MADE EASY PUBLICATIONS

POSTAL BOOK PACKAGE 2027

CIVIL ENGINEERING

CONVENTIONAL PRACTICE SETS VOLUME - IV

CONTENTS

■■■■

IRRIGATION ENGINEERING

CONVENTIONAL PRACTICE SETS

Page No. 1 - 98

2 CHAPTER Soil Water Plant Relationship

Q.1 Explain the term Base period and Crop period. After how many days will you order irrigation in order to ensure healthy growth of crops if:

(i) Field capacity of soil = 29%
(ii) Permanent wilting point = 11%
(iii) Density of soil = 1300 kg/m^3
(iv) Effective depth of root zone = 700 mm
(v) Daily consumptive use of water of the given crop = 12 mm

Consider moisture content must not be less than 25% of the water holding capacity between the field capacity and permanent wilting point.

Solution:

Base period: It is the time between first watering of the crop after sowing to the last watering before harvesting.

Crop period: It is the time between sowing and harvesting of the crop. Thus crop period is marginally larger than base period.

In usual usage, both crop period and base period imply the same connotation.

Numerical: Available moisture = Field capacity – Permanent wilting point

= 29 – 11 = 18%

Given moisture content must not be less than 25% of water holding capacity of soil between the field capacity and permanent wilting point.

∴ Readily available moisture = 75% of available moisture

= 0.75 × 18 = 13.5%

Thus irrigation will be required to raise the soil moisture content from 13.5% to 29%.

∴ **Depth of water stored is root zone** between these two limits of 13.5% and 29%

$$= \boxed{\frac{\gamma_d \cdot d}{\gamma_w}[\text{F.C.} - \text{Optimum moisture content}]}$$

$$= \frac{1300}{1000} \times 700(0.29 - 0.135)$$

$$= 0.14105 \text{ m} \simeq 0.141 \text{ m} = 141 \text{ mm}$$

Thus 141 mm of water is available for consumptive use. But daily consumptive use of water by crop = 12 mm/day

∴ 141 mm of water will be utilised in $\frac{141}{12}$ = 11.75 days ≈ 11 days

∴ After 11 days, irrigation will be required.

Q.2 Estimate the depth and frequency of irrigation required for a certain crop for the following data:
Root zone depth = 90 cm
Field capacity = 22%
Wilting point = 12%
Apparent specific gravity of soil = 1.5
Consumptive use = 22 mm/day
Efficiency of irrigation = 60%
Assume 50% depletion of available moisture as the indicator to begin application of irrigation water.

Solution:

Available moisture = FC – WP = 22 – 12 = 10%
Readily available moisture = 50% of available moisture = 5%
Irrigation will be done as soon as moisture content falls from 22% to 17%
Depth of irrigation water required to raise moisture content from 17% to 22%

$$= \frac{\gamma_d d}{\gamma_w}[F.C. - \text{ Optimum moisture content}]$$

$$= 1.5 \times 90\,(22\% - 17\%) = 6.75 \text{ cm}$$

$\therefore$ Water depth required in the field $= \dfrac{6.75}{0.6} = 11.25$ cm

Depth of water available to plants for evapotranspiration = 6.75 cm
Consumptive use = 22 mm = 2.2 cm/day
$\therefore$ 2.2 cm depth of water gets used up in one day
$\therefore$ Number of days required for 6.75 cm of water depth to be used up

$$= \frac{1}{2.2} \times 6.75 = 3.07 \text{ days}$$

Hence, 11.25 cm water depth will be supplies to fields at every 3 days.

Q.3 A certain crop is grown in an area of 3000 hectares which is fed by a canal system. The data pertaining to irrigation are as follows:

Field capacity of soil = 26%
Optimum moisture = 12%
Permanent wilting point = 10%
Effective depth of root zone = 80 cm
Relative density of soil = 1.4

If the frequency of irrigation is 10 days and the overall irrigation efficiency is 22%. Find (i) the daily consumptive use (ii) the water discharge (in m^3/sec) required in the canal feeding the area.

Solution:

Field capacity (F.C.) = 26%
Optimum moisture capacity (O.M.C.) = 12%
Permanent wetting point (P.W.P.) = 10%
Depth of water stored in root zone between F.C. and O.M.C.

$$= \frac{\gamma_d}{\gamma_w}[\text{F.C.} - \text{O.M.C.}]$$

$$= \frac{1.40 \times 80}{1.0}[0.26 - 0.12] = 15.68 \text{ cm}$$

Frequency of irrigation = 10 days

(i) Daily consumptive use of water $= \dfrac{15.68}{10} = 1.568$ cm

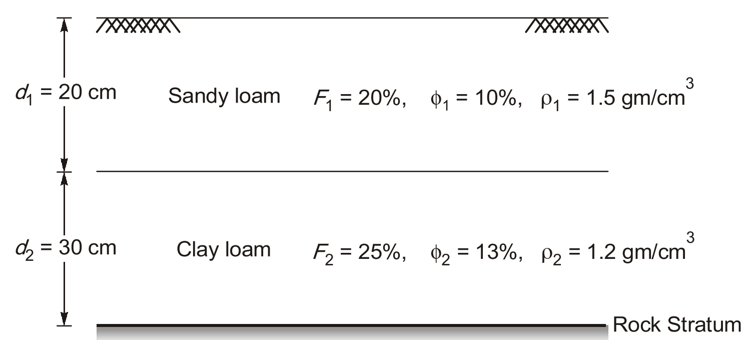
(ii) Total water required in 10 days $= \dfrac{3000 \times 10^4 \times 15.68}{100} = 4704000 \text{ m}^3$

Discharge required in canal $= \dfrac{4704000}{10 \times 24 \times 60 \times 60} = $ **5.44 cumec**

Q4 A soil 50 cm deep over rock has two horizons, the first being a fine sandy loam 20 cm thick and the second clay loam 30 cm thick. The field capacity, wilting point and volume weight for the first horizon are 20%, 10% and 1.5 gm/cm^3 respectively. The corresponding values for the second horizon are 25%, 13% and 1.2 gm/cm^3. Determine the available moisture storage capacity of the soil profile. If consumptive use requirements of a crop in a particular season is 0.5 mm/day and the soil is initially at field capacity, how long will the crop survive without irrigation?

Solution:

The soil profile can be shown as in the figure:



Let F be the field capacity, ϕ be the wilting point, d be the depth of soil, ρ be the density of soil and γ be the unit weight of soil.

Moisture storing capacity of sandy loam is given by

$$\boxed{d_s = \frac{\gamma_1 d_1}{\gamma_w}[F_1 - \phi_1]}$$

$$= \frac{\rho_1 d_1}{\rho_w}[F_1 - \phi_1] = \frac{1.5 \times 20}{1}\left[\frac{20}{100} - \frac{10}{100}\right]$$

$$= 3 \text{ cm}$$

Moisture storing capacity of clay loam is given by

$$\boxed{d_c = \frac{\rho_2 d_2}{\rho_w}[F_2 - \phi_2]}$$

$$= \frac{1.2 \times 30}{1}\left[\frac{25}{100} - \frac{13}{100}\right] = 4.32 \text{ cm}$$

$\therefore$ Total moisture storing capacity of the soil $= d_s + d_c = 3 + 4.32 = 7.32$ cm

It is given that consumptive use requirement of crop = 0.5 mm per day

$\therefore$ Maximum number of days in which the entire moisture storing capacity will be utilized

$$= \frac{\text{Moisture storing capacity of soil in cm}}{\text{Consumptive use requirement of crop in cm per day}}$$

$$= \frac{7.32}{0.05} = 146.4 \text{ days}$$

Thus, the crop can survive for a maximum of 146.4 days without irrigation.

Q.5 The depth of moisture in root zone at field capacity and permanent wilting point per m depth of soil are 0.5 m/m and 0.2 m/m respectively. Compute the field capacity and permanent wilting point. Take dry weight of soil as 13.73 kN/m^3.

Solution:

Depth of water stored in the root zone in filling the soil upto field capacity is given as

$$\boxed{h = \frac{\gamma_d dF}{\gamma_w}}$$

$$\Rightarrow \quad 0.5 = \frac{13.73 \times 1 \times F}{9.81}$$

$$\Rightarrow \quad F = \frac{0.5 \times 9.81}{13.73}$$

$$\Rightarrow \quad F = 0.3572$$

$$\Rightarrow \quad F = 35.72\%$$

Thus, field capacity is 35.72%.

Depth of water stored in the root zone in filling the soil upto permanent wilting point is given as

$$\boxed{h_1 = \frac{\gamma_d dP}{\gamma_w}}$$

$$\Rightarrow \quad 0.2 = \frac{13.73 \times 1 \times P}{9.81}$$

$$\Rightarrow \quad P = \frac{0.2 \times 9.81}{13.73}$$

$$\Rightarrow \quad P = 0.1429$$

$$\Rightarrow \quad P = 14.29\%$$

Thus, the permanent wilting point is 14.29%.

Q.6 The moisture content of soil in the root zone of an agricultural crop at certain stage is found to be 0.05. The field capacity of the soil is 0.15. The root zone depth is 1.1 m. The consumptive use of crop at this stage is 2.5 mm/day and there is no precipitation during this period. Irrigation efficiency is 65%. It is intended to raise the moisture content to the field capacity in 8 days through irrigation. Determine the necessary depth of irrigation. (Assume γ_d = 1.5 gm/cc)

Solution:

Depth of water required to raise the moisture content to the field capacity (without considering loss due to evaporation).

$$\boxed{d_w = \frac{\gamma_d}{\gamma_w} \times d \times (\text{FC} - \text{Existing moisture content})}$$

$$= 1.5 \times 1.1 \times (0.15 - 0.05)$$

$$= 0.165 \text{ m}$$

Adding, consumptive use @ 2.5 mm/day for 8 days.

$$\text{Water required} = 0.165 + \frac{8 \times 2.5}{1000} = 0.185 \text{ m}$$

$$\text{Irrigation efficiency} = 65\%$$

$$\therefore \quad \text{The necessary depth of irrigation} = \frac{185}{0.65} \text{ mm} = 284.62 \text{ mm}$$

Note: *This question is different from others as it is mentioned in the question itself that irrigation is done in a period of 8 days. So, to account for consumptive use in the period of 8 days, a depth of 2.5 × 8 mm is to be added to raise it to field capacity as otherwise, if not added, moisture content won't be raised to field capacity by the end of 8 days.*

Q.7 Estimate the depth and frequency of irrigation required for a certain crop, given

Root zone depth	: 90 cm
Field capacity	: 22%
Wilting Point	: 12%
Apparent Sp. gr. of soil	: 1.5
Consumptive use	: 22 mm/day
Efficiency of irrigation	: 60%

Assume 50% of depletion of available moisture as indicator to begin application of irrigation water.

Solution:

$$\text{Available moisture in root zone} = (F.C - W.P)\frac{\gamma_d}{\gamma_w} \times d$$

$$= (0.22 - 0.12) \times 1.5 \times 900 = \mathbf{135 \text{ mm}}$$

$$\text{Now, 50\% of available moisture} = 135 \times 0.5$$

$$d = \mathbf{67.5 \text{ mm}}$$

$$C_u = 22 \text{ mm/day}$$

$$\Delta t = \frac{\text{(50\% of available moisture depth)}}{C_u} = \frac{67.5}{22} = 3.068$$

Being on safe side, frequency of irrigation = **3 days**

$$\text{Depth of irrigation} = \frac{d}{\eta_{\text{irrigation}}} = \frac{3 \times 22}{0.6} = \mathbf{110 \text{ mm}}$$

Q.8 A sandy loam soil holds water at 140 mm/m depth between field capacity and permanent witting point. The root depth of the crop is 30 cm and the allowable depletion of water is 35%. The daily water use by the crop is 5 mm/day. The area to be irrigated is 60 ha and water can be delivered at 28 lps. The surface irrigation application efficiency is 40%. There are no rainfall and ground water contribution. Determine:

(i) allowable depletion depth between irrigations.
(ii) frequency of irrigation
(iii) net application depth of water
(iv) volume of water required
(v) time to irrigate 4 ha plot

Solution:

Moisture holding capacity of soil = 140 mm/m depth of root zone of crop.

Depth of root zone = 30 cm = 0.3 m

Moisture holding capacity of root zone

$= 140 \text{ mm/m} \times 0.3 \text{ m} = 42 \text{ mm} = 4.2 \text{ cm}$

Allowable depletion = 35%

(i) Available moisture depth or allowable depletion depth between irrigations

$= 0.35 \times 4.2 \text{ cm} = 1.47 \text{ cm}$

Daily use of water = consumption use = 5 mm/day

(ii) Frequency of irrigation

$$= \frac{\text{Available moisture}}{\text{Moisture consumed per day}} = \frac{1.47 \text{ cm}}{05 \text{ cm/day}}$$

$= 2.94$ days, say 3 days

(iii) Net water depth to be applied while irrigating each time after 3 days

$= 3 \times 0.5 = 1.5$ cm (in place of 1.47 cm)

Field irrigation requirement

$$= \frac{\text{Net irrigation requirement}}{\text{Efficiency of irrigation}} = \frac{1.5}{0.4} = 3.75 \text{ cm}$$

(iv) Quantity of water required in the field

$= 3.75$ cm of water depth $= 3.75 \text{ cm} \times$ Area of field

$$= 3.75 \text{ cm} \times 60 \text{ ha} = \frac{3.75 \text{ m}}{100} \times (60 \times 10^4) \text{m}^2 = 22500 \text{ m}^3$$

Hence, volume of water required to irrigate 60 ha area, each time at

3 days interval $= 22500 \text{ m}^3$

(v) Time to irrigate 4 ha when irrigation water is supplied @ 28 lps

Volume of water required to irrigate 4 ha plot

$$= 3.75 \text{ cm} \times 4 \text{ ha} = \frac{3.75}{100} \times (4 \times 10^4 \text{ m}^3) = 1500 \text{ m}^3$$

Time required to deliver 1500 m^3 of water @ 28 lps

$$= \frac{1500 \times 10^3 \, l}{28 \, l\text{ps}} = \frac{1500 \times 10^3}{28} s$$

$$= \frac{1500 \times 10^3}{28} \times \frac{1}{60 \times 60} \text{ hr} = 14.88 \text{ hr}$$

Q.9 **Wheat is to be grown in a field having a field capacity equal to 27% and the permanent wilting point is 13%. Find the storage capacity in 80 cm depth of the soil, if the dry unit weight of the soil is 14.72 kN/m³. If irrigation water is to be supplied when the average soil moisture falls to 18%, find the water depth required to be supplied to the field if the field application efficiency is 80%. What is the amount of water needed at the canal outlet if the water lost in the water courses and the field channels is 15% of the outlet discharge?**

Solution:

$$\text{Max. storage capacity or available moisture} = \frac{\gamma_d}{\gamma_w}\left[\frac{\text{Field capacity}}{100} - \frac{\text{Wilting point}}{100}\right]$$

where, $\gamma_d = 14.72 \text{ kN/m}^3$, d = depth of root zone = 0.8

SOIL MECHANICS AND FOUNDATION ENGINEERING

CONVENTIONAL PRACTICE SETS

Page No. 99 - 241

Properties of Soil

Q.1 A sampler with a volume of 45 cm^3 is filled with a soil sample. When the soil is poured into a graduated cylinder, it displaces 25 cm^3 of water. What is the porosity and void ratio of the soil.

Solution:

Given: Volume of soil sample, $V = 45 \text{ cm}^3$

When the soil sample is poured into cylinder, it displaces 25 cm^3 of water.

$\therefore$ Volume of solids, $V_s = 25 \text{ cm}^3$

Void ratio,
$$\boxed{e = \frac{\text{Volume of voids}}{\text{Volume of solids}}}$$

$$\Rightarrow \quad e = \frac{V - V_s}{V_s} = \frac{45-25}{25} = 0.8$$

Porosity,
$$\boxed{n = \frac{\text{Volume of voids}}{\text{Volume of soil sample}} \times 100}$$

$$= \left(\frac{V - V_s}{V}\right) \times 100$$

$$= \frac{45-25}{45} \times 100$$

$$n = 44.44\%$$

Q.2 In order to determine the water content, 370 g of a wet sandy sample was placed in a pycnometer. The mass of the pycnometer, sand and water full to the top of the conical cap was found to be 2148 g. The mass of pycnometer full of clean water was 1932 g. Taking G = 2.65, determine the water content of the sample

Solution:

$$\boxed{w = \left[\frac{M_2 - M_1}{M_3 - M_4}\left(\frac{G-1}{G}\right) - 1\right] \times 100 = \left[\frac{M}{M_3 - M_4}\frac{G-1}{G} - 1\right] \times 100}$$

where
M = wet mass of soil = 370 g

M_3 = 2148 g

M_4 = 1932 g

$$w = \left[\frac{370}{2148 - 1932} \times \frac{2.65-1}{2.65} - 1\right] \times 100$$

$$= 6.656\% \simeq 6.7\%$$

Q.3 The void ratio and specific gravity of a sample of clay are 0.73 and 2.7 respectively. If the voids are 92% saturated, find the bulk density, the dry density and the water content.

What would be the water content for complete saturation, the void ratio remaining the same?

Solution:

Given data: e = 0.73, G = 2.7, S = 92%

We know that $\boxed{Se = wG}$

$\Rightarrow \quad w = \dfrac{Se}{G}$

$\Rightarrow \quad w = \dfrac{0.92 \times 0.73}{2.7}$

$\Rightarrow \quad w = 0.2487$ or 24.87%

Now, $\boxed{\gamma = \dfrac{(G + Se)\gamma_w}{1+e}}$

$\Rightarrow \quad \gamma = \left[\dfrac{2.7 + (0.92 \times 0.73)}{1 + 0.73}\right] \times 9.81$

$\Rightarrow \quad \gamma = 19.12 \text{ kN/m}^3$

But Bulk density, $\boxed{\rho = \dfrac{\gamma}{g}} = \dfrac{19.12 \times 10^3}{9.81} = 1949.0316 \text{ kg/m}^3$

Dry density, $\boxed{\rho_d = \dfrac{\rho}{1+w}} = \dfrac{1949.0316}{1 + 0.2487} = 1560.85 \text{ kg/m}^3$

When $S = 100\%$

then $Se = Gw$

$\Rightarrow \quad w = \dfrac{Se}{G} = \dfrac{1 \times 0.73}{2.7}$

$\Rightarrow \quad w = 0.2703$ or 27.03%

Q.4 A soil has a void ratio of 0.70, degree of saturation 50% and G_S = 2.7. Find the water content, porosity, bulk density and dry density. By how much can the water content be increased without changing γ_d?

Solution:

Given: Void ratio (e) = 0.70, Degree of saturation (S) = 0.50, Specific gravity (G_s) = 2.70

(i) We know, $\boxed{Se = wG_s}$

$\Rightarrow \quad w = \dfrac{Se}{G_s} = \dfrac{0.50 \times 0.70}{2.70} = 0.1296$

$\therefore$ Water content, $w = 12.96\%$

(ii) Bulk density, $\boxed{\gamma_t = \left(\dfrac{G_s + Se}{1+e}\right)\gamma_w} = \left(\dfrac{2.70 + 0.50 \times 0.70}{1 + 0.70}\right) \times 9.81 = 17.6 \text{ kN/m}^3$

(iii) Dry density, $\boxed{\gamma_d = \dfrac{\gamma_t}{1+w}} = \dfrac{17.6}{1 + 0.1296} = 15.58 \text{ kN/m}^3$

(iv) Porosity, $\boxed{n = \dfrac{e}{1+e}} = \dfrac{0.70}{1 + 0.70} = 0.4118 = 41.18\%$

In order to have γ_d = constant

e = constant

We know, $Se = wG_s$

Taking, S = 100% [Maximum possible degree of saturation is 100% for w_{max}]

$\therefore$ $$\frac{100}{100} \times e = w_{max} \times G_s$$

$\Rightarrow$ $$w_{max} = \frac{e}{G_s} = \frac{0.70}{2.70} = 0.2593 = 25.93\%$$

$\therefore$ Increase in water content = (25.93 – 12.96)% = 12.97%

Therefore, water content may be increased by 12.97% without changing γ_d value.

Q.5 The liquid limit of a clay soil is 66% and its plasticity index is 25%.

(i) In what state of consistency is this clay, if its natural moisture content is 45%?

(ii) The void ratio of the clay on drying to minimum volume is 0.88. What is its shrinkage limit if the specific gravity of clay is 2.71?

Solution:

Given: $w_L = 66\%$; $I_P = 25\%$

(i) $$\boxed{I_P = w_L - w_P}$$

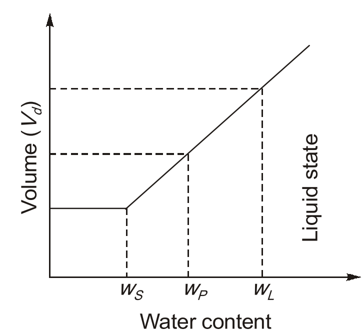
$$25 = 66 - w_P$$

$\therefore$ w_P (plastic limit) = (66 – 25)% = 41%

As moisture content, $w = 45\%$

and $w_P < w < w_L$

$\therefore$ Soil is in **plastic state**



(ii) At shrinkage limit, soil is fully saturated.

$\therefore$ $S = 1$; $e = 0.88$; $G = 2.71$

$$S.e = w_s \cdot G$$

$$1 \times 0.88 = w_s \times 2.71$$

$\therefore$ $w_s = 0.3247$

$\Rightarrow$ shrinkage limit, $w_s = 32.47\%$

Q.6 The moisture content, void ratio and specific gravity of soil solids of a given soil mass are 10.5%, 0.67 and 2.68 respectively. It is required to prepare three triaxial test specimens (dia 3.75 and height 7.5 cm) from this soil mass. Each specimen should have a moisture content of 15% and a dry density of 1.6 g/cc. Determine (i) the quantity of the given soil to be used for this purpose and (ii) the quantity of water to be mixed with it.

Solution:

Given: Specimen no. = 3; $d = 3.75$ cm; $h = 7.5$ cm; $w = 15\%$; $\rho_d = 1.6$ g/cc

Total volume of specimens = 3 × vol. of 1 specimen

$$V = 3 \times \frac{\pi}{4} \times d^2 \times h = 3 \times \frac{\pi}{4} \times 3.75^2 \times 7.5$$

$$= 248.505 \text{ cm}^3$$

Volume of solids, $$\boxed{V_s = \frac{V}{1+e}}$$

$$\rho_d = \frac{G \cdot \rho_w}{1+e}$$

$\Rightarrow$ $$1.6 = \frac{2.68 \times 1}{1+e}$$

$\therefore$ $e = 0.675$

$$V_s = \frac{248.505}{1+0.675} = 148.3612 \text{ cm}^3$$

Soil mass: w = 10.5%, e = 0.67; G = 2.68

(i) Let 'V' volume of soil mass is required,

$$\boxed{V_s = \frac{V}{1+e}}$$

$$148.3612 = \frac{V}{1+0.67}$$

$\Rightarrow$ $$V = 247.7632 \text{ cm}^3$$

Now, $$S.e. = w \cdot G$$

$$\boxed{\gamma = \left(\frac{G+Se}{1+e}\right)\gamma_w}$$

$\Rightarrow$ $$\boxed{\rho = \left(\frac{G+w\cdot G}{1+e}\right)\rho_w}$$

$$= \frac{2.68+0.105\times 2.68}{1.67}\times 1$$

$$\frac{W}{V} = \rho = 1.7733$$

$\therefore$ Quantity Required, $$W = (247.7632\times 1.7733) \text{ gm}$$

$$= 439.3585 \text{ gm}$$

(ii) Quantity of water to be mixed $= 0.15 \times W_s - 0.105\ W_s$

$$W_w = 0.045 \times W_s = 0.045 \times (G \cdot \rho_w \times V_s)$$

$$= 0.045 \times 2.68 \times 1 \times 148.3612$$

$$= 17.8924 \text{ gm}$$

Q.7 A core-cutter 12.6 cm in height and 10.2 cm in diameter weighs 1071 gm when empty. It is used to determine the in-situ unit weight of an embankment. The weight of core-cutter full of soil is 2970 gm. If the water content is 6% what are the in-situ dry unit weight and porosity? If the embankment gets fully saturated due to heavy rains what will be the increase in water content and bulk unit weight, if no volume change occurs? The specific gravity of the soil solids is 2.69.

Solution:

Given: Mass of empty core cutter = 1071 gm

Mass of core cutter + Mass of soil = 2970 gm

Mass of soil = (2970 – 1071) gm

M = 1899 gm

Volume of core cutter = Volume of soil sample

$$V = \frac{\pi}{4}\times(10.2)^2\times 12.6 \text{ cc}$$

$$= 1029.58 \text{ cc}$$

in-situ density, $\boxed{\rho = \frac{M}{V}} = \frac{1899}{1029.58} = 1.844 \text{ gm/cc}$

in-situ dry density, $\boxed{\rho_d = \frac{\rho}{1+w}} = \frac{1.84}{1+0.06} = 1.74 \text{ gm/cc}$

$\therefore$ in-situ dry unit weight, $\gamma_d = \rho_d \cdot g = 17.97 \text{ kN/m}^3$

$$\rho_d = \left(\frac{G}{1+e}\right)\rho_w$$

$$1.73 = \left(\frac{2.69}{1+e}\right)\times 1$$

$\Rightarrow$ $e = 0.55$

Porosity, $n = \frac{e}{1+e} = \frac{0.55}{1.55} = 0.3548 = 35.48\%$

If embankment gets fully saturated and no volume change takes place, then 'e' remains same.

$$S.e = w' \cdot G$$

or, $1 \times e = w' \cdot G$

or, $w' = \frac{0.55}{2.69} = 0.2045 = 20.45\%$

increase in water content $= w' - w = (20.45 - 6)\% = 14.45\%$

Now bulk density = Saturated density

$$\rho_{sat} = \left(\frac{G+e}{1+e}\right)\rho_w = \frac{2.69+0.55}{1.55}\times 1 = 2.09 \text{ gm/cc}$$

bulk unit weight = saturated unit weight

$= \gamma_{sat}$

$$= \rho_{sat}\times g = 2.09\times\frac{10^{-3}}{10^{-6}}\times 9.81\times 10^{-3} \text{ kN/m}^3 = 20.5029 \text{ kN/m}^3$$

Q.8 The soil in a borrow pit has a void ratio of 0.90. A fill of volume 20,000 m^3 is to be constructed with an in-situ dry unit weight of 19.2 kN/m^3. If the owner of borrow area is to be compensated at Rs. 2.5 per cubic metre of excavation then determine the cost of compensation. Take G = 2.68, γ_w = 9.81 kN/m^3.

Solution:

Fill: $V = 20{,}000 \text{ m}^3$; $\gamma_d = 19.2 \text{ kN/m}^3$; $G = 2.68$; $\gamma_w = 9.81 \text{ kN/m}^3$

$$\gamma_d = \left(\frac{G}{1+e}\right)\cdot\gamma_w$$

or, $19.2 = \frac{2.68}{1+e}\times 9.81$

$\Rightarrow$ $e = 0.37$

Volume of solids in fill, $\boxed{V_s = \frac{V}{1+e}}$

$$= \frac{20,000}{1.37}$$

$$= 14598.54 \text{ m}^3$$

Note: Volume of solids will remain constant.

Borrow $\rightarrow$ $e = 0.90$

Volume of solids to be taken, $V_s = 14598.54 \text{ m}^3$

Volume of soil to be taken, $V = V_s(1 + e) = 14598.54\,(1.90) = 27737.226 \text{ m}^3$

Cost of compensation $=$ Rs. $2.5 \times 27737.226 =$ Rs. 69343.065

Q.9 Four borrow areas are available from where the soil can be taken for construction of an embankment. The study gave the following information:

Borrow Area	Bulk density (kN/m^3)	Water Content (%)	Cost per m^3 (Rupees)
A	15.62	10	80
B	13.61	12	60
C	14.85	10	70
D	12.54	14	50

By calculation, show which one of these is the most economical for the embankment project. Take $G = 2.7$.

Solution:

Let us assume unit 'm^3' of solids is required for embankment,

Now,
$$\boxed{V_s = \frac{V}{1+e}} = 1 \text{ m}^3$$

$\therefore$
$$V = (1 + e) \text{ m}^3$$

$$\boxed{\gamma_d = \frac{G \cdot \gamma_w}{1+e}}$$

also,
$$\gamma_d = \frac{\gamma}{1+w}$$

$\Rightarrow$
$$\frac{\gamma}{1+w} = \frac{G \cdot \gamma_w}{1+e}$$

$\therefore$
$$(1 + e) = G \cdot \gamma_w \frac{(1+w)}{\gamma}$$

Let
$$\gamma_w = 10 \text{ kN/m}^3 \quad \text{and} \quad G = 2.7$$

$\therefore$
$$V = (1 + e) = \frac{2.7 \times 10 \times (1+w)}{\gamma}$$

$$\text{Cost} = V \times \text{Rate} = \frac{27 \times (1+w)}{\gamma} \times \text{Rate}$$

Area	γ(kN/m^3)	w(%)	Rate	Total Cost
A	15.62	10	80	Rs. 152.11
B	13.61	12	60	Rs. 133.31
C	14.85	10	70	Rs. 140
D	12.54	14	50	Rs. 122.73

$\therefore$ Borrow Area *D* is most economical.

SURVEYING AND GEOLOGY

CONVENTIONAL PRACTICE SETS

Page No. 242 - 352

1 CHAPTER Introduction

Q.1 A surveyor measured the distance between two points marked on the plan drawn to a scale of 1 cm = 1 m (RF = 1 : 100) and found it to be 50 m later on he detected that he used a wrong scale of 1 cm = 50 cm (RF = 1 : 50) for the measurement. Determine the correct length. Also determine the correct area if the measured area is 60 m^2?

Solution:

$$\text{RF of wrong scale} = \frac{1}{50}$$

$$\text{RF of correct scale} = \frac{1}{100}$$

$$\text{Correct length} = \frac{\text{RF of wrong scale}}{\text{RF of correct scale}} \times \text{Measured length}$$

$$= \frac{1/50}{1/100} \times 50 = 100 \text{ m}$$

$$\text{Correct area} = \left(\frac{\text{RF of wrong scale}}{\text{RF of correct scale}}\right)^2 \times \text{ Measured area}$$

$$= \left(\frac{1/50}{1/100}\right)^2 \times 60 = 240 \text{ m}^2$$

Q.2 Design a vernier for a theodolite circle which is divided into degrees and half degrees to read up to 30″.

Solution:

$$\text{Least count} = \frac{s}{n}, \quad s = 30'$$

Now $$30'' = \frac{30}{60} \text{ min.}$$

$\therefore$ $$\frac{30}{60} = \frac{30}{n}$$

$\Rightarrow$ $$n = 30 \times 2 = 60$$

59 such primary division should be taken from the main scale and then divided into 60 parts the vernier.

Q.3 The circle of a theodolite is divided into degrees and $\frac{1}{4^{\text{th}}}$ of a degree. Design a suitable decimal vernier to read up to 0.005°.

Solution:

$$\text{Least Count} = \frac{s}{n}; \; s = \frac{1}{4}^{\circ}; \text{ L.C.} = 0.005^{\circ}$$

$\therefore$ $$0.005 = \frac{1}{4} \cdot \frac{1}{n}$$

$$\Rightarrow \qquad n = \frac{1}{4 \times 0.005} = 50$$

Take 49 such primary divisions from the main scale and divide it into 50 parts for the vernier.

Q.4 Design an extended vernier for an Abney level to read up to 10′. The main circle is divided into degrees.

Solution:

$$\text{Least Count} = \frac{s}{n}\text{ ; } s = 1^\circ \text{ ; L.C.} = 10'$$

$$\therefore \qquad \frac{10}{60} = \frac{1}{n}; \quad \text{or} \quad n = 6$$

Take five spaces of the main scale and then divide it into six equal parts for the vernier.

Q.5 In a plan, a 10 cm scale drawn shrunk to 9.7 cm. If the scale of the given plan is written as 1 : 250, determine the actual length of a line which at present shows 10 cm.

Solution:

$$\text{Present representative factor (R.F.)} = \frac{1}{250} \times \frac{9.7}{10}$$

$$\text{Actual distance} \times \text{R.F.} = \text{Drawing distance}$$

$$\text{Actual distance} = \frac{10 \text{ cm}}{\frac{1}{250} \times \frac{9.7}{10}} = 2577 \text{ cm} = 25.77 \text{ m}$$

Q.6 A rectangular plot of land measures 20 cm × 30 cm on a village map drawn to a scale of 100 m to 1 cm. Calculate its area in hectares. If the plot is redrawn on a topo sheet to a scale of 1 km to 1 cm, what will be its area on the topo sheet? Also determine the R.F. of the scale of the village map as well as on the topo sheet.

Solution:

(i) Village map:

$$1 \text{ cm on map} = 100 \text{ m on the ground}$$

$$\therefore \qquad 1 \text{ cm}^2 \text{ on map} = (100)^2 \text{ m}^2 \text{ on the ground}$$

The plot measures 20 cm × 30 cm i.e., 600 cm^2 on the map.

$$\therefore \qquad \text{Area of plot} = 600 \times 10^4 = 6 \times 10^6 \text{ m}^2 = 600 \text{ hectares}$$

(ii) Topo sheet

$$1 \text{ cm on map} = 1 \text{ km on ground}$$

$$\Rightarrow \qquad 1 \text{ cm}^2 \text{ on map} = 1 \text{ km}^2 \text{ on ground}$$

$$= 10^6 \text{ m}^2 \text{ on ground}$$

$$\therefore 6 \times 10^6 \text{ m}^2 \text{ ground area is represented by } \frac{1}{1000 \times 1000} \times 6 \times 10^6 = 6 \text{ cm}^2 \text{ map area}$$

(iii) $$\text{R.F. of the scale of village map} = \frac{1}{100 \times 100} = \frac{1}{10000}$$

$$\text{R.F. of the scale of topo sheet} = \frac{1}{1 \times 1000 \times 100} = \frac{1}{100000}$$

Q.7 A plan drawn to a scale of 1 : 3000 was measured by a mistake a scale of 1 : 4000. Determine the percentage error in the measured length and measured area.

Solution:

Let the length on the plan = L

Actual length = 3000 L

$$\text{Percentage error} = \frac{4000L - 3000L}{3000L} = 33.33\%$$

$$\text{Percentage error in area} = \frac{\text{Measured area} - \text{Actual area}}{\text{Actual area}} \times 100$$

$$= \frac{(4000L)^2 - (3000L)^2}{(3000L)^2} \times 100 = 77.77\%$$

Q.8 The area of the plan of an old survey plotted to a scale of 10 metres to 1 cm measures now as 100.2 sq. cm as found by a planimeter. The plan is found to have shrunk so that a line originally 10 cm long now measures 9.7 cm only. Find (i) the shrunk scale, (ii) true area of the survey.

Solution:

(i) Present length of 9.7 cm is equivalent to 10 cm original length.

$$\therefore \quad \text{Shrinkage factor} = \frac{9.7}{10} = 0.97$$

$$\text{True scale R.F.} = \frac{1}{10 \times 100} = \frac{1}{1000}$$

$$\therefore \quad \text{R.F of shrunk scale} = 0.97 \times \frac{1}{1000} = \frac{1}{1030.93}$$

(ii) Present length of 9.7 cm is equivalent to 10 cm original length.

∴ Present area of 100.2 sq. cm is equivalent to

$$\left(\frac{10}{9.7}\right)^2 \times 100.2 \text{ sq. cm} = 106.49 \text{ sq. cm} = \text{Original area on plan}$$

Scale of plan is 1 cm = 10 m

$$\therefore \quad \text{Area of the survey} = 106.49\,(10)^2 = 10649 \text{ sq. m}$$

Q.9 In 1950, plan of a rectangular field was drawn with a scale of 1 cm = 40 m. The present dimension of field read as 30 cm × 10 cm. If an original reference line of 9.4 cm now reads 10 cm then what is the actual area of field?

Solution:

$$\text{Extended factor,} \quad \text{E.F.} = \frac{\text{Extended length}}{\text{Original length}} = \frac{10}{9.4} = 1.06$$

$$\therefore \quad \text{R.F.}_{\text{[Extended scale]}} = (\text{E.F.}) \times \text{R.F.}_{\text{[original scale]}}$$

Original scale, 1 cm = 40 m

$$\therefore \quad [\text{RF}]_{\text{Original scale}} = \frac{1}{4000}$$

$$\therefore \quad \text{RF}_{\text{[Extended scale]}} = 1.06 \times \frac{1}{4000} = \frac{1}{3760}$$

⇒ Extended scale, 1 cm = 37.6 m

$$\therefore \quad \text{Actual area of field} = 30 \times 10 \times (37.60)^2 = 424128 \text{ m}^2 = 42.4128 \text{ ha}$$

■■■■

HIGHWAY ENGINEERING

CONVENTIONAL PRACTICE SETS

Page No. 353 - 408

1 CHAPTER Highway Development & Planning

Q.1 Briefly describe the factors which are considered in the planning and decision making process for a highway.

Solution:

Factors which are considered during decision making process of highway are as following:

(i) *Social factor*: Factors such as population growth, current population, land use, congestion, travel patterns, existing transport facilities etc. are considered during decision making process of highway planning.

(ii) *Historical factor*: Factors such as preservation of historical sites and building during highway construction are also considered.

(iii) *Economic factors*: During highway planning total cost, current funds, alternate options, benefits, internal rate of return, utility of roads per unit length, commercial benefit and other economic advantages and disadvantages are also considered.

(iv) *Geographical factor*: Topography, geology, highway location, cost of right of way are also considered.

(v) *Environmental factor*: Effect of environment due to highway project both during construction and operations, and methods to mitigate the hazardous effect on environment also considered.

(vi) *Traffic factor*: Factors such as trip purpose, orientation, parking availability, peak per hour volume, safety, freight movement are also considered.

(vii) *Codel and legal factors*: Factors such as building codes, zoning ordinates, regulations, other laws affecting the highway project are also considered.

Q.2 Briefly describe planning surveys for highways. How are these used and interpreted?

Solution:

Highway planning phase includes:

(i) Assessment of road length requirement for an area.

(ii) Preparation of master plan showing the phasing of plan in annual and or five year plans.

The planning surveys consists of following studies, the details are as follows:

(a) Economic studies

In order to estimate the economics involved and to give economic justification for each plan, economic studies are to be undertaken. Details to be collected include:

(i) Population and its distribution.

(ii) Trend of population growth.

(iii) Agricultural and industrial products, areawise.

(iv) Existing communication, recreation and education facilities.

(v) Per capita income.

(b) Financial studies

Financial studies are essential to study the financial aspects like sources of income and manner in which funds for the project may be mobilized. Following details should be collected:

- Sources of income and estimated revenue from taxation on road transport.
- Living standards.
- Resources at local level, toll taxes, vehicle registration and fines etc.
- Future trends in financial aspects.

(c) Traffic or road use studies

Traffic surveys should be carried out in order to collect the following details:

- Traffic volume in vehicle per day, annual average daily traffic, peak and design hourly traffic volume.
- Origin and destination studies.
- Traffic flow patterns.
- Mass transportation facilities.
- Accident analysis.
- Future trends and growth in traffic

(d) Engineering studies

The studies include:

- Topographic surveys.
- Soil surveys.
- Location and classification of existing roads.
- Road life studies.
- Traffic studies.
- Special problems in drainage, construction and maintenance of roads.

Q.3 Enumerate the major policies and objectives of the 3rd twenty-year road development plan (1981-2001) of India.

Solution:

The 3rd twenty year road development plan (1981-2001) was prepared by the road using of the ministry of shipping and transport with the active co-operation from a number of organisations and other Highway Engineering experts. This document was released in 1985 at Lucknow so called 'Lucknow Road Plan'.

The major policies and objectives of this road plan are as under:

1. The road network should be developed so as to preserve the rural oriented economy and to develop small towns with all essential facilities. All the villages with population over 500 should be connected by all weather roads by the end of this century.
2. The future road development should be based on the new road system consisting of primary, secondary and tertiary road systems.
3. The overall road density in the country should be increased to 82 km per 100 sq. km area by the year 2001. The corresponding values of planned road densities are 40 for hill areas of altitude upto 2100 mtr. above MSL and 15 km per sq. km area for altitude above 2100 meter.
4. The National Highway network should be expanded to form square grids of 100 km sides so that no part of the country is more than 50 km away from a NH.
5. The lengths of SH and MDR required in a state or region should be decided based on both areas and number of towns with population above 5000 in the state or region.
6. Expressways should be constructed along major traffic corridors to provide fast and easy travel. Total length of 2000 km is targeted.
7. All the towns and villages with population over 1500 should be connected by major district roads and the villages with population 1000 to 1500 by other district roads. There should be a road within a distance of

3 km in plains and 5 km in hilly terrain connecting all villages or groups of villages with population less than 500.

8. Roads should also be built in less industrialized areas to attract the growth of industries.
9. Long term master plans for road development should be prepared at various levels i.e. Gram Panchayat, district, state and national levels. The road network should be scientifically and technologically decided to provide maximum utility.
10. The existing roads should be improved by rectifying the defects in the road, geometrics, widening of pavements, improving the riding quality of the pavement surface and strengthening of the pavement structure to save vehicle operation cost and thus to conservation of energy.
11. There should be improvements in environmental quality and road safety.
12. The plan has set the target length of NH to be completed by the end of seventh, eighth and ninth five year plan periods.

Q.4 Following five alternate road plan development proposals with particulars as mentioned below are available:

Proposal	Number of towns and villages served along with population range					Total industrial products in thousand tonnes
	<2000	2001-5000	5001-10000	10001-20000	> 20000	
A	80	10	25	5	1	60
B	115	120	30	10	2	370
C	340	230	25	20	4	350
D	150	200	100	35	6	750
E	200	90	70	60	3	500

If the total road length of proposals A, B, C, D and E are respectively 200 km, 380 km, 605 km, 700 km and 400 km, calculate the utility rate per unit length of each road proposal and indicate the priority based on saturation system. Assume the utility units as follows:

For population :

Range		Unit
< 2000	:	0.25
2001 to 5000	:	0.50
5001 to 10000	:	1.00
10001 to 20000	:	2.00
> 20000	:	3.00

For products :

One unit for 1000 tonnes.

Solution:

Proposal A:

Population units $= (80 \times 0.25 + 10 \times 0.50 + 25 \times 1.00 + 5 \times 2.00 + 1 \times 3.00)$

$= (20 + 5 + 25 + 10 + 3) = 63$

Product units $= (60 \times 1) = 60$

$\therefore$ Total utility units $= (63 + 60) = 123$

Utility rate $= \dfrac{123}{200} = 0.615$

Proposal B:

Population units $= (115 \times 0.25 + 120 \times 0.50 + 30 \times 1.00 + 10 \times 2.00 + 2 \times 3.00)$

$= (28.75 + 60 + 30 + 20 + 6) = 144.75$

RAILWAY, AIRPORT, DOCK, HARBOUR & TUNNELING

CONVENTIONAL PRACTICE SETS

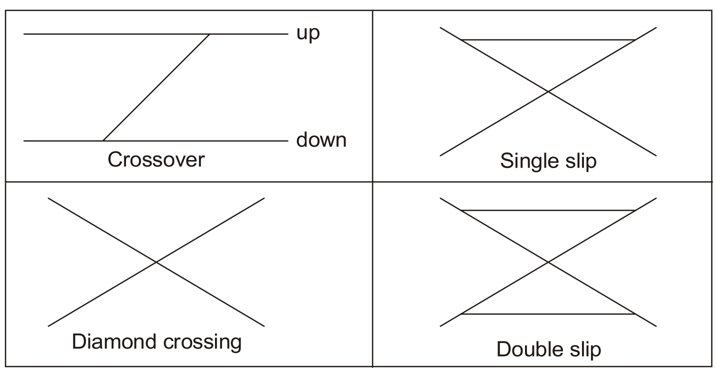
1 CHAPTER Railway Track

Q.1 Differentiate between single slip and double slip in rails. If the tread diameter on both the rail is the same then show that the slip is about 0.029 m per degree of central angle of Broad Gauge (BG).

Solution:

Double slip and single slip: A **double slip** is a narrow angled diagonal flat crossing of two lines combined with four pairs of points in such a way as to allow vehicle to change from one straight track to other or go straight. In double slip train can move from either track to other one.

In single slip, arrangement of points are such that it provide for only one switching possibility train moving on one track can move to other track or go straight but train at other track can go only straight.



Date given: BG track $G = 1.676$

Say radius of track is R, $\theta = 1°$

Linear travel by inner wheel = wR_i

Linear travel by outer wheel = wR_0

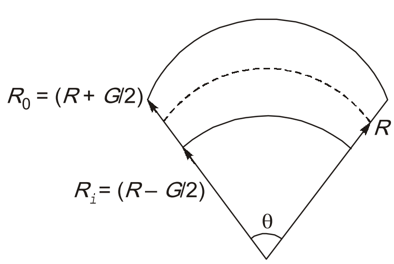
$$\text{Slip} = wR_i - wR_o$$

$$= wR_0 - wR_i = w\left(R + \frac{G}{2}\right) - w\left(R - \frac{G}{2}\right)$$

$$= wG$$

$$= \left(\frac{2\pi}{360} \times \theta\right) \times G = \frac{2\pi}{360°} \times 1° \times 1.676$$

$$= 0.029 \text{ m}$$



Q.2 What is meant by 'creep' in railway track? What are the cause of creep? How is creep measured? What are the remedial measures for correction of creep?

OR

Discuss the causes and effects of creep in a rail track; also discuss its management.

Solution:

Creep: Creep is defined as longitudinal movement of the rail with respect to sleepers due to movement of traffic over a period of time. Its value varies from almost nothing to about 16 cm.

Effects of creep in a rail track:

(a) Creep may leads to buckling of track in lateral directions.

(b) Square geometry arrangement of sleepers get disturbed and leads to distorted gauge and alignment.

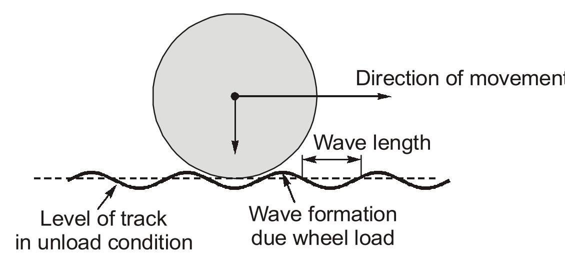
(c) Rail joints are opened out and bolt holes get elongated leads to premature fracture of fish plate and bolts.

(d) Point and crossing get disturbed.

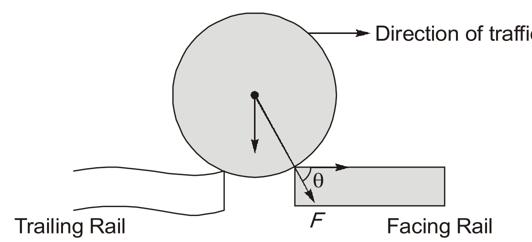
(e) The joints get continuously jammed, and maintenance and replacement become difficult.

Reason of creep:

(a) **Wave motion theory:** Due to wheel load a wave in rail is created in direction of traffic, resulting in creep.



(b) **Percussion theory:** Due to horizontal component of (load + kinetic) force *F*, at expansion joint, creep is observed.



(c) **Dragging Theory:** Due to fraction force between wheel & rail a drag force generate opposite to movement of train, resulting in creep.

(d) Due to braking & acceleration (skidding + slipping).

Following are some of avoidable causes of creep:

(a) Rails are not property fastened with sleepers.

(b) Loose packing of ballast around sleepers.

(c) Improper expansion gaps.

(d) Too light rail for heavy traffic

(e) Sharp gradients and sharp curves.

(f) Uneven spacing of sleepers etc.

Preventive and remedial measures of creep:

(a) Rails should be firmly held to sleepers.

(b) Bearing load of fastenings should always be slightly more than the ballast resistance.

(c) Ballast should be properly packed specially around sleepers and shoulders.

(d) Use of creep anchors at adequate internal.

(e) When creep became excessive (> 150 mm) causing maintenance problems. The same should be adjusted by pulling back manually or mechanically during pulling back operation survey of expansion joint, gaps and rail to rail joint with sleepers should be carried out properly.

Measurement of creep:

(a) Creep posts are erected every kilometer on either side of the track and position of joints is marked on one of the posts.

(b) Then measurement of creep is taken at an internal of about 3 month.

(c) Creep in excess of 150 mm should not be allowed on a straight and levelled track.

(d) In approaches of points and crossing. There should be no creep allowed.

Q.3 Why is it necessary to provide adequate drainage facility for a railway track? Suggest remedial measures to solve the following problems, due to poor drainage of railway track, giving suitable sketches.

(i) Wet earth clogging the ballast

(ii) Ballast sinking into the wet earth.

Solution:

Adequate drainage is necessary in railway track for following reasons:

1. To maintain bearing capacity of formation soil.
2. To prevent settlement of track embankment.
3. Excessive water reduces track stability and results in ballast pockets and unstable formation.
4. If surface and subsurface water not properly drained out it results in soft spots, unstable banks, cutting, bank slips and land slides.
5. In rainy season, due to water logging, wet earth clogging of ballast may happen which further reduce its ability to drain.

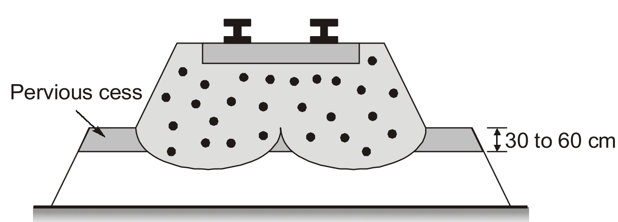
(i) The following remedial measures can be a adopted to solve the problem of wet earth clogging of ballast:

(a) to unclogg the ballast, clearing of shoulder ballast is often sufficient. In this process shoulder ballast is removed to a certain depth, then it is cleaned and repacked again. It can be done manually or by the mechanized way.

(b) If ballast is old than it has to be removed and replaced by new ballast. It can be done by simple dumping the new ballast and raising the track, then old ballast can be removed by under cut.

(ii) Following remedial measures can be adopted to prevent ballast sinking in wet earth:

(a) **Use of pervious cess:** It is provided to remove water pocket in formation.



(b) **Perforated pipe and trench drains:** Water is collected and drained out by combination of perforated pipe and trench drains.