44th BCS Question Solution

Structure

1. a) Determine the maximum deflection of the steel beam shown in fig. Given E = 200 GPa, I = 60 × 10^6 mm^4.

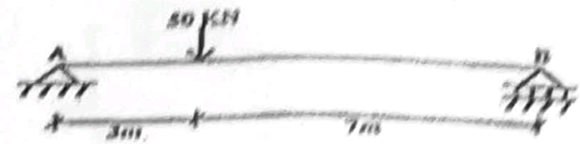
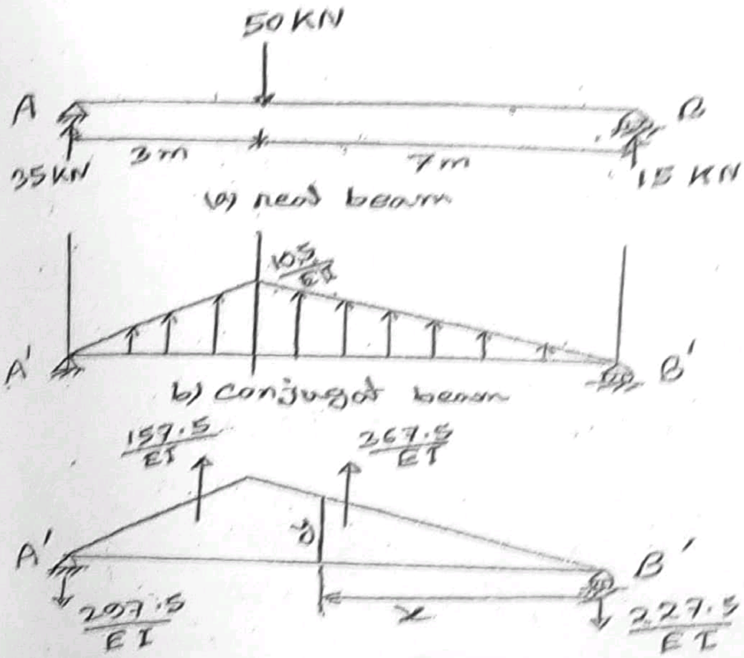


Fig. 1(a)

Solution:



$\Sigma M_{A'} = 0$

$\Rightarrow \frac{157.5}{EI} \times \frac{2}{3} \times 3 + \frac{367.5}{EI} \times (3 + \frac{7}{3}) - R_{B'} \times 10 = 0$

$\Rightarrow R_{B'} = \frac{227.5}{EI}$

$\therefore R_{A'} = \frac{297.5}{EI}$

Consider maximum moment at a distance x from B.

Shear at x distance from B.

$-\frac{227.5}{EI} + \frac{1}{2} \times \frac{15x}{EI} \times x = 0$

$x = 5.51$ m

$\Delta_{max} = -\frac{227.5}{EI} \times 5.51 + \frac{1}{2} \times \frac{15 \times 5.51}{EI} \times 5.51 \times \frac{5.51}{2}$

$$= -\frac{835.31\ KN\text{-}m3}{EI}$$

$$= -\frac{835.31 \times 10^{3}\ KN\text{-}mm3}{200\frac{KN}{mm2} \times 60 \times 10^{6} mm4}$$

= - 69.61 mm (deflection is downward) (**Ans**)

b) Determine the vertical displacement of joint C of the truss shown in fig. Take, A = 250 mm² and E = 200 GPa for each member.

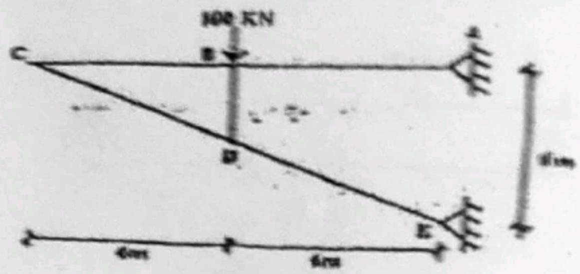
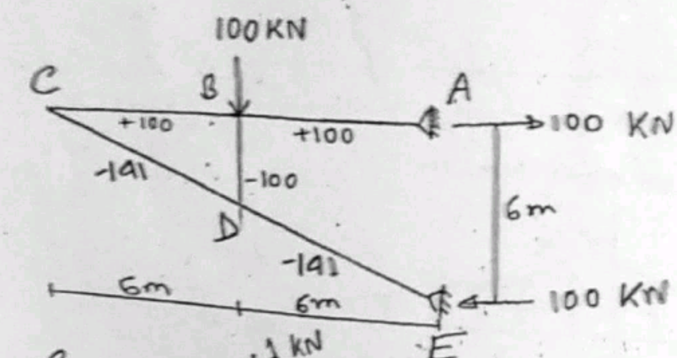
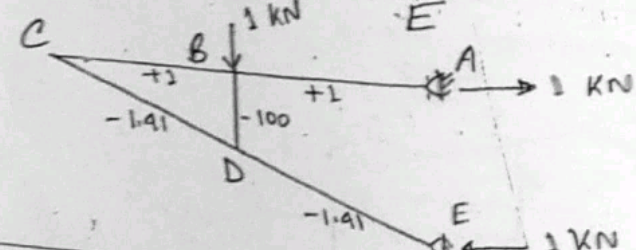


Fig. 1(b)

Solution:





Member	Length, L	n_o	n_1	$n_o n_1 L$
AB	6	+ 100	1	600
BC	6	+ 100	1	600
BD	3	-100	-1	300
CD	6.71	-141	-1.41	1334
DE	6.71	-141	-1.41	1334
				Total = 4168

Deflection at E = $\sum \frac{n_o n_1 L}{AE}$

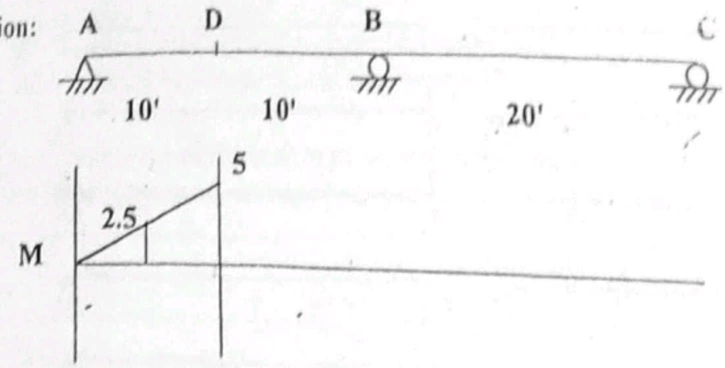
$$= \frac{4168 \times 1000 \times 1000}{250 \times 200 \times 1000}$$

= 83.36 mm (Ans)

2. a) Page no. 32 (same as)

b) Draw influence line diagram for (+ve) moment at D of the continuous beam shown in fig. Take influence line ordinates at 5 ft intervals.

Solution:



3. a) Page no. 28

b) **i) Conjugate beam method:**

The conjugate-beam methods is an engineering method to derive the slope and displacement of a beam. A conjugate beam is defined as an imaginary beam with the same dimensions (length) as that of the original beam but load at any point on the conjugate beam is equal to the bending moment at that point divided by EI.

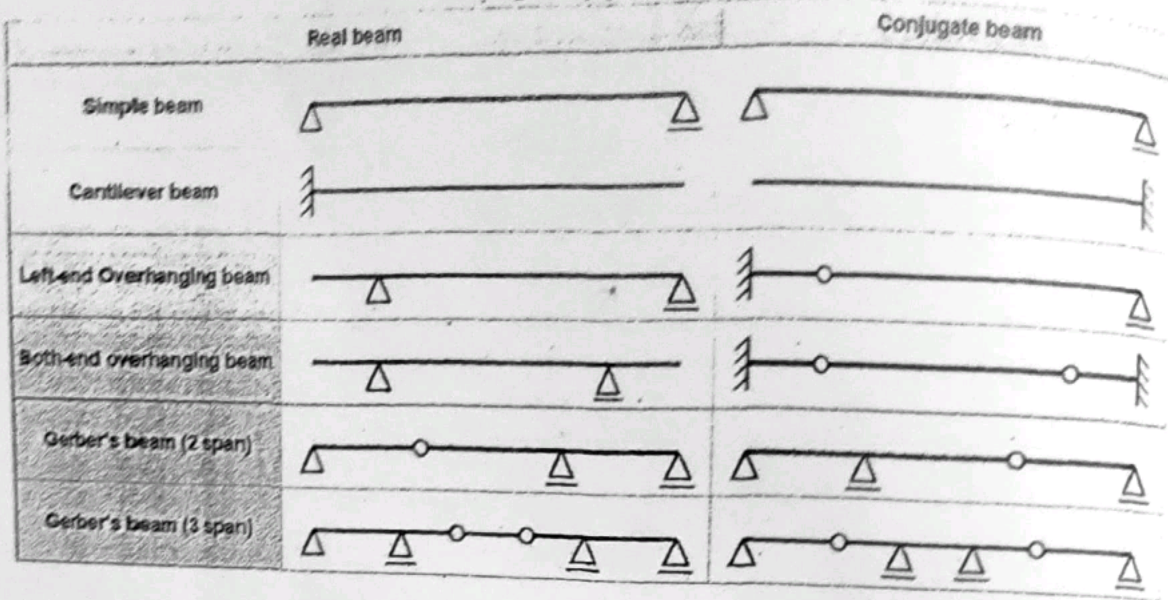
Relationships between real beam and conjugate beam:

1) Span of the conjugate beam is equal to the real beam.
2) Load at any point on the conjugate beam is equal to the bending moment at that point divided by EI.
3) The slope at a point in the real beam is numerically equal to the shear at the corresponding point in the conjugate beam.
4) The displacement of a point in the real beam is numerically equal to the moment at the corresponding point in the conjugate beam.

Real support vs Conjugate support

Real beam	Conjugate beam
Fixed support: $v = 0$, $\theta = 0$	**Free end**: $\overline{M} = 0$, $\overline{Q} = 0$
Free end: $v \neq 0$, $\theta \neq 0$	**Fixed support**: $\overline{M} \neq 0$, $\overline{Q} \neq 0$
Hinged support: $v = 0$, $\theta \neq 0$	**Hinged support**: $\overline{M} = 0$, $\overline{Q} \neq 0$
Middle support: $v = 0$, θ:continue	**Middle hinge**: $\overline{M} = 0$, $\overline{Q}$:continue
Middle hinge: v:continue, θ:discontinue	**Middle support**: $\overline{M}$:continue, $\overline{Q}$:discontinue

Examples of conjugate beam



ii) Virtual work method:

The virtual work method, also referred to as the method of virtual force or unit-load method, uses the law of conservation of energy to obtain the deflection and slope at a point in a structure.

To illustrate the principle of virtual work, consider the deformable body shown in Figure. First, applying a virtual or fictitious unit load $P_V = 1$ at a point Q, where the deflection parallel to the applied load is desired, will create an internal virtual or imaginary load f and will cause point Q to displace by a certain small amount. Then, placing the real external loads P_1, P_2, and M on the same body will cause an internal deformation, dS, and an external deflection of point Q to Q′ by an amount Δ.

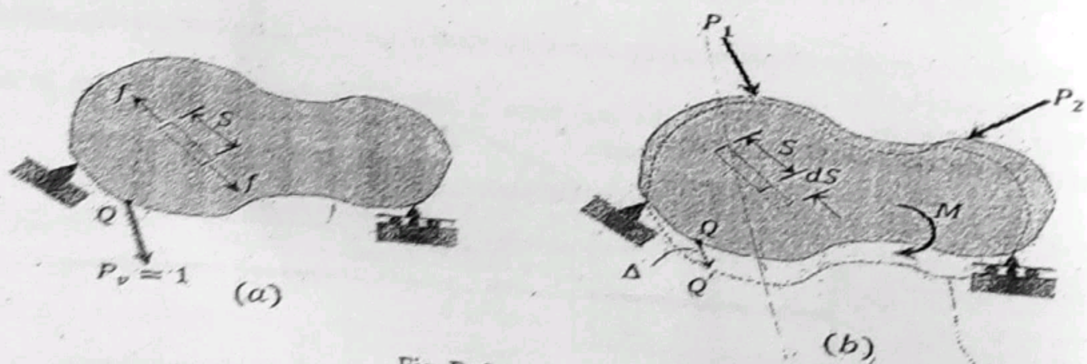


Fig. Deformable body.

Upon placement of the real load, the point of application of the virtual load also displaces by Δ, and the applied unit load performs work by traveling the distance Δ. The work done by the virtual forces are as follows:

External work done by the unit load $P_V = P_v \times \text{Displacement} = 1 \times \Delta$ (8.1)

Internal work done by the virtual load $f = f \times dS$ (8.2)

Applying the principle of conservation of energy by equating equation 8.1 and equation 8.2 suggests the following:

External work done = Internal work done

Virtual Loads

$$1 \times \Delta = f \times dS \quad (8.3)$$

Real displacements

Where,

- $P_V = 1$ = external virtual unit load
- f = internal virtual load.
- Δ = external displacement caused by real loads.
- dS = internal deformation caused by real loads.

Similarly, to obtain the slope at a point on a structure, apply a unit virtual moment M_V at the specified point where the slope is desired, and apply the following equation derived via the principle of conservation of energy:

Virtual Loads

$$1 \times \theta = f_\theta \times dS \quad (8.4)$$

Real displacements

Where,

- $M_V = 1$ = external virtual unit moment.
- f = internal virtual load.
- θ = external rotational displacement caused by real loads.
- dS = internal deformation caused by real loads.

Water Resources Engineering

4. a) Page no. 219
   b) Page no. 259
5. a) Page no. 226, 246 & 254
   b) The culturable command area of a watercourse is 1200 hectares. Intensities of sugarcane and wheat crops are 20% and 40% respectively. The duties for the crop at the head of the watercourse are 730 hec/cumec and 1800 hec/cumec respectively. Find (i) discharge required at the head of the watercourse; and (ii) the design discharge at the outlet assuming a time factor of 0.8.

Solution: C.C.A. = 1200 hectares

Area to be irrigated under sugarcane = C.C.A. x Intensity of irrigation

$$= 1200 \times \frac{20}{100} = 240 \text{ hectares.}$$

Area to be irrigated under wheat $= 1200 \times \frac{40}{100} = 480$ hectares.

Discharge required for sugarcane $= \frac{240}{730} = 0.329$ cumec

Discharge required for wheat $= \frac{480}{1800} = 0.271$ cumec

i) The required discharge is summation of the two, i.e. $= 0.329 + 0.271 = 0.6$ cumec **(ans)**

ii) The design discharge at the outlet $= \frac{0.6}{0.8} = 0.75$ cumec **(ans)**

6. Page no. 262 (same as)

7. a) Page no. 367
   b) Page no. 408

8. a) i) **Super chlorination:**

Super chlorination, also known as hyper chlorination, temporarily increases the free chlorine residual in a water distribution system. A high free chlorine residual (i.e. above 5 mg/L) is effective against most bacteria (including Legionella) and can be used in hot, warm and cold water distribution systems, although in hot water systems chlorine degrades rapidly.

In practice, super chlorination is best applied to cold water systems while thermal treatment is preferable for hot water systems.

ii) **Pump characteristic curve:**

The pump characteristic curves can be defined as 'the graphical representation of a particular pump's behavior and performance under different operating conditions'. The head is plotted on the vertical axis and the flow rate or discharge on the horizontal axis.

The operating properties of a pump are established by the geometry and dimensions of the pump's impeller and casing. Curves relating total head, efficiency, power, and net positive suction head required (NPSHR) to discharge or pump capacity (Q) are utilized to describe the operating properties (characteristics) of a pump. This set of four curves is known as the pump characteristic curves or pump performance curves.

Classification of Pump Characteristic Curves:

Pump characteristics curves can be classified into four groups: (i) Main characteristic curves, (ii) Operating characteristic curves, (iii) Constant efficiency curves, and (iv) Constant head and constant discharge curves.

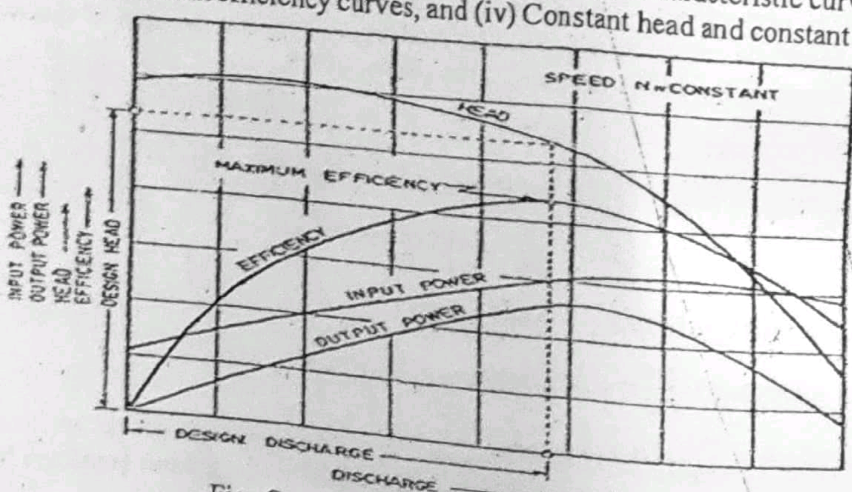


Fig: Operating characteristic curves

iii) Page no. 354

iv) **DO sag curve:**

The curve obtained when the concentration of dissolved oxygen in a river into which sewage or some other pollutant has been discharged is plotted against the distance downstream from the sewage outlet. The Oxygen Sag Curve represents the various levels for BOD (Biological Oxygen Demand), which is the total demand for oxygen by all the individuals in that particular area. It also includes DO (Dissolved

Oxygen) or the amount of available oxygen in the water. Certain organisms can survive at higher or lower DO levels. When pollutants (waste or excess fertilizer) enter the water, BOD and DO levels change, producing the oxygen sag curve.

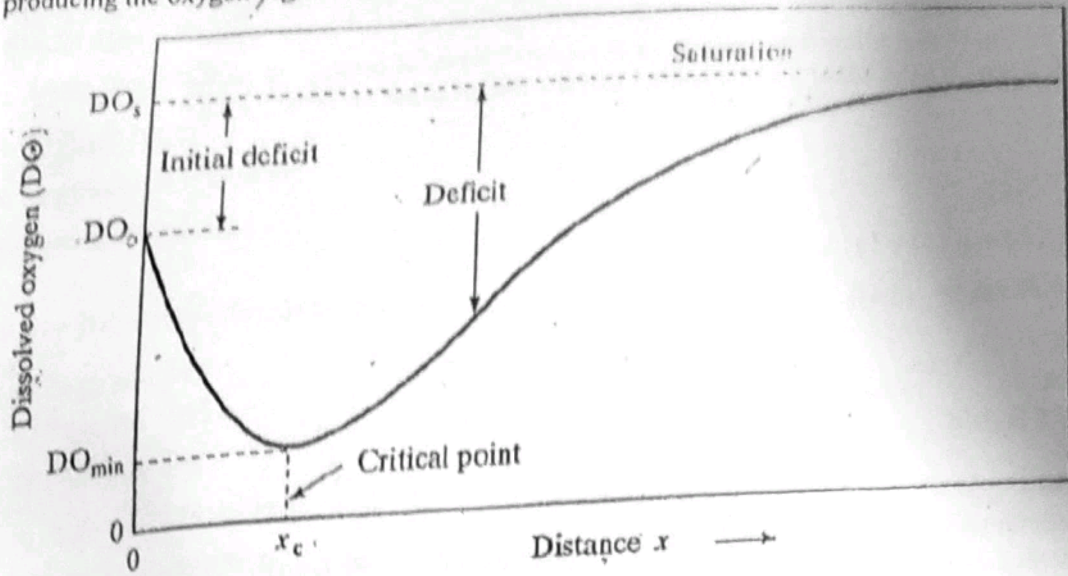


Fig: DO sag curve

v) Artesian aquifer:

An artesian aquifer is an underground layer which holds groundwater under pressure. This causes the water level in the well to rise to a point where the pressure is equal to the weight of water putting it under pressure. This type of well is called an artesian well. Water may even reach the ground surface if the natural pressure is high enough, in which case the well is called a flowing artesian well.

b) Page no. 365

9. a) Page no. 376
   b) Page no. 398

RCC

10. a) i) Page no. 64
   ii) Page no. 68
   iii) Page no. 83
   b) Page no. 48 (same as)

11. a) Page no. 80
   b) Page no. 84
   c) Page no. 116

12. a) Page no. 117
   b) Page no. 121.(same as)

13. a) Page no. 293
    b) Page no. 274
    c) Calculate the maximum allowable speed on a horizontal curve of radius 350 m if the maximum allowable value of lateral coefficient of friction is 0.15 and the rate of super elevation is 0.07.

Solution:

$$e + \mu = \frac{V_a^2}{127R}$$

$$\Rightarrow V_a^2 = (0.07 + 0.15) \times 127 \times 350$$

$$\Rightarrow V_a = 98.89 \text{ km/hr} \quad \textbf{(Ans)}$$

14. a) Page no. 305
    b) Page no. 292
    c) Page no. 280 & 344

15. a) Page no. 346
    b) Name of methods to design the thickness of flexible pavement are given below:
       i. Empirical methods
       ii. Semi-empirical methods
       iii. Analytical or mathematical methods.
       iv. Mechanistic-empirical methods.

    c) Page no. 344

Foundation Engineering

16. a) Page no. 137
    b)

17. a) Page no. 155
    b) Page no. 137
    c) Page no. 165
18. a) Page no. 148
    b) Page no. 176
    c)

Structure:

1. a) Page no. 28 (same as)
   b) Page no. 63
2. Page no. 16 (same as)
3. Page no. 22 (same as)

Water Resources Engineering:

4. a) Page no. 219
   b) Page no. 245
   c) Page no. 259

5. a) Page no. 229 & 230
   b) Flood management: Flood management aims to reduce the human and socio-economic losses caused by flooding and is part of the larger field of risk management.

Options:

- ⇨ Construction of Dams and Reservoirs.
- ⇨ Construction of embankment.
- ⇨ Redirecting the excess water to canals and floodways.
- ⇨ Excess water can be used for groundwater replenishment.
- ⇨ The self-closing flood barrier (SCFB) is a flood defense system designed to protect people and property from inland waterway floods caused by heavy rainfall, gales or rapid melting snow.
- ⇨ Having a planned disaster preparedness plan and an integrated solution and approach.

6. a) Page no. 215
   b) Solution:

Mean depth, $D = \frac{1.9+1.8+1.5+1.4+1.3+1.2}{6} = 1.52$ m

mean deviation, $d = \frac{(1.9-1.52)+(1.8-1.52)+(1.52-.5)+(1.52-1.4)+(1.52-.3)+(1.52-.2)}{6} = 0.223$ m

The water distribution efficiency, $\eta_d = (1-\frac{d}{D}) = (1-\frac{0.223}{1.52}) = 0.853$ (Ans.)

c) i) Water storage efficiency: It is the ratio of the water stored in the root urns during irrigation to the water needed in the root zone prior to irrigation (i.e. field capacity - existing moisture content). It may be represented by η_s.

ii) Page no. 248
iii) Page no. 216

Environmental Engineering:

7. a) Page no. 375

b) Solution: Note: $Q = VA$

$$\Rightarrow 70 = 3 \times \frac{\pi d^2}{4}$$

$$\Rightarrow d = 5.45 \text{ m (ans)}$$

8. a) Slow Sand Filtration (SSF): In slow sand filtration, water is allowed to pass through a bed of fine sand which retains most of the impurities present in water. It is suitable for the development of a surface water based water supply system in developing countries. The main purposes of slow sand filter are to:

- reduce the number of micro- organisms present the water;
- Retain fine organic and inorganic solid matters;
- Oxidize organic compounds dissolved in water.

Characteristics: The important characteristics of SSF are as follows:

- rate of filtration is low, 0.1 – 0.3 m^3 per m^2 per hr;
- very high removal of turbidity and colour, (80-85%) and bacteria (95-99.9%);
- cleaning of filter bed by scraping and removal of a top layer of sand;
- no pre-treatment is generally required;
- not suitable for water having turbidity greater than 30 NTU;
- not very effective in removing colloidal matters;
- low-cost of operation and maintenance.

Rapid sand filtration (RSF)

In rapid sand filtration, the filtration rate is higher as compared to SSF due to the use of larger and relatively uniform size sand particles as filter medium. The filter beds usually include a coarse sand layer about 1 m thick laid on top with a layer of graded gravel about 0.5 m thick. The gravel is under laid by an under drainage system. There are several applications of RSF for the treatment of water for public water supplies.

Characteristics: The major characteristics of RSF are as follows:

- high filtration rate about 5-15 m^3 per m^2 per hour;
- high removal of turbidity and colour (80-85%) and bacteria (85-95%);
- cleaning of filter bed by backwashing;
- pre-treatment such as coagulation, flocculation and sedimentation at required;
- suitable for all types of turbid and coloured water;
- relatively high cost of operation and maintenance;

The high filtration rate is achieved by using coarse sand with an effective size i the range of 0.4-1.2 mm. The RSF can be both gravity type and pressure type.

b) Page no. 396

9. a) Page no. 365 & 393

b) Solution:

Effluent flow from septic tank = 90 x 10 = 900 l/day

long-term infiltration rate = 30 l/m² day

infiltration area required = Q/I = 900/30 = 30 m^2

assuming a 1.25 m diameter, the effective depth of the soak pit will be $= \frac{30}{\pi \times 1.25} = 7.6$ m

However, if the ground water table is high, two soak pits each of 1.25 m dia and 4.0 m deep may be provided. Alternatively, if sufficient land area is available, drain-field trenches can also be designed for the disposal of septic tank.

RCC:

10. a) Page no. 64

b) Page no. 117 (same as)

11. a) Page no. 68

b) Page no. 123 (same as)

12. Page no. 126

Transportation Engineering:

13. a) Factors: Highway geometrics are greatly affected by so many factors. The important factor being the following:

1. Topography
2. Design speed
3. Traffic factors
4. Volume and capacity factors
5. Environmental and other factors

1. Topography: Topography of the area significantly affects the geometric design of highways. The area under consideration may be plain, rolling, mountainous and steep. The design standards for different classes of roads are different for different areas classification. In hilly terrain it is necessary to allow for steeper gradients and sharper horizontal curves.

2. Design speed: It is the most important factor controlling the geometric design elements of highways. It is decided taking into account the overall requirement of the highway. Different speed standards are assigned for different class of the road. Further terrain and topography also influence the design speed standards. Design of almost every geometric design element of a road is dependent on the design speed. Road width, clearance requirement, sight distance, radius of horizontal curves, Super-elevation, gradient etc. are all affected by design speed.

3. Traffic factors: Vehicular characteristic and human characteristic of road users also affect geometric standards of any road. It is very difficult to standardise traffic flow condition. Cars, buses, trucks, motor cycles all have different speed and acceleration characteristics. Physical, mental and psychological characteristics of drivers and pedestrians also affect traffic behaviour.

4. Volume and capacity factors: The road way facility is not designed for the peak traffic flow but for slightly lower values. Hence a reasonable value of traffic volume is decided by multiplying the peak flow with a factor. The ratio of volume to capacity affects the level of service of the road

5. Environmental and other factors: Landscaping, noise, air pollution and aesthetic conditions also affect road geometries. Some important roads such as express way are designed for higher speed standards. In order to maintain uninterrupted flow of traffic road ways may be provided grade separated intersections and controlled access.

b)
c) Page no. 346

14. a) Page no. 319
b) Major resistance:
1) Resistance due to friction and wave action.
2) Resistance due to curve.
3) Resistance due to gradients.
4) Resistance due to speed of the train.

Minor resistance:
1) Resistance offered by various internal parts of the locomotive itself,
2) Inertia resistance especially during starting, and
3) Brake resistance as brakes consume power during their use.

15. a) Page no. 285 & 286
b) Page no. 283
c) Page no. 310

Foundation Engineering:

16. a) Page no. 189
Assumptions:

- The base of footing is rough.
- The footing is laid at a shallow depth, i.e. $D_f \leq B$.
- The shear strength of the soil above the base of the footing is neglected. The soil above the base is replaced by a uniform surcharge γD_f.
- The load on the footing is vertical and is uniformly distributed.
- The footing is long i.e. L/B ratio is infinite, where B is the width and L is the length of the footing.
- The shear strength of the soil is governed by the Mohr-coulomb equation.

b) Page no. 136

17. a) Page no. 133

b) Page no. 163

c) i) Page no. 153 & 155

ii) Page no. 152

iii) Page no. 153 & 165

18. a) Page no. 144 & 175

b) <u>Solution:</u>

Given, Ws = 690 gm; w = 18 %; G_s = 2.7; G_w = 0.89

$W_w = 697.5 - 690 = 7.5$ gm

For wax, $\gamma_b = \frac{W}{V} = G_w \gamma_w$

$\Rightarrow V_w = \frac{7.5}{0.89 \times 1} = 8.43 \text{ cm}^3$

$Vs = 355 - 8.43 = 346.57 \text{ cm}^3$

For soil, $\gamma_b = \frac{Ws}{Vs} = \frac{690}{346.57} = 2 \text{ gm/cm}^3$ **(Ans.)**

$\gamma_d = \frac{\gamma_b}{1+w} = \frac{2}{1+0.18} = 1.69 \text{ gm/cm}^3$ **(Ans.)**

we know, $\gamma_d = \frac{G_s \gamma_w}{1+e}$

$\Rightarrow 1.69 = \frac{2.7 \times 1}{1+e}$

$\Rightarrow e = 0.6$ **(Ans.)**

and, $S\,e = w\,G_s$

$\Rightarrow S = \frac{2.7 \times 0.18}{0.6}$

$= 0.81 = 81\%$ **(Ans.)**