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Detailed Solutions

SSC-JE 2018 Mains Test Series (PAPER-II)

Civil Engineering Test No : 8

Q.1 (a) Solution:

$$\text{Total flow of sewage} = 2600 \times 125 = 325 \text{ m}^3/\text{day}$$

$$\text{BOD per day} = \frac{350 \times 325}{1000} = 113.75 \text{ kg}$$

$$\text{Assuming rate of loading} = 300 \text{ kg/hectare/day}$$

$$\text{Surface area of oxidation pond required} = \frac{113.75}{300} = 0.38 \text{ ha} = 3800 \text{ m}^2$$

Assuming $L = 2B$

$\Rightarrow$ $2B^2 = 3800$

$\therefore$ $B = 43.60$ m

and $L = 87.20$

Using pond with effective depth = 1.2 m

$$\text{Capacity of pond} = 87.2 \times 43.6 \times 1.2 = 4562.3 \text{ m}^3$$

$$\text{Now detention time} = \frac{4562.3}{325} = 14.04 \text{ days}$$

Hence provide an oxidation pond with,

$L = 87.20$ m,

$B = 43.6$ m

and depth, $D = 1.2 + 1 = 2.2$ m

Q.1 (b) Solution:

Given: Water content, $w = 10\% = 0.1$

$$\text{Air content, } a_c = 6\%$$
$$\text{Specific gravity of soil solids, } G = 2.68$$
$$\text{Diameter of specimen, } d = 15 \text{ cm}$$
$$\text{Height of specimen, } h = 12.5 \text{ cm}$$

$$\text{Air content, } a_c = \frac{V_a}{V_v} = 0.06$$
$$V_a = 0.06\ V_v$$
$$V_w = 0.94\ V_v$$
$$V_a = 0.06\left(\frac{V_w}{0.94}\right) = 0.0638\ V_w$$

$$\text{Volume of specimen, } V = \frac{\pi}{4} \times 15^2 \times 12.5 = 2208.9 \text{ m}l$$
$$V = V_s + V_w + V_a$$
$$2208.9 = V_s + V_w + 0.638 V_w = V_s + 1.0638 V_w$$

Writing volumes in terms of mass,

$$2208.9 = \frac{M_s}{2.68 \times 1.0} + 1.0638\left(\frac{M_w}{1.0}\right)$$
$$= \frac{M}{2.68} + 1.0638 \times 0.1\ M_s \qquad (\text{Since } M_w = 0.10\ M_s)$$
$$M_s = 4606.54 \text{ gm.}$$
$$M_w = 460.65 \text{ gm}$$
$$\text{Mas of wet soil, } M = M_s + M_w = 4606.54 + 460.65 = 5067.19$$
$$\text{Bulk density, } \rho = \frac{M}{V} = \frac{5067.19}{2208.9} = 2.294 \text{ gm/m}l$$
$$\text{Dry density, } \rho_d = \frac{\rho}{1+w} = \frac{2.294}{1+0.10} = 2.085 \text{ gm/m}l$$
$$e = \frac{G\rho_w}{\rho_d} - 1 = \frac{2.68 \times 1.0}{2.085} - 1 = 0.285$$

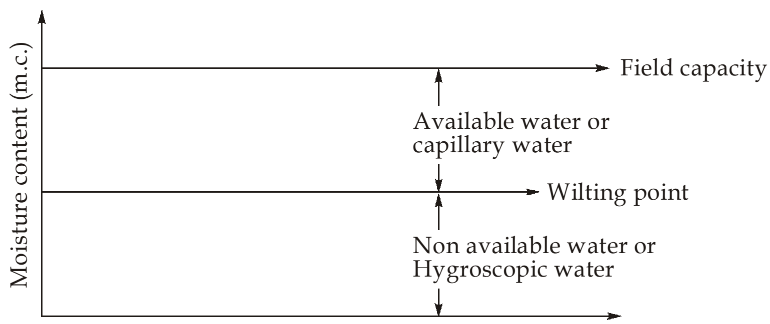
Q.1 (c) Solution:

(a) **Hygroscopic water :** This water forms very thin film around soil particles and is not available to the plant. The water is held so tightly by the soil that it cannot be taken up by the roots.

- Not held in the pores, but on the particle surface. This means clay will contain much more of this type of water than sands because of surface area differences.
- Hygroscopic water is held very tightly by forces of adhesion and this water is not available to the plant.

- Gravity is always acting to pull water down through the soil profile. However, the force of gravity is counteracted by forces of attraction between water molecules and the soil particles and by the attraction of water molecules to each other.

(b) **Permanent wilting point :** The permanent wilting is that water content at which plant can no longer extract sufficient water for its growth, and wilts up. It is the point at which permanent wilting of plants takes place. It therefore, becomes evident that the water which is available to the plants is the difference of field capacity water and permanent wilting point water.



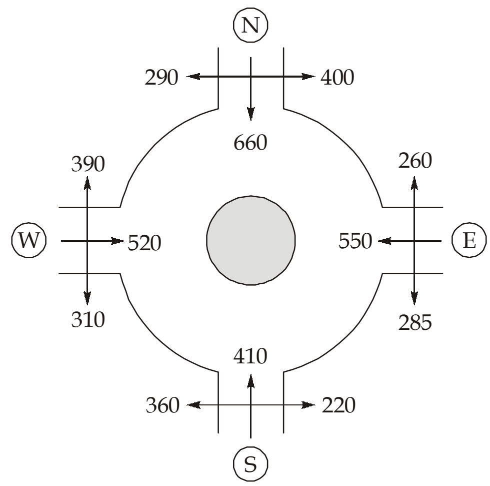
(c) **Consumptive use or Evapotranspiration :** Consumptive use for a particular crop may be defined as the total amount of water used by the plant in evapotranspiration (building of plant tissues) and evaporation from adjacent soil or from plant leaves in any specified time.

The value of consumptive use (c_u) may be different for different crops, may be different for the same crop at different times and places.

Factors affecting consumptive use :

- Evaporation which depends on humidity.
- Mean monthly temperature.
- Growing monthly temperature.
- Growing season of crop and cropping pattern.
- Monthly precipitation.
- Irrigation depth or the depth of water applied for irrigation.
- Wind velocity in the locality.
- Soil and topography.
- Irrigation practices and methods of irrigation.

Q.1 (d) Solution:



Calculation of weaving ratio,

$$P = \frac{b+c}{a+b+c+d}$$

where, b and c are weaving traffic, a and d are non-weaving traffic

For North-East leg :

$$P = \frac{660+290+220+520}{400+660+290+220+310+520} = 0.7042$$

For South-East leg :

$$P = \frac{660+550+260+310}{285+660+290+550+260+310} = 0.7558$$

For South-West leg :

$$P = \frac{410+220+290+550}{360+260+410+220+290+550} = 0.7034$$

For North-West leg :

$$P = \frac{520+310+410+260}{390+520+310+410+260+220} = 0.711$$

Practical capacity of rotary is given by,

$$Q_P = \frac{280W\left(1+\frac{e}{W}\right)\left(1-\frac{P}{3}\right)}{\left(1+\frac{W}{L}\right)}$$

where:

$$e = \frac{e_1 + e_2}{2} = \frac{10+10}{2} = 10 \text{ m}$$

e_1 = Entry width = 10 m

e_2 = Exit width = 10 m

W = Width of weaving section = e + 3.5

= 10 + 3.5 = 13.5 m

L = Length of weaving section

= 3.5 × 13.5 = 47.25 m

P = Maximum weaving ratio = 0.7558

$$\therefore \quad Q_P = \frac{280 \times 13.5 \times \left(1 + \frac{10}{13.5}\right)\left(1 - \frac{0.7558}{3}\right)}{\left(1 + \frac{13.5}{47.25}\right)}$$

= 3828 PCU/hr

Q.2 (a) Solution:

Here, Staff intercept, S = 2.550 – 2.500

= 0.050 m

n = 5 div (deviation)

d = 2 mm = 0.002 m (length of one division)

D = 100 m (distance between level and staff)

From the relation, $$R = \frac{ndD}{S} = \frac{5 \times 0.002 \times 100}{0.050} = 20 \text{ m}$$

The sensitiveness of the bubble α' is

$$\alpha' = \frac{S}{nD} \times 206265 = \frac{0.05 \times 206265}{5 \times 100} = 20.62 \text{ seconds}$$

So, the radius of curvature is 20 m and the angular value of one division is 20.62 seconds.

Q.2 (b) Solution:

Bench mark is a fixed point of known elevation above the datum. Any point whose elevation is definitely known can be used as a bench mark. However, a relatively permanent object having a marked point whose elevation is known is usually taken as the bench mark. A triangle is generally cut or pointed around the bench mark to indicate the location.

The following types of bench marks are used depending upon the permanency and precision.

(i) GTS bench mark: The great trigonometrical survey (GTS) bench marks are established by the Survey of India throughout the country. The levels of the GTS bench marks are determined very accurately with respect to the mean sea level at Bombay Port.

(ii) Permanent Bench mark: The permanent bench marks are established at a closer interval between widely spaced GTS bench marks. These bench marks are established by the Survey of India or some other government agency such as PWD. The permanent bench marks are usually established on relatively permanently natural or artificial points such as isolated rocks, culverts, gate pillars of public buildings. These are generally less accurate than GTS bench marks.

(iii) Temporary bench marks: These are bench marks established temporarily whenever required. These are generally the points at which a days work is closed and from which next days work is started.

(iv) Arbitrary bench marks: These are bench marks whose elevations are arbitrary assumed for levelling of a small area. The elevations assumed do not refer to any fixed datum such as MSL.

Given data:

First RL = 51.45 m; Last RL = 63.50 m; ΣBS = 87.755 m; ΣFS = 73.725 m

We know that, arithmetic check for entries in a field level book is given by

$$\boldsymbol{\Sigma BS - \Sigma FS = \text{Last } RL - \text{First } RL}$$

If LHS and RHS are equal, then entries are correct, otherwise the difference between LHS and RHS is the closing error of the work. Thus

$$\Sigma BS - \Sigma FS = 87.755 - 73.725 = 14.03 \text{ m}$$

$$\text{Last } RL - \text{First } RL = 63.50 - 51.45 = 12.05 \text{ m}$$

$$\therefore \quad \text{Closing error} = 14.03 - 12.05 = 1.98 \text{ m.}$$

Q.2 (c) Solution:

(i) Tractive resistance : Tractive resistance are the forces which resist the movement and speed of train. The speed of train must be adequate enough to overcome the resistance offered by the locomotive trailing the load and other agencies against its movement. The various forces are classified into four categories:

(a) Train resistance

(b) Resistance due to track profile

(c) Resistance due to starting and acceleration

(d) Wind resistances

(ii) Coning of wheels : The wheel is coned at a slope of 1 in 20 to keep it in the central position automatically. It has the following advantages:

(a) Coning prevents wheels from slipping

(b) It reduces wear and tear of the wheel flanges and rails which occurs due to rubbing action of flanges with inside faces of the rail head.

(c) It provides a possibility of lateral movement of the axle with its wheels.

(iii) Objectives of signalling : The various objects of providing and operating signals are as follows:

(a) To provide facilities for the efficient movement of trains.

(b) To ensure safety between two or more trains which cross or approach each other's path.

(c) To provide facilities for the maximum utility of the track.

(d) To provide facilities for safe and efficient shunting operations.

(e) To guide the trains movement during maintenance and repairs of the track.

(f) To safeguard the trains at converging junctions and to give directional indications at diverging junctions.

Q.2 (d) Solution:

1. For *DC*: There is a linear variation of *BM* between *D* and *C*. Hence, there is no load between *D* and *C* (resulting in constant SF) and hence $R_D = \frac{0.625}{2.5} = 0.25 \text{ kN}(\downarrow)$.

2. At *C* : There is sudden change in BM from –0.625 kNm to +11.875 kNm. Hence, there is anticlockwise moment = 0.625 + 11.875 = 12.5 kNm at *C*, causing concavity upwards, for remaining portion.

3. For *CB* : From C to B, there is linear variation of BM, resulting in constant $SF = \frac{dM}{dx}$ $= \frac{\text{Initial BM} - \text{Final BM}}{2.5} = \frac{11.875 - 10.625}{2.5} = 0.5 \text{ kN}$. Since, R_D = 0.25 kN only, there exists a point load = 0.5 – 0.25 = 0.25 kN (↓) at *C*.

4. For *BA* : From *B* to *A*, there is parabolic variation of *BM*. Hence, there will be linear variation in *SF*, indicating udl between *A* and *B*.

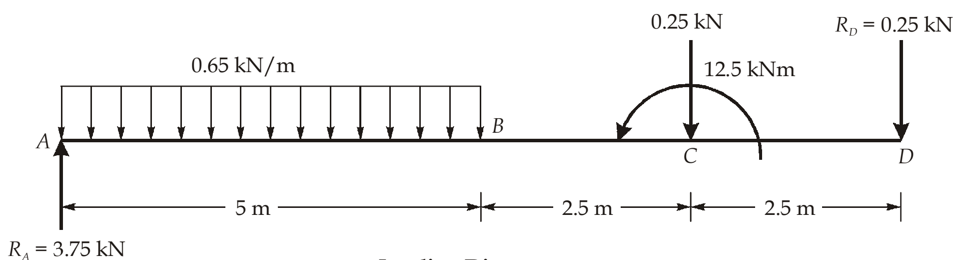
Taking moments about *A*, we have

$$M_A = 0 = -0.25 \times 10 - 0.25 \times 7.5 + 12.5 - \frac{w \times 5^2}{2}$$

$$\Rightarrow \quad w = 0.65 \text{ kN/m}$$

Hence, $R_A = 0.65 \times 5 + 0.25 + 0.25 = 3.75 \text{ kN} (\uparrow)$

The loading diagram is shown below:



Loading Diagram

Q.3 (a) Solution:

(i) Initial compression: If soil is partially saturated, then immediately after the application of load, the volume decreases due to expulsion of air as well as due to compression of pore air which is called initial compression.

At the end of initial compression of soil, it becomes fully saturated if load is sufficiently large. The result of initial compression is the immediate settlement which is usually determined by using elastic theory, even though the deformation itself is not truely elastic. Computation of immediate settlement has to be made in the design of shallow foundations.

(ii) Primary consolidation: After the initial compression, soil is fully saturated and further decrease in volume occurs due to expulsion of pore water. (Water is incompressive, hence volume change due to compression of pore water in negligible). It is a time dependent phenomenon which depends upon permeability of soil and magnitude of load applied. The rate of flow is controlled by pore pressure, the permeability and compressibility of soil. With the passage of time as the pore pressure dissipates, the rate of flow decreases and eventually, flow ceases altogether, leading to a condition of constant effective stress. This signifies the end of primary consolidation.

(iii) Quick sand condition: It is a type of soil condition but not the type of sand in which net effective vertical stresses becomes zero, when seepage occurs vertically up through the sands/cohesionless soils.

In such a condition, the soil molecules become weightless (Floating condition) and cohesionless soil molecules starts flowing with the water. Such a condition may cause piping failure below the dams.

Q.3 (b) Solution:

With a load factor of 1.5, the factored load is

$$1.5 \times 1500 = 2250 \text{ kN}$$

Lateral ties

$$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$$

Assuming 0.8% steel, as we have to provide minimum reinforcement

$$2250 \times 1000 = 0.4 \times 25 (A_g - 0.008 A_g) + 0.67 \times 415 \times 0.008 A_g$$

$$A_g = 185270 \text{ mm}^2 = \frac{\pi}{4} D^2$$

$$D = 486 \text{ mm}$$

Adopt an overall diameter of 500 mm.

$$\text{Area of longitudinal steel} = 0.008 \times 185270 = 1482 \text{ mm}^2$$

Thus provide 8-16 mm longitudinal bars.

Use 6 mm mild steel lateral ties

$$\text{Pitch } p \le 500 \text{ mm} \quad \text{(lateral dimension)}$$

$$\le 16\,\phi_L \quad (16 \times 16 = 256 \text{ mm})$$

$$\le 300 \text{ mm}$$

Adopt a pitch of 250 mm c/c.

Q.3 (c) Solution:

The problem is described by five variables.

Let, $f(P, N, D\, \rho, \mu) = 0$

These variables are expressed by three fundamental dimensions = M, L and T. Therefore, the number of π-terms = (5 – 3) = 2. Let N, D and ρ are taken as the repeating variables in determining the π-terms.

Then,

$$\pi_1 = N^{a1} D^{b1} \rho^{c1} P$$

$$\pi_2 = N^{a2} D^{b2} \rho^{c2} \mu$$

Substituting the variables in terms of their fundamental dimensions M, L, T we get,

$$M^0 L^0 T^0 = \left(T^{-1}\right)^{a1} (L)^{b1} \left(ML^{-3}\right)^{c1} ML^2 T^{-3}$$

and

$$M^0 L^0 T^0 = \left(T^{-1}\right)^{a2} (L)^{b2} \left(ML^{-3}\right)^{c2} ML^{-1} T^{-1}$$

Equating the exponents of M, L and T, we get

$$C_1 + 1 = 0, \quad b_1 - 3c + 2 = 0, \quad -a_1 - 3 = 0$$

which gives, $a_1 = -3, \quad b_1 = -5, \quad c_1 = -1$

and hence, $$\pi_1 = \frac{P}{\rho N^3 D^5}$$

Similarly from other equation,

$$c_2 + 1 = 0$$
$$b_2 - 3c_2 - 1 = 0$$
$$-a_2 - 1 = 0$$

which gives $a_2 = -1, \quad b_2 = -2$ and $c_2 = -1$

Hence, $$\pi_2 = \frac{\mu}{\rho N D^2}$$

Therefore, the problem can be expressed in terms of independent dimensionless parameters, as,

$$f\left(\frac{P}{\rho N^3 D^5}, \frac{\mu}{\rho N D^2}\right) = 0$$

$$\Rightarrow \quad \phi\left(\frac{P}{\rho N^3 D^5}, \frac{\rho N D^2}{\mu}\right) = 0$$

$$\Rightarrow \quad \frac{P}{\rho N^3 D^5} = \phi'\left(\frac{\rho N D^2}{\mu}\right)$$

$$\therefore \quad P = \rho N^3 D^5 \phi'\left(\frac{\rho N D^2}{\mu}\right)$$ Hence Proved.

Q.3 (d) Solution:

Bearing stiffeners are provided to transfer concentrated loads on the girder and heavy reactions at supports to the full depth of the web. These are required when the web has insufficient strength for any of the limit state of web yielding, web crippling, or sideway web buckling.

A bearing stiffener at the support is called an end bearing stiffener. Bearing stiffener should be placed:

1. tight with the web.
2. straight i.e., it should not be crimped or joggled

3. in pair of two or four angles, symmetrically placed on two both sides of the web for a riveted/bolted plate girder and two or four plates for welded plate girder.

Bearing stiffeners should be designed for the applied load or reaction less the local capacity of the web, F_w given by;

$$F_w = \frac{(b_1 + n_2)\, t_w f_{yw}}{\gamma_{m0}}$$

where, b_1 = stiff bearing length, n_2 = length obtained by dispersion through the flange to the web junction at slope of 1 : 2.5 to the plane of flange.

t_w = thickness of web, f_{yw} = yield stress of the web

Bearing stiffeners are required to prevent sidesway web buckling only under a limited number of circumstances. Sidesway web buckling should be checked when the compression flange is not restrained against movement relative to the tension flange.

Q.4 (a) Solution:

Harmful substances in brick earth:

- **Lime :** When a desirable amount of lime (not exceeding 5%) is present in the clay, it results in good bricks, but if it is present in excess then it changes the colour of the brick from red to yellow and causes bricks to melt and hence change in shape.
- **Pebbles, gravels and grits :** They do not allow the clay to be mixed thoroughly and spoil the appearance of the brick. Bricks with pebbles and gravels results in weak and porous bricks.
- **Iron pyrites :** They tend to oxidise and decompose the brick during burning. The brick may split into pieces. Pyrites decolourize the bricks.
- **Alkalies :** Alkalies forming less than 10% of the raw clay, are of great value as fluxes especially when combined with silicates of alumina. It is in the form of soda or potash. Alkalies cause the bricks to loose their shape.
- **Organic matter :** On burning green bricks, the organic matter gets charred and leaves pores making the bricks porous and hence the water absorption is increased and strength is reduced.
- **Carbonaceous materials :** It is in the form of bituminous matter or carbon and greatly affects the colour of raw clay.
- **Sulphur :** It will cause formation of spongy, swollen structure in the brick and the brick will be decoloured by white patches.
- **Water :** A large proportion of free water generally causes clay to shrink considerably

during drying whereas combined water causes shrinkage during burning.

Efflorescence in bricks:

This defect is caused because of alkalies present in the bricks. When bricks come in contact with moisture, water is absorbed and alkalies crystallise. On drying, grey or white powder patches appear on the brick surface. This can be minimised by selecting proper clay materials for brick manufacturing, preventing moisture to come in contact with the masonry, by providing waterproof coping and by using water repellant materials in mortar and by providing damp proof course.

Remedy:

The only satisfactory treatment may be to render the wall after removing all loose material and raking out the mortar which may itself be impregnated.

Q.4 (b) Solution:

Given: y = 1.20 m, m = 1.5, S_0 = 0.0004, n = 0.022 and Q = 1.50 m^3/s

$$\text{Area, } A = my^2 = 1.5 \times (1.2)^2 = 2.16 \text{ m}^2$$

$$\text{Wetted perimeter, } P = 2y\sqrt{m^2+1} = 2 \times 1.2 \times (3.25)^{1/2} = 4.327 \text{ m}$$

$$\text{Hydraulic radius, } R = \frac{A}{P} = \frac{2.16}{4.327} = 0.50 \text{ m}$$

$$\text{Top width, } T = 2my = 2 \times 1.5 \times 1.2 = 3.60 \text{ m}$$

$$\text{Velocity, } V = \frac{Q}{A} = \frac{1.50}{2.16} = 0.694 \text{ m/s}$$

$$\text{Friction slope, } S_f = \frac{n^2V^2}{R^{4/3}} = \frac{(0.022)^2 \times (0.694)^2}{(0.50)^{4/3}} = 0.000588$$

$$\frac{dy}{dx} = \frac{S_0 - S_f}{1 - \left(\frac{Q^2T}{gA^3}\right)} = \frac{0.0004 - 0.000588}{1 - \left(\frac{(1.5)^2 \times 3.6}{9.81 \times (2.16)^3}\right)} = -0.000205$$

Water surface slope relative to horizontal,

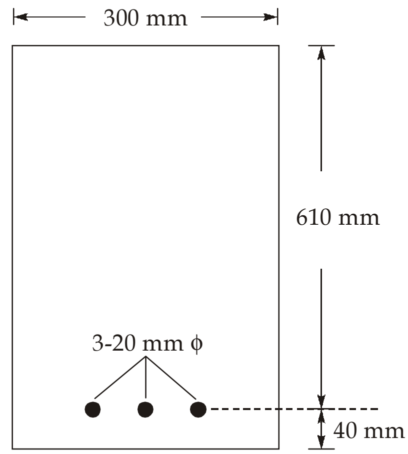
$$S_w = \frac{dy}{dx} - S_0$$

$$= -0.000205 - 0.0004 = -0.000605$$

Q.4 (c) Solution:

$$\text{Area of tension steel, } A_{st} = 3 \times \frac{\pi}{4} \times (d)^2 = 3 \times \frac{\pi}{4} \times (20)^2$$

$$= 942.48 \text{ mm}^2$$



Limiting depth of neutral axis,

$$(x_u)_{\text{lim}} = 0.48d \quad \text{(For Fe415)}$$

$$= 0.48 \times 610 = 292.80 \text{ mm}$$

Actual depth of neutral axis, $x_u = \dfrac{0.87 f_y A_{st}}{0.36 f_{ck} b}$

$$= \frac{0.87 \times 415 \times 942.48}{0.36 \times 20 \times 300} = 157.54 \text{ mm}$$

$\therefore \quad x_u < x_{u,\text{lim}}$

The section is under-reinforced.

Moment of resistance, $MR = 0.36 f_{ck} Bx_u (d - 0.42x_u)$

$$= 0.36 \times 20 \times 300 \times 157.54 (610 - 0.42 \times 157.54) \text{ Nmm}$$

$$= 185.059 \text{ kNm}$$

Let 'w' kN/m be factored UDL and 'W' kN be factored point load.

Given, $wl = 4W$

$\therefore$ Bending moment at centre of beam;

$$BM = \frac{Wl}{4} + \frac{wl^2}{8}$$

$$BM = \frac{Wl}{4} + \frac{(wl)l}{8} = \frac{Wl}{4} + \frac{4Wl}{8}$$

$$= \frac{3}{4} Wl$$

Equating BM with MR, $\frac{3}{4}W_u l = 185.059$

$$\Rightarrow \quad W = \frac{185.059 \times 4}{3 \times 6} = 41.12 \text{ kN}$$

$$\therefore \quad w = \frac{4W}{l} = \frac{4 \times 41.12}{6} = 27.41 \text{ kN/m}$$

∴ Safe concentrated working load

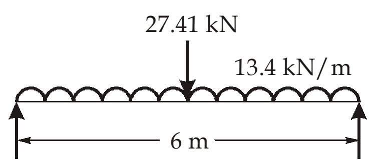
$$= \frac{W}{1.5} = \frac{41.12}{1.50} = 27.41 \text{ kN}$$

Factored dead load, w_d = (0.3 × 0.65 × 25) × 1.50
= 7.3125 kN/m

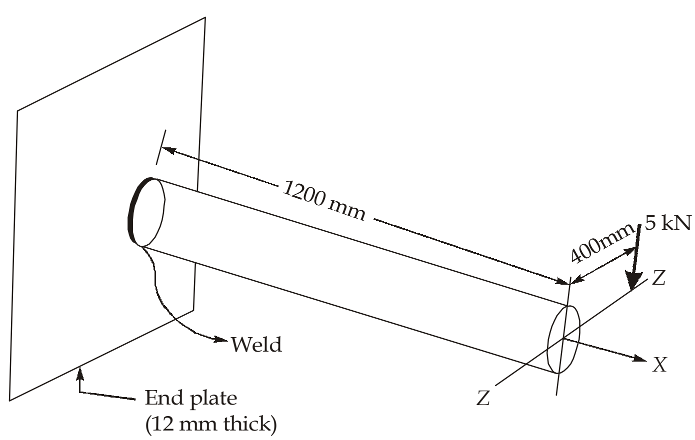
∴ Factored superimposed UDL = $(w - w_d)$
= (27.41 – 7.3125)
= 20.1 kN/m

Safe superimposed working UDL

$$= \left(\frac{w - w_d}{1.50}\right) = \frac{20.1}{1.50} = 13.4 \text{ kN/m}$$



Q.5 (a) Solution:



Schematic loading arrangement

For shop welded connection, partial safety factor, γ_{mw} = 1.25 and for Fe410 grade steel;

f_u = 410 MPa and f_y = 250 MPa.

For the given CHS connected by fillet weld of effective throat thickness, t_e

$$A_e = \pi D t_e = \pi \times 130 \times t_e = 130\,\pi t_e \text{ mm}^2$$

$$I_Z = \pi\left(\frac{D^3}{8}\right)t_e = 274625\,\pi t_e \text{ mm}^4$$

$$I_P = 2I_Z = 2\pi\left(\frac{D^3}{8}\right)t_e = 549250\,\pi t_e \text{ mm}^4$$

Design forces: Factored shear force, $V_u = 5.0$ kN

Factored bending moment, $M_u = 5 \times 1.2 = 6$ kNm

Factored torsion, $T_u = 5 \times 0.40 = 2.0$ kNm

$$\text{Design strength of weld, } F_{dw} = \frac{f_u}{\sqrt{3}\gamma_{mw}} = \frac{410}{\sqrt{3} \times 1.25} = 189.37 \text{ MPa}$$

Stresses in the weld due to applied forces,

$$\text{Shear stresses, } q = \frac{V_u}{A_e} = \frac{5 \times 10^3}{130\pi t_e} = \frac{12.24}{t_e} \text{ MPa}$$

$$\text{Bending stresses, } f_b = \frac{M_u(D/2)}{I_Z} = \frac{6 \times 10^6 \times 65}{274625\pi t_e} = \frac{452.04}{t_e} \text{ MPa}$$

$$\text{Shear stresses due to torsion, } f_t = \frac{T_u(D/2)}{I_P} = \frac{2 \times 10^6 \times 65}{549250\pi t_e} = \frac{75.34}{t_e} \text{ MPa}$$

The bending stress is type of direct stress in longitudinal direction, however, as the failure of fillet weld is pressured along its throat, it may be treated as shear stress. At the point of maximum stress the shear stress due to torsion acts horizontally is transverse direction. Whereas the direct shear is in vertical direction. Thus, all the three shear stresses are perpendicular to each other. The equivalent shear stress may be taken as,

$$\text{Equivalent shear stress} = \left(q^2 + f_b^2 + f_t^2\right)^{1/2}$$

$$= \frac{(12.24^2 + 452.04^2 + 75.34^2)^{1/2}}{t_e} = \frac{458.44}{t_e}$$

The resultant stress must not exceed the design strength of the weld i.e.

$$\frac{458.44}{t_e} = 189.37$$

$$\Rightarrow \quad t_e = 2.42\text{mm}$$

$\therefore$ Size of weld, $S = \dfrac{2.42}{0.70} = 3.46$ mm say 4.0 mm

For 12 mm thick plate minimum size of weld = 5 mm

So, use 5 mm fillet weld all round hollow section for connection of CHS with the end plate.

Q.5 (b) Solution:

1. The test is based on the principle that velocity of sound in a solid material is a function of $\sqrt{\dfrac{E}{\rho}}$, where E is modulus of elasticity and ρ is density.
2. An ultrasonic pulse apparatus consists of a transmitter and a receiver which are held against the faces of concrete.
3. The apparatus generates pulse of ultrasonic frequency which are transmitted through concrete by the transmitter. On the other face , the receiver receives the pulse and the apparatus record them.
4. The velocity of pulse is found which is correlated to the strength of the concrete.
5. Higher the velocity of pulse, greater is the strength of concrete.
6. It is only one of the dynamic test that shows the potential concrete strength in-situ.

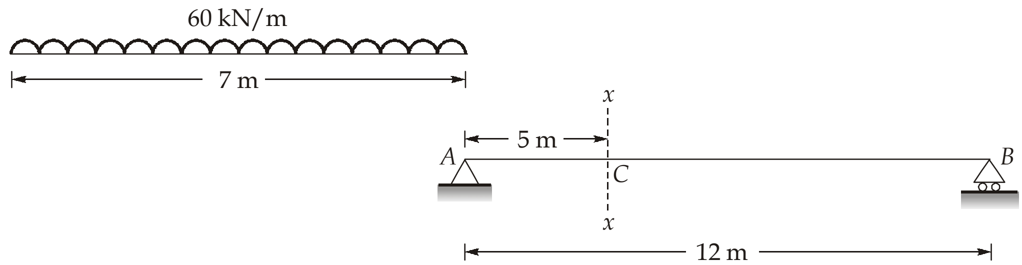
Advantages :

1. Can be used for existing structure and those under construction.
2. Establishes Uniformity of concrete.
3. Determines modulus of Elasticity.
4. Detection of cracks.

Disadvantages :

1. Holes have to be cut in the formwork so that transducers can be in direct contact with the concrete surface.
2. As concrete ages, the rate of increase of pulse velocity slows down much more rapidly than the rate of development of strength.
3. Accuracy depends on the careful calibration as well as on the use of the same concrete mix proportions and aggregate in making the test samples used for calibration as in the structure.

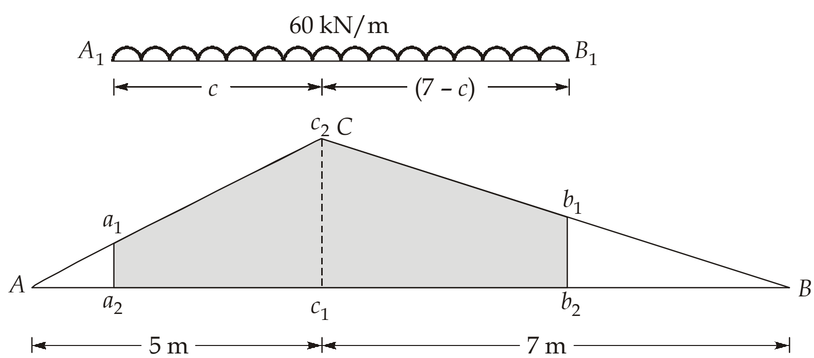
Q.5 (c) Solution:



Influence line diagram for BM at *x-x* (at 5 m from left end)

The ordinate C_1C_2 of IL diagram for BM = $\frac{x(l-x)}{l} = \frac{5(12-5)}{12} = \frac{5\times 7}{12} = 2.92$

IL for BM at *x-x* is shown below:



UDL is shorter than the span, the load is arranged such that area of IL diagram under load is maximum. For this condition

$$a_1a_2 = b_1b_2$$

Let tail of load be at distance c from C (*x-x* section),

For maximum BM at C;

$$\frac{AC}{CB} = \frac{A_1C}{CB_1}$$

$$\Rightarrow \quad \frac{5}{7} = \frac{c}{7-c}$$

$$\Rightarrow \quad 5(7-c) = 7c$$

$$\Rightarrow \quad 35 - 5c = 7c$$

$$\Rightarrow \quad c = \frac{35}{12} = 2.92 \text{ m}$$

The end ordinates of diagram are :

$$a_1a_2 = \frac{2.92}{5}(5 - 2.92) = 1.21472 \simeq 1.215$$

$$b_1b_2 = \frac{2.92}{7}(7 - 4.08) = 1.218$$

Maximum BM at C = Load intensity × Area of ILD covered by load

$$= 60\left[\frac{1}{2}(1.215 + 2.92) \times 2.92 + \frac{1}{2}(2.92 + 1.218) \times 4.08\right]$$

$$= 60\,[6.0371 + 8.441]$$

$$\therefore \quad M_C = 868.72 \text{ kNm}$$

Q.5 (d) Solution:

For maximum discharge, the pipe outlet must be at the maximum water level in the water course.

$$\therefore \quad H = (101.50 - 101.15) - \left(\frac{0.15}{2}\right) = 0.275 \text{ m}$$

We know, Discharge, $Q = C_d A\sqrt{2gH}$

$$= 0.62 \times \frac{\pi}{4}(0.15)^2 \times \sqrt{2 \times 9.81 \times 0.275} = 0.0254 \text{ m}^3/\text{s}$$

Flexibility, $F = \frac{m}{n} \times \frac{h}{H}$

and $\frac{m}{n} = \frac{1}{2} \times \frac{3}{5} = 0.30$

($\because q \propto H^{1/2}$ and $Q \propto H^{5/3}$ from Manning's equation)

$$\therefore \quad F = \frac{0.3 \times (101.5 - 101.15)}{0.275} = 0.38 < 1$$

Hence, the setting is sub-proportional.

Q.6 (a) Solution:

(i) If the soil is submerged but no seepage is occurring, the factor of safety against slippage will be the same as for 'dry' case, as long as there is no change in the value of ϕ'.

$$F = \frac{\tan\phi'}{\tan\beta}$$

$$\tan\beta = \frac{\tan 35°}{1.3} = 0.5386$$

$$\beta = \tan^{-1}(0.5386) = 28.31°$$

β = 28.31° for both dry and submerged soil.

(ii) When the flow occurs at and parallel to the ground surface.

$$F = \frac{\gamma'}{\gamma_{sat}} \cdot \frac{\tan\phi'}{\tan\beta}$$

$$\therefore \quad \tan\beta = \left(\frac{19-9.81}{19}\right)\frac{\tan 35°}{1.3} = 0.26$$

$$\beta = 14.6°$$

(iii)
$$F = \left(1-\frac{\gamma_w h}{\gamma_{sat} z}\right)\frac{\tan\phi'}{\tan\beta}$$

$$z = 4 \text{ m}; \quad h = 4 - 1.5 = 2.5 \text{ m}; \quad \beta = 28°$$

$$F = \left(1-\frac{9.81\times 2.5}{19\times 4.0}\right)\frac{\tan 35°}{\tan 28°} = 0.892$$

Q.6 (b) Solution:

$$c = 68 \text{ kN/m}^2, \phi = 20°, \gamma = 18.2 \text{ kN/m}^3$$

$$A = 0.45, B = 0.85$$

The height of the fill has been increased from 2 to 5 m. This will result in the development of increased pressures at the base of the bund, where shear strength is to be determined.

Now, increase in pore pressure due to additional overburden pressure is given by equation, as

$$\Delta u = B\left[\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)\right] \quad \text{...(i)}$$

where, $\Delta\sigma_1$ = Increase in the vertical pressure due to additional 3 m fill

$\Delta\sigma_3$ = Increase in the lateral pressure

$$= \frac{\Delta\sigma_1}{3}\text{(as per given assumption)}$$

We will first calculate $\Delta\sigma_1$

$\Delta\sigma_1$ = Increase in vertical pressure due to 3 m extra overburden

$$= \gamma\text{(depth of overburden)} = 18.2 \times 3 = 54.6 \text{ kN/m}^2$$

$$\therefore \quad \Delta\sigma_3 = \frac{\Delta\sigma_1}{3} = \frac{54.6}{3} = 18.2 \text{ kN/m}^2$$

Substituting values in equation (i), we get

$$\Delta u = 0.85[18.2 + 0.45(54.6 - 18.2)] \text{ kN/m}^2 = 29.4 \text{ kN/m}^2$$

Initial vertical pressure, $\sigma_1 = \gamma \times$ Initial depth of over-burden

$= 18.2 \times 2 = 36.4 \text{ kN/m}^2$

Increase in σ_1, $\Delta\sigma_1 = 54.6 \text{ kN/m}^2$

Decrease due to part of this pressure going as pore pressure

$= \Delta u = 29.4 \text{ kN/m}^2$

Hence, the net effective pressure at the base, immediately on construction (σ')

$= \sigma_1 + \Delta\sigma_1 - \Delta u$

$= 36.4 + 54.6 - 29.4 = 61.6 \text{ kN/m}^2$

Shear strength developed at the base, immediately after construction

$= c + \sigma' \tan\phi$

$= (68 + 61.6 \times \tan 20°) \text{ kN/m}^2 = 90.42 \text{ kN/m}^2$

Q.6 (c) Solution:

(1) Acid Test : A sample of stone weighing about 50 to 100 gm is placed in a solution of HCL (one percent strength) for seven days. The solution is agitated at regular intervals. A stone that maintains its sharp edges and keeps its surface free from powder at the end of this period is considered suitable for building material purposes. If the stone specimen contains calcium carbonate its edges are broken and powder is formed on the surface. Such a stone possesses poor weathering resistance. This test is more commonly performed on sandstones.

(2) Attrition Test : This test predicts the rate of wear of stones against the grinding action under traffic therefore this test is primarily used for stones to be used in road construction. The test procedure is as follow.

- Samples of stones are broken into pieces of about 60 mm size.
- The sample pieces, weighing around 5 kg, are put in the two cylinders of Deval's attrition test machine. These cylinders have a diameter of about 20 mm and length 340 mm. Their axes of these cylinders make an angle of 30 degree with the horizontal.
- Cylinders are rotated about the horizontal axis for 5 hours at the rate of 30 rpm.
- The specimen pieces are then taken out from the cylinders and they are passed through a sleeve of 1.5 mm mesh.
- The quantity of material retained on the sieve is weighed.
- Percentage wear is found to judge the stone.

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

3. **Crushing Test :** Stone samples are cut into cubes of size 40 × 40 × 40 mm. These are finely dressed and finished. The number of samples shall not be less than three. These specimens are placed in water for about 72 hours prior to test and therefore tested in saturated condition.

Load bearing surface in then covered with plaster of Paris or a plywood of about 5 mm thickness. Load is applied axially on the cube at a rate of 14 N/mm^2 per minute. Crushing strength of the stone load at which the sample crushes or fails divided by the area of the bearing face of the specimen.

4. **Crystalline Test :** Not less than four cubes of stone with side as 40 mm are taken and are dried for 72 hours and weighed. They are then immersed in a 14% solution of Na_2SO_4 for 2 hours. The cubes are then dried at 100°C and weighed. The difference in weight is noted. This procedure of drying, weighing, immersion and reweighing is repeated atleast 5 times. Each time, change in weight is noted and it is expressed as a percentage of original weight.

Although $CaSO_4$ crystallization in the pores of stone causes decay of stone due to weathering. But as $CaSO_4$ has low solubility in water, it is not used for test.

5. **Freezing and thawing test :** Stone specimen is kept immersed in water for 24 hours. It is then placed in a freezing machine at –12°C for 24 hours. The specimen is then brought to atmospheric temperature. This must be done in shade to prevent any effect due to wind, sun rays, rain etc. this procedure is repeated several times and the behaviour of stone is carefully observed.
6. **Hardness Test :** The test procedure is as follows : A cylinder of diameter 25 mm and height 25 mm is taken out from the sample of stone and weighed. The sample is placed then in Dorry's testing machine and it is subjected to a pressure of 12.50 N/mm^2. Annular steel disc of the machine is then rotated at a speed of 28 rpm. Coarse sand of standard specification is sprinkled on the top of disc while rotating. The specimen is taken out and weighed after about a thousand revolutions. The coefficient of hardness for the stone specimen is found to judge the suitability for use.

$$\text{Coefficient of hardness} = \frac{20 - (\text{Loss in weight in g})}{3}$$

7. **Impact Test :** Impact test is used to determine the toughness of a stone sample. In this test, a cylindrical specimen of diameter 25 mm and height 25 mm is taken out from the stone and placed on a cast iron anvil. A steel hammer of weight 20 N is then dropped on the cylinder axially. The height of the drop is increased successively from 1 cm to n cm in the nth fall when the specimen breaks.
   Here '*n*' gives the toughness index for the stone.
8. **Microscopic Test :** The stone sample examined under a microscope and studied to predict the quality of stone. The properties that are examined are
   a. Average grain size
   b. Existence of pores, fissures, veins and shakes
   c. Mineral constituents
   d. Nature of cementing material
   e. Presence of any harmful substance
   f. Texture of stone etc.
9. **Smith's Test :** Smith's test is performed to find out the presence of any soluble matter in a stone sample. Chips or pieces of stone are taken and they are placed in a glass tube filled with clear water. After sixty minutes, the tube is vigorously stirred. Presence of earthy matter will convert the clear water into dirty water. If water remains clear, stone is considered durable and free from any soluble matter.
10. **Water Absorption Test :** The test procedure is as follows :
   a. A stone sample, about 50 gm weight, is prepared. Its actual weight is recorded as W_1 gm.
   b. Cube is then immersed in distilled water for a period of about 24 hours. After 24 hours the cube is taken out of water and its surface wiped off of water with a damp cloth.
   c. It is weighed again. Let the weight be W_2 gm.
   d. The cube is then suspended freely in water and weighed. Let this be W_3 gm.
   e. The specimen is then kept in a boiling water for about five hours.
   f. Cube is removed and surface water is wiped off with a damp cloth. Its weight is recorded. Let it be W_4 gm.

From the above observations, values of the following properties of stones are obtained.

Percentage absorption by weight after 24 hours = $(W_2 - W_1) \times \frac{100}{W_1}$

Percentage absorption by volume after 24 hours = $(W_2 - W_1) \times \frac{100}{(W_2 - W_3)}$

Volume of displaced water = $W_2 - W_3$

$$\text{Percentage porosity by volume} = (W_4 - W_1) \times \frac{100}{(W_2 - W_3)}$$

$$\text{Specific gravity} = \frac{W_1}{(W_2 - W_3)} \text{kg/m}^3$$

$$\text{Saturation Coefficient} = \frac{\text{Water absorption}}{\text{Total porosity}} = \frac{(W_2 - W_1)}{(W_4 - W_1)}$$

Q.6 (d) Solution:

(i) Advantages of sanitary landfill over open dumps:

Sanitary landfills have four advantages over open dumps:

(i) Sanitary landfill ensure deposit of wastes in an organized way alongwith daily coverage of waste.

(ii) There is geological isolation of waste from the environment.

(iii) Appropriate engineering preparations are carried out before the site is ready to accept wastes.

(iv) Staff management on site to control operations.

	Anticipated landfill problems	Action planned to mitigate problem
1.	Litter	Provide proper fencing, control working face area.
2.	Dust	Periodic watering
3.	Odors	Ensure prompt and consistent coverage of exposed wastes.
4.	Leachates	Diversion of runoff and drainage of precipitation incipient on landfill; if necessary; install underdrains and collection / treatment system.
5.	Air quality impairment	Control dusts
6.	Health equipment and collection vehicle movement	Provide proper traffic directions and spotters; ensure adequate approach roads.
7.	Methane gas generation	Install appropriate gas control venting system, minimise water infiltration into waste drainage system.

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