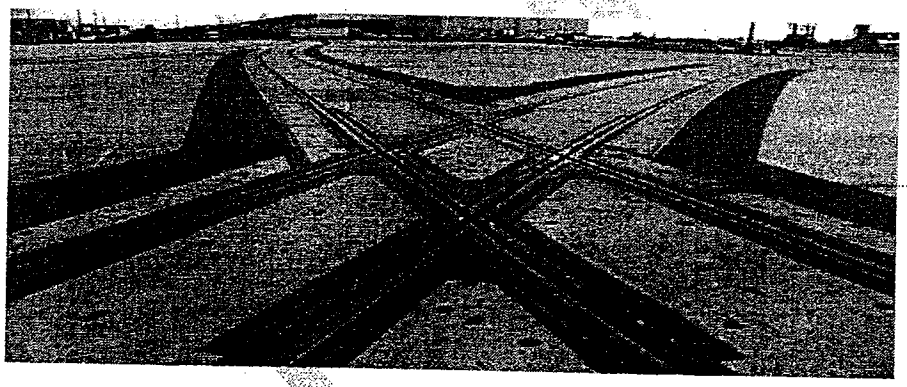


Fig. Diamond Crossing

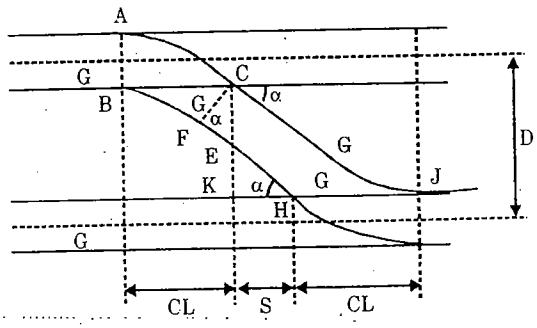
5. Cross Over :

- When two adjacent parallel tacks, which may be straight or curved, are connected by two sets of turnouts, the connecting portion (line) is known as cross over.
- Use of reverse curves between two crossings shortens the length of cross over.
- Cross over are useful to change the track when trains approaching from one direction

Design of Cross Over :

Case -1 :

Cross over with straight intermediate portion and equal crossing angles for both tracks.



D = Distance between centres of parallel tracks.

α = Angle of crossing

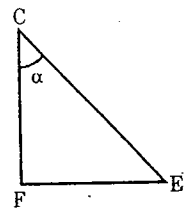
S = Horizontal projection of intermediate track

CL = Curve load

G = Gauge

$$CK = D - G$$

From Δ CEF



$$\cos\alpha = \frac{G}{CE}$$

$$CE = G\sec\alpha$$

$$EK = (D-g) - G\sec\alpha$$

From Δ HEK

$$\tan\alpha = \frac{EK}{S}$$

$$S = [(D-G) - G\sec\alpha]\cot\alpha$$

$$S = (D-G)N - GN\sec\alpha \quad [\cot\alpha = N,\ N = \text{crossing number}]$$

Q. A cross over occurs between two BG track using turn outs and same crossing number J in 12, with straight intermediate portion in between reverse curve.

If c/c distance between track = 6.5, find total length of cross over.

Sol. N = 12, D = 6.5 m, G = 1.676

Total length of crossover

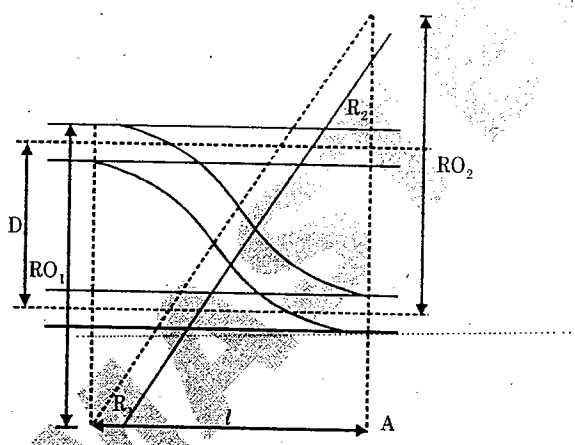
$$l = 4GN + (D-G)N - \sqrt{1+N^2}\,G$$

$$l = 4\times1.676\times12 + (6.5-1.676)\times12 - \sqrt{1+12^2}.1676$$

$$l = 118.15 \text{ m}$$

Case-2 :

Cross over with curved path between two turn outs having different crossing angles.



For turnout 1, Crossing number is 1 in N_1 and for turnout 2. crossing number 1 in N_2. l is total length of cross over.

$$R_{01} = 1.5G + 1.5GN_1^2$$

$$R_1 = R_{01} - \frac{G}{2}$$

$$R_{02} = 1.5G + 1.5GN_2^2$$

$$R_2 = R_{02} - \frac{G}{2}$$

Crossing No. at 1st turnout $= N_2 = 12$

Crossing No. at 2nd turnout $= N_2 = 16$

$$R_{01} = 1.5G + 2GN_1^2$$

$$R_{01} = 485.202 \text{ m}$$

$$R_1 = RO_1 - \frac{G}{2} = 484.364 \text{ m}$$

$$R_{02} = 1.5G + 2GN_2^2 = 860.620 \text{ m}$$

$$R_2 = 859.788 \text{ m} \quad \text{[Refer fig. of case-2]}$$

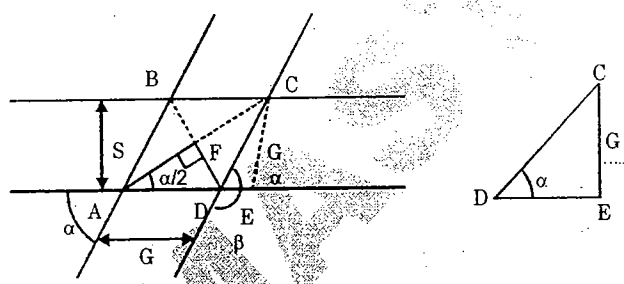
$$O_1O_2 = 1344.152 \text{ m}$$

$$O_1A = 1344 - 152 - 6.20 \simeq 1337.952 \text{ m}$$

Total length of cross over $l = \sqrt{O_1O_2^2 - O_2A^2} = 128.95$ m

$$l = 128.95 \text{ m}$$

Q. Design a diamond crossing between two B.G. tracks crossing each other at an angle 1 in 10°.



For diamond crossing AB = BC = CD = DA

From ΔCDE

$$\sin\alpha = \frac{CE}{CD}$$

$$CD = CE \operatorname{cosec}\alpha$$

$$CD = G \operatorname{cosec}\alpha = G\sqrt{1 + \cot^2\alpha} = 1.676\sqrt{1+100}$$

$$CD = 16.84 \text{ m}$$

6. Single slip and double slip crossing :

- It is improvement over diamond crossing. In diamond crossing the trains cannot be taken from one track to another track.
- But in the slip arrangement train can move from one track to another.
- A single slip is one in which the tracks can be changed from one direction only.
- Double slip is one in which the track can be changed from both directions.
- It consist 2 acute angle crossings, 2 obtuse angle crossings and 4 check rails.

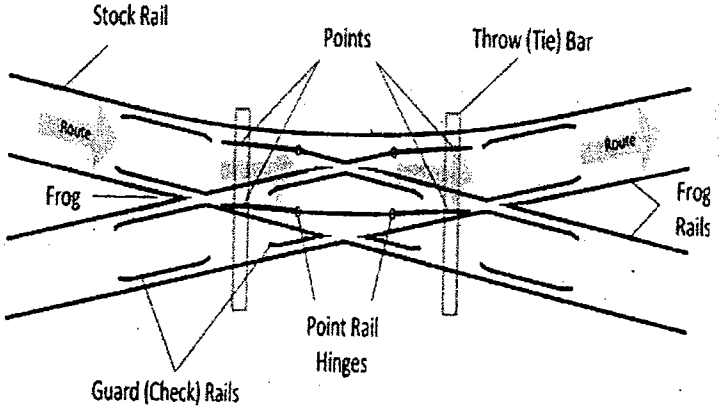


Fig. Single Slip

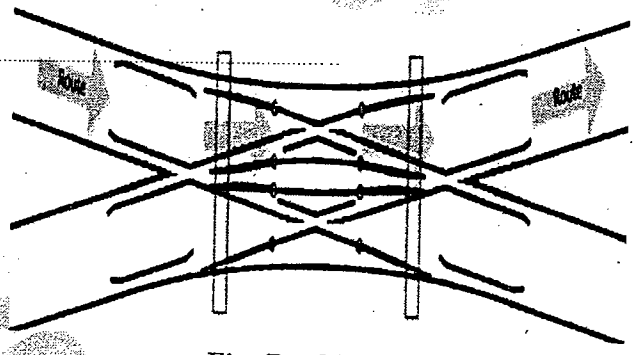


Fig. Double Slip

7. Scissor Cross over or Double Cross over :

- It is combination of one crossover the other cross over in the opposite direction.
- It enables the trains to change the track from either direction along the main track

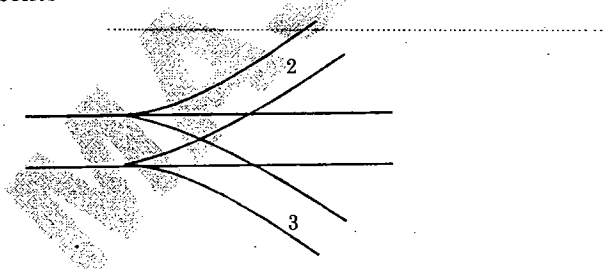
OBJECTIVE QUESTIONS

1. Which of the following are track junctions
   1. Turnouts 2. Diamond crossing 3. Cross over
   4. Scissor crossing 5. Elevated crossings
   (a) 1, 2 and 3 (b) 2, 3 and 5 (c) 1, 2, 3 and 4 (d) all of these

2. Symmetrical split consists
   (a) a pair of points, 4 curved lead rails, 2 check rails and 1 crossing
   (b) two pairs of points, 6 curved lead rules, 2 check rails and 2 crossings
   (c) a pair of points, 2 curve lead rail, 4 check rails, 3 crossings
   (d) two pair of points, 4 curved lead rails, 2 check rail, a pair of crossings

3. Double turnout or tandem consist of
   (a) two pairs of points, 4 acute angle crossings, 4 check rails
   (b) two pair of points, 3 acute angle crossings, 4 check rails
   (c) a pair of points, 4 acute angle crossing, 6 check rails
   (d) a pair of points, 6 acute angle crossings, 4 check rails

4. The fig. shown below represents



   (a) Symmetrical split (b) Three throw switched
   (c) Diamond crossing (d) Scissor and crossing

5. Diamond crossing consist of
   (a) 4 acute angle crossing, 4 obtuse angle crossing, two check rail
   (b) 2 acute angle crossing, 2 obtuse angle crossing, 1 check rails

8. Limitation of diamond crossing is
   (a) Speed is limited with 40 kmph on the diamond crossing
   (b) It is only useful for B.G. track
   (c) It can't transfer rail from one track to another track.
   (d) It require large area to construct.

9. Cross over 1 in 10 exist between two G parallel tracks with ?? 5 m. The length of straight track is
   (a) 16.4 m (b) 18.4 m (c) 19.2 m (d) 19.92 m

10. Which is used for changing the direction of engine ?
   (a) Cross over (b) Turnout
   (c) Triangle or turn tables (d) Scissor crossing

For Question 11 to 15 **Code :**
   (a) If A and R both are correct and R is correct explanation for A.
   (b) If A and R both are correct but R is not correct explanation for A.
   (c) If only A is correct
   (d) If only R is correct.

11. Assertion (A) : Scissor crossing is provided where space does not permit provision of two separate cross over.
   Reason (R) : A scissor crossing consists of four pair of switches, six acute angle crossings and four obtuse angle crossing.

12. Assertion (A) : A turnout is a combination of points and crossings which enable a branch line to take off from main railway line.
   Reason (R) : Turn outs are in great use in railway marshalling yards.

13. Assertion (A) : When a turnout is taken off from curved track, it is called gauntlet track.
   Reason (R) : When a turnout from a curved track turns away in the opposite direction, the curve are said to be contarary flexure.

14. Assertion (A) : In design of cross over the reverse curve is introduced between two switch at the ends.
   Reason (R) : Use of reverse curve reduces the total length of cross over.

15. Assertion (A) : To remove the limitation of diamond crossings single slip or doubled slip

EXPLANATIONS

1.(c). In elevated crossing no track junction is formed.

6.(a). Flattest diamond crossing would be 1 in 10.

8.(c) Diamond crossing can't provide facility to transfer train from one track to another.

9.(a) Total length of cross over

$$l = 4GN + (D-G)N - G\sqrt{1+N^2}$$

$$l = 4 + 1.676 \times 10 + (5 - 1.676) \times 10 - 1.67\sqrt{1+10^2}$$

$$l = 16.9 \text{ m}$$

15.(c). Diamond crossing does is of provide facility of transferring train from one track to another track, this can be by single slip and double slip arrangements.

IES MASTER

CHAPTER 8

Stations & Yards and Equipments in Station Yards

Railway Station :

A railway station is the selected place where trains halts for following purposes.

1. For exchange of passengers and goods.
2. For control of train movements like over taking, detaching and connecting engine or comportment.
3. Taking diesel, coal or water.

Site Selection for Railway Station :

Following factors should be considered while selecting the site for station.

1. Sufficient land area according to no. of plat form.
2. Accessibility with town or city.
3. Approach road to station site.
4. Site drainage
5. Station site alignment
6. Based on the type of station and yard.

Classification of Railway Station :

1. Operational Classification :

a) Block Station : Class A, class B and class C stations.

b) Non Black Station - Class D station / flag station (situated in between two block station).

c) Special Class station Not covered in A, B, C, D type.

Loop :

When branch line from a main line again terminates at the same main line, it is called a loop. The arrangements of loops can be either of the following types (Fig.)

(a) Split-loop (b) Trailing loop (c) Straight and loop

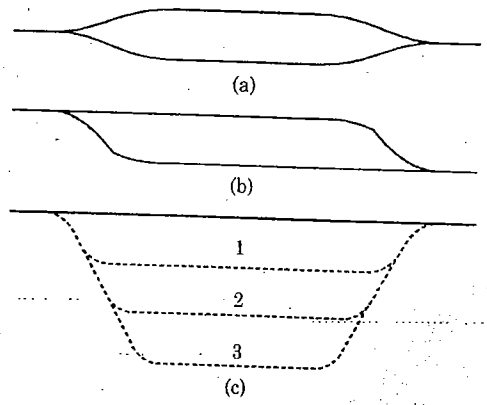


Fig. Loops

Sidings :

When a branch line from main line or a loop line terminates at a dead end with a buffer stop or sand hump, it is called sidings.

- It provides temporary storage for wagons.

Station Yards :

Yard is a system of track laid for receiving storing, sorting, making up new trains, dispatch of vehicles and for other purposes.

Types of Yards :

1. Passenger bougie yards; 2. Goods yards; 3. Marshalling yards; 4. Locomotive yards

1. Passenger bougie yards :

- The main function is to provide safe movements of passengers and vehicles for the use of passengers.
- Passenger platform may be regarded as passenger bougie yard.

2. Goods Yards :

The main function is to provide facilities for receiving, loading unloading, delivery of goods and

- Marshalling yards is said to be a machine to receive, breakup, reform and despatch trains onwards.
- Trains and other loads are received, sorted out and new trains are formed and dispatched to their destinations.
- Important functions of marshalling yards are

  1. Reception; 2. Sorting; 3. Departure.

Types of Marshalling Yards :

1. Flat Yards :

- The entire space of the yard is almost level, all the movements of wagons are carried out by means of engine running through diesel or electricity.
- This is used when limited land is available on plains.

2. Gravitational Yards :

- Tracks are laid at such gradient that wagons can move of their own under the action of gravity.
- Movement of wagon is controlled by manual Wagon brakes.

3. Hump Yards :

- In humpyards, summit or artificial hills are provided and wagons are pushed upon a hump by engine.
- Morden practise is to use hump yards because shunting operations are done more quickly than flat or gravitational yards.

4. Locomotive Yards :

- These are the yards where locomotives are housed and where all the facilities like coaling, watering, repairing, cleaning, oiling are provided for servicing of the locomotives.
- These are installed at the junctions stations.

Equipments in Station Yards

1. Cranes :

In large stations cranes are used for loading and unloading heavy articles.

2. Weigh bridges :

These are provided in goods yard to get the wt of loaded wagon.

7. Triangles :

- It consists of three sides of short length tracks in the form of a triangle.
- These are used for changing the direction of engine.
- Tun tables are also used for the same propose.

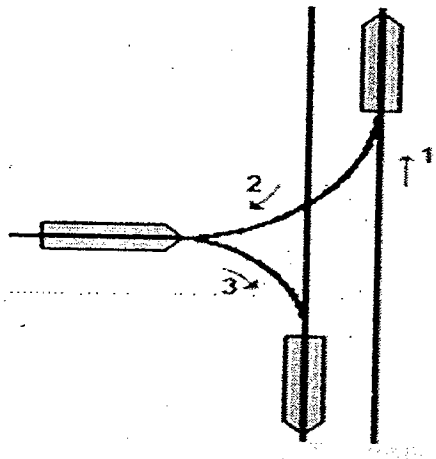


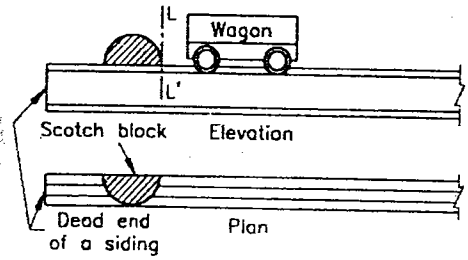
Fig. Triangle

8. Traverser :

- This is sued to transfer wagons or locomotives one of a time to and from parallel tracks without necessity of shunting.
- It is always preferred to turnouts, cross over where the space available is less.

9. Scotch blocks :

- It is used to separate all the sidings and shunting lines from through running lines.



11. Fouling Marks :

Fouling marks are the points fixed between a pair of converging tracks to indicate a foul or possibility of collision of vehicles beyond these points.

12. Sand Hump on Snag Dead End :

- This is also a method to prevent the vehicles from running off the track at teh end of siding.
- This is suitable for a level ground.
- In this method, a hump of sand with a rising gradient at the dead end of siding is provided.

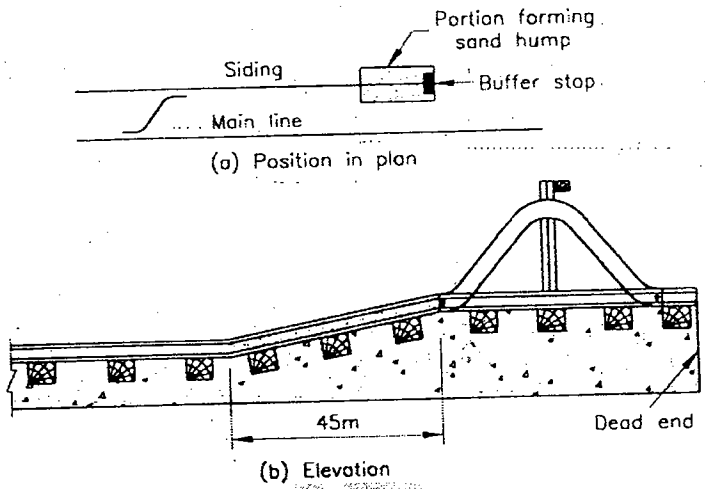


Fig. Sand Hump on Snag Dead End

OBJECTIVE QUESTIONS

1. Minimum length of passenger platform should be
   (a) 200 m (b) 180 m (c) 250 m (d) 280 m

2. The main function of siding is
   (a) To provide temporary storage of wagons
   (b) To allow faster train to pass the passenger train
   (c) To unload the goods train

5. When available space is limited for lay out of marshalling yard which of the type of marshalling yard is selected.
   (a) Gravitational yard
   (b) Hump yard
   (c) Cabin yard
   (d) Flat yard

6. Drop pit is used for
   (a) Removing the ballast from the railway track.
   (b) Dumping the scrap of train, rail and wagons
   (c) Dumping the ash received from locomotive boilers
   (d) Removing the wheel of the engine

7. The siding and shunting lines are separated through main lines by
   (a) Triangle (b) traverser (c) scotch block (d) turn tables

8. To prevent vehicle/train from running of dead end, the arrangement provided is
   (a) Trap switches (b) Traverser (c) Snag dead end (d) Fouling mask

9. To change the direction of engine which one of the arrangement is used.
   (a) Turn table (b) Traverser (c) Trap switches (d) Scotch block

10. Consider the following statements

    State-1 : On modern practise hump yards are used for shunting operations.
    State-2 : Shunting can be done more quickly as compare to gravitational yards.
    (a) Only state is correct
    (b) Only state 2 is correct
    (c) Both are correct and 2 is correct explanation for 1.
    (d) Both are correct but 2 is not correct explanation for 1.

ANSWER

1. (b)	**2.** (a)	**3.** (b)	**4.** (a)	**5.** (d)
6. (d)	**7.** (c)	**8.** (c)	**9.** (a)	**10.** (c)

CHAPTER 9

Signalling and Control Systems

Signalling consists of the systems, devices and means by which trains are operated efficiently and tracks are used to maximums extent and maintaining the safety of the passengers.

Classification of Signals :

Classification of signals is based on following characteristics :

1. Operational characteristics
2. Functional characteristics
3. Locational characteristics
4. Special characteristics.

1. Operating characteristics :

Based on the way of their operation signals can be classified as :

i) Detonating signals

ii) Hand Signals

iii) Fixed signals

2. Functional Characteristics :

Signals can be classified on the basis of their functions as below :

i) Stop or semaphore type signals.

ii) Warmer signals

iii) Shunting signals

iii) Calling on signals

iv) Point indicators

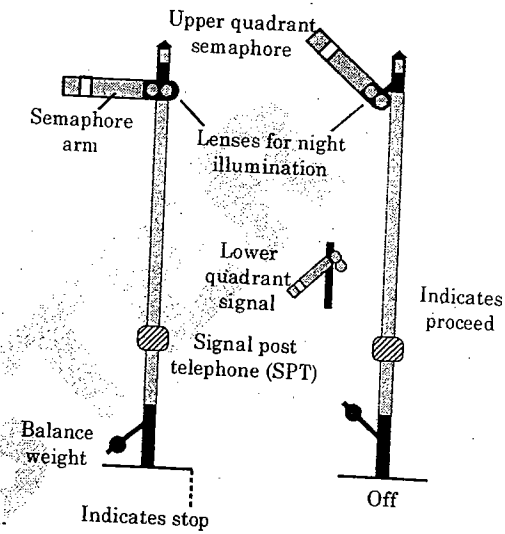
These signals are explained in detail below :

Fixed Signals :

are usually a semaphore type, fixed at a place.

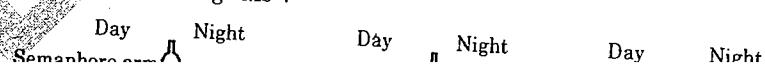
Semaphore type or stop signals :

- The principle of a design of semaphore signals is to show the stop-position of any failure that happens to be in the apparatus.
- The signal mechanism is so arranged that in normal position it indicates stop position.
- It has a movable arm which remain horizontal in the normal position.
- The side of the arm facing the driver is painted red with a white vertical band.
- The height of the centre of the arm is 7.5 m above the round.
- If arm is horizontal, stop or danger indication.
- If arm is inclined to 45° to 60° indication is proceed.



Warner Signals :

- A semaphore signal at the entrance is combined with a warner system.
- Warner arm is similar to semaphore arm except V notch at the end and on the warner arm, and the arm is painted yellow.
- Warner signal is posted at the same post of semaphore signal at 1.8 m to 2.1 m below the semaphore signal.
- Warner arm is painted with yellow instead of red.
- Warner arm (only) in horizontal position stop
- Warner arm (only) in inclined position - proceed.
- Indication given by Warner signals :



- They are of the shape of circular disc with red bond on white back ground when red bond of disc in horizontal - stop when the red bond is inclined position at 45° - proceed.

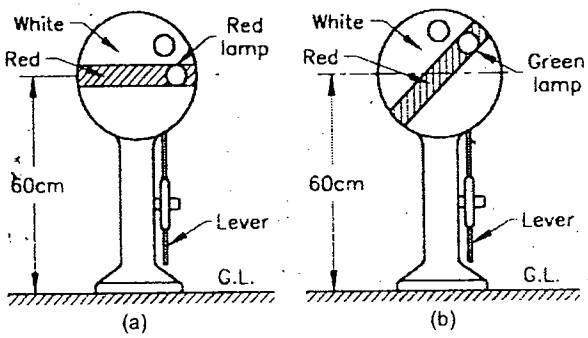
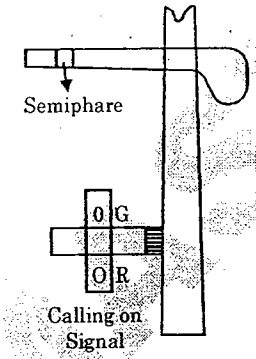


Fig. Indications of shunting signals

Calling on Signal :



- These signal consist of arm below and parallel to home semaphore signal.
- When a train stops with the semaphore signal indication, calling on signal permits train to proceed with caution.
- Thus signal is very much useful when repair work is going on.

Automatic Signal :

- Its arm is similar to warner's arm, the only difference is the V natch is pointing outwards and the arm is painted with red colour.

2. Advance Starter Signal :

- Advance starter may also combined with the sorter signal, placed 180 m beyond the trailing points and switches.
- The advance starter signal becomes the last stop signal at the station where it is provided.

Reception Signal :

Which controls the reception of trains into a station are known as creception signal.

a) Outer Signal :

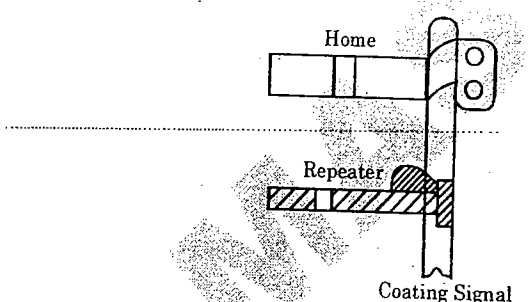
- The outer is the first stop signal at a station where it is provided, thus the first stop signal which indicates the entry of train from bloc to station yard.
- It is place 0.54 km away from station yard on BG tracks.

b) Home Signal :

- Due to its location at the door of station, it is termed as home signal.
- The home signal has bracketed arm which shows which line is to be used.

Special Signals :

a) Repeater or co-acting signal :



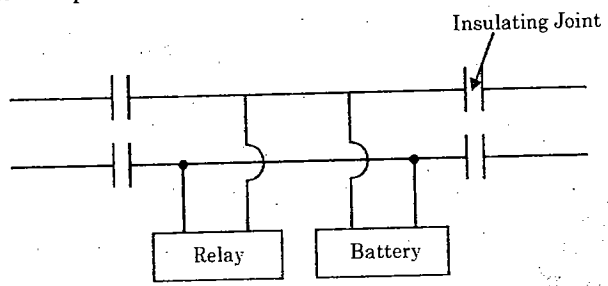
If drivers visions is obstructed by (i) an over bridge between the signals or (ii) due to sharp curve, a signal as provided with duplicate arm of smaller size at a suitable position which repeats the indication of the signal ahead. Repeating and co-acting signal serves same purpose of providing visibility but co-acting signal is provided on the same post a lower level at which main signal exist.

b) Routing Signal :

- Routing signals are provided at the point of diversion where no. of lines exist at the station taking off different locations

Track Circuiting :

- A track circuit is an electrical circuit formed along with running rails and connected to signal, cabin, block instrument etc.
- Thus function of track circuting is to indicate the presence of a train on the track showing whether the track is occupied or clear.



- For obtaining a tack circuit, the ends of rails forming the circuit are isolated by using insulated rail joints. The ends of the rails on one sides are connected to the two terminals of the battery.

Detonating :

During the foggy and cloudy weather when hand or fixed signals are not visible, detonators are placed on the rails which explode with a loud sound when the train passes over them. Thus sound draws attention of the driver to the proximity of the signals. From safety point of view, the detonators must be placed on the rails at least 400 m to 500 m ahead, of the signals.

Control System :

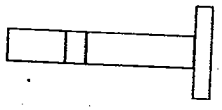
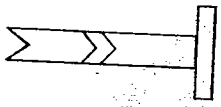
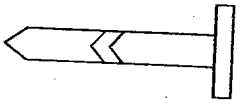
Absolute block system or space interval system/

- Most extensively used in India.
- In this system the entire track is divided into sections called block sections.
- These instruments are used to show as the whether the section ahead is clear or resolved for a train.

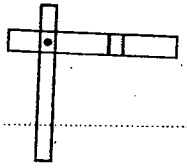
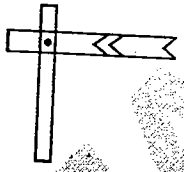
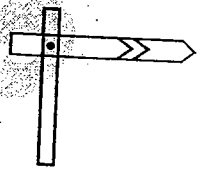
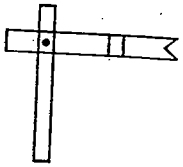
OBJECTIVE QUESTIONS

1. Which of the following pair are correctly
   1. Detonating Signals Operational
   2. [illegible] Functional

3. Which one of the following is operation signal
   (a) Semaphore signal (b) Warmer signal (c) Starter signal (d) Fixed signal
4. Which of the following signal is used to warn driver about the signal ahead diving intense fog.
   (a) Warner signal (b) Outer Signal (c) Home signal (d) Detonating Signal
5. At normal position semaphore signal represents.
   (a) Proceed with caution (b) Stop
   (c) Proceed (d) Diversion ahead
6. Which of the following represents semaphore arm

(a) 
(b) 
(c) 
(d)

7. Which of the following represents warner's signal in railway

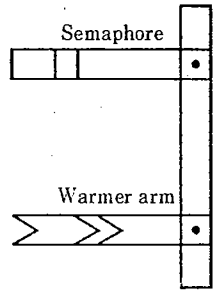
(a) 
(b) 
(c) 
(d) 

8. Treadle bar is used for
   (a) Interlocking points and signal (b) Setting points are signal
   (c) Setting marshalling yard signals (d) Track maintenance.
9. Which one of the following signals is provided beyond the trailing points and switches in a railway yard ?
   (a) Repeater signal (b) Departure signal (c) Advance starter (d) Routing signal
10. Which one of the following signal is installed as the second signal post for better visibility ?
   (a) Routing signal (b) Calling on signal (c) Co-acting signal (d) repeating signal

11. Metal [illegible]

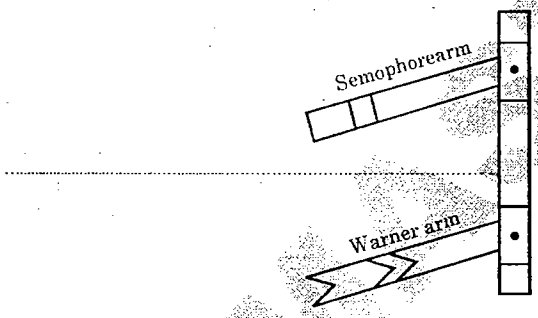
12. Which of the following are reception signals
    (a) Semaphore (b) Warner (c) Home (d) Starter

13. The following warner signal represents



    (a) Proceed (b) Proceed with caution
    (c) Stop (d) N.O.T.

14. The following warner signal represents



    (a) Proceed with caution (b) Proceed
    (c) Stoop (d) N.O.T.

15. The order of signal, if a train passes a station without stoppage.
    1. Warner
    2. Outer
    3. Home
    4. Starter

18. The signal posted at the door of station, indicates which line is to be used is
    (a) routing signal
    (b) co-acting signal
    (c) reception signal
    (d) home signal

19. Which of the control system is most extensively used in India.
    (a) Following train system
    (b) Absolute block system
    (c) Pilot guard system
    (d) Automation block system

20. Purpose of track circuiting is
    (a) To ground the leakage of electricity
    (b) To increase performance of he locomotive
    (c) To indicate the presence of trains on the track
    (d) All of these

ANSWER

1. (a)	**2.** (c)	**3.** (d)	**4.** (d)	**5.** (b)
6. (a)	**7.** (b)	**8.** (a)	**9.** (c)	**10.** (c)
11. (d)	**12.** (c)	**13.** (a)	**14.** (b)	**15.** (a)
16. (d)	**17.** (c)	**18.** (d)	**19.** (b)	**20.** (c)

EXPLANATIONS

8.(a). Lock bar also called Tradle bar is provided for the purpose that the point may not be operated while train is on it l.c. for interlocking points and signals.

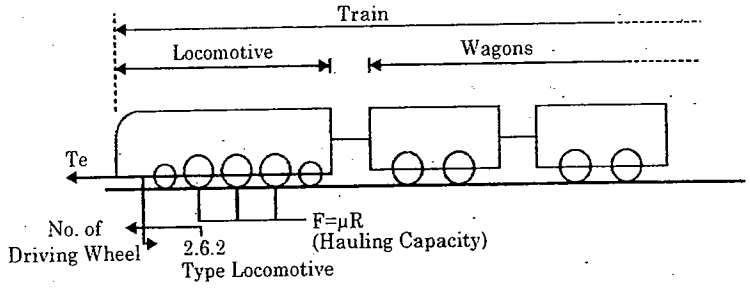
10.(c). Repeater and co-eating signals are provided for better visibility but co-acting

17.(c). Advance shorter signal when installed becomes the last stop signal for train.

18.(c). Track circuiting is done in order to find out the location of a train on track, it also tells the spacing between two trains on the same track

CHAPTER 10

Traction and Tractive Resistance(s)



Imp. Forces in the Movement of the train :

1. Tractive Effort :

This is the pull applied by engine on the driving wheel for the movement of the train.

2. Hauling Capacity :

This is maximum value of friction force that can be obtained between rails and driving wheel.

$$F = \mu R = \mu N = \mu n W_d$$

n = no. of pair of driving wheel w_d = axle load

μ = coefficient of friction (0.30 to 0.10)

- Maximum axle load in India are 28.56 tonnes for BG and 17.34 tonnes for M.G.
- Locomotives are designated based on no. of **non driving** and **driving wheel**.

Tractive Resistance :

There are no. of forces which resist the movement and speed of the train, these are

1. Train resistance
2. Resistance due to track profile.
3. Resistance due to starting and acceleration.
4. Wind Resistance.

1. Train Resistance (R_T)

a) Resistance Independent of Speed (R_{T1})

- It is also called rolling resistance.
- Reasons for this resistance are
  - i) Journal friction - friction between internal parts of engine and wagon.
  - ii) Friction between wheels and wagon rail
  - iii) Resistance due to wave action.

$$R_{T1} = 0.0016 \text{ w tonnes}$$

w = wt of train (locomotive + wagons) in tonnes.

b) Resistance Dependent on the speed :

$$R_{T2} = 0.00008 \text{ w.V. (tonnes)}$$

w = wt of train is tonnes

V = speed of train in kmph

c) Atmospheric Resistance :

- This resistance developed on the ends and side of the train, even if wind velocity is zero.

$$R_{T3} = 0.0000006 \text{ wV}^2$$

w = wt of train in tonnes

V = speed of train in kmph

$$\text{Total Train Resistance} = R_T = R_{T1} + R_{T2} + R_{T3}$$

2. Resistance Due to Track Profile :

a) Resistance Due to Gradient :

b) Due to Curvature :

- Wheel base being rigid does not allow vehicle to take curve linear path.
- Lateral skid and transverse slip occurs, which leads resistance against motion of train.

$$Rc = \begin{Bmatrix} 0.0004\,WD^\circ - \text{for BG} \\ 0.0003\,WD^\circ - \text{for MG} \\ 0.0002\,WD^\circ - \text{for NG} \end{Bmatrix} \text{tonnes}$$

3. Resistance Due to starting and acceleration :

a) Resistance due to starting :

for locomotive = 0.15

W_1 = wt. of locomotive in tonnes

for wagon = 0.005

W_2 = wt. of wagons in tonnes

Total resistance due to starting – $0.15\ W_1 + 0.005W_2$

b) Due to Acceleration (Ra) :

$$Ra = 0.28W\left(\frac{V_2 - V_1}{t}\right)_{tonnes}$$

[V_1 and V_2 are in kmph; time (t) is in sec.]

4. Wind Resistance :

$$R_w = 0.000017aVw^2 \text{(tonnes)}$$

a = exposed area of train in m^2

V_w = speed of wind in kmph

Note :

- Till wind velocity is not given (or it is asked to calculate wind resistance) and resistance due to starting and acceleration of the train, only train resistance and resistance due to profile are calculated.
- If profile is given straight and level only train resistance is to be calculated.
- To move the train Hauling capacity must be a bit greater than total resistance and tractive effort must be greater than hauling capacity.

To calculate Hauling Capacity, we need no. of driving wheels pairs, it can be found by "Designation locomotive" 6 driving wheels means – 3 pairs.

Given $\mu = 0.2$, w_d = 22 tonnes, V = 75 kmph

Hauling capacity of locomotive

$$H.C. = \mu n w_d$$

$$H.C. = 0.20 \times 3 \times 22$$

$$H.C. = 13.2 \text{ tonnes}$$

Case - I :

When train is moving on straight level track.

$$H.C. = \text{Total resistance}$$

$$H.C. = \text{Train Resistance } [\because \text{ other res. will not be there.}]$$

$$H.C. = R_{T1} + R_{T2} + R_{T3}$$

R_{T1} = Res. Independent of speed = 0.0016 w

R_{T2} = Res. dependent on speed = 0.00008 wV = 0.006 w

R_{T3} = Atmospheric resistance = 0.0000006 wV^2 = 0.003375 w.

$$13.2 = 0.0016w + 0.006w + 0.003375w$$

$$w = \frac{13.2}{0.01097}$$

$$w = 1202.73 \text{ tonnes}$$

1202.73 tonnes, this is the max. wt. of train that engine can pull.

Case-2 :

$$H.C. = \text{Train Resistance} + \text{Resistance Due to track profile}$$

$$H.C. = R_{T1} + R_{T2} + R_{T3} + w\tan\theta$$

$$H.C. = 0.0616w + 0.00008wV + 0.0000006wV^2 + w\tan\theta$$

wt. of the train = 1201.73t

V = speed of the train

θ = 1 in 180 (Given)

$$\Rightarrow 13.2 = 0.016 \times 1202.73 + 0.00008 \times 1202.73 \times V$$

$$H.C. = R_{T1} + R_{T2} + R_{T3} + \underbrace{w\tan\theta}_{\text{Gradient}} + \underbrace{0.0004wD}_{\text{curvature}}$$

$$13.2 = 0.016w + 0.00008wV + 0.0000006wV^2 + w\tan\theta + 0.0004wD$$

$$13.2 = 1.9248 + 0.00008 \times 1202.73V + 0.0000006 \times 1202.73 + 6.6818 + 09624$$

$$V^2 + 133.33V - 5028.3 = 0$$

$$V = 30.65 \text{ kmph}$$

The max. speed train can achieve is 30.65 Kmph

Q.2 Find out the steepest gradient on a straight track using the following datas' for train having 20 wagons.

Wt of each wagon = 18 tonnes

Rolling Resistance of Wagon = 2.5 kg/tonnes

Speed of train = 50 Kmph

Wt of locomotive = 120 tones

Tractive Effort of locomotive = 12 tonnes

Rolling Resistance of locomotive = 3.5 kg/tonnes.

Sol.

Note :

Train resistance independent of speed is also known as rolling resistance.

wt. of train (w) = wt of wagons + wt. of locomotive

$$w = 20 \times 18 + 120$$

$$w = 480 \text{ tonnes}$$

Hauling capacity or tractive effort of train = 12 tonnes

Total Resistance :

Train resistance + Res. due to track profile

$= R_{T1}$(Rolling Resistance) $+ R_{T2} + R_{T3}$ + Resistance due to slope

(R_{T1}) Total rolling resistance = Rolling resistance of wagon + Rolling res. of locomotive

$$R_{T1} = 2.5 \times 360 + 3.5 \times 120 = 1320 \text{ kg}$$

straight level BG track. Load on each axle is 25t, and coefficient of a friction in between rail and wheel is 0.20. Find :

i) total weight of the train, that can be hauled with speed of 80kmph on straight levelled track.

ii) Total weight of the train that can be hauled with speed of 80 kmph on a straight track with grade of 1 in 200.

iii) Total weight of the train that can be hauled with speed of 80 kmph on grade of 1 in 200 accompanied with curve of 2D°.

Sol.

$$\text{Pair of driving wheel (n)} = \frac{8}{2} = 4$$

$$\text{Hauling capacity of locomotive} = n\mu w_d$$

$$= 4 \times 0.20 \times 25$$

$$H_C = 20t$$

Case-1 : On straight level track

$$\text{Total resistance} = \text{Train Resistance}$$

$$= RT_1 + RT_2 + RT_3$$

$$\text{T.R.} = 0.0016w + 0.00008w.V + 0.0000006wV^2$$

where w = Total weight of train.

From Equation

$$\text{T.R.} = \text{Hauling Capacity}$$

$$20 = 0.0016w + 0.00008w \times 80 + 0.000000w(80)^2$$

$$20 = [0.0016 + 0.0064 + 0.00384]w$$

$$W = 1689.19t$$

Total weight of train that can be hauled on straight track is

$$W = 1689t$$

Case-2 : Straight track with gradient 1 in 200.

$$\text{Total Resistance} = \text{Train Resistance} + \text{Resistance due to grade}$$

$$\text{T.R.} = 0.0016w + 0.00008wV + 0.0000006wV^2 + w\tan\theta$$

From eqn $\quad$ T.R. = H.C.

$$T.R. = 0.0016w + 0.00008wV + 0.0000006wV^2 + w\tan\theta + 0.0004w \times D^\circ$$

From the eqn.

$$T.R. = H.C.$$

$$20 = 0.0016 + 6.4 \times 10^{-3} + 3.84 \times 10^{-3} + 5 \times 10^{-3} + 0.0008$$

$$0.01764w = 20$$

$$w = 1133.78t$$

Total weight that locomotive can haul on a track with gradient 1 in 200 and curve of 2D° is 1133t.

OBJECTIVE QUESTIONS

1. The resistance to motion of the train, offered by the friction between the metal surface of rails and the wheels is known as
   (a) Rolling resistance (b) Bearing resistance
   (c) Track resistance (d) N.O.T.

2. Which of the following equation is correct for the movement of the train.
   Te = Tractive effort, H.C. = Hauling capacity, T.R. = Total Resistance
   (a) T.R. ≥ H.C. ≥ Te (b) Te ≥ H.C. ≥ T.R. (c) Te ≥ T.R. ≥ H.C. (d) H.C. ≥ T.R. ≥ Te

3. A train is hauled by 2 - 8 - 2locomotive with 22.5 tones lad on each driving axle. Assuming the coefficient of rail-wheel friction to be 25, what would be the hauling capacity of the locomotive ?
   (a) 15.0 tones (b) 22.5 tones (c) 45 tones (d) 90.0 tones

4. The load on each axle of a locomotive is 20 tones. If the coefficient of friction is 0.2, then hauling capacity due to 3 pairs of driving wheel will be
   (a) 26.4t (b) 19.8t (c) 13.2t (D) 6.6t

5. What is the curve resistance for 50 tones train on a B.G. track of 4° cone.
   (a) 0.05t (b) 0.06t (c) 0.08t (d) 0.01t

6. Resistance due to gradient, expression is
   (a) $w\tan\theta$ (b) $w\cot\theta$ (c) $w\cos\theta$ (d) $w\sec\theta$

10. Maximum side wind resistance occurs when wind force is acting of an angle of
(a) 90° to direction of motion of train
(b) 60° to direction of motion of train
(c) 45° to direction of motion of train
(d) 30° direction of motion train

ANSWER

1. (c)	**2.** (b)	**3.** (c)	**4.** (d)	**5.** (c)
6. (d)	**7.** (c)	**8.** (c)	**9.** (c)	**10.** (b)

EXPLANATIONS

3.(b). Locomotive of designation 2-8-2 have 4 no. of hours of driving wheels.

4.(c).

$$H.C. = \frac{4 \times 22.5 \times 0.25}{n \times w \times \mu} = 22.5t$$

4.(c).

axle load (= w) = 22t $\mu = 0.2$ n = 3

$$H.C. = n \times w \times \mu$$
$$= 3 \times 22 \times 0.2$$
$$= 13.2\,t$$

5.(c). Curve resistance for train on BG track
$= 0.0004w \times D$

8.(d). H.C. on straight track = D

$$H.C. = n\mu w_d = 4 \times 0.2 \times 25$$
$$H.C. = 20\,t$$

The resistance on grade

$$= wfm\theta$$
$$= 5 \times \frac{2}{100} = 1t$$

Total H.C. req.
= 20 t

9.(d).

wt of train= 300t

Unused H.C. = $w\tan\theta$

CHAPTER 11

Miscellaneous Topics

Interlocking of Signals and Points :

In the signalling observations, it is absolutely necessary that only that signal is lowered for which route, is meant and the route has been correctly set in advance, so interlocking is the device which helps in proper and safe working of the signals.

Methods of Interlocking :

1. Mechanical :

- It consists of tappets and lock bars. These bars are placed at right angle to each other.
- Point lock fitted in the middle of the track a little in front of the toes of tongue rail is used to ensure that each switches are correctly set.

2. Track Circuiting :

This indicates the portion of track is weather occupied or clear.

Maintenance of Track :

Reasons of Maintenance :

- The strength of track goes on deteriorating due to movement of high speed trains, heavy axle loads etc.
- The track is also subjected to other deteriorating effects like rain water, action of sun and wind.

Maintenance of track can be divided into two parts :

1. Daily Maintenance :

- This maintenance is carried out by packing of ballast, surfacing of track, boxing and levelling the track and lifting the track.
- Spot packing consists of correcting the defect at a particular point and involves lifting of 5 to 7 sleepers.
- Packing is the method of forcing and packing stone ballast below the sleepers by ramming with beater-pic.-axe.
- Due to heavy loads and vibration caused by running trains the ballast under the sleepers gets loose, the depressions are formed in the plane of rails.
- Methods of packing of ballast

  a) Through Packing :

  This is the process of repacking of ballast under the sleeper in required width and depth. It is done by Beater-pix-axe rammer.

  b) Scissor Packing :

  Packing diagonally under rail seat is called scissor packing.

  c) Shovel packing :

  This method of packing is adopted for point and crossing where the use of beater-pic-axe for packing becomes difficult.
- A blowing off joint is caused when a joint is situated on a loose and dusty ballast. When wheel loads pass over the sleepers resting on loose and dusty ballast, the sleepers sinks.

B. Maintenance of Track Alignment :

If track alignment is disturbed, it may result in the bad riding and consequent derailment.

Cause of Distortion in alignment

- The increased hammering action of wheels on one rail only may displace the original alignment of the track.
- Thus increased hammering action on one rail may result into variation in cross level, inadequate S.E. on curves. Non uniformity of gauge, improper packing of ballast etc.
- Due to temperature variation in hot weather, the thermal tresses and heavy creep of rail may result in distortion of alignment of rail.

Realignment of curved track :

- It is done by using bar and track liners.
- The process of pushing the track is known as slewing

- Graphiting of fish plate is done for protecting fish plats against corrosion and to allow free expansion and contraction of rail.

Track Imprest :

A stock of all useful materials such as rails, sleepers, fish plates, bolts, spikes and other fittings are permanently maintained at selected place for immediate replacement, these materials are known as track impressed.

Instruments used for maintenance of track

Shovel or Ballast tank :

The track is opened out and ballast round the sleeper is pulled aside by mean of ballast forks or shovels.

Crow Bars :

Crow bars are used to raise sleepers to a desired height and also use in replacement of track.

Spliced rail :

It is used to find difference in the elevation of outer and inner rail.

Cant Board :

To check the super elevation on the curves cant boards are used.

Rail Tongs :

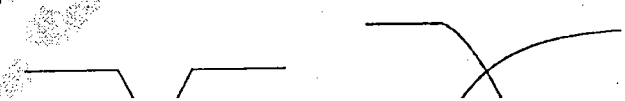
To lift and carry rails.

Claw Bar :

To remove dog spikes out of sleeper

Sleeper tong :

To lift up sleepers



Mallet :

To check the sleepers for packed, mullets are used.

Jim Craw :

It issued to bend the rails or break the rails.

Track Standards of Indian Railway

Std. for rails -

1. 90 UTS (90 ultimate tensile strength) rails are used with box N type wagons.
2. 90 R rails are used only upto speed of 130 kmph.
3. Higher UTS rails are used of curves is sharper than 3° or grade is sleeper than 1 in 100.

Std. for Sleepers :

- CST-9 sleepers are only used upto speed of 130 kmph.
- If metal sleepers are used track should have wooden sleepers at the joints.

Safety in Railway :

- Advance methods for preventing accidents are

1. **Automatic Warning Systems**

   Brakes are automatically applied. If driver ignores the warning given earlier.

2. **Speed Recorders:**

   These instruments keep the record of speed and if at any moment speed goes more than the permissible one at that section the driver is informed by sound of buzzer.

3. **Electronic System :**

   Under development stage in India. In U.S. coded current is passed through the rail which is picked up by locomotive and transformed into a colour light cab signal.

Some Important Points :

1. Magniflux, ultrasonic dectors, sono rail and kertz are used for detecting cracks in rail.
2. Cab signal device or intermittent reversible coaded track. Circuit device is used to check the continuity of track.
3. Bell and flasher type signal is used at the level crossing of highway and railways.
4. Sleeper cribs are temporary supports or piers for girders and consist of old wooden sleepers with packing. These sleeper cribs are very much useful for strengthening of the damaged culverts

3. Gas turbine and air cushion
4. Magnetic leviation vehicle.

1. Linear Motor and Wheel :

- Linear induction motor offers almost unlimited scope for attaining super high speed.
- Applying poly phase A.C. power to the primary windings of this linear motor will induce current in the short circuited form and thus will produce huge thrust to the train.
- So super high speed can be achieved easily.

2. Linear Motor and Air Cushion Vehicle :

Combined system of linear motor and air cushion may, perhaps offer the best prospects of superhigh speed operation upto 500 kmph.

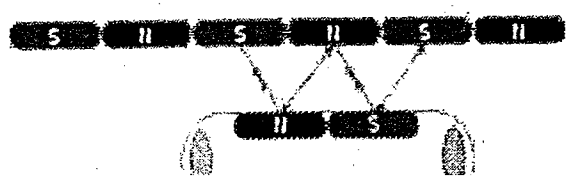
3. Gas turbine and Air cushion (or tacked Air Cushion Vehicle) (TACV)

Two high powered Gas turbines are accompanied with a 2.3 India screw to propel the train at speed more than 300 kmph.

4. Magnetic Leviation Technique (Mag Lev)

Maglev (derived from magnetic levitation) is a method of propulsion that uses magnetic levitation to propel vehicles with magnets rather than with wheels, axles and bearings. With maglev, a vehicle is levitated a short distance away from a guide way using magnets to create both lift and thrust.

Maglev trains move more smoothly and somewhat more quietly than wheeled mass transit systems. Their non-reliance on traction and friction means that acceleration and deceleration can surpass that of wheeled transports, and they are unaffected by weather. The power needed for levitation is typically not a large percentage of the overall energy consumption, most of the power is used to overcome air resistance (drag), as with any other high-speed form of transport. Although conventional wheeled transportation can travel very quickly, a maglev system allows routine use of higher top speeds than does conventional rail, and it is this type which holds the speed record for rail transportation.



1. Wave Formation :

As the speed of train exceeds 250 kmph, the wave formed in rails gets deeper and travels at faster speed, this increases creep of the rail and requires elastic fastners.

2. Adhesion between wheels and rails :

Hauling capacity to Haul the train is obtained by friction force in between wheels of locomotive and rails and the friction factor decreases with increase in speed, so to get sufficient H.C. the load of locomotive has to be very huge.

3. Vibrational Limitations :

Due to track irregularities, vibration of rolling stock increases with the speed.

4. Problem on curved track :

Centrifugal force increases with square of the speed so maintaining proper S.E. and cont deficiency is very tough task.

Track Recording :

- More objective and quantitative assessment of track is made by actually measuring the ground track parameters in permanent basis. It is done by track recording.
- Most useful equipment of track recording is "Track Recording Car".

Track Recording Car :

- Track recording car of Amester type is used by Indian Railways.
- This car makes continuous record of various geometric parameters such as unevenners, twist super elevation and versines.
- Feelers are used to measure gauge and curvature of the Railway track.

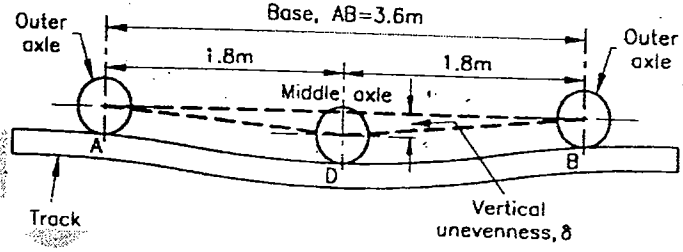


Fig. Measurement of Uneveness by track recording car

Track tolerance :

ii) On curved track : ±5 mm

- Track recording Car is used to record various parameters such as unevenness, gauge, twist or skew super elevation.
- Unevenness is measured with Ast.

Modern Methods of Track Maintenance :

1. Mechanized Maintenance (or Mech. tamping)

a) Off track tamping :

- These work in pairs from opposite sides of the slepers under the rail seat to ensure maximum consolidation of ballast.
- These off -track tampers work in pairs from opposite sides of the sleepers diagonally under the rail seat to ensure maximum consolidation of ballast.

b) On track tamping :

- Self propelled vehicles are used to tamp the sleepers automatically.
- The heavy on-track tampers are certainly superior to off-track tampers in respect of control, efficiency, quality of work and retention of tamping.

2. Measured shovel packing (M.S.P.) :

- It is scientific technology of manual maintenance of track without the use of very sophisticated equipments or machines.
- In the M.S.P method, track defects like unevenness and voids, are accurately measured, the track is lifted by means of jacks and measured quantities of small broken stone chipping are placed under the sleeper, to bring the track to the predetermined levels.
- Densometer, Fleximeter, Viseur and Mire, Packing Shovel, Lifting Shovel and Dosing Shovel are used in M.S.P.

3. Directed track maintenance (D.T.M.)

- Unlike conventional maintenance system, in D.T.M. only specified track length is supervised and checked for the track defects. Structural strength requirement of track components to support super / high speed. Step involved in D.T.M.

  i) Identification of defects.

  ii) Record of observation

- It is recommended to use prestress concrete sleepers for higher speed.
- For super high speeds continuous sleeper slab is used (like in DMRC)

3. Fastness :

- Elastic fastener are used for allowing high speed and super high speed tracks.
- Types of elastic fastener are

1. Pandrol Clip :

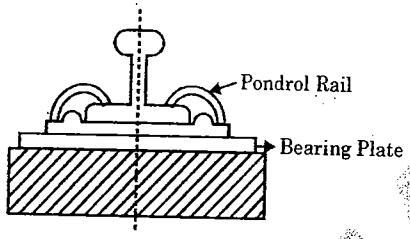
- It is a type of elastic fastener used by I.R. and can be fitted on wooden steel; C.I. or concrete sleepers.
- It posses almost all the characteristics of a ??.

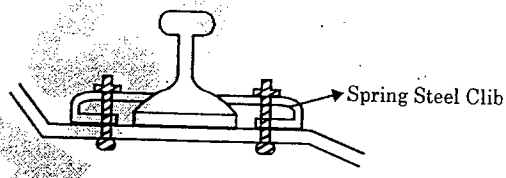
2. Spring Steel Clip :

- This is a double elastic fastening used on pres tressed concrete sleepers block.
- In DMRC this clip is used to connect rails with sleepers.

3. Sigma slip :

- Special elastic fastening used to connect rail with CST-13 sleepers.





OBJECTIVE QUESTIONS

1. Which of the following is not related to periodic maintenance of the track
   (a) Checking of gauge
   (b) Maintenance of packing
   (c) Maintenance of proper drainage
   (d) Maintaining the continuity of track.

2. Which of the method is used for repacking of ballast at the points and crossing.
   (a) Through packing (b) Shovel packing

4. Match **List-I** and **List-II** using the code below :

List-I	List-II
A. Shovel	1. To lift the rail
B. Crowbar	2. To remove dog spikes out of sleepers
C. Rail tongs	3. To correct track alignment
D. Claw bar	4. To handle ballast

Code :

	A	B	C	D
(a)	3	4	2	1
(b)	4	3	2	1
(c)	4	3	1	2
(d)	3	4	1	2

5. The process of pushing the track is known as

(a) Packing (b) Brossing (c) Graphiting (d) Slewing

6. Which of the following pairs are correctly matched

1. Feelers car	To find curvature and gauge
2. Mallet	For ramming of ballast
3. Beater pick axe	To check sleeper for packing
4. Jim crow	To bend the rail

Codes :

(a) only 1 and 2 (b) 1, 2 and 4 (c) 1 and 4 (d) 1, 3, 4

7. Which of the following are correctly matched

1. Shovel	To handle ballast
2. Amsler car	To find unevenness of rails
3. Sonirail	To find density of rail
4. Graphiting	To crack of rail

(a) 1 and 2 (b) 3 and 4 (c) 1 and 3 (d) 1 and 4

8. Match **List-I** with **List-II** using the codes given below :

9. Match **List-I** with **List-II** using the codes below :

List-I	List-II
A. Unevenness	1. Track Recording
B. Gauge	2. Amster Car
C. Super elevation	3. Feeler and spring
D. Alignment	4. Gyroscopic pendulums

Codes :

	A	B	C	D
(a)	2	3	1	4
(b)	3	2	1	4
(c)	2	3	4	1
(d)	3	2	4	1

10. Match **List-I** with **List-II** using the codes given below.

List-I	List-II
A. Dynamomete	1. Arrangement for turning the direction of engine
B. Crossing Station	2. Information about condition of railway track
C. Ruling Gradient	3. Station on single line track at which trains can pass
D. Tern table	4. Maximum rising gradient of railway track.

Codes :

	A	B	C	D
(a)	2	3	1	4
(b)	2	3	4	1
(c)	3	2	4	1
(d)	3	2	1	4

11. Which of the fallowing instruments are related to maintenance work of track :
    1. Jim Crow
    2. Gauge Bar
    3. Sand Hump
    4. Shovel
    5. Track Liner

13. Strengthening the old and damaged culverts, the old wooden sleepers are used as a structural material, thus temporary support is known as

(a) sleeper imporest (b) sleeper kertz (c) sleeper skew (d) sleeper crib

14. "Super high sped" term is used for speed

(a) Greater than 100 kmph (b) greater than 200 kmph

(c) greater than 250 kmph (d) grater than 350 kmph

15. For achieving super high speed which of the following technique can be used :

1. Linear motor and wheel
2. Linear motor and air cushion
3. Gas turbine and air-cushion
4. Magnetic leviation vehicle

(a) 1 and 4 (b) 2 and 3 (c) 1 and 3 (d) all of these

16. The maximum tolerance in gauge variation on BG track having degree of curvature 3° are

(a) +13 mm, –3 mm (b) +13 m, –13 mm (c) +18mm, –9 mm (d) +18 mm

17. Match **List-I** with **List-II** using codes below

List-I	**List-II**
A. Rail flawdetector	1. Gauge and curvature
B. Oscillograph car	2. Twist and skew
C. Track recording trolly	3. Safety and stability of rolling stock
D. Feeler car	4. Defect of split with split head.

Codes :

	A	B	C	D
(a)	1	2	3	4
(b)	4	3	2	1
(c)	3	2	1	4
(d)	2	3	4	1

From Q 18 to Q 22 **Codes :**

(a) Both A and R are correct, and R is correct explanation.

20. Assertion (A) : The pandral clip is a fit and forget type of fastening and is made from silicone manganese spriting steel bar and is heat treated.

Reason (R) : The pendrol clip has a point contact and cause indentation on the rail due to heavy toe load and contact area.

21. Assertion (A) : Conventional type track fasteners are not suitable for super high speed railways.

Reason (R) : Due to heavy loads and vibrations, the Nonelastic fasteners get loosen and resulting subsequent deterioration of track and components.

22. Assertion (A) : Magnetic Leviation technique and gas turbine and air cushion techniques will be used to achieve super high speeds.

Reason (R) : Speed greater than 250 kmph is known as super high speed.

ANSWER

1. (d)	**2.** (b)	**3.** (c)	**4.** (c)	**5.** (d)
6. (c)	**7.** (a)	**8.** (b)	**9.** (c)	**10.** (b)
11. (c)	**12.** (b)	**13.** (d)	**14.** (c)	**15.** (d)
16. (a)	**17.** (b)	**18.** (a)	**19.** (c)	**20.** (b)
21. (a)	**22.** (b)			

EXPLANATIONS

1.(d). Checking the continuity of track is done under daily maintenance by a gang in very section of railway track.

2.(b). Shovel packing is used for repacking of

11.(c) Sand Hump or Dead end is used at the end of siding in order to prevent the train to go beyond the track of siding

AIRPORT

CHAPTER 1

Airport

- In 1903, first power driven plan was invented by Wright Brothers.
- Air transportation began in India in 1911 for miltary purposes.

Various Modes of Transportation

- Roadways
- Railways
- Waterways
- Airways

Advantages of Air Transportation

- Major advantage of air transportation is maintain highest speed.
- It canbe easily access the remote and different region which is inaccessible through other mode of transportation.
- It is reliable transportation for relief and rescue operation.
- Air transportation is used for axial photography.
- It can also used for agricultural spraying

Disadvantage of Air Transportation

- Air transportation is costliest mode of transportation.
- Air craft generates high level of noise pollution.
- It consume high energy fuel.

- **Primary Airports :**
  - Which handle more than 10,000 passengers each year.

B. According ICAO [Internation Civil Aviation Organisation]

1. Based on runway length of airport.
   - The classification has been done using code letters A to E.
   - In which A type of airport has the longest runway length and E-type has shortest.
2. Classification based on ESWL and type pressure of Aircraft
   - This classification is done by numerical number 1 to 7.
   - In which perpendicular represnts maximum ESWL and maximum type pressure and 7 represents minimum both.

Basic Features of Aircraft and its Characteristics

1. Field Length

- An aircraft type is required to demonstrate the field length required for following cases :
  - To complete a take off to 10.5 m altitude with all engines operating.
  - To complete a take off to 10.5 m altitude with an engine failure at a critical point.
  - To stop after aborting a take off with an engine failure at same critical point.
  - To stop after landing from a height 15 m.

2. Aircraft component :

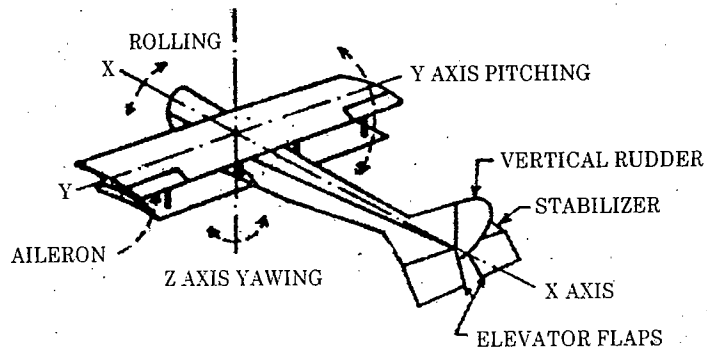
A. Engine

1. Piston Engine : Suitable to operate at low altitudes and moderate speeds.
2. Turbojet : Efficiency is higher at high altitude owing to the drop in the atmospheric density and greater temperature difference through the turbine.
3. Turbo Prop : Performs well at low altitude as well as high altitude.
4. Ram Jet : No moving parts, must be operate at high speed.
5. Rocket Engine : No limit on alltitude since oxygen in the atmosphere is not relied upon for combustion. Engine carries its own supply to oxygen.

B. Wings

The purpose of an aircraft wing is to support the machine in the air when the engine has given

C. Three Control :



Elevator	:	Control the pitching
Rudder	:	Used for turning or yawing movement.
Aileron	:	Used to control of rolling moment.

D. Fuselage :

- Main body part of aircraft
- Provides for power plant, fuel, cockpit, passengers, cargo etc.

3. Type of Propulsion :

- Propeller usually has two or more blades which are driven round in circular path.
- The blades reflect air backwards with acceleration and thus impard forward thrust to the aeroplane. This is called propulsion.
- Size of aircraft, speed characteristic, weight covering capacity etc depend upon type of propulsion generate.
- The basic runway length is also depend on it.

4. Size of Aircraft

- Wing span, length, height, distance between wheel base, tail width etc are major factors, which are considering during the design of taxiway.
- Size of hanger and apron, width of hanger is depend upon height, which is known as empenage height, and wing span.

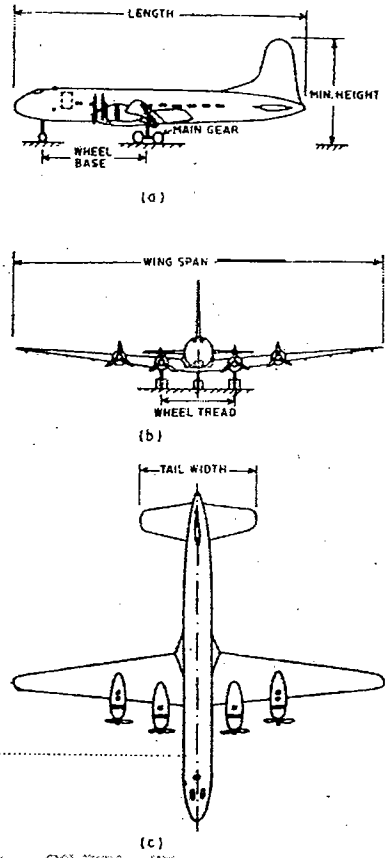
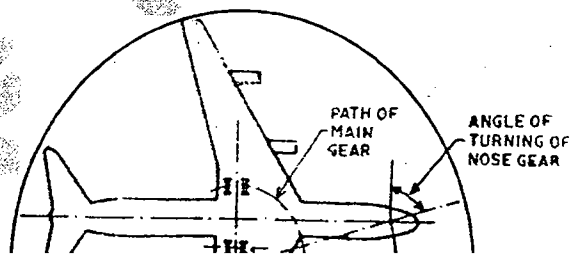


Fig. Aircraft Dimensions : (a) Side view, (b) Front view and (c) Plan.



6. Minimum Circular Radius :

- The minimum radius with which the aircraft can take turn in space.
- It depend upon the type of aircraft, air traffic volume and weather condition.
- During planning, desirable spacing between adjacent airport should provide.
- In case, this spacing not provide then operation timing should be manage to avoid collision. This affect the capacity of each airport.

7. Speed

- Cruising Speed/ Ground Speed : Aircraft speed w.r.t. ground when aircraft is in air at its maximum speed.
- Air speed : – Aircraft speed relative to wind.

8. Weight of Aircraft

- Weight of the aircraft directly influence the length of runway, thickness of runway, taxiway, apron and hanger.

Weight Component :

- Empty operating weight = constent weight of aircraft
- Zero fuel weight = empty operating weight + maximum payload
- Maximum take off weight = empty operating weight + flexible combination of payload and fuel.
- Maximum landing weight < maximum take off weight (because fuel is burned during flight)
- Maximum ramp weight > Maximum take off weight (extra fuel required for taxing etc).

9. Jet Blast :

- Aircraft eject hot exhaust gases with high speed
- The bituminous pavement is affected by jet blast. Therefore it is desirable to provide the cement concrete pavement at least at the touchdown portion.
- It also affect the position, size and location of gate.

10. Noise :

- It is major concern for discussion on layout, capacity of airport as well as surrounding area.
- Aircraft nose level is increase with maximum gross weigth of aircraft.
- For future technology, noise footprint is recommendent is 1 km^2 for 90 PNdB and 3 km^2 for

2. Max. ramp weight of an aircraft.
   (a) equal to max. take off wt.
   (b) more than max take off wt.
   (c) less than max take off wt.
   (d) equal to max. landing wt.

3. Max. landing wt. of an aircraft.
   (a) equal to max take off wt
   (b) more than max take off wt
   (c) less than max take off wt
   (d) equal to zero fuel weight

4. Fastest transportation if
   (a) Roadways (b) Railways (c) Water ways (d) airways

ANSWER

1. (a) **2.** (b) **3.** (c) **4.** (d)

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CHAPTER 2

Airport Planning

Airport Site Selection :

Factors affecting the selection of suitable site for airport are :

- **Airport Use :**
  - The selection of site depends upon airport use i.e., whether for civilian or military used.
- **Proximity to Other Airports :**
  - The selected site should be at considerable distance from existing airport so that landing and take off operations are not interference.
- **Topography :**
  - A raised grounds example hill top or pleatue area ideal site for airports.
  - Due to less, obstruction more uniform wind, natural drainage and better visibility due to less fog.
- **Obstrcution and Visibility :**
  - In landing and take-off operations, aircraft looses or gains altitute very slowly so long clearance area should be provided on either side of runway.
  - Poor visibility, lowers the traffic capacity of airports so site selected shouldbe free from visibility reducing conditions like fog, smoke and haze.
  - Fog generally settles in the area where wind blow is minumum.
- **Wind :**

- **Future Development :**
  - Based on future traffic growth, the selected site should be capable of accomodating new runway and other facilities.
- **Drainage and Soil Characteristics :**
  - Natural drainage should be available at selected site.
  - Most desirable soil is one which contain resonable amount of sand and gravels.

Servey for Site Selection

1. Traffic Survey.
2. Metrological survey
   - To determine direction, duration, intensity of wind, rainfall pattern and intensity.
3. Topographical survey.
4. Soil Survey
5. Material Survey.
   - To ascertain the availability of stable constrain materials nearby the site.
6. Drainage Survey.
   - To determine the quantity of strom water and location of the drains to disposed.

Estimation of Future Air Traffic Need

- To develope the figure for future air traffic for an airport is one of the most import task in planning of airport.
- Based on the estimate, the various component parts of airport are planned and there implementation is recommended in stages.
- The various data collected for airtraffic forecasting are :-
  (i) Annual passenger volume
  (ii) Annual volume of aircraft
  (iii) Peak day and peak hour volume of passanger and aircraft
  (iv) Air cargo
  (v) Air Mail
  (vi) General Aviation

Airport Obstruction and Runway Orientation

residential area development and factories which may produce smokes, may contain explosive materials, in the areas covered by this law.

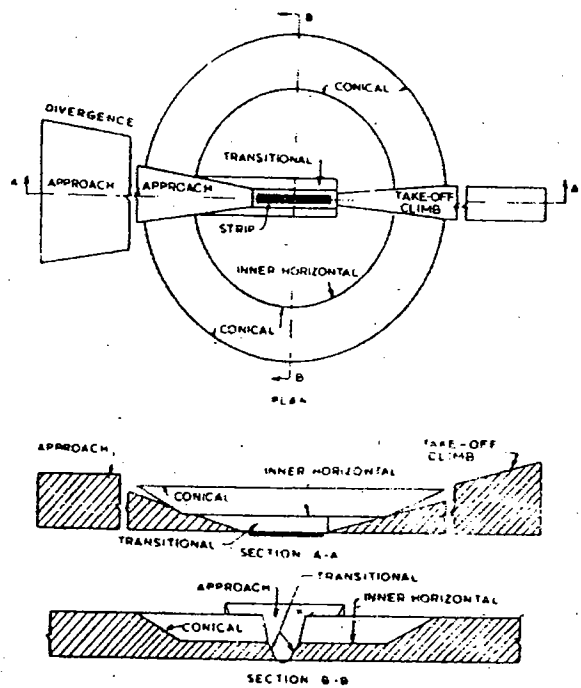
Classification of Obstruction :

Obstruction to safe air navigation are broadly divided into the following two categories :-

(i) Object protruding above certain imaginary surface.

(ii) Object exceeding their limiting height above the ground surface in approach zone and turning zone.

Imaginary Surface :



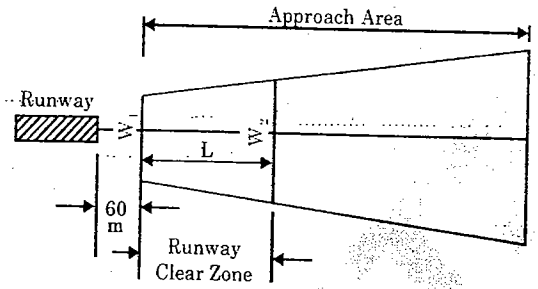
Schematic View of Imaginary Surfaces

- **Take of climb surface :** It shall be established beyond end of runway or clearway for each runway direction intended to be used for the take off aircraft.

- **Outer Horizontal surface :** It is a circular in plane with centre located at APR.
  – The height of OHS is 150m above the APR elevation.

Approach Zone :

- The wide clearance areas known as approach zone are required on either side of runway alog the direction of landing and take off of aircraft.
- Over this area, the aircraft can safely loose or gain altitude.
- The whole of this area has to be kept free from obstruction and as sucn zoning laws are implemented in this area.



	w_1	w_2	L
Instrument Runway	300 m	525 m	750 m
Non-Instrument Runway	150	270	600
Large instrument small	75	135	300

Fig. Runway Clear Zone

Clear Zone :

- The inner most portion of approach zone, which is the most critical portion from obstruction view point is known as clear zone.
- The purchase of land in this zone is recommended for the effective implementation of zoning laws.
- The minimum length of clear zone is 750 m for instrument runway.
- For non-instrument runway and large airport, minimum length of clear zone is 600 m.
  [Instument runway : Runway which is equiped with device permitting the landing under condition of poor visibility].

OBJECTIVE QUESTIONS

1. Min. width of clearway for instrument runway
   (a) 75 m (b) 150 m (c) 300 m (d) 250 m

2. As per ICAO, min. width of safely area for instrumental runway should be
   (a) 70 m (b) 300 m (c) 150 m (d) 450 m

ANSWER

1. (c) **2.** (b)

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CHAPTER 3

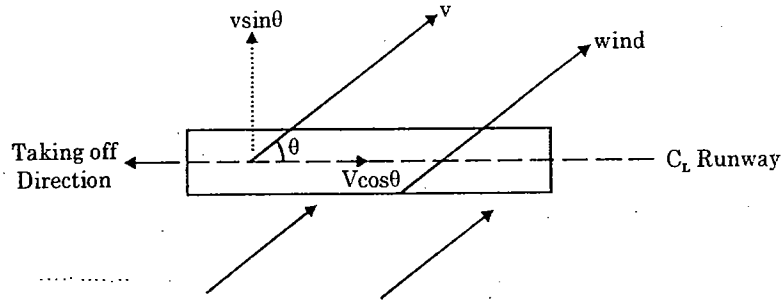
Runway Design

Runway Orientation :

- Runway is usually oriented in the direction of prevaiting wind i.e., the direction of wind opposite to the direction of landing and take off.
- The head wind provides greater lift force on the wing of aircraft when it is taking off, so that aircraft rises above the ground much earlier and in a shorter length of runway.
- During landing, head wind provides breaking effect to the aircraft so that it comes to stop in a shorter length of runway.
- If landing and take-off operation, done along the wind direction would require longer runway.

Cross Wind Component and Wind Coverage

- It is not possible to obtain the direction of wind along the direction of the central line of runway through out the year.
- If the direction of wind is at an angle to runway centre, its component are shown below



Wind Coverage :

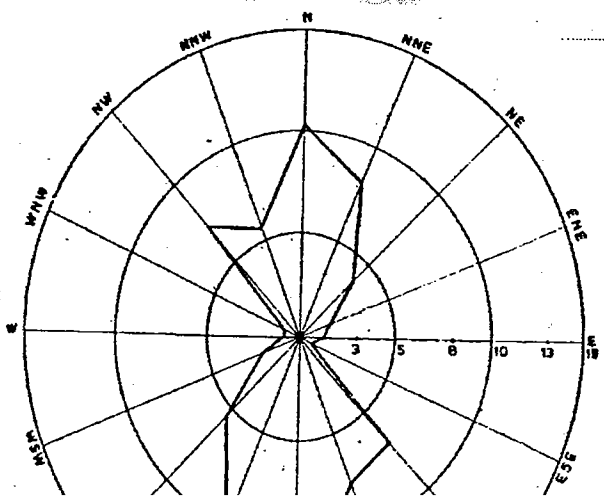
- The percentage of time in a year during which cross wind component with in the permissible limit as specified above, is called wind coverage.
- According to FAA, runway landing mixed air traffic should be planned that wind coverage is 95% and permissible crosswind component should not exceed 25 KmpH.
- For busy airport, wind coverage may be increased to 98–100%.

Wind Rose :

- The graphical representation of wind data's i.e., direction, duration and intensity, is called wind rose.
- The wind data of atleast five years and prefeably of 10 years should be considered while desigining an airport.
- This diagram used for orientation of runway.
- Wind rose diagrams can be plotted in two types as follows :

Type - 1 : Showing direction and duration of wind :

- The raidus lines indicate the wind direction and each circle represents the duration of wind.
- The best direction of runway is usually along the direction of the longest line on wind rose diagrame.
- Calm period : Percentage of time during which wind intensity is less than 6.4 kmph.



- The runway should be oriented along the direction indicated by central line.

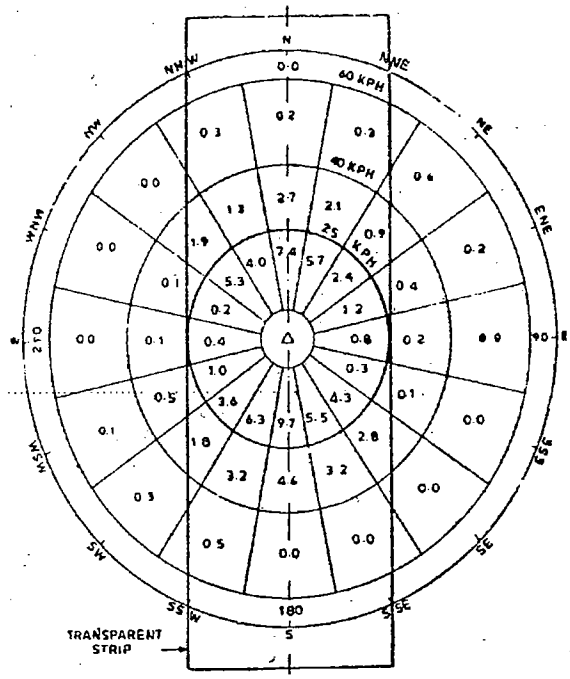


Fig. : Wind Rose Diagram Type - 2

Basic Runway Length :

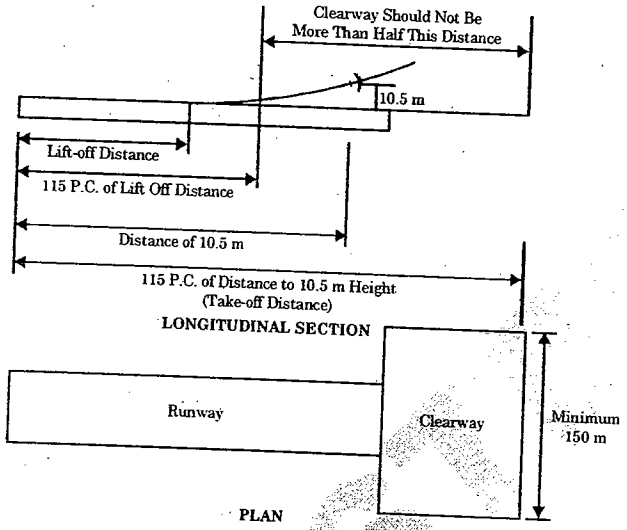
Basic Runway Length :

- It is length of runway under the following **assumed condition** at airport :-
  - (i) Airport altitude is at sea level.
  - (ii) Temperature at airport is standard (15°C)
  - (iii) Runway is levelled in longitudinal direction
  - (iv) No wind blowing on runway
  - (v) Aircraft is loaded at its full loading capcity
  - (vi) There is no wind blowing enroute to destination

(ii) Normal Take Off Case :

In this case, minimum clearway width should be 150 m and it is also kept free from obstruction.

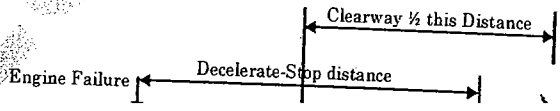
- Clearway ground area or any object on it should not protrude a plane inclined upward at a slope of 125% from the runway end.



(iii) Engine Failure Case :

In this case, basic runway length may consider either clearway or stopway or both.

- Stoping is the area beyond the runway.
- It is mainly used to deceleration of aircraft and bringing it to stop during aborted take.
- The strength of stopway should be sufficient to carry weight of aircraft without structural damage to aircraft.
- If the engine has failed at speed less than the designated engine failure speed, aircraft deaccelerated with use of stopway.
- If engine fail at speed, higher than designated speed, then there is no option except to continue to take off and turn in turning zone and land again for nomal take off.



Correction for Elevation, Temperature and Gradient

- The basic runway length, on discussed above is for mean sea level elevation, having standard atmospheric condition.
- Necessary corrections are to be applied for elevation, temperature and gradient for actual site of construction.

1. Correction For Elevation :

- As the elevation increase air density reduce.
- Lift reduce on the wing of aircraft and aircraft required greater ground speed.
- To achieve greater ground speed, longer length of runway required.
- According to ICAO, BRL (basic runway legnth) **should increase at rate of 7% per 300 m rise in elevation from MSL.**

2. Correction For Temperature :

- Airport reference temperature = $T_a + \frac{T_m - T_a}{3}$

  where, T_a = monthly mean of average daily temperature of hottest month

  T_M = monthly mean of maximum daily temperature
- As airport reference temperature rise, same effect as the rise in elevation.
- According ICAO, BRL after have been corrected for elevation, should further increase by 1% for 1°C rise in airport reference temperature above the standard atmosphere temperature at that elevation.
- Temperature gradient of standard atmosphere from MSL to altitude where temperature is 15.5°C is (–) 0.0005°C per meter.
- Temperature gradient become zero above the elevation where temp is 15.5°C

3. Check For Total Correction For Elevation Plus Temperature :

- According to ICAO, if combine correction exceed 35% of BRL, then these correction should be further check by specific study at the site by model test.

4. Correction For Gradient :

- In steeper gradient, to attain the desire ground speed, longer length of runway required.
- ICAO does not recommend any correction for gradient.

Airport reference temperature $= T + \frac{T_m - T_a}{3} = 26.32 + \frac{43.72 - 26.32}{3} = 32.12°C$

Q. Length of runway understandard conditions is 1620 m. The airport site has an elevation of 230 m. It is reference temperature is 32.94°C. If the runway is to be constructed with effective gradient of 0.2%. Then determine the corrected runway length

Sol.

(i) Correction for elevation $= \frac{7}{100} \times 1620 \times \frac{270}{300} = 102$ m

Corrected length $= 1620 + 102 = 1722$ m

(ii) Determination of standard atmospheric temperature of the given elevation

$= 15° - 0.0065 \times 270 = 13.18°C$

(iii) Corrected for Temperature :

$\Delta\tau$ = rise in temperature $= 32.9° - 13.18° = 19.72°C$

Correction $= \frac{1722}{100} \times 19.72 = 340$ m

Corrected length $= 1722 + 340 = 2062$ m

(iv) **Check :** for both correction combine

Total correction in % $= \frac{2060 - 1620}{1620} \times 100$

According to ICAU, this combine correction should not exceed 35%

(v) Correction for Gradient $= \frac{20}{400} \times 2062 + 0.2 = 82.487$

Corrected length $= 2062 + 82.40 = 2144.48$ m

Finaly after correction, nearly corrected length ≈ 2150 m

OBJECTIVE QUESTIONS

1. As per ICAO, min. basic runway length of A and E type of airport.

(a) 1500 m & 600 m
(b) 2100 m & 750 m
(c) 1500 m & 750 m
(d) [illegible]

5. For determine the basic runway length, landing case require that aircraft should cause to a stop within %P of landing distance. The value of
   (a) 40% (b) 50% (c) 60% (d) 70%

6. In wind rase, data consist min. period of
   (a) 6 month (b) 1 year (c) 5 year (d) 10 year

7. If the monthly mean of avg. daily temp for the hottest month of the year is 25°C and monthly mean of max. daily temp. of the same month of the year P & 46°C the aircraft reference temp P.
   (a) 32°C (b) 35.5°C (c) 40°C (d) 25°C

8. The standard condition assumed for basic runway length
   (a) airport altitude is at sea level (b) temp. at airport is standard (15%)
   (c) No wind blowing on raunway. (d) All above

9. As per ICAO, basic runway length with increased a rate by P% per Q% M rise in elevation. The value of P & Q are respective.
   (a) 70 and 300 (b) 7 and 250 (c) 5 and 300 (d) 5 and 250

10. In basic runway length correction in temp., the temp. gradient is
    (a) 0.0005°C (b) 0.0060°C (c) 0.0055°C (d) 0.0045°C

11. The engine failure case for determining the basic runway length way require.
    (a) only clearway (b) only stop way
    (c) either clear way or stop way (d) either clear way and stop way both

12. The length of runway under standard condition is 2000 m. The elevation of airport site is 300 m and its reference temperature is 33.05°C. If runway is to be constructed with an effective gradient of 0.25% then correct runway length.
    (a) 250 m (b) 2000 m (c) 2700 m (d) 200 m

13. The runway orientation is made so that landing and take off one
    (a) against the wind direction (b) along the wind direction
    (c) perpendicular (d) none of these

14. Which statement is correct :

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CHAPTER 4

Runway Geometric Design

Airprot Classification

- Geometric standard of an airport depend upon the type of aircraft, weather condition and use of airport i.e., International or Domestic.
- Airport has been classified by various agencies like Intenational Civil Aviation Organisation (ICAO). Federal Aviation Agency (FAA), United States Airforce etc.

ICAO Classification :

- It classified in the two ways

(i) Based on Basic Runway Length

- Using code A to E
- Airport type A, having longest runway.
- Airport type E, having shortest runway

Airport Type	Basic Runway length (m)		Runway Width (m)	Maximum Length Gradient (%)
	Maximum	Minimum		
A		2100	45	1.5
B	2099	1500	45	1.5
C	1499	900	30	1.5
D	899	750	22.5	2
E	749	600	18	2

- Code 1, use for maximum ESWL and type pressure
- Code 7, use for minimum ESWL and type pressure

Geometric Design of Runway

- Most of airport having international air service. So its desire to have a common design standard as per recomended by ICAO.
- Runway can handle maximum gross take-off weight for all type of aircarft with safety. Maximum gross take off weight is sum of maximum structural weight and fuel for trip.
- The following items are to be consideration in geometric design of runway.

(i) Runway Length :

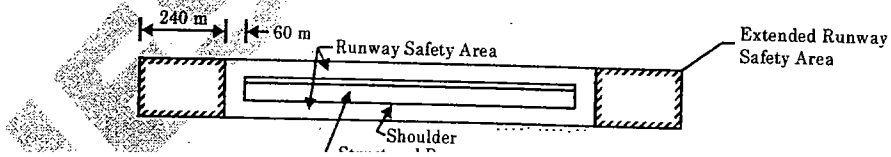
- Basic runway length is different for different type of airport.
- Actual length of runway obtained by correction of elevation, temperature and gradient if applied.

(ii) Runway Width :

- ICAO recommend the pavement width varying from 10m to 45 m.
- The typical transverse aircraft traffic is concentrated at central 24 m.
- There is another consideration, i.e., outer engine should not damage by dust of solders of runway.

(iii) Width and Length of Safety Area :

- Width of safety area is runway plus shoulder on either side of runway plus the area that is cleared, graded and drained.
- Shoulders are unpaved, used for emergency during aircraft operation and impart a sense of openess to pilot.
- According ICAO, for non-instrumental runway width of safety area is minimum 150 m (for A, B, C) and 78 m for (D, E type)
- For instrumental runway minimum width should be 300 m.
- Length of safety area is 60 m beyond runway at both end.



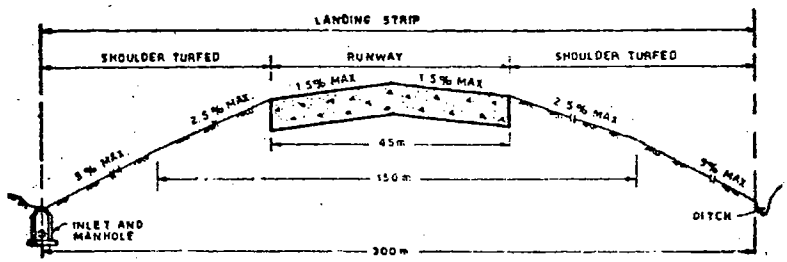


Fig. Runway Cross Section

(v) Longitudinal and Effective Gradient :

- More longitudinal gradient, require more runway length
- ICAO recommend Maximum Limit :

  For longitudinal gradient :-

  A, B, C type → 1.5% (Maximum)

  D, E type → 2% (Maximum)

  For effective Gradient

  A, B, C type → 1% (Maximum)

  D, E type → 2% (Maximum)

(vi) Rate of Change of Longitudinal Gradient :

- ICAO Recommended : [Maximum Limit]

  For A and B type → 0.1 % per 30 m length

  C type → 0.2% per 30 m length

  D, E type → 0.4% per 30 m length

(vii) Sight Distance

- If there is two runway or runway and taxiway intersection each other, sufficient sight distance required.
- ICAO recommend that for A, B, C type of airport, any two point having 3 m above surface of runway should be mutually visible from a distance equal to **half of runway length.**

3. As per ICAO, for A, B, C type of airport, site clearance of 3 m high object is equal to
   (a) full runway length
   (b) half runway length
   (c) 1/3 runway length
   (d) none of above

ANSWER

1. (a) **2.** (a) **3.** (b)

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CHAPTER 5

Airport Capacity

Airport Capacity :

- Number of movement of aircraft which are airport can handles safely within unit time usually an hour.
- Movement refers to landing or take off operation.
- Airport capacity during IFR condition is usually less than during VFR condition.
- Airport operating capacity depends upon :-
  - Runway configuration and connected taxiway
  - Airport characteristic and there arrival and departure ratio
  - Weather condition
  - Obstruction in airport vicinity
  - Loading apron space
  - Navigation aids

Runway Capacity :

- Ability of a runway system to accomodate aircraft landing and take off.
- It usually express in operation per hour or operation per year.
- Following factors are affecting runway capacity :-

1. **Air Traffic Control :**

   In Vicinity of airport, the minimum allowable horizontal separation is typically 3.6 to 8 nautical km depending upon aircraft size, availability of reader and sequencing of operation.

- By limiting use of runway during certain hour of the day due to noise, capacity is affect.

4. Layout and design of runway system :

Principle factor which affect capacity :

- Numebr spacing, length and orientation of runway
- Number, location and design of exit taxiway

Gate Capacity

Gate : It is defined by an aircraft parking space, adjacenet to a terminal building and used by a single aircraft for the loading, unloading of passengers, baggage and mail.

- Ability of specified number of gate to accomodate aircraft loading and unloading operation under condition of continuous demand.
- Gate is defiend by an aircraft parking space adjacent to terminal building for loading and unloading of passengers.
- Gate capacity is increase of weighted avg. gate occupancy time for all aircrafts.
- Gate occupancy time opened upon.
  - Types of aircraft
  - Amount of baggage and nail
  - wheter the flight is an originating, turn around or through flight.
  - $$\text{Gate capacity} = \frac{1}{\text{weighted service time}}$$

or

$$\text{Gate capacity} = \min \text{all} \left[\frac{Gi}{Ti\,Mi}\right]$$

For Gate System :

Gi → no. of gate that can accomodate

Ti → Mean gate occupancy time of aircraft

Mi → Fraction of aircraft class i demanding service.

Taxiway Capacity

- Taxiway capacity directly affect the runway and gate capacity.

$$C_{SGs} = \frac{1}{\text{weighted service time}}$$

$$= \frac{1}{(.15 \times 25) + (.35 \times 45) + (.5 \times 60)}$$

$$= 0.015 \text{ aircraft/min/gate}$$

Capacity for all gate $C = G_{SG} \times \text{no. of gate}$

$$= 0.0215 \times 10$$

$$= 0.215 \text{ aircraft/min}$$

$$C = 13 \text{ aircraft/hour}$$

OBJECTIVE QUESTIONS

1. **Assertion :** The ratio of arriving and departing aircraft influence the airport capacity

   Reason : Landing operation is generally given priority over the taking off operation.

   Select your answer based on the coding system given below:

   a) Both A and R are true and R is correct explanation of A.

   b) Both A and R are true but R is not the correct explanation of A.

   c) A is true but R is false.

   d) A is false but R is true.

2. **Assertion** : Airport capacity during IFR condition is usually less than that during VFR condition

   Reason : During year weather condition (VFR), the aircraft on final approach to runway can be spaced closer during poor.

   Select your answer based on the coding system given below:

   a) Both A and R are true and R is correct explanation of A.

   b) Both A and R are true but R is not the correct explanation of A.

   c) A is true but R is false.

   d) A is false but R is true.

CHAPTER 6

Taxiway Design

Basic Factor for Layout of Taxiway

- Main function of taxiway to provide access to the aircraft from the runway to loading apron or service hanger and back.
- Taxiway should be so arranged that landed aircraft, during taxing toward apron should not interfere with aircraft taxing for take off.
- Route of taxiway should be shortest from apron to runway.
- Taxiway should be located at various point so that landing aircraft leaves the runway as early on possible. Such taxiway is also called exit taxing.
- There should be avoid an intersection between runway and taxiway.
- Exit taxiway should be designed for high turn off speed. It result the reduction of runway occupying time, hence increase in airport capacity.

Geometric Design of Taxiway

- Speed of aircraft at taxiway is much lower than speed at runway.
- Thus, design standard for a taxiway is not as rigid as they are for runway.
- The following items are considering during the geometric design of taxiway :

(i) Length of taxiway :

- It should be short as practicable.
- No specific recommendation by any agencies.

(ii) Width of taxiway :

– Transverse gradient should not exceed 1.5% for A, B and min. should be 0.5%, ICAO recommend.

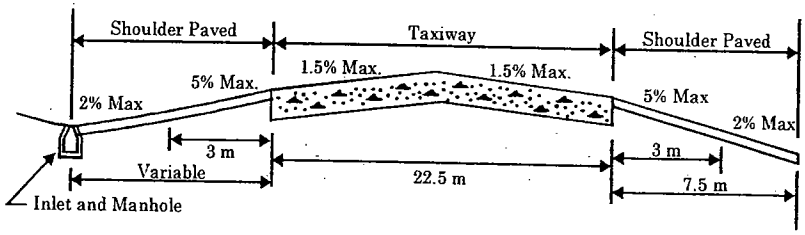


Fig. Taxiway Cross Section

(v) Rate of change of longer gradient :

– ICAO recommend, max limit of rate of change

- For A, B, C type airport ® 1 % in 30%
- For D, E type airport ® 1.2% in 30%.

(vi) Sight distance :

– Since speed at taxiway is slower, so that sight distance.

– ICAO recommend :

- For A, B, C type airport, surface of taxiway should be visible from 3 m height at 300 m distance.
- For D, E type airport, surface of taxiway should visible from 2.1 m height at 250 m distance.

(vii) Turning radius :

– Whenever change in the direction of taxiway horizontal curve is required.

– The curve should be so designed that aircraft can negotiate it without significant reduce in speed. So radius should large.

– Large circular curve is preferred.

– Radius of the curve $R = \frac{V^2}{125f}$

R = Radius in meter

V = Speed in kmph

f = Transverse coefficient of friction i.e. assumed 0.13.

– For large subsonic jet transportation, min R = 12 m. (What ever be the speed)

– For supersonic transport, min R = 180 m.

- According to Horonjeff, the radius of taxiway should be provided that distant of the oleo strut of main gear is not less than 6 m from the pavement.
- According to Horonjeff

$$R = \frac{0.388W^2}{\frac{T}{2} - S}$$

W = Wheel base of aircraft in meter

T = Width of taxiway pavement (meter)

S = Distance between midway point of the main gears and edge of taxiway pavement in meter

Q. A taxiway is to be designed for operating aircraft having following character.

Wheel base = 17.70 m

Tread of main loading gear = 6.62

Turning speed = 40 kmph

Coefficient of friction between type and pavement = 0.13

Sol :

(i) Turning radius $= R = \frac{V^2}{135f}$

$$= \frac{10^2}{175 \times 0.13}$$

$$= 98.5 \text{ m}$$

(ii) From horizontal equation $= R = \frac{0.388W^2}{\frac{T}{2} - S}$

Here W = 17.70 m

T = 22.5 m (standard width = 45 m)

$$S = 6 + \frac{6.62}{2} = 9.31 \text{ m}$$

If there is more than two, then it will be distributed along the runway length.

(ii) ***Exit speed :*** Location of exit taxiway should be at that point where aircraft having sufficient reduced speed to take safe turn.

(iii) Weather condition : Wind, temp, tog etc. affect the landing speed of aircraft.

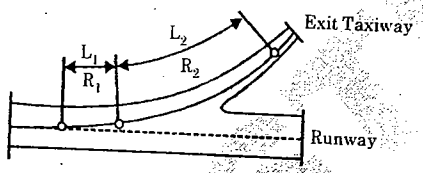
(iv) Topographic feature :

- High altitude or deep valley reduce the visibility, which may affect the landing speed.
- Obstruction in approach zone and turning zone also affect the landing speed of aircraft.

Design of exit taxiway connecting runway :

Following point should be consider during design of exit taxiway :

- Most significant factor is turning radius and exit speed.
- Slightly widen entrance which gradually tapper to the normal width of taxiway preferred.
- Total angle of turn of 30°-45° can be negotiate satisfactory.



L_1 = Length of entrance curve

R_1 = Radius of entrance curve

L_2 = Length of central curve

R_2 = Radius of central curve

Fig. Radius of Curvature for Exit Taxiway

- Length of larger radius curve can be empirically obtain by

$$L_1 = \frac{(0.28V)^3}{CR_2}$$

C = Coefficient = 0.39

Separation Clearance :

- This is the distance between parallel taxiway.
- It depends upon :

Size of gate position depends upon the type of aircraft, min. turning radius, aircraft parking configuration.

(ii) Number of gate position :

- Number of gate position depends upon the peak hourly aircraft movement and time during which each aircraft remain in a gate position.
- This time is also known as 'Ramp time' which is few minutes for small aircraft and more than hour for big aircraft.
- Generally it is 10 min for small aircraft and 60 min for big aircraft.
- Number of gate position = $\frac{\text{Capacity of runway}}{60 \times 2} \times$ Average gate occupancy time
- Here runway capacity is in unit of movement per hour.
- In above formula, it is assumed that each aircraft occupying a gate position, represent two aircraft movement. i.e. loading and take off.

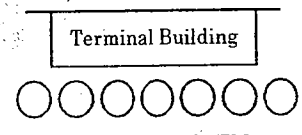
(iii) Aircraft parking system :

– Apron size depends upon the aircraft grouped adjacent to terminal building in various ways :

(i) Frontal system :

– Very simple and economical

– Use for small airport



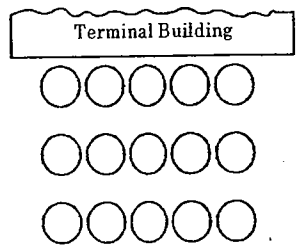
FRONTAL SYSTEM

(ii) Open area system :

– Aircraft parked in row

– Passenger may have to walk or vehicle convergence is required.

– Passenger may exposed to weather, noise and hot blast of jet aircraft.



OPEN APRON SYSTEM

(iii) Finger system :

– Provide protection to passenger to weather, noise, fume.

– Future expansion easier.

– Aircraft remain close to terminal building.

– Mostly used system of parking (1 GI)

- This system having large construction cost.
- Passenger may change the level several time.
- This system used in loss angles.
- Advantage of this system is less turning is required for in and out of gate (position).

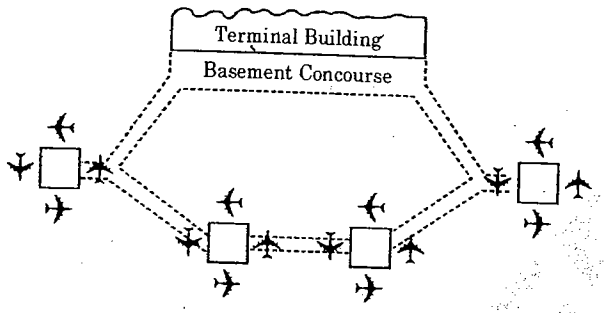


Fig. Aircraft Parking System

Holding Apron

- At the busy airport, aircraft have to line up for take off.
- Storage area for waiting of aircraft before take off is called holding apron.

Hanger :

- Hanger is the covered area for repair and servicing the aircraft.
- Hanger depends upon the size of aircrafts and turning radius.
- Number of hanger depends upon peak hour volume of aircraft and depends of hanger on rental basis by cliff airline agencies.

OBJECTIVE QUESTIONS

1. As per ICAO, rate of change in long gradient of taxiway at A, B, C type airport
   (a) 1% in 30 m (b) 1.2% in 30
   (c) 1.5% in 20 m (d) 2% in 30 m
2. Min. turning radius taxiway for subsonic aircraft is
   (a) 100 m (b) 120 m (c) 150 m (d) 180 m

5. Which of the following used for servicing and repair of aircraft.
   (a) Aprno (b) Hanger
   (c) Terminal building (d) Holding appron.

6. For super sonic transport min. turning radius of taxiway is
   (a) 60 m (b) 120 m (c) 180 m (d) 240 m

ANSWER

1. (a) **2.** (b) **3.** (b) **4.** (c)

5. (b) **6.** (c)

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CHAPTER 7

Visual Aids & Drainage System

Visual Aids

- Pilot need visual aids for prospective view of runway during landing and taking off operation in all type of weather of every time.
- Runway edges and runway central line is the amongst item which should be clearly visible to pilot.
- In the day time visibility, it enhance by marking with line and number, having maximum contrast under all condition.
- In night time, its essential to provide adequate lightening at airport, runway and taxiway.
- Prospective view of runway should be visible from 60 m height and near 1100 m distance.

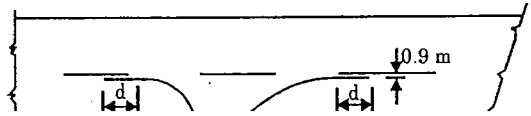
Airport Marking

Airport marking is divided in to following :

1. Runway Marking :

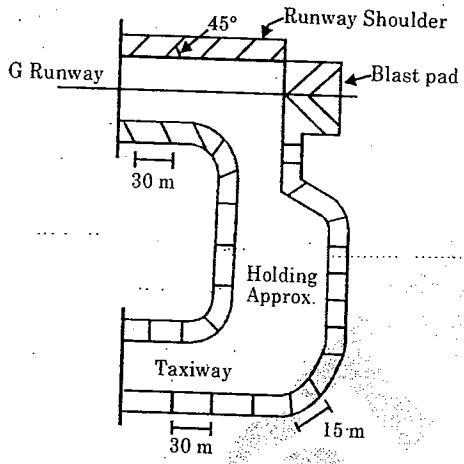
- Runway marking consist the marking of central line, edge strip, touch down zone or landing zone.
- Al marking is done in white paint.

2. Taxiway Marking :



3. Runway and Taxiway shoulder marking

- Shoulder Marking if done in yellow paint.
- It has diagonal line having width of 0.9 m for runway shoulder.
- For taxiway shoulder and apron holding shoulder having perpendicular market.
- Blast pad at the end of runway have marked with chevron pattern.



4. Apron Marking

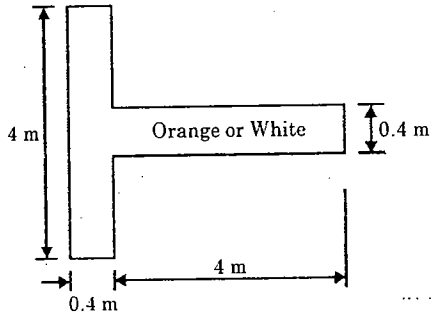
- This marking is done by yellow paint.
- Since paron is likely to fuel spillway, paint should be fuel resistant.
- Some guide line are painted on apron to help pilot in manoeuvreing the aircraft on the apron

5. Wind Director Indicator

- It has the wind cone which is placed away from building so that no effect of air eddies.
- As per ICAO, the segment circle should have an inside diameter of 30 m and panel width varying from 0.9 m to 2.4 m
- It should colour which having better contrast with respect to its background so that from 300 m height, it should be visible.

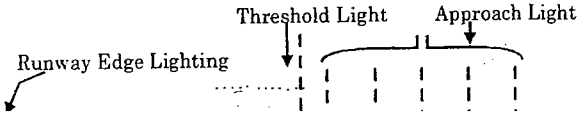
6. Landing Direction Indicator :

- It is form of T shape and placed centre of segmented circle.
- Purpose of indicate to the pilot the direction of active runway of the airport.



Airport Lighting :

- In the night duration, airport lighting is provide better visibility to landing and taking off operation with taxing etc.
- Colour and generate petten of lights used in airport lighting are standardized for all civil airports.
- Threshold lighting is provide 60 m ahead of runway threshold, where a pilot make decision whether to land or not.
- Taxiway lighting should be clearly identified and different with runway to avoid confusion.
- Exist taxiway should be lighted 360 m to 450 m ahead of turn off.
- All taxiway side lights are blue colored.
- Appron. and hanger area should have flood light having at least 12 m above pavement.
- Landing direction indicator is properly lighted for use in night duration.
- Runway edge lighting spaced at 60 m and central lighting spaced at 12.5 m - 15 m.
- Runway light usually white
- Taxiway edge lighting spaced at 60 m and central lighting spaced at 15 m.



- The capacity of airport is determine by ATC.
- Air traffic control with mainly concern with
  - i) Aircraft takes off from airport.
  - ii) Maintain proper altitude in air.
  - iii) Navigates from point to point safe.
  - iv) Land at another airport.

Air Traffic Control Aids :

- Visual flight rule (VAR) prevail when the weather condition is good ad pilot can manage with visual aid during operation without requirement of air traffic control.
- Instrumental flight rule (IFR) prevails when the visibility is inadequate during night time or due to cloudy or done to fog.
- In IFR, for pilot prepare flight plan and approve by air traffic control
- During all visibility condition following air traffic control aids are always available to pilot during flight.
  1. Airways aids
  2. Landing Aids

Grading of Airport Area :

Following point should be observed :

- Amount of cut and fill should be balance each other.
- Haulage distance and around to move earthwork should be min.
- Proper drainage should be done to ensure the stability of pavement.
- Plan should be prepare to carry to surface water away from runway, taxiway, apron. area and building area.

Airport Drainage :

- A Proper drainage is essential for safety of aircraft and long life of pavement.
- A drainage system in airfield normally serves three function :
  - Removal of surface runoff the airfield
  - Interception and diversion of surface and ground water flow originating from lands adjacent to the airfield area.

- In drainge system, drainage pipe having capacity to carry ground water as well as surface water.
- Drainage should be rapid.
- Drainage system should be design with consideration of future extension of runway.
- This main drainage line having sufficient capacity with future extension consideration.

Surface Drainage :

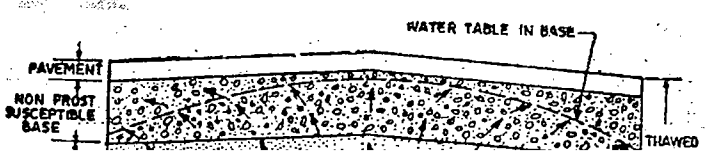
- Surface drainage design should be done by following objective, within the economic feasibility.
  1. Removal of surface runoff resulting the selected design storm without damage the airfield facilities.
  2. If surface runoff from storm is greater than designed storm, then there should min. damage to airfield facilities.
  3. Design should have max reliability of operations under all climate conditions .
  4. Design should done so that min. maintenance and operation difficulties are observed.
  5. During design future expansion should be under consideration.

Sub Surface Drainage :

- Main function of subsurface drainage are
  1. To remove water from a base course.
  2. To lower the ground water level in subgrade beneath the pavement.
  3. To intercept, collect and remove water flowing from the adjacent spring or previous area.
- Base drainage is normally required under following conditions.

1. When frost action occurred in subgrade beneath of pavement.

- During the thaw, water released by subgrade moved upward into base coarse and lateral drain.
- If there is inadequate drain, then base course become saturated and loose its strength which may cause of failure of pavement.



OBJECTIVE QUESTIONS

1. As per ICAO all marking of the runways are :
   (a) yellow (b) white (c) black (d) red
2. As per ICAO, all marking of taxiway are ??
   (a) yellow (b) white (c) black (d) red
3. As per ICAO, runway lighting colour are
   (a) yellow (b) white (c) blue (d) red
4. As per ICAO, taxiway lighting colour are
   (a) yellow (b) white (c) blue (d) red
5. Runway threshold is indicating a series of parallel lines starting from a distance of
   (a) 3 m from runway end (b) 8 m from runway end
   (c) 10 m from runway end (d) 15 m from runway end

ANSWER

1. (b) **2.** (a) **3.** (b) **4.** (c)
5. (b)

CHAPTER 8

Heliport

Heliports

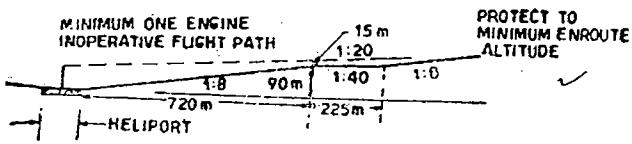
- Heliport / Helipad is the designed area when facilities are provided for take-off and landing of the helicopters.
- Helicopter having main advantage :
  - Helicopter can lift off the ground in a nearly vertical direction. This is referred to vertical take off and landing (VTOL).
  - During the winter weather, due to snow fall, aeroplane flights are risky.
  - Major travelling distance covered in all over the world is less than 400 km. In developed country, it is more preferred than aeroplane.
  - The military operation need the VTOL. So in military, it is most usable.
  - It is used for ambulance also.
- Helicopter characteristic is to ensure the flying with min. danger of life and property.
- Helicopter must be able to climble at the rate of 60 m per minute and the flight path gradient should be 4%.

Planning of Heliports :

- Heliport is used for landing and take off helicopter. It may provide the facilities for shelter, repair and servicing of helicopter, for processing of cargo, baggage and passengers and area for vehicular parking.
- The area, where helicopter actually land or take off, is called landing area.
- Remaining area is called terminal area.

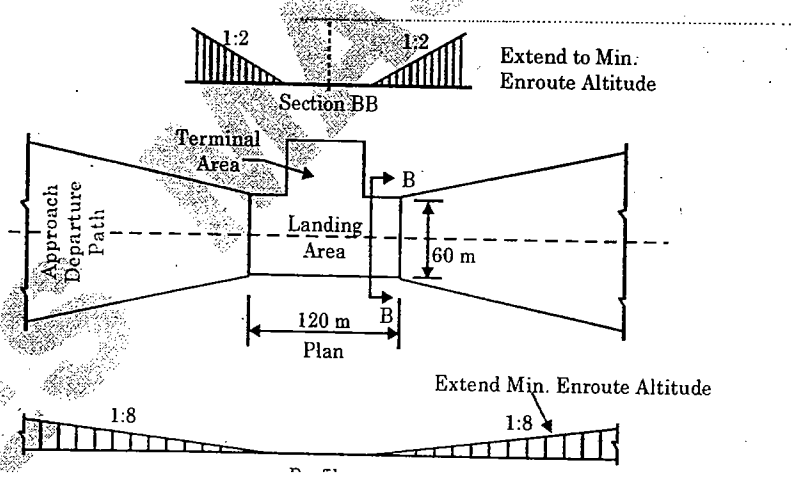
Site Selection :

- The general considerations in the choice of a suitable site for a heliport are as follows :
  - It should be located in close proximity to the traffic generating areas.
  - It should have a convenient areas by ground transportation e.g. roadway or railway
  - Site should be least objectionable for noise, during landing and take off the helicopter.
  - It is not practicable vertical landing and take off operation. So its should be establish the obstruction free in approach and departure path.
  - As per FAA recommendation, the obseruction clearance line should have slow of the 1 : 8. Beyond this distance, the slope of 1 : 40 is recommended for further flight upto a horizontal distance of 225m which is then followed by a slope of 1 : 8 upto minimum enroute altitude.



Obstructions in Approach Area

- The recommendation of ICAO is also the same except that the obstruction gradient should extend upto 750 m from toe of the slope. In transverse direction, the slope of obstruction clearance plane is 1:2.



- ICAO recommends the minimum width which is equal to twice the diameter of the main rotor of largest helicopter expected to use the heliport.
- It is preferable to arient the landing and take-off area of along the direction of wind.

Visual Aids and Marking :

- ICAO recommends that area of landing and take off should be fully identified with capital letter 'H'.
- Specification used for marking 'H'

  Height of letter → 3 – 4.5 meter

  Width of letter → 2 – 3.5 meter

  Width of letter → 0.45 meter
- Area should have sufficient lighting for night operation.

OBJECTIVE QUESTIONS

1. The heliports orientation is made so that landing and take off one
   (a) against the wind direction (b) along the wind direction
   (c) perpendicular (d) none of these
2. Size of landing area for multiengined helicopters operating under IFR condition
   (a) 22.5 × 22.5 m (b) 30 × 30 m
   (c) 22.5 × 30 m (d) 60 × 120 m

ANSWER

1. (b) 2. (d)

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PORT AND HARBOUR

CHAPTER 1

Water Transportation

- Broadly water transportation divided into two category :
  - Inland water transportation → through river or canal or lack
  - Ocean transportation → through ocean.
- Water transportation is the easiest and cheapest transportation.
- It has higher load carrying capacity.
- It develop the economic progress and international contact.
- In counter part, it is slow speed transportation and little-bit more risky due to storm and hurrieanes.
- If any accident occur like oil spillage, most of water species suffered which result into environment disturbance.

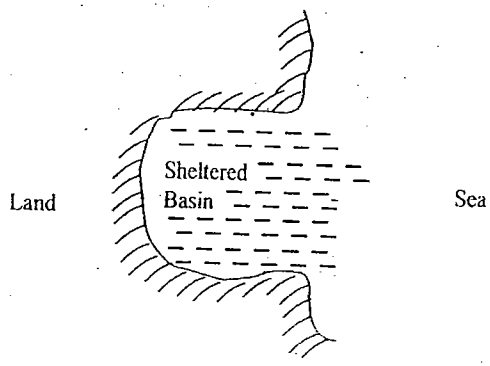
Harbour :

A harbour is a partly enclosed protected water area to provide safe and suitable accommodation for vessels, seeking refuge, supplies, refuelling, repairs or transfer of cargo.

- This is a haven for ships where they can be moored and sheltered from wind and waves.

Basic Requirement of Harbour :

- It have sufficient depth for draft of vessel.
- Breakwater must be provided to protect against destructive waves.
- At bottom, there should have sufficient anchorage system to secure ship against force of high



2. Semi Natural Harbour :

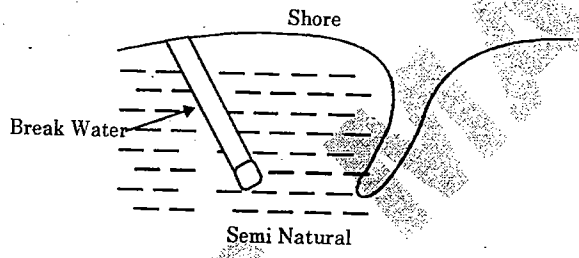
- Harbour which is protected from storms and waves in one side by natural configuration and other side of artificial configuration.

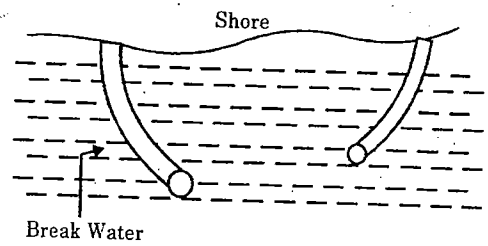
  Example : Visakhapatnam in India, Plymouth in England.

3. Artificial Harbour :

- Harbour which is protected from the effect of waves either by breakwater or by dredging.
- Madras Harbour is one of the artificial Harbour.

  Example : Jabel Ali in Dubai (largest).





B. On basis of Utility :

1. Refuse Harbour
2. Commercial Harbour
3. Fishing Harbour

- Main function to provide a sheltered area where vassals can moor.
- An easy accessibility of a Harbour implies a wide and straight approach, the direction of which consider with the direction of currents and the highest waves.
- Wide entrance is deriable for manoeuvreing.
- Deep water bay is ideal for harbour location.
- Rock bottom locations for the port site should be avoided except in unavoidable cases where the rock may be needed for the construction of dock.

Harbour Layout Elements :

Harbour Size :

- Harbour size depends upon the size ad no. of ships using at harbour
- It also depends upon convenience for manoeuvreing and navigation and also on adaptability of natural features.
- Minimum harbour area is equal to the space required for the dock plus the turning basin in front of them.
- Some basic component of harbour size :-

1. Harbour Depth :

- The channel depth is generally determined from the following formula :

$$D = D' + \frac{H}{3} + D''$$

where

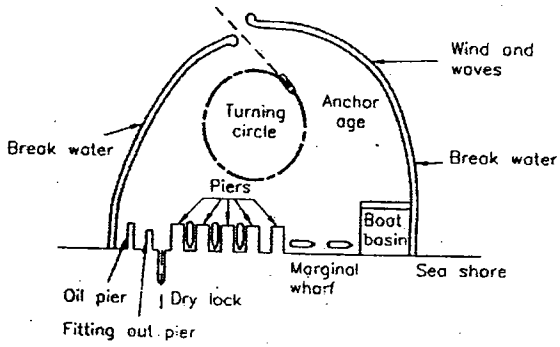
D' = The draft of the largest ship to be accommodated

H = The height of storm wave, crest to trough.

D'' = Allowance for squat of the moving ship.

- Depth of harbour and approach channel should be sufficient for ideal operating conditions and permit navigation at low water when ship is fully loaded.
- The max harbour depth below lowest low water is achieved as follows :

Max harbour depth = Loaded draft + 1.2 m (when bottom is soft)



3. Anchorage Area :

- The place where ships may be held for quarantine inspection await docking space, or await favourable weather condition is called ancharge area.
- The water area required for on anchorage depends upon number type and size of vessels.
- The anchorage area is calculated as the area of the circle having radius, R = 4 × depth of water + Length of ship + safe clearance to adjacent ship.
- Normally safe clearance to adjacent ship is 30 meter or equal to beam of vessel.

Harbour Entrances Channel :

- Channel which connect the harbour to the deep sea is entrance channel.
- The alignment of channel should be direct and ships should be able to approach berths without the need of manoeuvreing.
- The alignment should be smooth and devoid the sharp curves. The radius of curve should be larger than five times the length of largest ship expected.
- The width of entrance channel depends upon :
  - Max. size of ship expect
  - Accuracy of navigation aids
  - Whether ships are allowed to cross or pass one another.
- Normal width of entrance channels :

  Small harbours – ...100 m

Type of Entrance :

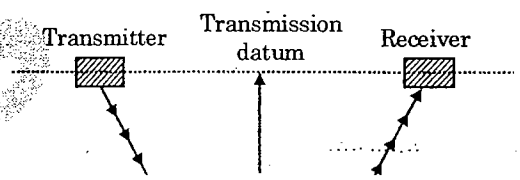
- Entrance without gates is known as tidal entrance.
- Entrance with gate is known as impounded entrance.

Soundings :

- The measurement of depth below the water surface is called sounding.
- Soundings are required for :
  - (i) making nautical charts for navigation.
  - (ii) measurement of areas subject to scour or silting and to ascertain the quantities of dredged material.
  - (iii) making sub-aqueous investigations to secure information needed for the construction, development and improvement of port facilities.
- For most of the engineering works soundings are taken from a small boat.

Fathometer : Echo-sounding :

- A fathometer is used for ocean sounding where the depth of water is too much, ship at which it is installed.
- It is an echo-sounding instrument in which water depth are obtained by determining the time required for the sound waves to travel from a point near the surface of the water to the bottom and back.
- It is adjusted to read depth in accordance with the velocity of sound in the type of water in which it is being used.
- The main parts of an echo-sounding apparatus are :
  1. Transmitting and receiving oscillators.
  2. Recorder unit.
  3. Transmitter/Power unit.



- It can be used to take simultaneous observations of two moving objects also.
- The principle of the instrument is that one object is seen directly, whereas the other is viewed through the reflection and both are bought to apparent coincidence.

Station Pointer :

- Station pointer is a three-armed protractor and consists of a graduated circle with a fixed arm and two movable arms to the either side of the fixed arm.
- It is used for plotting of soundings.

Hi-Fix :

- Observation by sextant has it limitations, both in distances covered and in speed.
- A high-precision light weight electronic position fixing system known as hi-fix has been developed and is extensively used.

* ***The best method for locating sounding to estimate the dredged material from the harbours is fixed intersecting ranges.***

OBJECTIVE QUESTIONS

1. **Assertion A :** Depth and width required at the entrance to a harbour are more than those required in the channel.

   Reason R : The entrance to a harbour is usually more exposed to waves as compared to the harbour itself.

   Select your answer based on the coding system given below:

   a) Both A and R are true and R is the correct explanation of A.
   b) Both A and R are true but R is not the correct explanation of A.
   c) A is true but R is false.
   d) A is false but R is true.

2. The maximum harbour depth below lowest low water is generally equal to

   (i) loaded draft + 1.2 m when bottom is rock
   (ii) loaded draft + 1.8 m when bottom is soft
   (iii) loaded draft + 1.2 m when bottom is soft
   (iv) loaded draft + 1.8 m when bottom is rock

4. Minimum width of ship clearance shall be

a) B or 30 m b) 1.5 B or 50 m c) 1.5 B d) 50 m

where "B" is beam of the design vessel

ANSWER

1 (a) **2.** (d) **3.** (d) **4.** (a)

MASTER

CHAPTER 2

Port

Some Definitions :

1. *Displacement Load.* It is the weight of the ship and its contents when fully loaded with cargo to the plimsoll mark or load line painted on the hull of the ship. It is generally in tonne.

2. *Displacement Tonnage.* It is the actual weight of the vessel or the weight of water displaced when afloat and may be either loaded or light.

3. *Plimsoll Mark or Load Line.* It is the depth under the maritime laws to which a ship may be loaded in different bodies of water during various seasons of the year.

4. *Displacement Light.* It is the weight in tonnes of the ship without cargo, fuel and stores.

5. *Dead Weight Tonnage.* It is the weight of cargo, fuel and stores a ship carries when loaded to the plimsoll mark.
   - It represents the carrying capacity of ship.

6. *Gross Tonnage.* It represents carrying capacity in volume measurement. It is the entire internal cubic capacity of a ship. Ships are registered with gross or net tonnage expressed in units of 100 cu.m.

7. *Net Tonnage.* It is the gross tonnage less the space provided for the crew, a machinery, engine room, and fuel.'

8. *Freight Tonnage or Cargo Tannage.* It forms the basis of freight charge. This tonnage may be

Port :

- Port is gateway from sea to land and vice-versa.
- In other words, it is a place where transport of men and materials changes from one mode to another.
- The ports can be either natural or artificial.
- The ports can also be either river port or sea port.

Requirement of Good Port :

- It should be easily connect with rail and highway so that commodities can transport easily and quickly.
- Port must possess adequate facilities for handling and storing the commodities passing through the port.
- Port must have facilities for servicing the ship.

Port in India :

- There are 13 major and 176 non-major sea ports in India.
- Out of 13, 12 are government and one, ennore port of Chennai, is the corporate.
- Kandla port – Gujrat – Major hub for oil import.
- Nhava Sheva – Maharastra - Also know as Jawahar Lal Nehru Port, handling large volume among total.
- Mumbai Port – Maharastra
- Marmagao Port – Goa – Best natural harbours in India.
- Panambur Port – Karnataka – also known as Manglone port and deep water all weather port.
- Cochin Port – Kerala
- Port Blair – Andaman – Youngest Sea Port
- Tuticorin Port – TN – artificial deep sea harbour
- Chennai Port – TN – Oldest port
- Vizag Port – Andhra Pradesh – Largest sea port in India.
- Pradeep Port – Orissa – Artificial, deep water port.
- Haldia Port - WB – also known as base of Indian Coast G

OBJECTIVE QUESTIONS

1. When a ship floats at its designed water line, the vertical distance from water line to the bottom of the ship is known as
   a) beam b) depth c) freeboard d) draft

2. Which of the following are repair docks ?
   a) marine railways, dry docks, floating docks, wet docks
   b) dry docks, wet docks, floating docks, lift docks
   c) dry docks, floating docks, lift docks, marine railways
   d) wet docks, lift docks, marine railways, dry docks

ANSWER

1 (d) **2.** (c)

ES MAST

CHAPTER 3

Natural Phenomena

- For planning and design of Harbour requires complete study of certain natural and meteoro logical phenomena and their consequences at and near the shore.
- These natural phenomena (tides, winds, waves, currents etc.) also effect the design of protection works in form of breakwater, offshore moorings etc.

TIDES :

- The level of ocean water undergoes a periodic rise and fall, thing natural phenomena is known as a tide.
- Tides are caused by force of attraction executed by the moon and sun. The influence of moon is greater than sun.
- Generally, there are two rises of flood tides and two falls (ebbs) of low tides every Lunar day i.e. 24 hours 50 min. These tides are called Semi diurnal tides.
- ***The mean sea level at Indian ports and harbours has generally been established based on analysis of tidal sea level flactuation over 19 years.***

Lunar Day :

Time taken by moon to make a complete revolution ground the earth. 50 minutes longer than solar day.

Spring Tides :

- These are highest tides which occurs intervals of half of Lunar month.
- They occur when the generating forces of moon and sun are additives

- Tidal range at coast play important role in determine the types of productive works and facilities at the harbours.
- Small range, the rise and fall in level of the berthed ship will be small.
- Large range, say more than 3 m, it is difficult to cope up with large rise and fall in the level of a berthed ships alongside the wharf.

Tidal force due to sun = 0.450 × tidal force due to moon.

$$Fs = 0.450 \times Fm$$

Wind :

- In maritimes works, speed of wind is express in knots.
- A knot is the length of one minute of area of a meridian and it varies in different latitudes.
- Generally 1 knot equal to 1.043 kmph.
- Wind causes waves to be formed in open sea.
- Stormy conditions known by various names like typhoon, cyclone, tornado etc. cause considerable have in the harbour area and must considered in its design.
- Wind, acting on ship, which are mooned, exerts a pulling force on the bollards (strong post where ship is moored). This force must be allowed for the design of dock wall.

Wave :

- Waves are generated by wind and their development depends upon the surface area of open sea exposed to wind action.
- In other word, the wave is generated by transfer of energy from air moving over the water surface.
- This transfer of energy can be either by normal pressure or by tangential stress between air and water.
- Waves of oscillation which is stationary, occur due to difference of pressure executed by moving air.
- Wave of translation which is due to tangential stress.
- Height of the wave (m) = $0.34\sqrt{F}$

  [where F is fetch in km.]

1. Compression due to direct horizontal force.
2. Shearing action at the projections on face of the wall.
3. Sea bed and foundation disturbance due to downwards force on the collapse of the wave.
4. Suction effect due to the return water after striking.

The above effect result in

1. Impact force
2. Vibration
3. Internal pressure
4. Contraction and expansion of the confined air in the pores and cavities of the structure.

– Internal pressure on air is 3.5 time the pressure of water on the face of wall, which damage the masonry structure if there is present.

- Marine structure face hydrostatic and hydrodynamic force both.
- The pressure is depend upon wave height, wave length and depth of water in the sea.
- For the design of coastal structure, a design wave height that is potentially most damaging is selected.
- Wave in deep and shallow water maintain a degree or symmetry through the depth.
- The deep water wave are those which occur in water having a depth greater than one half of the wave length ($d < L/2$), at which depth the bottom does not have any significant influence on the motion of water particles.
- For shallow water waves ($d < L/2$) they influence the bottom such the particles move in orbital motion.
- A unbroken wave is a wave of oscillation and even after breaking in deep water it will usually reform into oscillatory wave of reduced height. When it reaches to shallow water, it becomes a wave of translation.
- Since waves are not uniform, significant wave height is the average height of 1/3 highest wave. It denotes by $H_{1/3}$ for H_S.
- Average height $H_A = 0.6\ H_S$

  Highest wave $H_{max} = 1.87\ H_S$

- ***When a wave strikes a vertical breakwater in deep water, it is reflected back and on***

2. Sea-wall, bulkheads and revetments :

- These are the structure consturcted parrallel to shoreline to develop a demaracting line between land area and water area.
- A revetment is a protective pavement supported by an earth work.

3. Protective beaches or spending beaches :

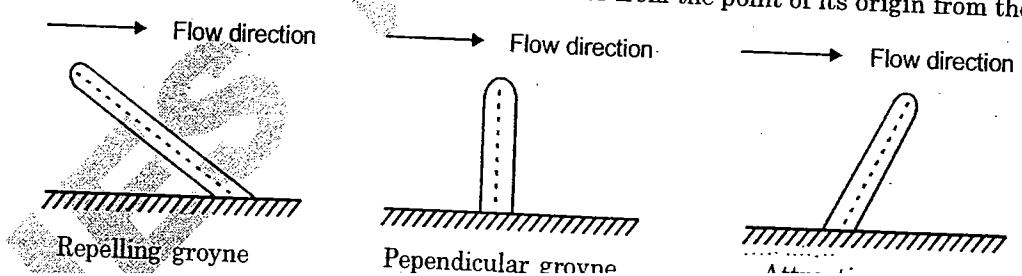
- It is found that beaches oif suitable dimensions can prove to be effective to grant protection to the adjecent upland from the effect of waves and tides.

4. Sand dunes :

- These are the formation along the coast and they prevent the movement of the tides and waves into the area behind them.

5. Groynes :

- These are structures which are built to protect beach or retard erosion of an existing or restored beach by trapping of littoral drift.
- These are usually perpendicular and little inclined to the shore.
- The type of groin depend upon following factors?
  1. Availability of material
  2. Foundation condition.
  3. Presence of absence of marine borers.
  4. Topography of the beach.
- Pependicular groyne projects normal to the river-flow from the point of its origin from the bank.
- Repelling groyne projects upstream inot the river-flow from the point of its origin from the bank.
- Attracting groyne projects downstream inot the river from the point of its origin from the bank.



OBJECTIVE QUESTIONS

1. As per Stevenson's empirical formula, the approximate value of the height of the wave in metres is given by

   a) $0.34\sqrt{F}$ b) $0.5\sqrt{F}$ c) $1.5\sqrt{F}$ d) $3.4\sqrt{F}$

   where F is the fetch in km.

2. As per Berlin's formula, the length of wave in metres is given by

   a) $1.34t^2$ b) $1.56t^2$ c) $1.74t^2$ d) $1.94t^2$

   where 't' is the period in seconds for two successive waves to pass the same section.

3. **Assertion A :** Intervention of undulations in the sea bed reduces the depth of wave at the section.

   Reason R : No wave can have a height greater than the depth of water through which it passes.

   Select your answer based on the coding system given below:

   a) Both A and R are true and R is correct explanation of A.
   b) Both A and R are true but R is not the correct explanation of A.
   c) A is true but R is false.
   d) A is false but R is true.

4. At a given port, the fetch is 400 nautical miles; the maximum height of storm wave will be

   a) 2.073 m b) 8.169 m c) 9.144 m d) 6.8 m

5. **Assertion A :** Basin walls have to be of much grater height than dock walls.

   Reason R : Tidal basins are subject to fluctuations of levels due to tidal variations.

   Select your answer based on the coding system given below:

   a) Both A and R are true and R is the correct explanation of A.
   b) Both A and R are true but R is not correct explanation of A.
   c) A is true but R is false.
   d) A is false but R is true.

6. The significant wave height is defined is the average height of th

9. **Assertion A :** Large size stones are required in stone revetment in shore protection.

Reason R : Resistance of stone to wave force is proportional to its volume and wave force is proportional to the exposed area of the stone.

Select your answer based on the coding system given below.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not a correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

10. Which of the following structures protects the shore by trapping of littoral drift?

a) groynes b) sea walls c) revetments d) moles

11. The lowest tide which occurs in half lunar month is called

(a) Spring tide (b) neap tide (c) Lunar tide (d) Tidal bore

12. Zigzag deposition and movement of sand on sea beach is called

(a) Littoral drift (b) Beach drift (c) Trough action (d) Sedimentation

ANSWER

1. (a)	**2.** (b)	**3.** (a)	**4.** (c)
5. (a)	**6.** (a)	**7.** (b)	**8.** (b)
9. (a)	**10.** (a)	**11.** (a)	**12.** (a)

CHAPTER 4

Breakwaters

Some Definitions :

1. **Breakwater.** This is a protective barrier constructed to form an artificial harbour with a water area so protected from the effect of sea waves as to provide safe accommodation for shipping.

2. **Quay.** This is a dock parallel to the shore. It may or may not be continuous with the shore.

3 **Quay Wall or Bulkhead.** These are protection walls of quay backed up by ground. It holds or supports ground in back of it.

4. **Wharves.** These are platforms or landing places for ships to come close enough to the shore for embarkation and disembarkation. They are built out into or on to the water. When along and parallel to the shore, then they are known as quays.

5. **Jetty or Pier.** This is dock that projects into the ship's basin at right angle or oblique from shore.
   - When it is built in combination with a breakwater then it known as break water pier.
   - The main function of a jetty is the preservation of a channel against the encroachment of littoral drift river sediment. They are generally built-in pairs.
   - The ships may use a pier on both sides whereas wharves are used only on one side.

6. **Mole.** This is a fill, usually rock, extending out from shore. The side slopes of this are provided with riprap or armour rock to protect it from erosion. The upper surface of mole is made wide enough to provide roadway, sidewalk, rail, road tracks, utilities, pipelines and conveying facilities to serve the pier.

- They are of two types known as breasting and mooring.

(a) **Breasting Dolphins.** These are larger marine structures for mooring vessels. They are designed to take impact of a ship when docking and to protect the dolphin and ship from damage.

(b) **Mooring Dolphins**. They are provided to hold a ship against the road side wind blowing in a direction away from the dock. They are away from the face of the dock. Hence they are not designed for the impact of the ship.

9. **Moorings for Ships.** They are comprised of ground tackle placed in fixed position for attaching a ship's line. Each unit of ground tackle consists of one or more anchors with chain, sinker and buoy to which the ship's line is attached.

10. **Fixed Mooring Berth.** This is a marine structure consisting of dolphins for tying up a ship and a platform for supporting the cargo-handling equipment.

11. **Dock Fenders.** They are horizontal wood members or a number of vertical wood members or rubbing strips fastened to the deck or face of the dock. They prevent a ship or dock from being damaged during mooring.

12. **Catwalks.** They are used to provide access to and between dolphins. They serve as a convenient means of running out ship's lines to their moorings.

Breakwaters :

- A breakwaters is a structure constructed with the purpose of protecting an area from the effect of sea waves so that ships can safely be moored in that area.
- A breakwaters, which substitute a quay wall and which can be used as a platform for loading and unloading cargo in calm water is known as a mole.
- The height of breakwaters depends upon its purpose, extent of enclosed water area and the nature of existing shipping work.
- Generally, breakwaters height is kept equivalent to 1.2 to 1.25 times of the height of the wave expected above the high water level.
- The breakwaters should be so designed that waves do not break on the wall.

Types of Breakwaters

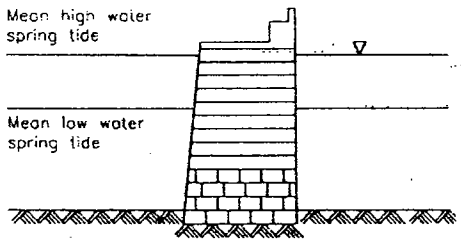
Breakwaters are of three types

1. Vertical sided

3. Hydrostatic pressure caused by braking waves.
4. Complex forces developed by the onrush and down-rush of waves on a sloping surface.

Vertical Sided Breakwater :

- A vertical sided breakwater is a wall built with stone masonry, concrete blocks or caissons.
- It can also be constructed with two walls of sheet piles and the area between the walls filled with concrete subsequently.
- Vertical sided breakwaters are preferably found on rock so that scour is avoided.
- The top width is made at least equal to the height of the maximum wave.



Rubble Mound Breakwater :

- These are the most common types of breakwaters. They are constructed with stone rubble.
- The mount consists of three parts :
  1. The armour (or cover)
  2. The first under-layer
  3. The second under-layer (or core)
- The stability of the section depends upon the weight and shape of the armour block, the interlock between individual blocks and the slopes to which they are laid. Heavy blocks are the best. Weights of individual stones in the armour can be as high as 5T to 10T.
- The under-layer is made up of stones weighing roughly one-tenth the weight of the stones in the armour. The core is composed of small stones having individual weights, 1/200 to 1/6000 of the armour stones.
- The slope on the seaward side is in the range of 1 in 1.25 to 1 in 2. The slope on the protected

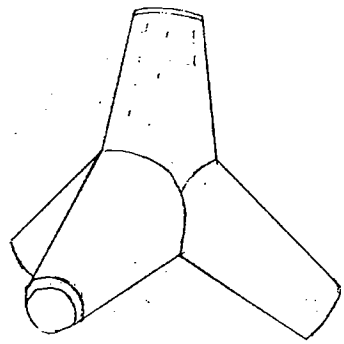
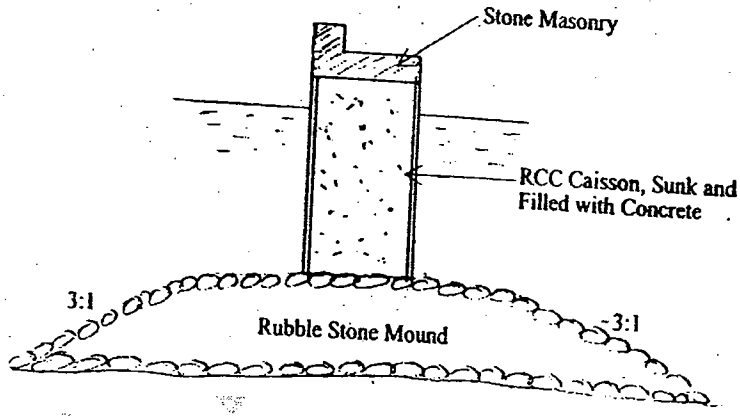


Fig. Tetrapond used for Armour Breakwater

Composite Breakwater :

- Composite breakwaters are those with a rubble mound as a major foundation and a vertical sided wall as a superstructure.



Fenders :

- A fender in the form of a cushion is provided on a jetty face for ships to come in contact.
- These fenders absorb the impact of the ship and protect them from damage.
- In designing a fender system, the critical factor to be considered include the mass of the ship to be berthed, the speed of berthing and, the environmental conditions at the

- Wharves built parallel with the shore are called quays.
- They are built to retain and protect the embankment or filling.
- The space required alongside a wharf for breathing depends upon following factors
  1. Size and type of ship served.
  2. Availability of materials.
  3. Wharf configuration.
- Wharves can broadly be classified as :-

(a) Open type wharves :

- Whearves of open construction have their decks supported by piles or cylinder.
- The open type of wharf locations where, however, a low-level super structure is required.
- Open type of wharf substructure offers littlerestriction to water movements; hence it can be used to support piers in rivers and coastal areas a like.

(b) Soild type wharves :

- Wharves of solid construction have their deck supported by sheet pile cells, bulkhead, cribs, caisson and quay walls.
- Solid fill type of wharf structure provides adequate resistance to the impact of mooring vessels, besides other advantages.
- Solid fill structures are stable and inexpensive (except in deep water) and require little maintenance.

OBJECTIVE QUESTIONS

1. As compared to wall type breakwater, mound type breakwater
   a) requires skilled labour
   b) requires low maintenance cost
   c) requires less material
   d) results in less damage due to gradual failure
2. If H is the height of the wave expected, then the height of the breakwater is generally taken as .....

(ii) Slip is the space of water area between two adjacent piers where ships are berthed,

(iii) Pier head is a structure constructed near the tip of a break water near the harbor entrance.

Of the statements

a) (i) and (ii) are correct
b) (ii) and (iii) are correct
c) (i) and (iii) are correct
d) (i), (ii) and (iii) are correct

5. Match List -I (Description) with List II (Structure) and selecat the correct answer using the codes given below the lists:

List I

A. Constructed approximately perpendicular to the shore to retard erosion of an existing beach

B. Structure that are placed parallel to the shoreline to separate the land from the water

C. Built roughly perpendicular to the shore for maintaining an entrance channel

D. Built generally parallel to the shoreline to protect a shore area

List II

1. Jetties
2. Break waters
3. Seawalls
4. Groins
5. Wharfs

	A	B	C	D
(a)	4	3	1	5
(b)	5	2	4	3
(c)	1	4	5	3
(d)	4	3	1	2

6. **Assertion (A) :** Breakwaters are common in natural harbours

Reasons (R) : Breakwaters help in controlling wave action and sand movement into the harbour area.

(a) Both A and R are true and R is correct explanation of A

(b) Both A and R are true but R is not a correct explanation of A

CHAPTER 5

Dock

- A dock is an artificial enclosure for the reception of ships.
- It can either be enclosed or regulated by lock gate or open to the tides.
- Docks can be broadly classified as harbour docks and repair docks.

Harbour Dock [Wet Dock] :

- Dock which is used for berthing of vessels to facilitate loading and unloading of passengers and cargo are known as wet dock.

Classification of Wet Docks :

1. Wet docks in tidal basin :

- In ports on the open sea coast protected by an outlying breakwater, basins are formed within its shelter.

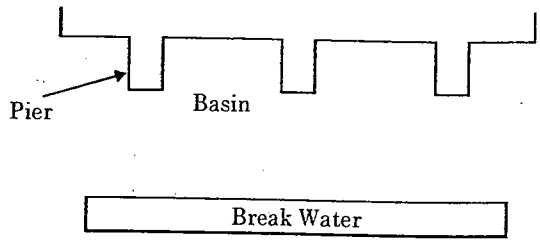
Advantage of Tidal Basin :

- Vessel can come in and berth or leave at all times.
- Costly arrangement, like lock gate for closing of entrances are not required.

Disadvantage :

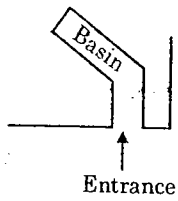
- If range of tide is more, then operations of loading and unloading are serious effected.
- The fluctuations of water level will cause the rubbing of sides of ships again the berths.

2. Enclosed wed dock :



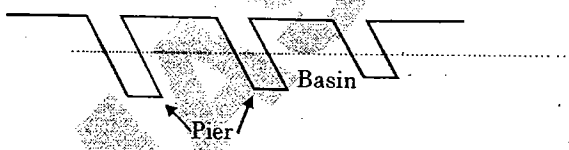
– The length and breath could be adjusted to give max gauge.

- Diamond Shape :



– For the same perpendicular distance between the long sides, the long sides could be conveniently extended.

- Inclined Pier Type :



– It consists of a number of projecting piers into the basin or dock.

– DOCKS could be located on inland ports of rivers, at estuaries or an open sea coast.

– The width of entrances depends on the beam of widest ship, the dock has to receive. Here beam of ship refers to width of ship.

Repair Dock (Dry Dock) :

- Docks which are used for repair of vessels, are known as dry dock.
- In port, harbours with some tidal range will push up the vessels at tide and leave it there beached when the tide recedes.

- This stands still like a grave of dead body hence it is called graving dry dock.
- The main components of growing dry dock are : the floor, the walls and entrance.

Force Acting on Graving Dock :

1. Weight of ship resting along the centre line of dock floor, when dock is empty.
2. Weight of water on the floor when dock is flooded.
3. Upward pressure under the floor when it is being emptied.
4. Earth and hydrostatic pressure behind the side wall.
5. Load imposed by the shores on the inside face of side walls.
6. Surcharge on the side wall.

2. Marine Railway dry dock OR slipway :

- Spillways are used for building of ships or for repairs.
- A slipway consists of inclined path of timber or stone upon which a series of rails are fixed and they run up from a sufficient depth of water to the required height above the high water level.
- The lower end of the ship is tidal and open to the water.
- The ship ways on which the ship after being pulled upto the highest point can be traversed sideways to other berth are known as the traversing slip ways.

3. Lift Dry Dock :

- These are platforms lowered into and raised from the water.
- Raising and lowering is achieved by hydraulic power applied through a series of cylinders placed on the both sides of the platform.

4. Floating type of Dry clock :

- Floating dock may be defined as a floating vessel which can lift a ship out of water and retain it above water by means of its own buoyancy.
- To receive a ship, the structure is sunk to required depth by ballasting its interior chambers with water the ship is floated into position and berthed.
- The dock is raised bodily with the berthed ship by unballasting the chamber by pumping out the water.

OBJECTIVE QUESTIONS

1. Which of the following conditions of loading imposes the greatest load on the foundation in case of dry docks?
   a) when the dock is empty
   b) when the dock is empty with the ship of maximum tonnage
   c) when the dock is full of water
   d) when the dock is dry and is under construction

2. A ship is berthed in a chamber and lifted by principles of buoyancy Such a chamber is called.
   a) Dry dock b) Wet dock c) Floating dock d) Refuge dock

3. Consider the following statements:
   1. Dock is a marine structure for mooring up vessels, loading and unloading of passengers and/ or cargo.
   2. Dry dock is generally used only for carrying out repairs, inspections and painting.
   3. Wet dock is an enclosed or partially enclosed basin provided with locks and entrance gate to keep the water level at a fairly constant level.

   Which of the statements given above are correct ?
   (a) 1, 2 and 3 (b) 2 and 3 (c) 1 and 2 (d) 1 and 3

ANSWER

1. (c) 2. (c) 3. (a)

TUNNELING

CHAPTER 1

Tunnel Engineering

A tunnel is an engineering structure, artificial gallery, passage or roadway beneath the ground, under the bed of a stream, or through a hill or mountain.

Such underground passage constructed without removing the overlaying rock or soil may be used for the transportation of passenger, freight, water, sewage or gas etc.

Advantage of tunnel

i) For carrying public utilities like water or gas, railway lines or roads across a stream or mountain tunnels may be cheaper than bridge or open cut.

ii) Tunnel avoid the dangerous open cat adjacent to the structure.

iii) Tunnels save tearing up of expensive pavements and so lesser maintenance costs and operating expenses.

iv) Cost of hauling is decreased due to lighter grades, possible in the tunnels.

v) Aerial warfare and bombing of cities have given intangible values to tunnels.

vi) It is generally assumed that when the cut required will have a vertical depth exceeding 20m, it is less expensive to build tunnel.

Classification of tunnel

1. Classification based on purpose

   (a) Traffice Tunnel

      i) Railway tunnel

      ii) Highway tunnel

3. Classification based on position or Alignment

(a) Saddle or Base tunnel:

- To minimize the length of tunnel, the track is led through velleys as long as natural slope of the valley.

(b) Spiral tunnel:

- In narrow valleys, the additional length for minimum permissible radius is obtained by forming loop into the interior of mountain.

(c) Off spur tunnels

- Tunnel that are made to short cut minor local obstacles.
- They are very short in length.

Shape and Size of tunnels

In deciding upon the sectional profile of a tunnel two factors have to be taken into consideration.

(i) Shape of the section best suited to the conditions

(ii) The interior dimensions of this section

Shape of Tunnels

- The shape of the sectional profile of a tunnel should be such that the lining is able to resist the pressure exerted by the unsupported walls of the tunnel excavation.
- In quick sands or material without cohesion the pressures will act normal to the line of profile.
- Circular section will be best suited to these conditions
- Commonly adopted sections are

i) Poly centric ii) Circular section iii) Horse shoe iv) Egg-shaped

v) Elliptical vi) Rectangular

Circular Section

- Circular section is the best resisting external and internal forces and provides the greatest cross sectional area for the least perimeter.

Horse Shoe Section

- The floor of tunnel is flat enough to give working space to workers.
- It is suitable for soft rocks.
- It is best suited for traffic operations, used in railways and highwa

Egg Shaped

- It is used for sewers, in combined sewerage system.
- Smaller cross section at the bottom maintains required self cleansing velocity both in dry and storm wheater flow.

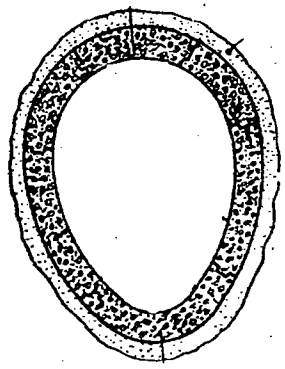


Fig. Egg-Shaped Section

Tunnel alignement and surveying

- After the ends of the tunnel have been fixed centre line should be located exactly to find exact length it tunnel
- It also furnish a reference line by which the exavation is directed.

Operation Involved in Surveys

i) Locating the centre line on ground

ii) Transfering centre line to inside tunnel

iii) Providing required grade at the bottom of tunnels

iv) Checking tunnel cross section.

- In short tunnels centre line may be accurately located by means of common the odolite with wooden stakes.
- In long tunnels the centre line is fixed by triangulation using micrometer and transit theodolite.
- Long tunnels are generally driven by working from several points at one time by means of

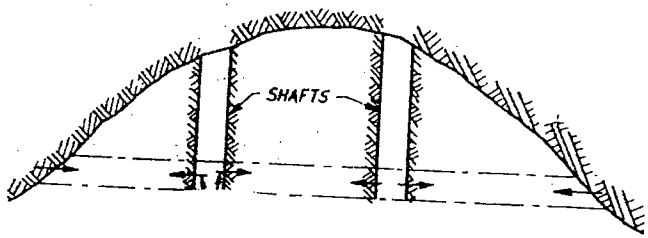


Fig. Shaft

Size of a shaft

Size of a shaft is governed by the following factors

i) Amount of muck to be hoisted

ii) Hoisting system to be adopted

iii) Size of muck car

iv) No. of workmen

v) Space required to carry pipe and wiring

vi) Type of construction equipments to be used

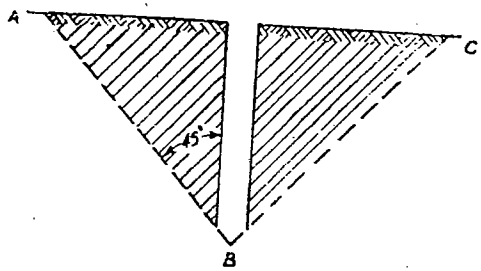
Drills and Drilling

- Priar to excavating rocks, rocks are loosened by drilling holes, filling them with explosives and firing them.

The Theory of drilling

In deciding upon the sectional profile of a tunnel two factors have to be taken into considration.

(a) The drill hole normal to face when exploded with proper charge will break out the rock in the following pattern.



(b) If two similar hole

(ii) Abrasion Drills

- These drills grind rock into small particles through abrasive effect of a bit that rotates in the hole.
- This is self propelled drill mounted on a truck or crawler tractor and used to drill holes upto approximately 100 meter.
- Diamond abrasive drill can drill in desired direction from vertically down word to upwards.

(iii) Fusion piercing

- A recent development in drilling holes for blasting purposes is by fusion piercing method.
- It produces burning mixture of oxygen and flux bearing fuel such as kerosene at the end of a blow-pipe
- Drill bits are the portion of a drill which contacts the rock and disintegrates it.
- Types of Bits
  (a) Forged Bits
  (b) Detachable Bits

Blasting

- Blasting is the operation performed to loosen rock so that it may be excavated or removed from its existing position
- Blasting is accomplished by discharging explosive that has been placed in a hole specially provided for this purpose.

Driving tunnels in Rock

For driving tunnel through rock, the following operations are usually involved.

i) Setting up and drilling.
ii) Loading holes and shooting the explosives.
iii) Ventilation and removing dust of explosion.
iv) Loading and hauling muck
v) Siding of tunnel
vi) Placing reinforcing steel
vii) Concrete lining

Methods of tunnelling in Rock

Advantages

- As fuel section has to be attacked , the work is expedited.
- Mucking track could be laid progressively, along with the tunnelling.
- Tunnelling is continuous.

Disadvantages

- Full face attack requires heavy mechanical equipment.
- Method may not be possible for the unstable rocks.
- Limited for short spans.

2. Headaing and Bench Method

- This method involves the driving of the top portion in advance of the bottom portion, as shown in the fig. below-
- It is used when tunnel section is very large and quality of the bed rock is not very satisfactory or unstable.

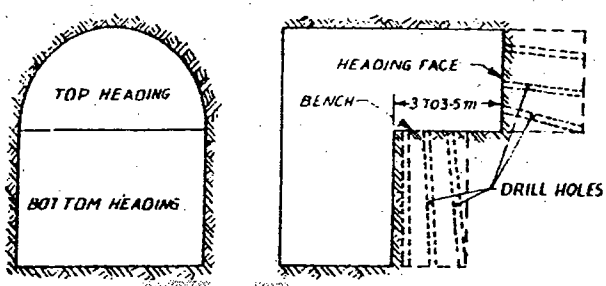


Fig. Heading and Benching Method

Advantages

- Simultaneous drilling and mucking is possible.
- Requires less power than in full face method.

3. Drift Method

- Rock tunnelling is sometime carried out first in smaller section of the proposed tunnel and then it is widened.
- This method is called drift method.

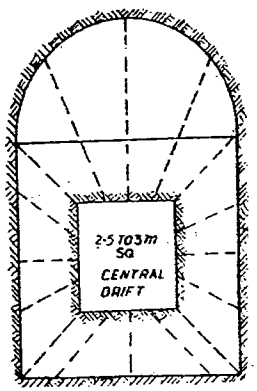


Fig. Centre Drift

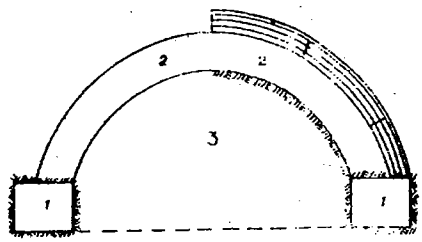
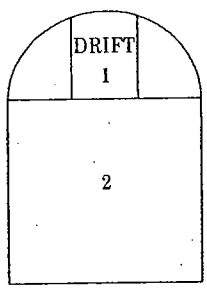


Fig. Sid Drift



Fit. Top Drift

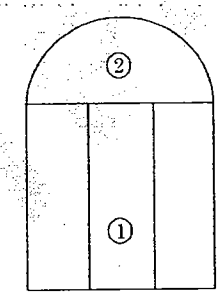


Fig. Bottom Drift

Driving tunnels in Soft ground

The material which can be excavated with tools like picks, shoval, are etc. and no heavy or costly equipments are required is termed as soft ground.

Method of soft ground tunneling

There are varieties of methods of tunnelling through soft ground and can be classified as follows.

(A) Method requiring use of timber

i) Fore poling method

ii) Needls Beam method

iii) Belgian method

- The process of fore-poling method is slow and tedious requiring skilled labour.
- Inclined polling boards as shown in fig support the roof

2. Needle Beam Method

- Needle beam consists of a stout timber beam or a composite flitched beam and form the main temporary support during the excavation of the tunnel.
- This method is suitable for soil where roof can stand for a few minutes.
- This method is more economical as compare to other method, and works all right on the brick lining.

3. Belgium Method

- This is popular method and is suitable for all classes of moderately firm or hard soils, where height of the over burden is very small.
- Roof arch is constructed before the side walls and inverts are built.
- Excavation there for begins by driving to centre heading which is enlarged towards the springins.

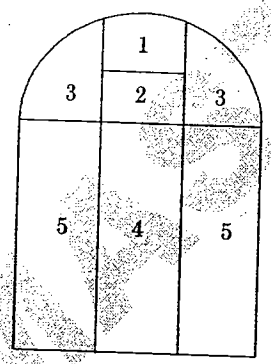


Fig. Sequence of Drilling in Belgium Method

4. American Methods

- American method is used for Railways and high ways tunnels.
- A top drift is driven and supported by laggins, cap-timber and two posts.
- Sides of the drift are then widened and shoulder timber are placed supported by inclined struts from the sill.

5. English Method

- This method involves the use of lot of timber.
- The distinctive characteristics of the method are the excavation of full section of the tunnel at once and alternate masonary work.
- Masonary lining is built in one piece from foundation to the crown making possible strong homogeneous construction

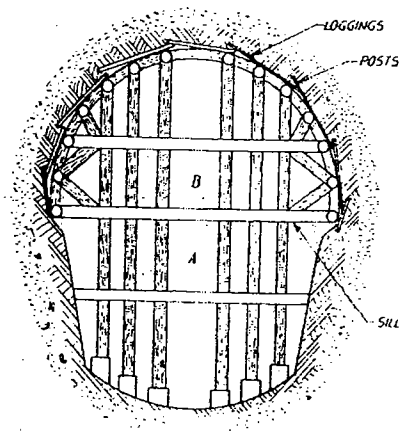
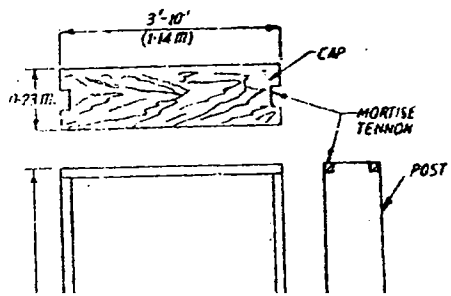


Fig. English Method

6. Army Method

- It is useful method for driving small tunnels through soft but not runnig ground.
- This method is mainly used for laying underground sewers.



7. German Method

- German method consists in excavating first a gallery in side walls roof arch is then excavated, before taking out the centre drift.
- This method employs 3 drifts.

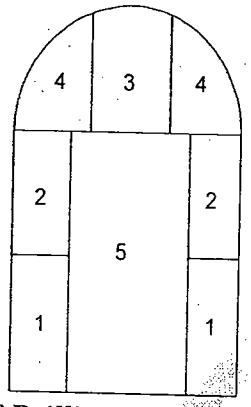


Fig. Sequence of Drilling in German Method

B. Other Methods

1. Linear Plate Method

- Pressed steel plates are used to support the soil, during excavation of short length.
- The standard size of the plate is 0.91 mx 0.41m.
- The corrugated plates have high section modulous can be used for the larger tunnels without the ribs.

2. Shield Method

- A shield is a movable frame which supports the face of a tunnel and the ground immediately behind the face and provides protection under which the tunnelling is carried out.
- The components of shield are

  (i) The skin (ii) Cutting edge (iii) Propelling Jack

  (iv) The port holes (v) The fuel

3. Compressed air Tunnelling :

- The recent method of tunneling using compressed air is very usefull in many soft and water

- The air pressure required to force back the perlocating water or water mixed soil and keep the tunnel dry varies with the nature of ground and the depth of the cover.

Hauling of Muck

- Mucking and Hauling refers to the operation of loading and removing excavated or hosted materials and dumping it at predetermined site.
- Methods of mucking are
  (a) Mucking by hand
  (b) Mucking by machine
- Necessities of Mucking are
  1. To Make enough room for a machine to work
  2. The final cleaning of bottom of tunnel before placing inverts.

Self Mucking

- Where gradient of tunnel is 1 in 50 or steeper, attempts are made to make such tunnels of self mucking by providing inclination of 40° or more to the horizontal.
- This method is more commonly used in full face method.

Car Changers

- One of the most important operations to assure rapid transportation and a minimum loss of time is efficient changes for cars.
- Muck removal from the tunnel is called tunnel haulage.
- Muck is hauled from the tunnel in narrow guage muck cars, pulled by locomotive or by trucks.

Ventilation and Lighting

Requirements of a ventilation system

A tunnel ventilating system must fulfill the followoing major requirements.

i) The fume from blasting must be cleared quickly from the working face so that work can be resumed after blasting without delay.

ii) It must prevent accumulation of dangerous concentration of fumes any where along the length of the tunnel.

iii) It should reduce to safe limits the dust produced by the tunnel operations.

Blowing

- In blowing method fresh air is blown by blower fans mounted in one or more input shafts.
- This method is not employed for tunnel more than few hundred meters long.

Exhausting

- This method involves extraction of the vitiated air from the tunnel by means of one or more exhaust fans.
- Fresh air being drawn into the tunnel via its portals or thorugh inlet shaft.

Combination of blowing and exhausting

- The most efficient ventilation sytem relies upon combination of blower and exhaust fans, operation through suitably placed in let and out shafts.
- Soon after blasting exhaust system is used to drop smoke and gases and rest of the time it is reversed and supplies fresh air alongwith blowing system.

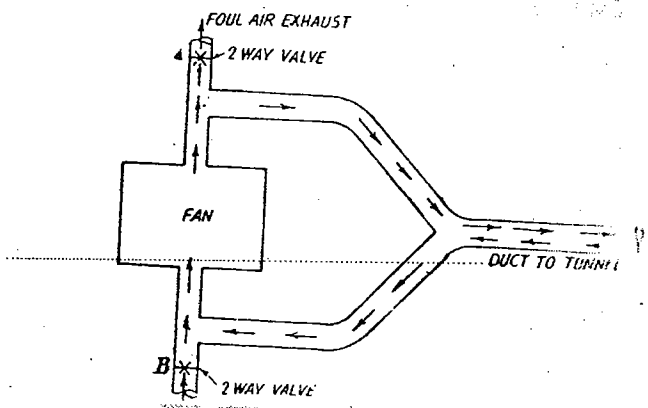


Fig. Combination fo blow-in and blow out

Lighting

- In tunnelling operation activities can't be carried out effectively if the lighting is bad.
- A light intensity of 260 lumens per square meter in the working area is considered satisfactory.

3. Match **List-I** (Shape of tunnel) with **List-II** (attribute for preference) and select the correct answer using the code given below

List-I	**List-II**
A. Horse shoe section	1. Give self cleansing velocity even in dry wheather
B. Circular	2. Suitable for soft rocks
C. Egg shaped	3. Best suited for non cohesive soils
D. Segmental roof section	4. Suitable for soft materials
	5. Suitable for sub ways

Codes :

	A	B	C	D
(a)	2	3	4	5
(b)	5	4	1	3
(c)	3	2	4	1
(d)	2	3	1	5

4. Which one of the following is a component of a shield for tunneling?
(a) Linear plate (b) Trench jack (c) Stiffener (d) Cutting edge

5. Which of the following method of tunneling is used in hard rocks
(a) Fore poling method (b) Needle beam method
(c) Heading and Benching method (d) Shield tunnelling method

6. Tunnel alignment is carried out by
(a) surface theodolite traverser (b) triangulation
(c) compass traverser (d) aerial photography

7. With reference to tunnelling, which of the following factors are to be considered for deciding the size of the shaft?
1. System used for hoisting
2. Size of muck car
3. Quantity of muck to be lifted
4. Eventual use of the muck

C. Drift method
D. Compressed air method

3. Simultaneous drilling and mucking is possible
4. Tunnelling is continuous.

Codes :

	A	B	C	D
(a)	4	3	2	1
(b)	3	4	1	2
(c)	4	3	1	2
(d)	3	4	2	1

10. A mucking operation is to be carried out by hauling truck of 6 m^3 capacity. Further

1. Volume of muck per blast = 60 m^3
2. Time alloted for mucking = 60 min, with operating efficiency of 50 min. per hour.
3. Effective cycle time of houling car = 25 min.

What is number of houling trucks required for mucking?

(a) 3 (b) 4 (c) 5 (d) 6

11. Which one of the following method is generally considered the best for tunnel ventilation?

(a) Driving a drift through tunnel
(b) Blow in method
(c) Blow out method
(d) Combination of Blow in and Blow out methods

12. Which one of the following methods of tunnelling is employed if the strata is sub aqueous?

(a) Shield tunnelling (b) Drift system
(c) Linear plate method (d) Compressed air method

13. Weisbach triangle method is used for which one of the following purpose?

(a) To carry out surface alignment of a tunnel
(b) To transfer levels under ground for a tunnel
(c) To connect surface and underground tunnel surveys
(d) To connect two ends of under ground tunnel

14. How can additional access, quick removal of muck and natural ventilation in long tunnels be

16. Which of the following statements are correct about horse shoe section of tunnel construction?

1. If is suitable only for soft rocks
2. Best suited for traffic purposes
3. Used in subways
4. The perimeter is less than that of circular

(a) Only 1 and 2 (b) Only 3 and 4 (c) Only 1, 2 and 3 (d) All of these

17. Shaft can be used for which of the following purposes?

1. To Provide ventilation
2. To Provide opening for removal of the excavated materials
3. To Pumpout the water from tunnel

(a) only 1 and 2 (b) only 2 and 3 (c) only 1 and 3 (d) all of these

18. Which of the following drill is capable of drilling from vertically down ward to upwards?

(a) Fusion piercing (b) Shot drill
(c) Diamond abrasion drill (d) Percussion drill

19. Whic of the foollowing method of tunnel construction in soft grounds is used in highways and railways?

(a) Needle Beam method (b) English method
(c) American method (d) Forepoling method

20. Match **List-I** with **List-II**, using the codes given below :

List-I	**List-II**
A. Full face method	1. For tunnelling large cross sectional area through soft ground driving a top drift and then widening the sides.
B. Heading and Bench method	2. Rock tunnelling carried out first in smaller cross section then widened.
C. Drift method	3. For driving the top portion in advance of the bottom portion for very large tunnel cross section in unstable rocks.
D. American method	4. For tunnelling of small cross sectional area in stable

(b) Both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

21. Asertion (A) : Open cut is economical than tunnelling for depth of over burden less than 20 meters.

Reason (R) : Heading and Bench method is suitable for tunnelling in soft soils.

22. Asertion (A) : The most efficient ventilation system relies upon a combination of blower and exhaust fans.

Reason (R) : Exhaust system is used to drop smoke and gases and blower is used to blow fresh air in the tunnel.

23. Asertion (A) : Compressed air tunnelling is useful in many softs and water bearing soils.

Reason (R) : Air pressure force back the percolating water or water mixed soil and keep the tunnel dry.

ANSWER

1. (d)	**2.** (a)	**3.** (d)	**4.** (d)	**5.** (c)
6. (b)	**7.** (d)	**8.** (b)	**9.** (c)	**10.** (c)
11. (d)	**12.** (d)	**13.** (d)	**14.** (c)	**15.** (a)
16. (a)	**17.** (d)	**18.** (c)	**19.** (c)	**20.** (b)
21. (c)	**22.** (a)	**23.** (a)		

EXPLANATIONS

1.(d) In full face method of tunnel construction whole section is attacked at the same time i.e. excavation is done along the perimeter.

2.(a) In segmental roof section roof is segment of circle, sides are vertical with flat floor. This cross section is commonly used in subways or navigation tunnels.

4.(d) Componens of shield are

1) The skin
2) Cutting edge
3) Propelling jacks
4) The hood
5) The tail
6) Port holes

5.(c) Methods of tunnelling in rocks

i) Full face method
ii) Drift Method
iii) Heading and Bench method

6.(b) The centre line of tunnel on the ground [alignment of tunnel] is located by means of triangulation with the help of micro meter and transit theodolite.

8.(b) Compressed air method is used for constructing tunnel in soft ground and water bearing stratum.

10.(c) Capacity of truck = 6 m^3

Volume houlded by one truck in one cycle

$= 6\ m^3$

In 2 cycle $= 12\ m^3$

Volume of muck

$= 60\ m^3$

No. of truck required

$$= \frac{60}{12} = 5$$

11.(d) In combination of Blowing and Exhausting method of ventilation, Exhaust system is used to drop smoke and gases and blower is used to blow of fresh air in the tunnel. Thats why it is considered better than any other system of ventilation.

14.(c) Shaft and adits can be used to remove muck and provide natural ventilation.

15.(a) In quick sands or other materials without cohesion, the pressure will be normal to the line of profile, requiring curve all round and circular section is one best suited to them.

16.(a) Segmental roof section section is used in the subways.

The perimeter of horse shoe section is more than the perimeter of circular section.

18.(c) Diamond Abrasion drills can drill in any