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Detailed Solutions

ESE-2024 Mains Test Series

Civil Engineering Test No : 8

Q.1 (a) Solution:

(i)

$$\text{Area, } A = 0.06 \text{ ha} = 600 \text{ m}^2$$

$$Q = 0.025 \text{ m}^3/\text{sec} = 90 \text{ m}^3/\text{hr}$$

$$\text{Infilteration capacity, } f = 6 \text{ cm/hr} = 0.06 \text{ m/hr}$$

$$\text{Average depth of flow, } y = 10 \text{ cm} = 0.1 \text{ m}$$

Now, time required,
$$t = \frac{y}{f}\ln\left(\frac{Q}{Q-fA}\right) = \frac{0.1}{0.06}\ln\left(\frac{90}{90-0.06\times 600}\right)$$

$$= 0.85 \text{ hr} \simeq 51 \text{ minutes.}$$

Maximum area that can be irrigated,
$$A_{max} = \frac{Q}{f}$$

$$= \frac{90}{0.06} = 1500 \text{ m}^2 = 0.15 \text{ hectares}$$

(ii)

$$\text{Discharge, } Q = 60 \text{ m}^3/\text{sec}$$

As per Lacey's theory,

$$\text{Silt factor, } f = 1.13$$

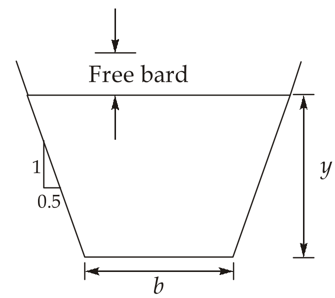
$$\text{Velocity, } V = \left(\frac{Qf^2}{140}\right)^{1/6} = \left(\frac{60\times 1.13^2}{140}\right)^{1/6} = 0.90 \text{ m/sec}$$

$$\text{Area, } A = \frac{Q}{V} = \frac{60}{0.90} = 66.67 \text{ m}^2$$

$$\text{Hydraulic mean depth, } R = \frac{5}{2}\left(\frac{V^2}{f}\right) = \frac{5}{2}\times\frac{(0.90)^2}{1.13} = 1.79 \text{ m}$$

$$\text{Wetted perimeter, } P = 4.75\sqrt{Q} = 4.75\sqrt{60} = 36.79 \text{ m}$$

For a trapezoidal channel with $\frac{1}{2}H:1$ V slopes



$$\text{Perimeter, } P = b+\sqrt{5}.y$$

$$\text{Area, } A = \left(b+\frac{y}{2}\right)y$$

$$\therefore \quad 36.79 = b+\sqrt{5}y$$

$$\text{and} \quad 66.67 = by + \frac{y^2}{2} \quad \ldots\text{(i)}$$

From equation (i) and (ii)

$$\Rightarrow \quad y = 2 \text{ m}$$

$$b = 32.3 \text{ m}$$

$$\text{Bed slope, } S = \frac{f^{\frac{5}{3}}}{3340Q^{\frac{1}{6}}} = \frac{(1.13)^{\frac{5}{3}}}{3340\times(60)^{\frac{1}{6}}} = \frac{1}{5390.65} \simeq 1 \text{ in } 5391$$

Hence, regime channel will have width of 30.1 m, depth of 2 m and a bed slope of 1 in 5391.

Q.1 (b) Solution:

Following preservatives are commonly used for the preservation of timber:

1. **AsCu Treatment :** AsCu is special preservative which was developed at the Forest Research Institute, Dehradun.

   1 Part by weight of hydrated arsenic pentoxide, ($As_2O_5.2H_2O$).

   3 Part by weight of blue vitriol or copper sulphate, ($CuSO_4.5H_2O$).

   4 Part by weight of potassium dichromate ($K_2Cr_2O_7$) or sodium dichromate ($Na_2Cr_2O_7.2H_2O$).

   This material is available in powder form. To prepare a solution of this material, six parts by weight of AsCu are mixed in 100 parts by weight of water.

   AsCu preservative gives timber protection against the attack of white ants. The surface treated with this preservative can be painted, polished, varnished or waxed.

2. **Chemical Salts** :These are water-borne preservatives and they are mostly salts dissolved in water. The usual salts used are copper sulphate, mercury chloride, sodium fluoride and zinc chloride. These preservatives are odourless and non-inflammable.
3. **Coal Tar:** The timber surface is coated with hot coal tar with the help of brush. The coal tar becomes workable when heated. This process is known as tarring. The coal tar has unpleasant smell and appearance. It makes timber unsuitable for painting. It is cheap and fire resistant.
4. **Creosote Oil:** In this case, timber surface is coated with creosote oil. The process is known as creosoting (Bathel's process). Creosote oil is obtained by the distillation of tar. Creosoting is carried out as follows:
   - Timber is thoroughly seasoned and dried.
   - It is then placed in an air tight chamber.
   - Air is pumped out from the chamber.
   - Creosote oil is then pumped under a high pressure of about 7 to 10 kg/cm^2 and at temperature of about 50°C.
   - After a period of about 1 to 2 hours, when timber has sufficiently absorbed creosote oil, it is taken out of chamber.
   - Creosote oil is one of the best antiseptic. It is a black or brown liquid, weakly affected by water, neither volatile nor hygroscopic, harmless to wood or metal, inflammable, with an unpleasant odour and having low wood-penetrating ability to the extent of 1 mm to 2 mm only.
   - Creosote oil should not be used for interior surfaces of dwelling houses, foodstuff-storage premises, in underground installations and near inflammable surfaces.
5. **Oil Paints:** The timber surface is coated with 2 or 3 coats of oil paint. It is to be noted that the wood should be seasoned, otherwise sap will remain confined and it will lead to the decay of timber. The oil paints preserve timber from moisture and makes it durable.
6. **Solignum Paints**: These paints preserve timber from white ants as they are highly toxic in nature. They can be mixed with colour pigment and applied in hot state with the help of brush. The timber surface may therefore be given the desired colour or appearance.

Q.1 (c) Solution:

(i) Lap length (in m) is given by

$$L = \left(0.02\sqrt{h^2 + Dh}\right) \text{ meters}$$

Where, h = Depth of wheel flange below rail top level in cm.

D = Diameter of wheel in cm.

Now, $$L = 0.02\sqrt{(3.2)^2 + 160 \times 3.2} = 0.457 \text{ m}$$

Now, extra widening width (in cm), W_e is given by -

$$W_e = \frac{13(B+L)^2}{R}$$

where, B = Wheel base (in m), L = Lap length (in m)
R = Radius of curve (in m)

$$\therefore \quad W_e = \frac{13(6+0.457)^2}{150} = 3.61 \text{ cm}$$

(ii) 1. **Dock:** The enclosed area provided for berthing ships to keep them afloat uniform level to facilitate loading and unloading is called the dock.

2. **Harbour:** The sheltered area of the sea in which vessels could be launched built or repaired, or could seek refuge during storm and provide loading and unloading facilities of cargo and passengers is called a harbour.
3. **Berth:** The space where cargo is unloaded or loaded into a vessel is known as berth.
4. **Dry dock:** Docks used for repair works of vessels are called dry docks.
5. **Littoral drift:** The exposed coasts are subjected to erosion at certain sections and siltation at some other sections due to wind and waves striking the shore. These waves tend to stir up and move the lighter particles of sand in suspension. The process of movement and deposition of sand near the fore shore is known as littoral drift.

Q.1 (d) Solution:

In hard rocks generally following methods are more common:

(i) Full face method. (ii) Heading and benching method
(iii) Drift method (iv) Pilot tunnel method

1. **Full face method:**

- This method is adopted for tunnel whose length is not more than 3 m. Large size tunnels in rocks are always driven by this method. With the development of drill carriage, this method is becoming more and more popular.
- This method is more suitable for tunnels having diameters less than 6 m and face area less than 19 m^2.

Advantages:

(i) It requires minimum equipment. Hence, it is simple in operation.
(ii) The magnitude of ground disturbance and settlement is minimum in this method.

2. **Heading and benching method:** The top portion is known as the heading and the bottom portion as bench usually. This method is adopted for railway tunnels. In this method of tunnelling, the top portion of heading will be about 3.70 to 9.6 m ahead of the bottom portion.

   Advantages:

   (i) In hard rock, the heading is bored first and the drill holes are driven for the bench or bottom portion at the same time as the removal of the muck.

   (ii) It requires less explosives than fully face method.

3. **Drift method:** Drift is a small tunnel, usually its size is 300 cm × 300 cm. In driving a large tunnel it has been found advantageous to drive a drift first through the full length or in a portion of the length of the tunnell prior to excavating the full bore.

   Advantages:

   (i) The drift assists in ventilating the tunnel during later operations.

   (ii) The quantity of explosive required is reduced.

4. **Pilot tunnel method:** In this method, usually two tunnels are to be driven (i) main tunnel and (ii) pilot tunnel. Actually this method is adopted to expedite the driving of the main tunnel. The cross-section of the pilot tunnel is usually 240 cm × 240 cm and driven parallel to the main tunnel. The pilot tunnel which is first driven to the full length is connected to the centre line of the main tunnel.

   Advantages:

   (i) The cross headings can be used for storing tools and materials during construction period.

   (ii) It is cheaper than central shaft method.

Q.1 (e) Solution:

(i)

Water conveyance efficiently,

$$\eta_c = \frac{\text{Water delivered to the fields}}{\text{Water supplied into the canal at the head}} \times 100 = \frac{120}{130} \times 100 = 92.30\%$$

(ii) Water application efficiency,

$$\eta_a = \frac{\text{Water stored in the root zone during irrigation}}{\text{Water delivered to the field}} \times 100$$

Water supplied to the field during 9 hours @ 120 litres per second

$$= \frac{120 \times 9 \times 60 \times 60}{1000} = 3888 \text{ m}^3$$

Run off loss in the field = 430 m^3

Deep percolation losses in the field = 100 m^3

$\therefore$ Water stored in the root zone = 3888 – 430 –100 = 3358 m^3

$\therefore$ Water application efficiency = $\frac{3358}{3888}\times 100 = 86.37\%$

(iii) Water storage efficiency,

$$\eta_s = \frac{\text{Water stored in the root zone during irrigation}}{\text{Water needed in the root zone prior to irrigation}}\times 100$$

Moisture holding capacity of soil

= 25 cm per m depth × 1.7 m depth of root zone = 42.5 cm

Moisture already available in root zone at the time of start of irrigation

$$= \frac{50}{100}\times 42.5 = 21.25 \text{ cm}$$

Additional water required in root zone = 42.5 – 21.25 = 21.25 cm

$$= \frac{21.25}{100}\times 1.8\times 10^4 = 3825\,\text{m}^3$$

But actual water stored in root zone = 3358 m^3

$\therefore$ Water storage efficiency (η_s) = $\frac{3358}{3825}\times 100 = 87.79\%$

(iv) Water distribution efficiency, $\eta_d = \left(1-\frac{d}{D}\right)$

where, D = mean depth of water stored in the root zone.

$$= \frac{1.7+1.2}{2} = 1.45 \text{ m}$$

Deviation from the mean at upper end (absolute value) = $|(1.7-1.45)| = 0.25$ cm

Deviation from the mean at lower end (absolute value) = $|(1.2-1.45)| = 0.25$ cm

d = average of the absolute values of deviations from mean = $\frac{0.25+0.25}{2} = 0.25$

$$\therefore \quad \eta_d = \left(1-\frac{0.25}{1.45}\right)\times 100\% = 82.76\%$$

Q.2 (a) Solution:

(i)

For M20 concrete, the following proportion is there.

$$W_c : W_s : W_a = 1 : 1.5 : 3$$

$$\text{Water-cement ratio, } \frac{W}{c} = 0.5$$

$$\text{Air Content} = 2\% \text{ by volume}$$

$$\text{Total volume of concrete} = 5 \text{ m}^3$$

$$G_c = 3.15, G_S = 2.6, G_a = 2.5$$

Now, net volume of concrete = Total volume – Volume of air in concrete

$$= 5 - \left[\frac{2}{100} \times 5\right] = 4.9 \text{ m}^3$$

Now, $4.9 = \text{Volume of water} + \text{Volume of solids}$

$$\Rightarrow \quad 4.9 = \frac{0.5 \times W_c}{1000} + \left[\frac{W_c}{G_C \times 1000} + \frac{W_s}{G_s \times 1000} + \frac{W_a}{Ga \times 1000}\right]$$

$$\Rightarrow \quad 4900 = 0.5W_c + \frac{W_c}{3.15} + \frac{1.5W_c}{2.6} + \frac{3W_c}{2.5}$$

$$4900 = 2.5944\, W_c$$

$$\Rightarrow \quad W_c = 1888.68 \text{ kg}$$

$$\therefore \quad W_s = 1.5\, W_c = 2833.02 \text{ kg}$$

$$W_a = 2\, W_c = 5666.08 \text{ kg}$$

$$\text{Volume of cement} = \frac{1888.68}{1500} = 1.26 \text{ m}^3$$

$$\text{Volume of sand} = \frac{2833.04}{1700} = 1.67 \text{ m}^3$$

$$\text{Volume of coarse aggregate} = \frac{5666.0862}{1600} = 3.54 \text{ m}^3$$

(ii)

Tests for stones: The building stones are to be tested for their different properties. Following are such tests for the stones:

1. **Acid test:** In this test, a sample of stone weighing about 0.50 to I N is placed in a solution of hydrochloric acid having strength of one per cent and it is kept there for seven days. The solution is agitated at intervals. A good building stone maintains its sharp edges and keeps its surface free from powder at the end of this period. If edges are broken and powder is formed on the surface, it indicates the presence of calcium carbonate and such a stone will have poor weathering quality. It is natural that this test cannot be applied to the limestones. This test is usually carried out on the sandstones.

2. **Attrition test:** This test is done to determine the rate of wear of stones which are used in road construction. The results of test indicate the resisting power of stones against the grinding action of traffic. The following procedure is adopted:
   (i) The sample of stone is broken into pieces of about 60 mm size.
   (ii) Such pieces, weighing 50 N, are put in both the cylinders of Dovel's attrition test machine. The diameter and length of cylinder are respectively 200 mm and 340 mm.
   (iii) The cylinders are closed. Their axes make an angle of 30° with the horizontal.
   (iv) The cylinders are rotated about horizontal axis for 5 hours at the rate of 30 rpm.
   (v) After this period, the contents are taken out from the cylinders and they are passed through a sieve of 1.50 mm mesh.
   (vi) The quantity of material which is retained on the sieve is weighed.
   (vii) The percentage wear is worked out as follows:

$$\text{Percentage wear} = \frac{\text{Loss in weight of stones}}{\text{Initial weight of stones}} \times 100$$

3. **Crushing test:** The compressive strength of stone is found out with the help of this test.

   The sample of stone is cut into cubes of size 40 mm x 40 mm x 40 mm. The sides of cubes are finely dressed and finished. The minimum number of specimens to be tested is three. Such specimens should be placed in water for about 72 hours prior to test and thereafter tested in saturated condition.

   The load-bearing surface is then covered with plaster of paris or 5 mm thick plywood. The load is applied axially on the cube in a crushing test machine. The rate of loading is 13.72 N/mm^2 per minute. The crushing strength of the stone per unit area is the maximum load at which its sample crushes or fails divided by the area of the bearing face of the specimen.

4. **Crystallisation test**: In this test, at least four cubes of stone with side as 40 mm are taken. They are dried for 72 hours and weighed. They are then immersed in 14 per cent solution of Na_2SO_4 for 2 hours. They are dried at 100°C and weighed. The difference in weight is noted. This procedure of drying. weighing, immersing and reweighing is repeated at least five times. Each time, the change in weight is noted and it is expressed as a percentage of original weight.

   It is to be noted that the crystallisation of $CaSO_4$ in pores of stone causes the decay of stone due to weathering. But, as $CaSO_4$ has low solubility in water, it is not adopted in this test.

5. **Freezing and thawing test:** The specimen of stone is kept immersed in water for 24 hours. It is then placed in a freezing mixture at -12°C for 24 hours. It is then thawed or warmed at atmospheric temperature. This should be done in shade to prevent any effect due to wind, sun rays, rain, etc. Such a procedure is repeated several times and behavior of stone is carefully observed.

6. **Hardness test:** To determine the hardness of a stone, the test is carried out as follows:
   (1) A cylinder of diameter 25 mm and height 25 mm is taken out from the sample of stone.
   (ii) It is weighed.
   (iii) It is placed in Dorry's testing machine and pressed with a pressure of 12.50 N.
   (iv) The annular steel disc of machine is then rotated at a speed of 28 rpm.
   (v) During the rotation of disc, the coarse sand of standard specification is sprinkled on the top of disc.
   (vi) After 1000 revolutions, the specimen is taken out and weighed.
   (vii) The coefficient of hardness is found out from the following equation:

$$\text{Coefficient of hardness} = 20 - \frac{\text{loss in weight in gm}}{3}$$

7. **Impact test**: To determine toughness of a stone, the impact test is carried out in impact machine as follows:
   (i) A cylinder of diameter 25 mm and height 25 mm is taken out from the sample of stone.
   (ii) It is placed on cast-iron anvil of machine.
   (iii) A steel hammer of weight 20 N is allowed to fall axially in a vertical direction over the specimen.
   (iv) The height of first blow is 1 cm; that of second blow is 2 cm; that of third blow is 3 cm; and so on.
   (v) The blow at which specimen breaks is noted. If it is nth blow, a represents the toughness index of stone.

8. **Microscopic test**: In this test, the sample of stone is subjected to the microscopic examination. The thin sections of stone are taken and placed under the microscope to study various properties such as:
   (i) average grain size;
   (ii) existence of pores, fissures, veins and shakes;
   (iii) mineral constituents;

(iv) nature of cementing material;

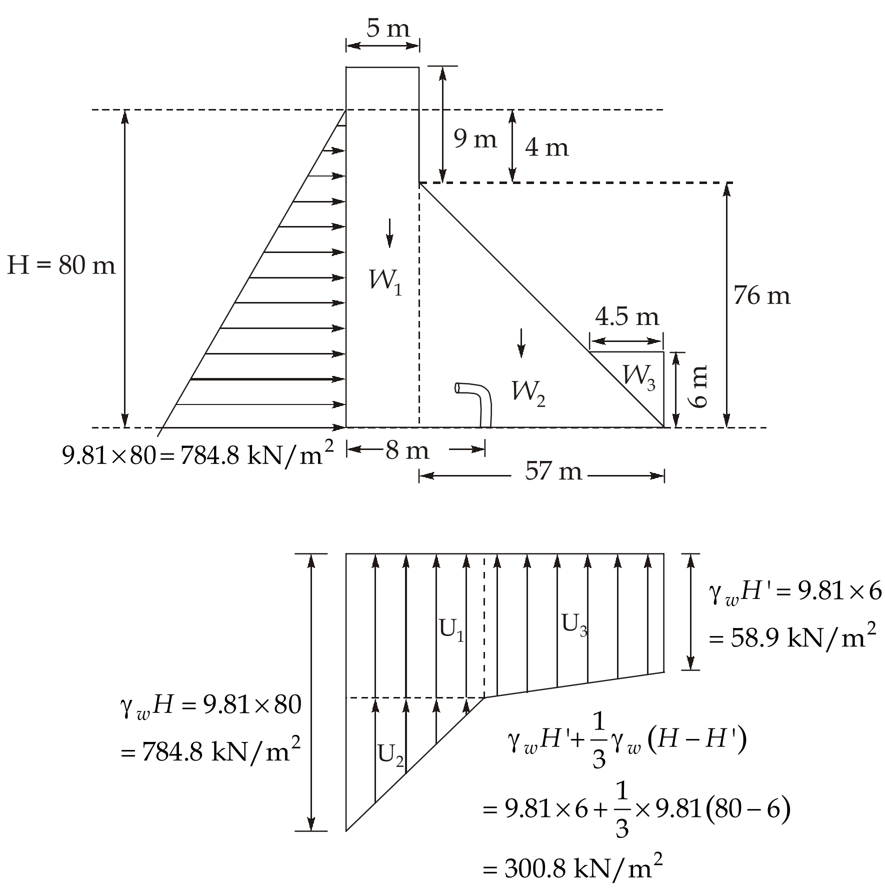
(v) presence of any harmful substance;

(vi) texture of stone; etc.

9. **Smith's test**: This test is performed to find out the presence of soluble matter in a sample of stone. The few chips or pieces of stones are taken and they are placed in a glass tube. This tube is then filled with clear water. After about an hour, the tube is vigorously stirred or shaken. The presence of earthy matter will convert the clear water into dirty water. If water remains clear, the stone will be durable and free from any soluble matter. On the other hand, if the water becomes dirty, it will indicate that the stone contains too much of soluble earthy and mineral matters.

Q.2 (b) Solution:

(i)



Name of the force	Designation	Magnitude (in kN/m)	Lever arm (m)	Moments about toe in (kN-m/m) (ACW: +)
1. Vertical forces				
• Downward weight of the dam	W_1	85 × 5 × 1 × 24 = 10200	59.5	606900
• Weight of water supported on d/s face	W_2	(1/2) × 57 × 76 × 1 × 24 = 51984	38	1975392
	W_3	(1/2) ×4.5 × 6 × 1 × 9.81 = 132.435	1.5	198.6525
• Uplift Pressure	U_1	– 300.8 ×8 × 1 = – 2406.4	58	–1395771.2
	U_2	–1/2 × 484 × 8 × 1 = – 1936	59.33	–114862.88
	U_3	–1/2 × 54 × (300.8 + 58.9) = –9711.9	33.05	–320978.295
2. Horizontal forces				
• Water pressure				
On U/s face	– P	– 1/2 × 784.8 × 80 × 1 = – 31392	26.67	–837224.64
On d/s face	P′	+1/2 × 58.9 × 6 = 176.7	4.0	+706.8

$\therefore$ Net positive moment = 117056.044 kN

Total Vertical force = 47578.14 kN

Distance of resultant force from the toe

$$\bar{x} = \frac{\sum M}{\sum V} = \frac{1170560.44}{47578.14} = 24.60 \text{ m}$$

$$\text{Eccentricity} = e = \frac{62}{2} - \bar{x} = 31 - 24.60 = 6.40 \text{ m}$$

$$\text{Vertical stress is given by } P_v = \frac{\sum V}{B}\left[1 \pm \frac{6e}{B}\right] = \frac{47578.14}{62}\left[1 \pm \frac{6 \times 6.40}{62}\right]$$

$\therefore$ Maximum vertical stress at toe, P_{max} = 1242.68 kN/m^2

Minimum vertical stress at heel, P_{min} = 292.10 kN/m^2

(ii) Major principal stress (s) at toe,

$$\sigma = P_{v(toe)} \sec^2\alpha - p' \tan^2\alpha$$

$$P_{v(toe)} = 1242.68 \text{ kN/m}^2$$

$$p' = 58.9 \text{ kN/m}^2$$

$$\tan\alpha = \frac{3}{4}$$

$$\Rightarrow \qquad \tan^2\alpha = \frac{9}{16}$$

$$\therefore \qquad \sec^2\alpha = 1 + \tan^2\alpha = 1+\frac{9}{16} = \frac{25}{16}$$

$$\therefore 1242.68\times\frac{25}{16} - 58.9\times\frac{9}{16} = 1908.56 \text{ kN/m}^2$$

(iii) Intensity of shear stress on a horizontal plane near toe,

$$\tau_0 = [p_{v(toe)} - p'] \tan\alpha = (1242.68 - 58.9) \times \frac{3}{4}$$

$$= 887.835 \text{ kN/m}^2$$

Q.2 (c) Solution:

- Hauling capacity of the locomotive is given by

$$\text{H.C} = \mu.W.N = \frac{1}{6}\times 30\times 4 = 20 \text{ tonnes} \qquad \ldots(i)$$

On a straight level track, train resistance is given by:

$$\text{Train resistance} = 0.0016\text{ W} + 0.00008\text{ Wv} + 6\times 10^{-7}\text{ Wv}^2 \qquad \ldots(ii)$$

W = Weight of train in tonnes including weight of the locomotive.

v = speed of train in kmph

Now equating (i) and (ii), we get

$0.0016\text{ W} + 0.00008\text{ Wv} + 6\times 10^{-7}\text{ Wv}^2 = 20$

$0.0016\text{ W} + 0.00008\times \text{W}\times 90 + 6\times 10^{-7}\text{ W}(90)^2 = 20$

$$\Rightarrow \qquad \text{W} = 1464.13 \text{ tonnes}$$

∴ The maximum permissible train load pulled by a locomotive is 1464.13 tonnes.

- In case, the train has to move up the gradient 1 in 250, the total train resistance is given by:

$$\text{Total train resistance} = 0.0016\text{W} + 0.00008\text{ Wv} + 6\times 10^{-7}\text{ Wv}^2 + \text{W}\times\frac{1}{250} \qquad \ldots(iii)$$

Hence, equating values from equation (i) and (iii) above, we get,

$$0.0016\times 1464.13 + 0.00008\times 1464.13\times v + 6\times 10^{-7}\times 1464.13\times v^2 + 1464.13\times\frac{1}{250} = 20$$

$$\Rightarrow \qquad v = 67.04 \text{ kmph} = 67 \text{ kmph}$$

$$\therefore \qquad \text{Reduction in speed} = 90 - 67 = 23 \text{ kmph.}$$

- If train moves with above gradient on a 3° curve, then total train resistance will be given as -

Total train resistance = 0.0016 w + 0.00008 w.v + 6 × 10^{-7} wv^2 + w.g. + 0.0004 w.D ...(iv)

Hence equating equation (i) and (iv), we get

$$0.0016 \times 1464.13 + 0.00008 \times 1464.13 \times v + 6 \times 10^{-7} \times 1464.73 \times v^2 + 1464.13 \times \frac{1}{250} + 0.0004 \times 1464.13 \times 3 = 20$$

$\Rightarrow$ v = 59.34 kmph

Hence reduction in speed = 90 – 59.34 = 30.66 kmph

Q.3 (a) Solution:

(i)

Laboratory tests on lime:

IS: 6920-1973 has specified ten laboratory tests for lime. The most commonly used tests are:

1. **Loss on ignition test (LOI):** The LOI test can be conducted to monitor the relative degree of calcination. It is also used in the testing stage to compare LOI of limestone from different deposits. It should be accompanied by a through visual inspection regarding over-burnt and under-burnt stone.

   Loss on ignition consists of strongly heating a sample of the material at a specified temperature, allowing volatile substances to escape, until its mass ceases to change. The simple test typically consists of placing a few grams of the material in a tare, pre-ignited crucible and determining its mass, placing it in a temperature- controlled furnace for a set time, cooling it in a controlled (e.g., water-free, CO_2-free) atmosphere, and re- determining the mass. The process may be repeated to show that mass-change is complete.

2. **Soundness test:** The soundness test is a very simple but important test. Its purpose is to determine how effectively the quicklime slakes. Small cores of over-burnt material may be present in the lime hydrate. They will slake very slowly. If a lime containing such cores is used in a plaster, at some future time the core will slake in the wall causing the material around it to pop out, hence the commonly known defect of popping. To avoid this defect, the lime hydrate supplied must be completely slaked, without any core of over-burnt material. This test is used to control the quality of lime produced during the course of production.

3. **Reactivity assessment of quicklime:** The addition of water to quicklime to produce a lime hydrate results in the evolution of heat. Lightly burnt quicklime will evolve heat, i.e., react at a faster rate than with the hard over-burnt quicklime. This phenomenon is used in this test to monitor the reactivity and hence the degree of burning of the quicklime produced.

4. **Determination of available lime by the rapid sugar test**: This method consists in taking 500 g sieved hydrated lime sample in a flask containing 20 ml distilled water. The corked flask is swirled and heated for two minutes. To this, 150 ml water and 15 g granulated sugar are added and flask re-corked and shaken at intervals for five minutes. The solution is allowed to stand for 30 minutes to one hour. The solution in the flask is titrated with the standard HCl solution with two drops phenolphthalein using standard procedure. The reading is noted; 1 ml of acid solution is equivalent to one per cent of available lime expressed as CaO.

Field tests on lime:

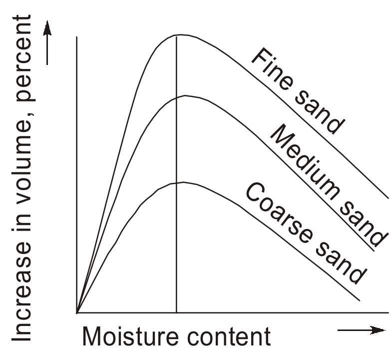
IS: 1624-1974 has specified a number of simple field tests for the limes. They can be readily performed.

1. **Visual examination:** Class C lime should be pure white in colour.
2. **Hydrochloric acid test:** The test consists in pouring ½ N hydrochloric acid to lime sample, measuring levelled tablespoonful, taken in a test-tube till effervescence ceases (about 100 ml acid would be required). The sample is left standing for 24 hours. Bubbling action will indicate presence of lime and volume of insoluble residue the unwanted inert material (adulteration) in the lime. The following observations would be helpful:
   1. Formation of good thick gel which does not flow when test-tube is inverted indicates class-A lime.
   2. Formation of flowing gel indicates class-B lime.
   3. No gel formation indicates class-C lime.
3. **Ball test:** A ball, about the size of an egg, made of the lime sample with just enough water is stored for six hours and then placed in a basin of water. The following inferences can be drawn:
   1. Expansion and disintegration of ball in a few minutes of its placement in water indicates class-C lime.
   2. Little expansion with a number of cracks in the ball indicates class-B lime.
   3. No adverse effect indicates that lime belongs to Class-A category.
4. **Impurity test**: A known weight of lime sample is mixed with water in a beaker and the solution is decanted. The residue is dried well in hot sun for eight hours and then weighed. If the residue is less than 10 per cent then the lime is good; 10 to 20 per cent is fair and above 20 per cent it is poor.
5. **Plasticity test** Lime sample is mixed with water to a thick paste and left overnight. It is spread on a blotting paper like butter with a knife to test its plasticity. Good lime is plastic in nature.

6. **Workability test:** To judge the workability of lime sample, 1: 3 lime-sand mortar is prepared and thrown on a brick wall by a trowel. If it sticks well and its workability is good.

(ii)

- **Bulking of fine aggregate:**The increase in the volume of a given mass of fine aggregate caused by the presence of water is known as bulking. The bulking of fine aggregate is caused by the films of water which push the particles apart. The extent of bulking depends upon the percentage of moisture present in the sand and its finners. It seen that bulking increases gradually with moisture content up to a certain point and then begins to decrease with further addition of water due to the merging of films, until when the sand is inundated. At this stage, the bulking. Practically vanishes. With ordinary sands the bulking usually varies between 15 to 30 percent. A typical graph as shown in figure gives the variation of per cent bulking with moisture content. Finer sand bulks considerably more and the maximum bulking is obtained at higher water content than the coarse sand In extremely fine sand, the bulking may be of the order of 40 per cent at a moisture content of 10 per cent but such sand is unsuitable for concrete. In the case of coarse aggregate, the increase in volume is negligible de to the presence of free water as the thickness of the moisture film is very small compared with particle size.



If the sand is measured by volume and no allowance is made for bulking, the mix will be richer than that specified because for given mass, moist sand occupies a considerably larger volume than the same mass of the dry sand. This results in a mix deficient in sand. The yield of concrete will also be reduced. It is necessary, in such a case, to increase the measured volume of the sand by the percentage bulking, in order that the amount of sand put into concrete is the amount intended for the nominal mix used (based on dry sand). If no allowance is made for the bulking of sand a nominal concrete mix 1:2:4, for example, will correspond to 1:1.74: 4 for a bulking of 15 per cent. If no allowance is made for bulking, the concrete strength may vary by as much as 25 per cent. Correction for bulking is not required when sand is measured by mass.

- **Field determination** This determination is based on the principle that in completely wet state, there is no capillary action and hence there is no bulking when sand is completely saturated. The method consists in pouring the moist sand in a 250 cc measuring cylinder; and the sand is consolidated and levelled by simple shaking. The depth of sand in measuring cylinder h_1 is noted. The sand is inundated, while stirring it, with water, i.e., water is added till level of water is above the sand. The submerged level depth of sand h_2 in cylinder is noted. The bulking of sand can be expressed as

$$\text{Bulking} = \frac{h_1 - h_2}{h_2} \times 100 \text{ per cent}$$

Q.3 (b) Solution:

(i)

For trapezoidal channel,

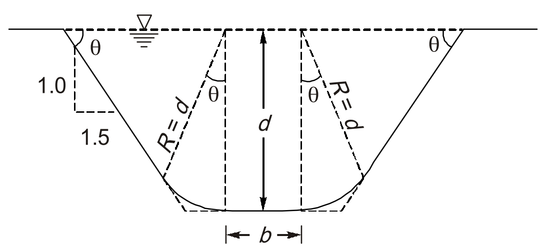
$$\text{Area, } A = bd + d^2(\theta + \cot\theta)$$

where b is bottom width and d is depth respectively,

$$\text{Perimeter, } P = b + 2d(\theta + \cot\theta)$$

Now, $\cot\theta = 1.5$

$\Rightarrow$ $\theta = 33.69° = 0.59$ radian



So, $A = bd + 2.09\, d^2 = 8d^2 + 2.09d^2 = 1009d^2$ ....(i)

Also, $P = b + 4.18\, d = 8d + 4.18\, d = 12.18d$ ...(ii)

$$\text{Velocity in the channel, } V = \frac{Q}{A} = \frac{120}{10.049d^2} = \frac{11.89}{d^2}$$

$$\text{Hydraulic radius, } R = \frac{A}{P} = \frac{10.09d^2}{12.18d} = 0.83d$$

As per Manning's formula,

$$\text{Velocity, } V = \frac{1}{n} \times R^{2/3} \times 5^{1/2} = \frac{1}{0.012} \times (0.83d)^{2/3} \times \left(\frac{1}{3600}\right)^{1/2} \quad \text{...(ii)}$$

Equating equation (i) and (ii)

$$\Rightarrow \quad \frac{11.89}{d^2} = \frac{1}{0.12}\times(0.83d)^{2/3}\times\left(\frac{1}{3600}\right)^{1/2}$$

On solving the equation, we get,

$$d = 2.34 \text{ m}$$

$$d = 2.35 \text{ (say)}$$

$$b = 8 \times d = 18.8 \text{ m}$$

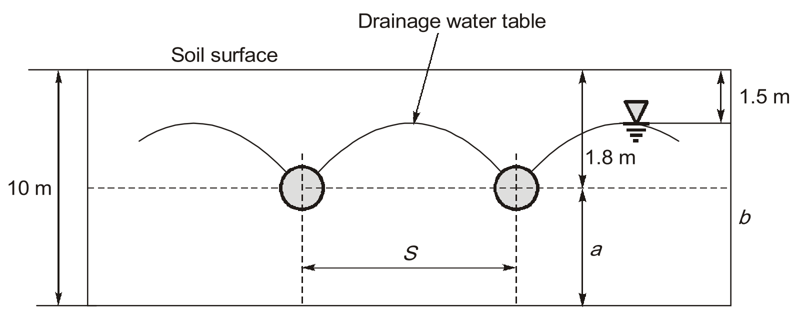
∴ Thus depth = 2.35 m

Width = 18.8 m

(ii)

1% of average rainfall in an area, $A = \frac{0.80A}{100}\text{m}^3$. This is to be removed in 24 hours.

So, $$Q_D = \frac{0.80A}{100\times24\times3600}\text{m}^3/\text{s}$$



Now, $$S = \frac{4k(b^2-a^2)}{Q_D} = \frac{4\times(1\times10^{-4})(b^2-a^2)}{Q_D}$$

$a = 10 - 1.8 = 8.2$ m, $\quad b = 10 - 1.5 = 8.5$ m,

δ = Spacing between the drains.

∴ $$S = \frac{4\times10^{-4}(8.5^2-8.2^2)\times100\times24\times3600}{0.80A}$$

But the area to be catered by drain is $S \times B$.

Where B = Breadth of the drain or its longitudinal length.

Taking this to be 1 m.

$$A = S\times1 = S$$

∴ $$S = \frac{21643.2}{S} \Rightarrow S = 147.12 \text{ m}$$

∴ Drains should be at 147 m c/c.

Q.3 (c) Solution:

(i)

Fire bricks:

These bricks are made from fire-clay. The process of manufacture is the same as that of ordinary clay bricks. The burning and cooling of fire-bricks are done gradually.

These bricks are usually white or yellowish white in colour. The weight of a fire-brick is about 30 to 35 N. The fire-bricks can resist high temperature without softening or melting. Hence they are used for linings of interior surfaces of furnaces, chimneys, kilns, ovens, fireplaces, etc. The compressive strength of these bricks varies from 200 to 220 N/mm^2. The percentage of water absorption for these bricks varies from 5 to 10.

Following are the three varieties of fire-bricks:

(1) Acidic bricks (2) Basic bricks (3) Neutral bricks.

1. **Acidic bricks**: These bricks are used for acidic lining. Following are the types of acidic bricks:
   - **Ordinary fire-bricks**: These bricks are prepared from natural fire-clay and they provide a good material for acidic refractory lining.
   - **Silica bricks**: These bricks contain a very high percentage of silica to the extent of about 95 to 97 per cent. A small quantity of lime, about 1 to 2 per cent, is added to work as binding material. These bricks are moulded under pressure and burnt at high temperature. The silica bricks can stand a high temperature upto about 2000°C. The compressive strength of such bricks is about 15 N/mm^2.
2. **Basic bricks:** These bricks are used for basic lining and basic refractory materials are used in the manufacture of such bricks. The magnesia bricks are prepared from lime and magnesia rocks. The dolomite may also be adopted for the manufacture of these bricks.
3. **Neutral bricks:** These bricks are used for neutral lining. They offer resistance to the corrosive action of slags and acidic fumes. As compared to the basic bricks, the neutral bricks are more inert to the slags. Following are the types of neutral bricks:
   - **Chromite bricks:** These bricks are prepared from a mixture of chrome, iron ore, ferrous oxide, bauxite and silica. Such bricks are unaffected by acidic or basic actions.
   - **High alumina bricks:** These bricks contain a high percentage of alumina and they are found to be more inert to the slags.

(ii)

Normal Consistency Test:

- The normal (standard) consistency of a cement paste is defined as that consistency which will permit a Vicat plunger having 10 mm diameter and 50 mm length to penetrate a depth of 33 to 35 mm from the top (or 5 to 7 mm from the bottom) of the mould.

Vicat's Apparatus:

- Vicat's apparatus assembly consists of a plunger 300 gm in weight with a length of 50 mm and diameter of 10 mm and a mould which is 40 mm deep and 80 mm in diameter.
- There are two attachments to the plunger viz.:
  (i) A square needle with 1 mm^2 cross-section is attached to the plunger for initial setting time test.
  (ii) A needle with an annular collar of 5 mm diameter is used for final setting time.

Test Procedure:

- To prepare the paste, take weighed quantity (300 g) of cement and place it in a crucible.
- Mix a weighed quantity of water (approximately 24% by weight of cement) for the first trial.
- The time of mixing or gauging should not be less than 3 minutes nor more than 5 minutes and gauging time should be counted from the time of adding water to the dry cement until commencing to fill the mould.
- The Vicat mould is filled with the paste, which is levelled off at its top.
- The mould is placed under the Vicat plunger.
- The Vicat plunger is brought down to touch the surface of paste in the mould and quickly released allowing it to sink into the paste by its own weight.
- Take the reading by noting the depth of penetration of the plunger.
- Similarly conduct the trials with increasingly water-cement ratios till the time, the plunger penetrates for a depth of 33 to 35 mm from the top (or 5 to 7 mm from the bottom).
- That particular percentage of water which allows the plunger to penetrate to a depth of 33 to 35 from the top (or 5 to 7 mm from the bottom) is known as the percentage of water required to produce a cement paste of normal (standard) consistency. This percentage is generally denoted by P.
- This test should be conducted at a temperature of 27° ± 2°C and a constant humidity of 90%.

Initial setting time test:

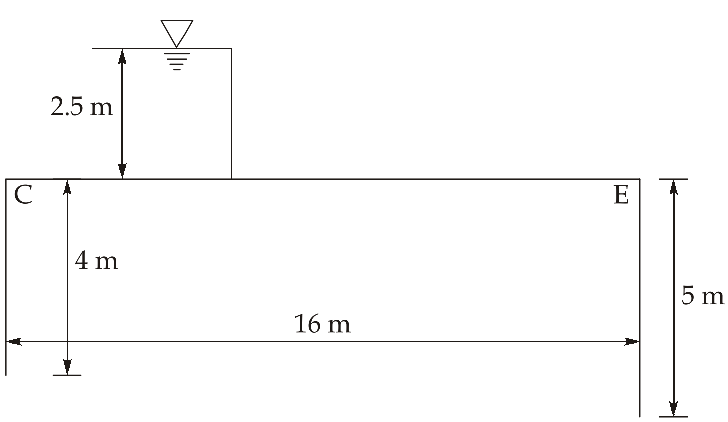
- It is the time elapsed between the moment that the water is added to the cement, to the time that the paste starts losing its plasticity.
- The test procedure is as follows:
  1. Take 300 gm of cement and make a cement paste of consistency 0.85 *P*.
  2. Attach the square needle to the Vicat plunger and lower it gently to make contact with the surface of test block and quickly release it.
  3. When the needle penetratess to a depth of 33 to 35 mm from the top (or 5 to 7 mm from the bottom), the test is completed.
- Initial setting time should not be less than 30 minutes for OPC and 60 minutes for low heat cement.

Final Setting Time Test

- The final setting time is the time elapsed between the moment the water is added to the cement and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure.
- The test procedure is as follows:
  1. Take 300 gm of cement and make a cement paste of consistency of 0.85 *P*.
  2. Replace the square needle by a needle with annular collar of 5 mm diameter.
  3. Lower the attachment to gently touch the surface of test block.
  4. If the needle makes an impression, while the annular collar of the attachment fails to do so, the cement is considered to be finally set. Thus, the paste has attained such hardness that the needle does not pierce through the paste more than 0.5 mm.
- The final setting time should not be more than 10 hours.

Q.4 (a) Solution:

(i)



We have to find ϕ_C and ϕ_E

(1) Upstream pile (ϕ_C)

Depth (d) = 4 m, Length (b) = 16 m

$$\alpha = \frac{b}{d} = \frac{16}{4} = 4$$

$$\phi_C = 100 - \phi_E$$

where $$\phi_E = \frac{1}{\pi}\cos^{-1}\left(\frac{\lambda - 2}{\lambda}\right)$$

where $$\lambda = \frac{1+\sqrt{1+\alpha^2}}{2} = \frac{1+\sqrt{1+4^2}}{2} = 2.56$$

Now, $$\phi_E = \frac{1}{\pi}\cos^{-1}\left(\frac{2.56-2}{2.56}\right) = \frac{1}{\pi}\times 77.36^\circ \times \frac{\pi}{180^\circ}$$

$$= 0.4298 \simeq 0.43 = 43\%$$

$\therefore$ $$\phi_C = 100 - 43 = 57\%$$

- Correction due to downstream pile

$$C = +19\sqrt{\left(\frac{D}{b'}\right)}\left(\frac{d+D}{b}\right)$$

where, D = Depth of downstream pile influencing pile = 5 m

d = Depth of upstream pile influenced pile = 4 m

b = b′ = 16 m

$\therefore$ $$C = +19\sqrt{\left(\frac{5}{16}\right)} \times \left(\frac{4+5}{16}\right) = 5.97 \simeq 6\%$$

$\therefore$ $$\phi_C = 57\% + 6\% = 63\%$$

$\therefore$ Uplift pressure at $C(P_C)$ = 0.63 × 2.5 = 1.575 m

(ii) For downstream pile (ϕ_E)

d = 5 m, b = 16 m

$$\alpha = \frac{b}{d} = \frac{16}{5} = 3.2$$

Now, $$\lambda = \frac{1+\sqrt{1+\alpha^2}}{2} = \frac{1+\sqrt{1+3.2^2}}{2} = 2.176$$

$$\phi_E = \frac{1}{\pi}\cos^{-1}\left(\frac{\lambda-2}{\lambda}\right) = \frac{1}{\pi}\cos^{-1}\left(\frac{2.176-2}{2.176}\right)$$

$$= \frac{1}{\pi}\times 85.35°\times\frac{\pi}{180°} = 0.474 = 47.4\%$$

Correction due to upstream pile

$$C = (-)19\times\left(\sqrt{\frac{4}{16}}\right)\times\left(\frac{5+4}{16}\right) \simeq -5.34\%$$

$\therefore$ Corrected, ϕ_E = 47.4 – 5.34 = 42.06%

$\therefore$ Uplift pressure at C = 0.4206 × 2.5 $\simeq$ 1.05 m

(ii)

1. **Aqueduct:** When the HFL of the drain is sufficiently below the bottom of the canal, so that the drainage water flows freely under gravity, the structure is known as an aqueduct. In this type of work, the canal water is taken across the drainage in a trough. Aqueduct is just like a bridge except that instead of carrying a road or railway, it carries a canal on its top. An aqueduct is provided when sufficient level difference is available between the canal and the natural drainage, and canal bed level is sufficiency higher than the HFL of drain.
2. **Syphon aqueduct:** If the H.F.L. of the drain is higher than the canal bed and the water passes through the aqueduct barrels under syphonic action, the structure is known as syphon aqueduct. In the case of a syphon aqueduct, the drain bed is generally depressed and provided with pucca floor,
3. **Super passage:** In these works, the drain is taken over the canal such that the canal water runs below the drain freely. When the FSL of the canal is sufficiently below the bottom of the drain trough, so that the canal water flows freely under gravity, the structure is known as super passage. However, if the FSL of the canal is sufficiently above the bed level of the drainage trough, so that the canal flows under syphonic action under the trough, the structure is known as a canal syphon or a syphon.
4. **Level crossing:** In this type of cross drainage work, the canal water and drain water are allowed to intemingle with each other. A level crossing is generally provided when a large canal and a huge drainage approach each other practically at the same level.

   A regulator is provided across the torrent (drainage) just on the downstream side of the crossing so as to control the discharge passing into the torrent. At the outgoing canal, a regulator is also provided so as to control the discharge into the canal. A regulator at the end of the incoming canal is also sometimes required.

Q.4 (b) Solution:

(i)

Given: N = 16, d = 12 cm = 0.12 m, G = 1.75 m

1. Curve lead (CL) = 2GN = 2 × 1.75 × 16 = 56 m

2 Radius, $R = R_0 - \frac{G}{2}$

where, $R_0 = 2GN^2 + 1.5\,G = 2 \times 1.75 \times 16^2 + 1.5 \times 1.75$

$= 898.625$ m

Now, $R = 898.625 - \frac{1.75}{2} = 897.75$ m

3. Switch lead (SL) $= \sqrt{2.R_0.d} = \sqrt{2 \times 898.625 \times 0.12} = 14.69$ m

4. Lead (L) = CL – SL = 56 – 14.69 = 41.31 m

Hence, overall length of curve = 56 m and radius of outer curve, R_0 = 898.625 m

(ii)

Given data : Turning speed, V = 50 kmph, Wheel base, w = 30 m, Tread of main landing gear, T = 6.0 m, Coefficient of friction, f = 0.13, Width of taxiway, T = 22.0 m

Let radius of taxiway is R

∴ Radius of taxiway will be maximum of

(i) $R = \frac{V^2}{125.f} = \frac{50^2}{125 \times 0.13} = 153.85$ m

(ii) From Horonjeff's equation, $R = \frac{0.388\,w^2}{\frac{T}{2} - S}$

where, $S = 6 + \frac{T'}{2} = 6 + \frac{6}{2} = 9$ m

Now, $R = \frac{0.388 \times (30)^2}{\left(\frac{22}{2}\right) - (9)} = 174.6$ m

(iii) For supersonic aircraft, minimum radius of taxiway, R_{min} is

$R_{min} = 180$ m

From above, maximum value of R is 180 m. Therefore radius of taxiway will be 180 m.

Q.4 (c) Solution:

(i)

A canal outlet or a module is a small structure built at the head of the water course so as to connect it with a minor or a distributary channel.

Canal outlets can be classified mainly into three classes.

1. Non-modular outlets:

- Non-modular outlets are those outlets whose discharge depends on the difference of water levels i.e. head difference between the distributary and the water course.
- The discharge through non-modular outlet varies widely with variations in the water level in either the distributary or the water course.
- Such an outlet is controlled by a shutter at it is located on upstream.
- Non modular outlets are vey much suitable for low head conditions.
- Example: Submerged pipe outlets and masonary slices.

2. Semi-modular outlets:

- Semi modular outlets are those whose discharge depends only on the water level in the distributary and is unaffected by the water level in the water course provided that a minimum working head required for working is available.
- Semi modular outlet is more suitable for achieving equitable distribution of water at all outlets of a distributary.
- Example: Pipe outlet, Venturiflume.

3. Modular outlets:

- Modular outlets are those outlets whose discharge is independent of difference of water levels in the distributary and these water course.
- Example: Gibb's module.

(ii)

Self-Compacting Concrete (SCC):

- It is defined as the concrete capable of encapsulating reinforcing bars and filling formwork through the action of gravity alone while maintaining its homogeneity.
- It achieves full compaction without the application of any external or internal vibration and it de-aerates by itself.
- The quantity of coarse aggregates gets reduced and super-plasticizers are added in high dose.
- The segregation resistance and stability of mix is achieved by increasing the fines content.
- Self-compacting concrete provides the following advantages:

  (i) Better surface finish (ii) Reduction in manpower at site
  (iii) Easier placing (iv) Faster construction
  (v) Greater freedom of design (vi) Improved durability

- Some important points regarding materials used in self-compacting concrete:
  (i) To control heat of hydration and shrinkage, the cement is kept reasonably low and is supplemented by the addition of pozzolanic materials like fly ash.
  (ii) The maximum size of aggregate is generally kept as 20 mm. Aggregates used should be of uniform quality with regard to shape and grading so as to reduce internal friction and improve the flowability of SCC.
  (iii) The grading of fine aggregates must be uniform throughout the work. As properties of fine aggregates have a greater influence on properties of fresh SCC, the properties of fine aggregates must be closely monitored.
  (iv) Super-plasticizers such as poly-carboxylated ethers are an essential component of SSC and provides the requisite fluidity. Viscosity modifying agents which helps to minimize the effect of variations of moisture content and fines in sand, and air entraining agents which improve freezing and thawing resistance can also be incorporated in the mix.

No-fine Concrete

- It is made up of only coarse-aggregates, cement and water.
- Normally aggregates of size passing through 20 mm and retained on 10 mm are used and aggregate cement ratio varies from 6 : 1 to 10 : 1.
- Unlike the conventional concrete in which water-cement ratio is the primary factor determining strength, the strength of no-fines concrete is dependent on the water-cement ratio, aggregate-cement ratio and unit weight of concrete.
- When conventional aggregates are used, no-fines concrete show a density of about 1600 to 1900 kg/m^3 but when light weight aggregates are used, the density may come down to upto 360 kg/m^3.
- The bond-strength of no-fines concrete is very low and hence reinforcement is not used along with no-fines concrete. However if reinforcement is required it is advisable to coat reinforcement with cement paste to improve the bond and also to protect it from rusting.
- It lacks cohesiveness due to absence of fine aggregates, thus it requires relatively long time for formwork removal.
- There is no standard method (slump/compaction factor) to measure the consistency/workability of no-fines concrete.

Q.5 (a) Solution:

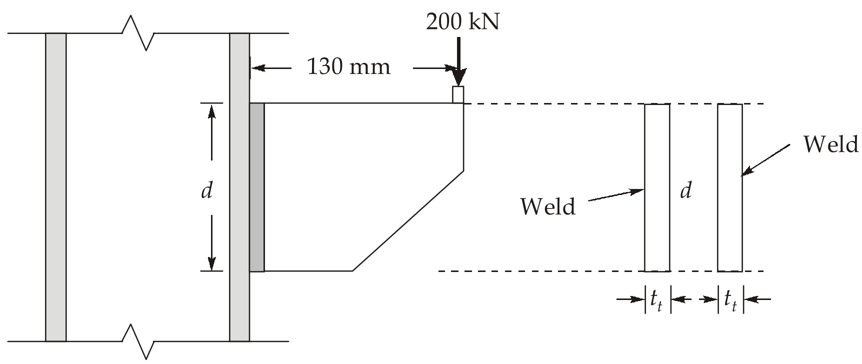
Factored load, P_u = 200 kN, e = 130 mm

Selection of size of the weld:

Minimum size of the weld for 12 mm plate = 5 mm.

Maximum size of the weld for 12 mm plate = 12 – 1.5 = 10.5 mm.

Let's adopt 8 mm size of weld.



Effective throat thickness $t_t = kS = 0.7 \times 8 = 5.6$ mm.

$$\therefore \quad d = \sqrt{\frac{6M}{2 \times t_t \times f_{wd}}}$$

where f_{wd} is given by

$$f_{wd} = \frac{0.8 f_u}{\sqrt{3} \times \gamma_{mw}} = \frac{0.8 \times 410}{\sqrt{3} \times 1.25} = 151.5 \text{ N/mm}^2$$

$$M = 200 \times 10^3 \times 130 \text{ N-mm} = 26 \times 10^6 \text{ N-mm}$$

$$\therefore \text{Approximate depth of weld, } d = \sqrt{\frac{6 \times 26 \times 10^6}{2 \times 5.6 \times 151.5}} = 303.21 \text{ mm}$$

Let us adopt d = 320 mm

Now direct shear stress on the weld is,

$$q = \frac{P}{2t_t \times d} = \frac{200 \times 10^3}{2 \times 5.6 \times 320} = 55.80 \text{ N/mm}^2$$

$$\text{Bending stress in the weld, } f_a = \frac{M}{I} \times y = \frac{26 \times 10^6 \times \frac{320}{2}}{\frac{2 \times 5.6 \times 320^3}{12}} = 136.02 \text{ N/mm}^2$$

$$\text{Equivalent stress, } f_e = \sqrt{f_a^2 + 3q^2} = \sqrt{136.02^2 + 3 \times 55.80^2} = 166.86 \text{ N/mm}^2$$

Also, $$\frac{f_u}{\sqrt{3}\times 1.25} = \frac{410}{\sqrt{3}\times 1.25} = 189.37 \text{ N/mm}^2$$

$\therefore$ $$f_e < \frac{f_u}{\sqrt{3}\times 1.25} \quad \text{(OK)}$$

Hence, adopt 8 mm as size of weld and depth of weld as 320 mm.

Q.5 (b) Solution:

Inflow

$$\text{Depth of surface inflow} = \frac{12\times 60\times 60\times 24\times 30}{8\times 10^6} = 3.888 \text{ m}$$

$$\text{Rainfall} = 10 \text{ cm} = 0.1 \text{ m}$$

$\therefore$ $$\text{Total inflow depth} = 3.888 + 0.1 = 3.988 \text{ m}$$

Outflow

$$\text{Depth of surface outflow} = \frac{16\times 60\times 60\times 24\times 30}{8\times 10^6} = 5.184 \text{ m}$$

$$\text{Evaporation} = 0.7\times\frac{25}{100} = 0.175 \text{ m}$$

Let seepage depth of flow be x

Now, total outflow depth = $5.184 + 0.175 + x = 5.359 + x$

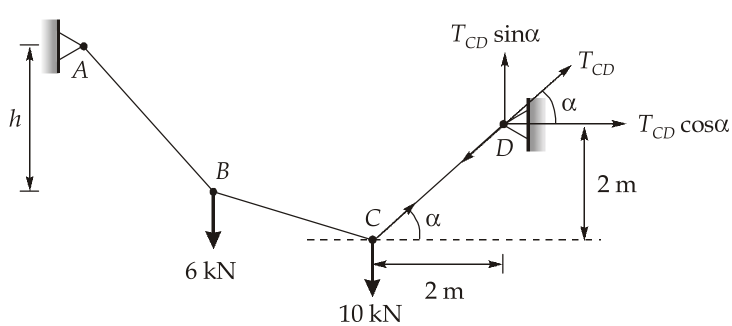
Now from water budget equation, (Total outflow) – (Total inflow) = Reduction in storage

$$(5.359 + x) - (3.988) = 1.5$$

$\Rightarrow$ $$x = 0.129 \text{ m}$$

Now seepage volume, $V = x \times \text{Area} = 0.129 \times 8 \times 10^6 \text{ m}^3 = 1.032 \text{ M m}^3$

Q.5 (c) Solution:



For CD, $$\tan\alpha = \frac{2}{2} = 1 \Rightarrow \alpha = 45°$$

So, $$\sin\alpha = \cos\alpha = \frac{1}{\sqrt{2}}$$

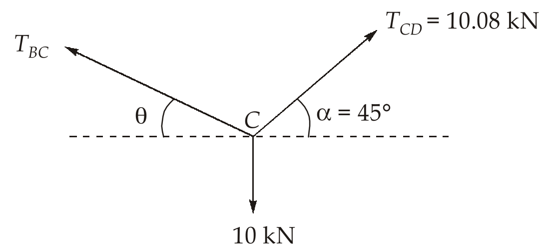
$$\sum M_A = 0,$$

$$-T_{CD}\cos\alpha\,(1.5) - T_{CD}\sin\alpha\,(6.5) + 6\times 2 + 10\times 4.5 = 0$$

$$\Rightarrow \quad \frac{-T_{CD}}{\sqrt{2}}\times 1.5 - \frac{T_{CD}}{\sqrt{2}}\times 6.5 + 12 + 45 = 0$$

$$\Rightarrow \quad T_{CD} = 10.08 \text{ kN}$$

Consider point C,



$$\sum F_x = 0$$

$$\Rightarrow \quad T_{CD}\cos\alpha - T_{BC}\cos\theta = 0$$

$$\Rightarrow \quad 10.08\cos 45^\circ - T_{BC}\cos\theta = 0$$

$$\Rightarrow \quad T_{BC}\cos\theta = 7.13 \text{ kN} \quad \ldots(i)$$

Also, $\sum F_y = 0$

$$\Rightarrow \quad 10.08\sin 45^\circ + T_{BC}\sin\theta - 10 = 0$$

$$\Rightarrow \quad T_{BC}\sin\theta = 10 - 10.08\sin 45^\circ = 2.87 \text{ kN} \quad \ldots(ii)$$

Dividing (ii) by (i) we get

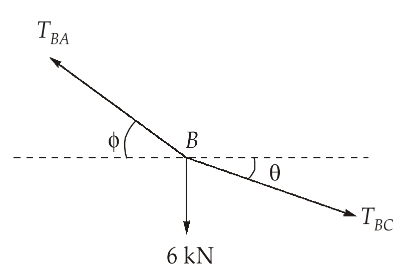
$$\frac{T_{BC}\sin\theta}{T_{BC}\cos\theta} = \frac{2.87}{7.13}$$

$$\Rightarrow \quad \theta = 21.93^\circ$$

$$\therefore \quad T_{BC} = \frac{2.87}{\sin 21.93^\circ}$$

$$\Rightarrow \quad T_{BC} = 7.68 \text{ kN}$$

Consider point B,



$$\sum F_x = 0$$

$$\Rightarrow \quad T_{BA}\cos\phi - T_{BC}\sin\theta = 0$$

$$\Rightarrow \quad T_{BA}\cos\phi = 7.12 \text{ kN} \quad \ldots(iii)$$

Also, $\sum F_y = 0$

$$\Rightarrow \quad T_{BA} \sin \phi - T_{BC} \cos \theta = 0$$

$$\Rightarrow \quad T_{BA} \sin \phi = 6 + 7.68 \times \sin 21.93°$$

$$\Rightarrow \quad T_{BA} \sin \phi = 8.87 \quad \text{...(iv)}$$

Dividing (iv) by (iii), we get

$$\frac{T_{BA} \sin \phi}{T_{BA} \cos \phi} = \frac{8.87}{7.12}$$

$$\Rightarrow \quad \phi = 51.25°$$

$$\therefore \quad T_{BA} = 11.37 \text{ kN}$$

Also, $\tan \phi = \frac{h}{2}$

$$\Rightarrow \quad h = 2 \times \tan(51.25°) = 2.49 \simeq 2.5 \text{ m}$$

Q.5 (d) Solution:

Advantages of belt-conveyor : The principal advantages of a belt conveyor system over other means of haulage are as follows:

(i) Continous and uniform haulage.
(ii) Low maintenance cost.
(iii) Low labour requirement
(iv) High reliability
(v) Ability to cross adverse terrain.
(vi) Excellent safety records.

Disadvantages of belt-conveyor :

(i) Very high initial cost
(ii) Requires skilled labour.
(iii) Needs continous supply of electric power.

Basic parts of belt conveyor system: The basic parts of a belt conveyor system consist of the following:

(i) **A continuous Belt :** A belt is specified by its width, thickness and weight like 90 cm-wide, 6 ply, 1.3 kg respectively.

Types of conveyor belt system are:

1. Standard 2. Shock pad 3. Stepped pad 4. Stepped ply

(ii) **Idlers:** Idlers provide support for a belt conveyor for the load carrying position of a belt. The idlers are designed to provide the necessary trussing, while for the return position of a belt, the idlers provide flat supports. These consist of rollers, brackets and the base.

(iii) Driving and tail pulleys: A belt conveyor may be driven through the head or tail pulleys or through an intermediate pulley. The pulley may be driven by an electric motor, or a gasoline or a diesel engine.

(iv) Feeders: The purpose of a feeder is to deliver materials to the belt at a uniform rate. A feeder may discharge the materials directly to the belt or through a chute in order to reduce the impact of falling, several types of feeders such as apron, reciprocating, rotary vane and rotary plow are available.

(v) Trippers: A tripper consists of a pair of pulleys which are so located pulley and under the other when the belt passes over the top pulley, the load will be discharged from the belt into a auxiliary hopper or chute.

Q.5 (e) Solution:

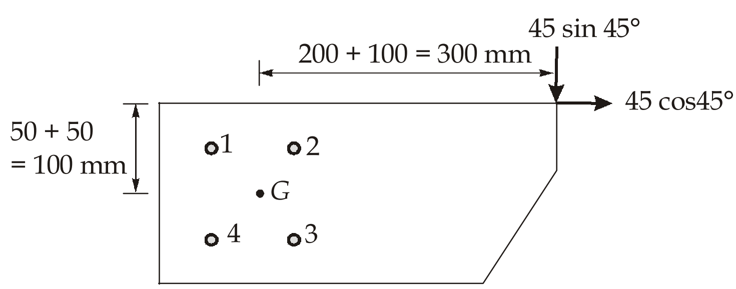
Given M-20 bolt of grade 4.6

Nominal diameter of bolt, d = 20 mm

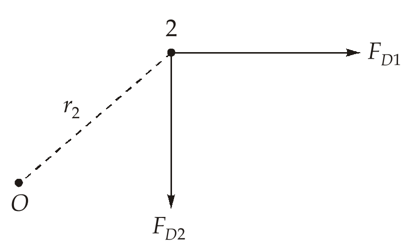
Diameter of bolt hole, d_o = 22 mm

Critical bolt is bolt number 2.

Now, we have to find torsional moment about C.G of bolt group.



Torsional moment, T = 45 sin 45° × 0.3 + 45 cos 45° × 0.1 = 12.73 kN-m



$$r_2 = \sqrt{50^2 + 50^2} = 50\sqrt{2} \text{ mm}$$

$$\sum r_i^2 = 4 \times \left(50\sqrt{2}\right)^2 = 20000 \text{ mm}^2$$

Direct shear force on the bolt,

$$F_{D1} = \frac{45\cos 45^\circ}{4} = 7.95 \text{ kN}, \quad F_{D2} = \frac{45\sin 45^\circ}{4} = 7.95 \text{ kN}$$

Torsional shear force on the bolt,

$$F_T = \frac{Tr_i}{\Sigma r_i^2} = \frac{12.73 \times 50\sqrt{2} \times 10^{-3}}{20000 \times 10^{-6}} \simeq 45 \text{ kN}$$

$$F_y = F_{D2} + F_T \sin 45° = 7.95 + 45 \sin 45° = 39.77 \text{ kN}$$

$$F_x = F_{D1} + F_T \cos 45° = 7.95 + 45 \cos 45° = 39.77 \text{ kN}$$

$$\therefore \quad F_R = \sqrt{F_x^2 + F_y^2} = \sqrt{(39.77)^2 + (39.77)^2} = 56.24 \text{ kN}$$

$\therefore$ Maximum shearing force on the bolt = 56.24 kN

Q.6 (a) Solution:

(i)

Welding offers the following advantages over bolting or riveting:

1. Welded connections eliminate the need for making holes in the members.
2. Welding offers airtight and water tight joining of plates and hence is employed in the construction of water/oil storage tanks, ships etc.
3. Welded joints are economical, since they enable direct transfer of stresses between the members.
4. Welded connections are usually aesthetic in appearance and appear less cluttered in contrast to bolted connections.
5. Welding offers more freedom to the designer in choosing section. Welding is practicable even for complicated shapes of joints.
6. Alterations can be made with less expense in case of welding as compared to bolting.
7. The efficiency of welded joint is more than a bolted joint. Infact 100% efficiency can be obtained using welding.
8. Due to elimination of holes, stress concentration effect is considerably less in welded connections.
9. The process of welding is relatively silent.

Limitations of welding:

1. Welding requires highly skilled human resources.
2. The inspection of welded joints is difficult and expensive, whereas inspection of bolted joints is simple.
3. Members jointed by welding may distort, unless proper precautions are taken.
4. Welded connections are prone to cracking under fatigue loading.
5. The possibility of brittle failure is more in case of welded joints than in bolted connections.

6. Costly equipments are required to make welded connections. Hence initial investment is high.

Following factors influence the welding cost:

1. Cost of preparing the edges to be welded (in case of groove welds).
2. Amount of weld material required.
3. Ratio of the actual arc time to overall welding time.
4. Cost of pre-heating (if any)
5. The handling required (cranes and special equipments needed during erection)
6. General over head costs.

(ii) The maximum permissible compressive stress, $\sigma_{per} = 110\ \text{N/mm}^2$

$$\text{Gross area required, } A_g = \frac{P}{\sigma_{per}} = \frac{180 \times 10^3}{110} = 1636.36\ \text{mm}^2$$

Let us take ISMB 125 from the available sections.

Minimum moment of inertia,

$$I_{yy} = 38.5 \times 10^4\ \text{mm}^2$$

$$\text{Minimum radius of gyration,} r_{min} = \sqrt{\frac{I_{yy}}{A}} = \sqrt{\frac{38.5 \times 10^4}{1700}} = 15.05\ \text{mm}$$

For the given end conditions.

$$\text{Effective length, } L_{eff} = \frac{L}{2} = \frac{2.4}{2} = 1.2\ \text{m.}$$

$$\text{Slenderness ratio, } \lambda = \frac{L_e}{\gamma_{min}} = \frac{1200}{15.05} = 79.73$$

From table

For $\lambda = 79.73$, σ_{ac} is given by

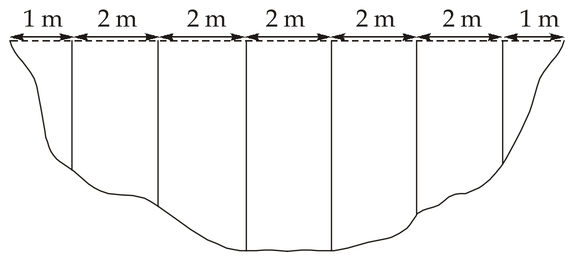
$$\frac{80-70}{101-112} = \frac{80-79.73}{101-\sigma_{ac}}$$

$\Rightarrow$ $$\sigma_{ac} = 101.297\ \text{N/mm}^2 < 110\ \text{N/mm}^2 \quad \text{(OK)}$$

$$\text{Permissible compressive load, } P = \sigma_{ac} \times A = \left(\frac{101.297 \times 1700}{1000}\right)\text{kN} = 172.20\ \text{kN}$$

As permissible compressive load is greater than the axial load, ISMB 125 can be taken to carry the given axial load.

Q.6 (b) Solution:



For the first and last segments, average width,

$$\bar{W} = \frac{\left(1+\frac{2}{2}\right)^2}{2\times 1} = 2 \text{ m}$$

For the rest of the segments,

$$\bar{W} = \left(\frac{2}{2}+\frac{2}{2}\right) = 2 \text{ m}$$

Since the velocity is measured at 0.6 m depth, the measured velocity is the average velocity at that vertical section $(\bar{V})$.

The calculation of discharge by the mid section method is shown in tabular form below: Segmental discharge, ΔQ_i is calculated as

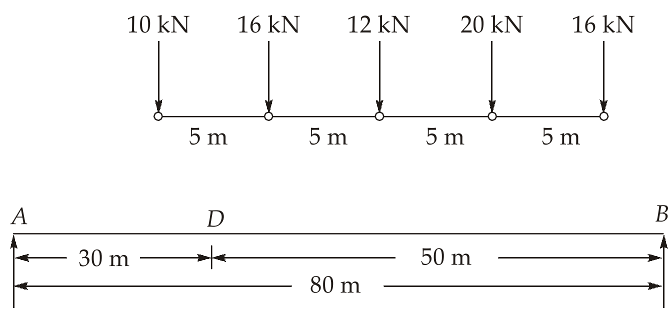
$$\Delta Q_i = \left(\bar{W}\times y\times \bar{V}\right)$$

Distance from left water edge (m)	Average width, $\bar{W}$ (m)	Depth, y (m)	$N_s = \frac{\text{Revolution}}{\text{second}}$	Velocity, $\bar{v}$ (m/s) ($\bar{V} = 0.5 N_s + 0.02$)	Segmental discharge, ΔQ; (in m³)
0	0	0	0	0	0
1	2	1.2	0.40	0.22	0.528
3	2	2.2	0.60	0.32	1.408
5	2	2.7	0.49	0.263	1.420
7	2	2.2	0.40	0.22	0.968
9	2	1.8	0.45	0.245	0.882
11	2	1.0	0.40	0.22	0.44
12	0	0	0	0	0
					$\sum \Delta Q_i = 5.646 \text{ m}^3/s$

Discharge in the stream = $5.646 \text{ m}^3/\text{s} \simeq 5.65 \text{ m}^3/\text{s}$

Q.6 (c) Solution:

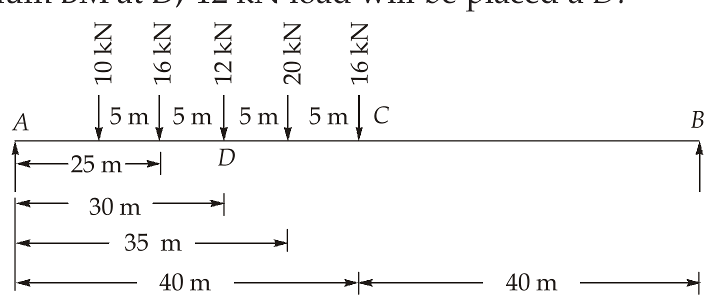
(i)



Average loads on span AD and BD,

Load crossing the section D	Average load on AD	Average load on BD	Remarks
16 kN	$\frac{10+16+12+20}{30}=\frac{29}{15}$	$\frac{16}{50}$	$(AD)_L > (BD)_L$
20 kN	$\frac{10+16+12}{30}=\frac{19}{15}$	$\frac{36}{50}$	$(AD)_L > (BD)_L$
12 kN	$\frac{13}{15}$	$\frac{48}{50}$	$(AD)_L < (BD)_L$

Hence, for maximum BM at D, 12 kN load will be placed a *D*.



$$\sum M_A = 0$$

$$\Rightarrow \quad R_B(80) = 10(20) + 16(25) + 12(30) + 20(35) + 16(40)$$

$$\Rightarrow \quad R_B = 28.75 \text{ kN}$$

$$\sum V = 0$$

$$\Rightarrow \quad R_A + R_B = 74 \text{ kN}$$

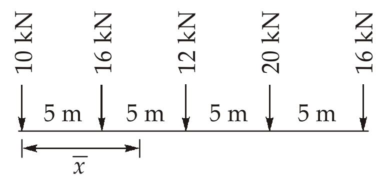
$$\Rightarrow \quad R_A = 45.25 \text{ kN}$$

$$\therefore \quad (M_{max})_D = R_A(30) - 10(10) - 16(5)$$

$$= 45.25 \times 30 - 10 \times 10 - 80 = 1177.5 \text{ kN-m}$$

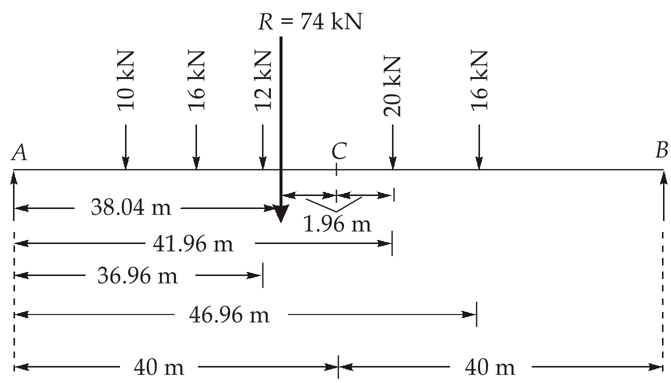
(ii) Absolute maximum bending moment:

Distance of CG of system of point loads from 10 kN load is given by



$$\bar{x} = \frac{16\times5+12\times10+20\times15+16-20}{74} = 11.08 \text{ m}$$

For absolute maximum BM, resultant load (74 kN) & 20 kN load (heaviest) must be placed equidistant from mid-span of beam.



Taking, $\sum M_A = 0$

$\Rightarrow$ $R_B(80) = 16(46.96) + 20(41.96) + 12(36.96) + 16(31.96) + 10(26.96)$

$\Rightarrow$ $R_B = 35.188$ kN

Maximum beam under 20 kN at 38.04 m from end B,

$= 35.188 \times 38.04 - 16 \times 5 = 1258.55$ kN-m

Q.7 (a) Solution:

(i)

Average value of equipment, P_{avg} is given by $P_{avg} = \dfrac{P(n+1)+S(n-1)}{2n}$

where, P = Total initial cost = Rs. 5,50,000

n = No. of years of useful life = 5 years

S = Salvage value = Rs. 50,000

$\therefore$ $$P_{avg} = \frac{5,50,000(5+1)+50,000(5-1)}{2\times5} = \text{Rs.}3,50,000$$

Annual deprication using straight line method,

$$= \frac{P-S}{n} = \frac{550000-50000}{5} = \text{Rs.}100000$$

(i) Annual cost of the equipments:

(a) Depreciation = Rs. 100,000

(b) Maintenance and repair cost @ 100% of depreciation = Rs. 100,000

(c) Investment @ 12% of $P_{avg} = \frac{12}{100} \times 3,50,000 = \text{Rs.}42000$

∴ Total annual fixed cost = 100,000 + 100,000 + 42000 = Rs. 2,42,000

∴ Hourly fixed cost = $\frac{242,000}{2000}$ = Rs. 121

(ii) Fuel consumption per hour = (Operating factor) × (Rated HP) × 0.20 litre.

= 0.6 × 180 × 0.20 = 21.6 litres

∴ Fuel cost per hour = 21.6 × 8 = Rs. 172.8

(iii) Lubricating oil consumption per hour

$$= \frac{\text{Rated HP} \times \text{operating factor} \times 0.003}{0.74} + \frac{C}{t}$$

where C is crankcase capacity.

$$= \left(\frac{180 \times 0.6 \times 0.003}{0.74} + \frac{40}{100}\right) \text{litres} = 0.838 \text{ litres}$$

Lubricating oil cost per hour = 0.838 × 50 = Rs. 41.9

∴ Cost of owning and operating per hour = (i) + (ii) + (iii)

= 121 + 172.8 + 41.9 = Rs. 335.7

(ii)

A contract may be terminated in anyone on more of the following conditions:

1. **Completion of work:** When the work is completed according to the contract agreements and the owner is satisfied, the security money is released and the contract is terminated.
2. **By agreement:** If due to some unavoidable circumstances, it is not possible to complete the work, the contract is terminated by mutual agreement.
3. **Due to breach of conditions the work:** If any party does not follow the conditions of contract, the other party has the right to terminate the contract due to such breach.
4. **By impossibility to complete:** When the site does not belong to the owner, or the land is acquired by the government or it is flooded or damaged due to natural calamities, the execution of work is impossible and the contract is terminated.
5. **By bankruptcy:** If either party becomes bankrupt, the contract may be terminated.

Q.7 (b) Solution:

(i) Given, $CN_{III} = 60$

Possible maximum retention, S (in mm) $= 254\left(\frac{100}{CN}-1\right)$

$$= 254\left(\frac{100}{60}-1\right) = 169.33 \text{ mm}$$

Now,
$$Q = \frac{(P-0.2S)^2}{P+0.8S} \quad \text{for } P > 0.2S$$

$$= \frac{(P-0.2\times169.33)^2}{P+0.8\times169.33} \quad \text{for } P > 0.2 \times 169.33$$

$$= \frac{(P-33.866)^2}{P+135.464} \quad \text{for } P > 33.866 \text{ mm}$$

Date	P(mm)	Q(mm)	
July 1	55	2.345	
July 2	25	0	$(\because P < 33.866\,\text{mm})$
July 3	45	0.687	
July 4	30	0	$(\because P < 33.866\,\text{mm})$
	$\sum P = 155$ mm	$\sum Q = 3.032$ mm	

Total runoff volume from the catchment,

$$V_r = 500\times10^4\times\frac{3.032}{1000}\text{ m}^3 = 15160 \text{ m}^3$$

(ii) Given, $CN_{III} = 70$,

$$S = 254\left(\frac{100}{CN}-1\right) = 254\left(\frac{100}{70}-1\right) = 108.86 \text{ mm}$$

Now,
$$Q = \frac{(P-0.2S)^2}{P+0.8S} \quad \text{for } P > 0.2S$$

$$= \frac{(P-0.2\times108.86)^2}{P+0.8\times108.86} \quad \text{for } P > 0.2 \times 108.86$$

$$= \frac{(P-21.772)^2}{P+87.088} \quad \text{for } P > 21.772 \text{ mm}$$

Date	P(mm)	Q(mm)
July 1	55	7.77
July 2	25	0.093
July 3	45	4.08
July 4	30	0.578
		$\sum Q =$ 12.521 mm

Now, total runoff volume from the catchment,

$$V_r = 500 \times 10^4 \times \frac{12.521}{1000} \text{ m}^3 = 62{,}605 \text{ m}^3$$

Q.7 (c) Solution:

Factored tensile load, $T = 450$ kN

$$\text{Required net area of section, } A_n = \frac{T}{0.9\dfrac{f_u}{\gamma_{m_1}}} = \frac{450 \times 1000}{\dfrac{0.9 \times 410}{1.25}} = 1524.39 \text{ mm}^2$$

Increasing the net area by about 25%, we get

Gross area of section, $A_g = 1.25 \times 1524.39 = 1905.49 \text{ mm}^2$

Let us choose ISA 150 × 75 × 10 having gross area, $A_g = (150 + 75 - 10) \times 10 = 2150 \text{ mm}^2$

Let us provide 20 mm diameter bolts of grade 4.6.

$$\text{Net tensile stress area of the bolts, } A_{nb} = 0.78 \times \frac{\pi \times d^2}{4} = 245 \text{ mm}^2$$

Diameter of the hole, $d_0 = 22$ mm

$$\text{Strength of the bolt in single shear} = \frac{f_{ub}}{\sqrt{3}\gamma_{mw}} A_{nb} = \frac{400}{\sqrt{3} \times 1.25} \times \frac{245}{1000} \text{kN} = 45.26 \text{ kN}$$

$$\therefore \text{Number of bolts required} = \frac{450}{45.26} = 9.94 \simeq 10$$

Let's provide 10 bolts at a pitch of 2.5 × 20 = 50 mm and edge distance of 35 mm.

Length of the gusset plate = 9 × 50 + 2 × 35 = 520 mm.

$$\text{Area of connected leg, } A_{nc} = \left[150 - 22 - \left(\frac{10}{2}\right)\right] \times 10 = 1230 \text{ mm}^2$$

$$\text{Area of outstanding leg, } A_{go} = \left[75 - \left(\frac{10}{2}\right)\right] \times 10 = 700 \text{ mm}^2$$

$$A_n = 1230 + 700 = 1930 \text{ mm}^2 > 1524.39 \text{ mm}^2$$

Tensile strength of angle section = $0.9 \times 1930 \times \frac{410}{1.25}$ N = 569.736 kN > 450 (OK)

Without lug angle, the length of the gusset plate is 520 mm. To reduce the length of connection, we shall now use lug angle.

Design of lug angle

Total factored tensile load = 450 kN

Gross area of connected leg, A_{gc} = $\left(150 - \left(\frac{10}{2}\right)\right) \times 10 = 1450 \text{ mm}^2$

Gross area of outstanding leg, A_{go} = $\left(75 - \frac{10}{2}\right) \times 10 = 700 \text{ mm}^2$

Load shared by outstanding leg of main angle = $\frac{450 \times 700}{(700 + 1450)} = 146.5$ kN

Load on lug angle = 1.2 × 146.5 = 175.8 kN

Required net area for lug angle = $\frac{175.8 \times 10^3}{0.9 \times \frac{410}{1.25}} \simeq 596 \text{ mm}^2$

Let us use ISA 150 × 75 × 8 angle with A_g = $(150 + 75 - 8)^8$ mm^2 = 1736 mm^2

Assuming that the section is weakend by one row of 20 mm - dia bolts.

∴ Net area = 1736 – 22 × 8 = 1560 mm^2 > 596 mm^2

The lug angle is also kept with its 75 mm long leg as outstanding leg.

Number of bolts required to connect 150 mm leg of lug angle with gusset plate

$$= \frac{175.8}{45.3} \simeq 4$$

∴ Provide four bolts of 20 mm diameter to connect lug angle with gusset plate.

Check:

$$\text{Load on connected leg} = \frac{450 \times 1450}{700 + 1450} = 303.5 \text{ kN}$$

$$\text{Required number of bolts} = \frac{303.5}{45.3} \simeq 7$$

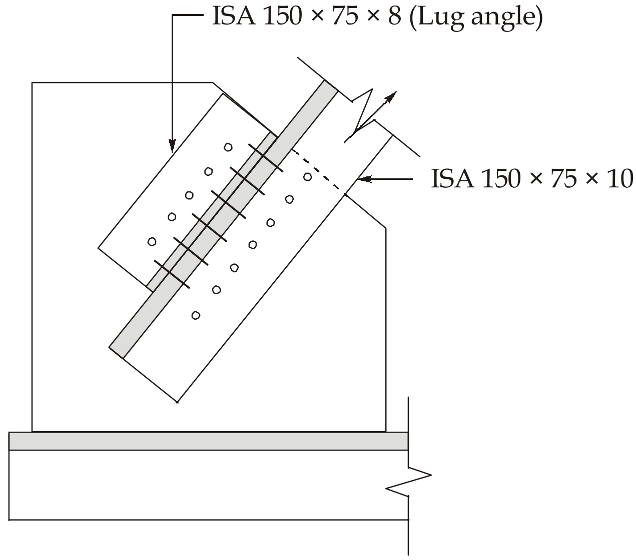
Hence provide seven 20-mm-diameter bolts to connect the diagonal tension member with the gusset plate.

Required number of bolts to connect outstanding legs of the two angles.

$$= \frac{1.4 \times 146.5}{45.3} \simeq 5$$

Hence provide five bolts of 20 mm diameters.

Required length of gusset plate = 6 × 50 + 2 × 35 = 370 mm



Q.8 (a) Solution:

(i)

Time required per trip in minutes (or cycle time) is given by:

$$\text{Cycle time} = \frac{D}{F} + \frac{D}{R} + G$$

where, D = Haul distance in metres

F = Forward speed in meters / minute

R = Reverse speed in meters/minute

G = Gear shifting time in minute

Now, $$\text{Cycle time} = \frac{40}{\frac{3\times1000}{60}} + \frac{40}{\frac{6\times1000}{60}} + 0.30 = 1.5 \text{ minutes.}$$

Now, output of bulldozer is given by = $\frac{5}{1.25} \times \frac{50}{1.5}$ = 133.33 cum/hr

(ii)

The output of a power shovel is affected by numerous factors which are enumerated as below :

1. **Class of material:** The output of a power shovel varies with the class of materials. It is apparent from the data given by Power Crane and Shovel Association of USA. The data shows the ideal output measured in cubic meter per 60 min hour, bank measure of a 2 cum power shovel.

Output for:

Sand and gravel = 330 m^3/hr.

Good common earth = 300 m^3/hr.

Wet, sticky clay = 185 m^3/hr.

2. **Depth of cut:** If the depth of the face from which a shovel is excavating material is too shallow, cycle time increases. Consequently, the output is reduced. If the depth of the face is greater than minimum required to fill the dipper, the output is increased.
3. **Size of hauling units:** Size of hauling units like trucks affect the output of a shovel. For optimum output, size of hauling units should be governed by size of a power shovel. If the shovel used is of smaller size, the size of hauling unit must be small while for a large shovel, the hauling unit must be of larger size.
4. **Angle of swing:** The angle of swing of a power shovel is the horizontal angle between the position of the dipper when it is excavating and the position when it is discharging the load. If the angle of swing is increased, the cycle time also gets increased while if the angle of swing is decreased, the cycle time also gets decreased. The output of shovel is inversely proportion to the cycle time.
5. **Job conditions:** Job conditions may be classified as excellent, good, fair and poor depending upon the situations of work site and climatic conditions. These conditions greatly affect the output of the power shovel.

Q.8 (b) Solution:

(i)

Maximum moment of inertia,

$$I_{uu} = \frac{I_{xx}+I_{yy}}{2} + \sqrt{\left(\frac{I_{xx}-I_{yy}}{2}\right)^2 + I_{xy}^2}$$

$$= \frac{20\times10^6 + 9.7\times10^6}{2} + \left(10^6 \times \left(\sqrt{\left(\frac{20-9.7}{2}\right)^2 + 8.3^2}\right)\right)$$

$$= 14.85 \times 10^6 + 9.77 \times 10^6 = 24.62 \times 10^6 \text{ mm}^4$$

Minimum moment of inertia,

$$I_{vv} = \frac{I_{xx}+I_{yy}}{2} - \sqrt{\left(\frac{I_{xx}-I_{yy}}{2}\right)^2 + I_{xy}^2} = 14.85 \times 10^6 - 9.77 \times 10^6$$

$$= 5.08 \times 10^6 \text{ mm}^4$$

Minimum radius of gyration, $r_{min} = \sqrt{\frac{I_{min}}{A_g}} = \sqrt{\frac{5.08 \times 10^6}{5025}} = 31.8$ mm

∵ It is a single angle discontinuous strut connected by more than one bolt.

∴ Effective length, $L_{eff} = 0.85 \times 5 = 4.25$ m

$$\lambda = \frac{L_{eff}}{r_{min}} = \frac{4250}{31.8} = 133.65$$

From table, let's find out the value of f_{cd} for $\lambda = 133.65$

$$\frac{140-130}{51-57} = \frac{140-133.65}{51-f_{cd}}$$

$$\Rightarrow \quad f_{cd} = 54.81 \text{ N/mm}^2$$

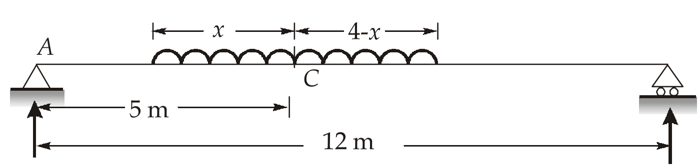
∴ Allowable compressive load,

$$P_{cd} = f_{cd} A_g = \frac{54.81 \times 5025}{1000} \text{ kN} = 275.42 \text{ kN}$$

∴ Working load / service load, $P = \frac{P_{cd}}{FOS} = \frac{275.42}{1.5} = 183.61$ kN

(ii)

Muller Breslau's principle states that the ILD for any stress function in a structure is represented by its deflected shape by removing the restraint offered by the stress function (SF, BM and reaction) and introducing unit displacement in positive direction of that stress function.



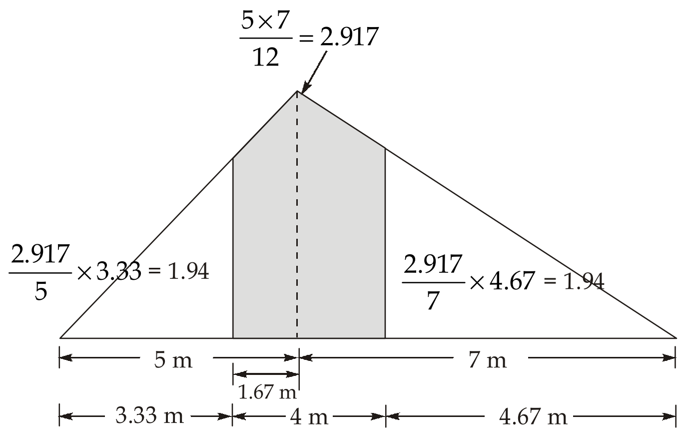
For UDL shorter than span, maximum bending moment occurs at a section if that section divides UDL and the span in the same ratio.

$$\therefore \quad \frac{x}{4-x} = \frac{5}{7}$$

$$\Rightarrow \quad x = 1.67 \text{ m}$$

ILD for BM at 5 m,

$$\frac{ab}{l} = \frac{5 \times 7}{12} = 2.917$$



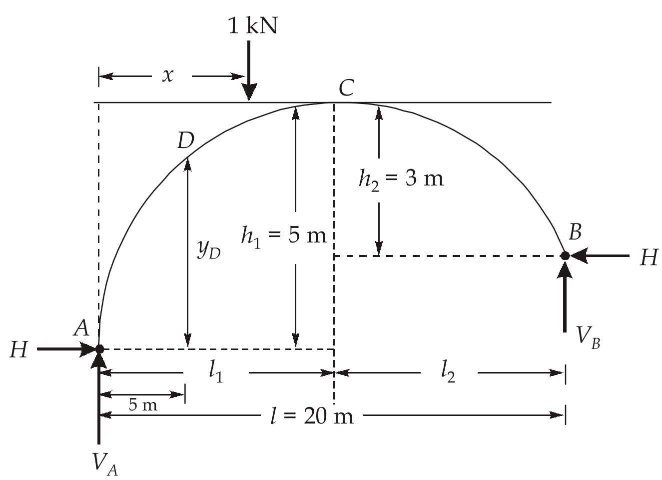
$\therefore$ Maximum BM at section C,

$$= \text{Area of ILD under UDL}$$

$$= 20\times\left[\frac{1}{2}\times(2.917-1.94)\times4+1.94\times4\right]$$

$$= 20 \times 9.714 = 194.28 \text{ kN-m}$$

Q.8 (c) Solution:



Here, $l = l_1 + l_2 = 20$ m

$$l_1 = \frac{l\sqrt{h_1}}{\sqrt{h_1}+\sqrt{h_2}} = \frac{20\sqrt{5}}{\sqrt{5}+\sqrt{3}} = 11.27 \text{ m}$$

$\Rightarrow$ $l_2 = 20 - l_1 = 8.73$ m

Consider a unit load at x distance from A, such that $0 < x < 11.27$ m i.e. load is in AC portion.

Using equilibrium equations,

$$\sum F_y = 0$$

$$\Rightarrow \quad V_A + V_B = 1 \qquad \ldots(i)$$

$$\sum M_C = 0 \qquad \text{(from left)}$$

$$V_A \times l_1 = H \times 5 + 1(11.27 - x)$$

$$\Rightarrow \quad 11.27\, V_A = 5H + 11.27 - x \qquad \ldots(ii)$$

$$\Rightarrow \quad \Sigma M_C = 0 \qquad \text{(from right)}$$

and $$V_B\, l_2 = H \times 3$$

$$\Rightarrow \quad \sum M_C = 0 \qquad [\because \text{From right}]$$

$$\Rightarrow \quad V_B \times 8.73 = 3H \qquad \ldots(iii)$$

From (ii) & (iii)

$$\Rightarrow \quad 11.27 V_A = \frac{5 \times V_B \times 8.73}{3} + 11.27 - x$$

$$\Rightarrow \quad 11.27\, V_A - 14.55\, V_B = 11.27 - x \qquad \ldots(iv)$$

From (i) and (iv)

$$\left.\begin{aligned} V_B &= 0.039x \\ V_A &= 1 - 0.039x \\ H &= 0.11x \end{aligned}\right\} (0 < x < 11.27)$$

When unit load is in portion BC at 'x' distance from B,

$$\sum F_y = 0, \quad \Rightarrow \quad V_A + V_B = 1 \qquad \ldots(v)$$

$$\sum M_C = 0, \quad \Rightarrow \quad V_B \times 8.73 = 3H + 1(8.73 - x) \quad \text{(From right)}$$

$$\sum M_C = 0 \quad \Rightarrow \quad V_A \times 11.27 = 5H \qquad \text{(From left)}$$

$$\therefore \quad 8.73\, V_B = 6.76\, V_A + 8.73 - x \qquad \ldots(vi)$$

From (v) and (vi),

$$V_A = 0.064\, x$$

$$\text{H} = 0.145\, x$$

Ordinate at $x = 5$ m, $$y_D = \frac{4hx}{l_1^2}(l - x) = \frac{4 \times 5 \times 5 \times (2 \times 11.27 - 5)}{(11.27 \times 2)^2} = 3.452 \text{ m}$$

Influence line for BM at *D*,

Case-1:

When unit load is in between A and D, at x from A i.e. $0 \le x \le 5$

Bending moment At D,

$$BM_D = \text{Beam moment} - \text{H-moment}$$
$$= V_A(5) - 1(5 - x) - H \times y_D$$
$$= (1 - 0.039x) \times 5 - 5 + x - 0.11x \times 3.452$$
$$= 0.4253x$$

At $x = 0$, $BM_D = 0$ kN-m

$x = 5$ m, $BM_D = 2.126$ kN-m

Case-2:

When unit load is in between D and C, at x from A i.e. $5 \le x \le 11.27$ m

$$BM_D = \text{Beam moment} - \text{H-moment}$$
$$= V_A(5) - H \times y_D$$
$$= (1 - 0.039x) \times 5 - 0.11x \times 3.452$$
$$= 5 - 0.574\,x$$

At $x = 5$ m, $BM_D = 2.126$ kN-m

$x = 11.27$ m, $BM_D = -1.48$ kN-m

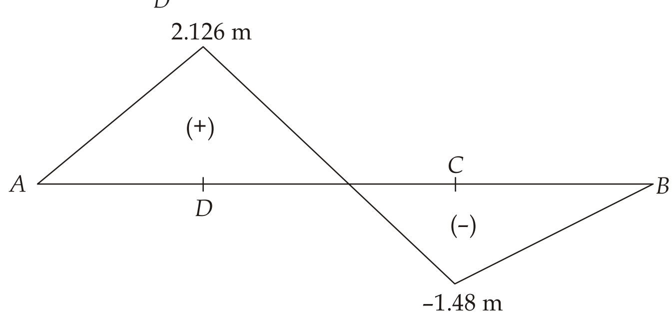
Case-3:

When unit load is in between BC at x from B i.e. $0 \le x \le 8.73$ m

$$BM_D = \text{Beam moment} - \text{H-moment}$$
$$= V_B(l - 5) - 1(l - 5 - x) - H\,[3 - (5 - 3.452)]$$
$$= (1 - 0.064x) \times 15 - (15 - x) - 0.145x \times 1.452$$
$$= -0.1705x$$

At $x = 0$ m, $BM_D = 0$

$x = 8.73$ m, $BM_D = -1.48$ kN-m



ILD for BM at D

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