Chapter -2-

Soil - Water - Plant relations

علاقة التربة - الماء - النبات

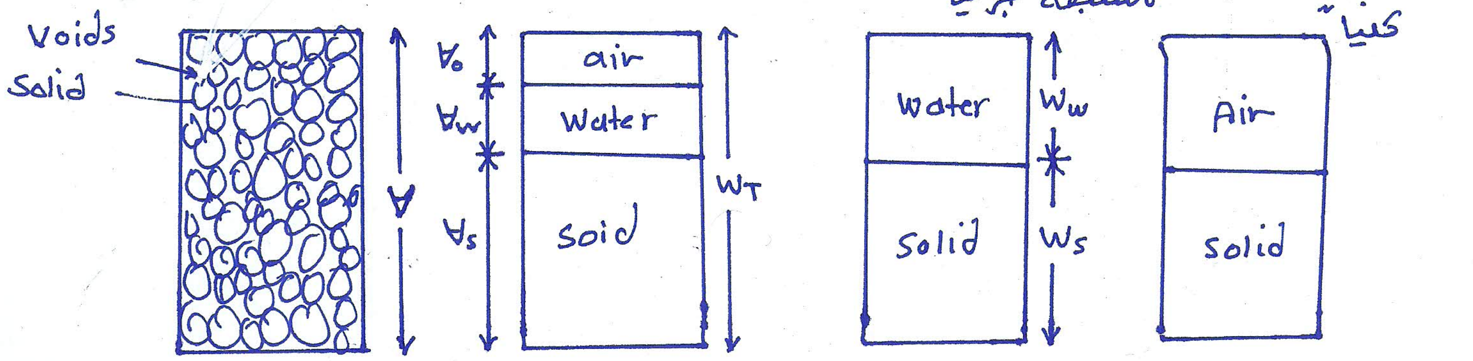
Soil classification تصنيف الترب

gravely soil	> 2 mm	according to USDA classification (united states depart. of agriculture)
Sandy soil	0.05 - 2 mm	
Silty soil	0.002 - 0.05 mm	
clay soil	< 0.002	

Soil - water relations

Soil compositions
- Solid
- water
- air

Soil phases
- dry
- Saturated
  - Partially Saturated مشبعة جزئيا
  - fully saturated مشبعة كليا



Soil skeleton — partially saturated — Fully Saturated — Dry soil

Volumetric Relations

Void ratio (e) نسبة الفراغات

$$e = \frac{\text{Volume of voids}}{\text{Volume of solid}} = \frac{\forall_v}{\forall_s}$$

porosity (n) المسامية

$$n = \frac{\text{Volume of voids}}{\text{Total volume}} = \frac{\forall_v}{\forall_T \text{ or } \forall}$$

Volumetric moisture content (ω) المحتوى الرطوبي الحجمي

$$\omega = \frac{\text{Volume of water}}{\text{Total volume}} = \frac{\forall_w}{\forall}$$

Degree of saturation S

$$S = \frac{\text{Volume of water}}{\text{Volume of voids}} = \frac{\forall_w}{\forall_v}$$

For fully saturated soil $\forall_w = \forall_v$ (no air), Thus ; $S = 1 = 100\%$

Note that ; $\omega = \frac{\forall_w}{\forall} = \frac{\forall_w}{\forall_v} \cdot \frac{\forall_v}{\forall}$

$$\boxed{\omega = S \cdot n}$$

and $n = \frac{e}{1+e}$, $e = \frac{n}{1-n}$

Real spesific gravity (G_s) الكثافة النسبية الحقيقية :-

هي النسبة ما بين وزن وحده الحجوم من التربة الجافه على وزن وحده الحجوم من الماء

$$G_s = \frac{\gamma_s}{\gamma_w} , \quad \gamma_s = \text{soid density} = \frac{W_s}{\forall_s} , \quad G_s \gamma_w = \frac{W_s}{V_s}$$

Apparent Spesific gravity (G_b) الكثافة النسبية الظاهرية

$$G_b = \frac{\gamma_b}{\gamma_w} \quad \text{where } \gamma_b = \frac{W_s}{\forall}$$

هي وزن وحده الحجوم من التربة الكلية الى وزن وحده الحجوم من الماء

$$G_b \gamma_w = \frac{W_s}{V} \quad \text{i.e ,} \quad V = \frac{W_s}{G_b \gamma_w}$$

Moisture by weight (W)

$$W = \frac{W_w}{W_s} \quad \text{(water content by weight)}$$

Also, $\omega = \frac{V_w}{V} = \frac{W_w/\gamma_w}{W_s/(G_b\gamma_w)} = G_b \frac{W_w}{W_s}$

$$\therefore \boxed{\omega = G_b W}$$ ← علاقة مهمة تربط المحتوى الرطوبي الوزني مع المحتوى الرطوبي الحجمي

كما ان هناك علاقة مهمة تربط المحتوى الرطوبي الحجمي (ω) بعمق الماء في التربة dw وكالاتي :

$$\boxed{d_w = \omega d}$$

من خلال هذه العلاقة يمكن تحويل عمق التربة المستقبة الى عمق ماء بضربه في المحتوى الرطوبي الحجمي .

اشتقاق المعادله اعلاه كالآتي :

$V = \frac{W_s}{G_b\gamma_w}$, $V_s = \frac{W_s}{G_s\gamma_w}$ ← previously defined

$$\frac{V_s}{V} = \frac{G_b}{G_s}$$

Further $1-n = \frac{V_v}{V} = \frac{V-V_v}{V} = \frac{V_s}{V} = \frac{G_b}{G_s}$

$$\therefore \boxed{G_b = G_s(1-n)}$$

also $\omega = G_b W \Rightarrow \omega = G_s(1-n)W$

also $V = A.d$ —① where V: total volume of soil, A: surface area, d: root zone depth

and $\frac{V_s}{V} = 1-n \Rightarrow V_s = V(1-n)$ —②

sub. eq ① & eq ② in $W_s = V_s G_s \gamma_w$

yeilds, $W_s = V(1-n)G_s\gamma_w \Rightarrow W_s = Ad(1-n)G_s\gamma_w$

$$W = \frac{W_w}{W_s} = \frac{W_w}{Ad(1-n)G_s\gamma_w} = \frac{V_w\gamma_w}{Ad(1-n)G_s\gamma_w}$$

∴ The volume of water in the root-zone soil V_w is:

$$V_w = W\,A\,d\,(1-n)\,G_s$$

Also, $V_w = A \cdot d_w$ where A: soil surface area

$$d_w = \frac{V_w}{A} = \frac{W\,A\,d\,(1-n)\,G_s}{A} = \overbrace{W\,(1-n)\,G_s}^{\omega}\,d$$

$$\therefore \quad d_w = \omega \cdot d$$

Ex1: A moist soil sample has a volume of 484 cm^3 in the natural state and a weight of 7.9N. The dry weight of the soil is 7.36N and the relative density of the particles is 2.65. Determine the porosity, soil moisture content, volumetric moisture content and degree of saturation.

Sol.

$$n = 1 - \frac{G_b}{G_s} \quad \text{where} \quad G_b = \frac{W_s}{\gamma_w V}$$

$$= 1 - \frac{1.55}{2.65} = 0.415 \approx 41.5\%$$

$$G_b = \frac{7.36}{9810\,\frac{N}{m^3} * 484\,cm^3 * 10^{-6}} = 1.55$$

$$W = \frac{W_w}{W_s} \quad \text{where} \quad W_w = W_T - W_{dry}$$

$$W_w = 7.94 - 7.36 = 0.58N$$

$$W = \frac{0.58}{7.36} = 0.0788 = 7.88\%$$

$$\omega = G_b W \Rightarrow \omega = 1.55 * 0.0788 = 12.214\%$$

$$S = \frac{\omega}{n} = \frac{12.214}{41.5} = 0.294 = 29.4\%$$

EX 2: For a given soil has a spesific gravity of 2.65. The weight of soil sample is 1.8N. After drying in an oven, it weights 1.5N. Compute the Apparent spesific gravity

Sol.

$$G_s = \frac{W_s}{V_s \cdot \gamma_w}$$

$$2.65 = \frac{1.5}{V_s * 9810 \frac{N}{m^3}} \Rightarrow V_s = 57.7 * 10^{-6} \ m^3 \text{ or } 57.7 \ cm^3$$

$$W_w = W_T - W_s$$

$$= 1.8 - 1.5 = 0.3N$$

$$V_w = \frac{W_w}{\gamma_w} \Rightarrow V_w = \frac{0.3}{9810} = 30.6 * 10^{-6} \ m^3 \text{ or } 30.6 \ cm^3$$

$$V = V_s + V_w$$

$$= 57.7 + 30.6 = 88.3 \ cm^3$$

$$G_b = \frac{W_s}{V \gamma_w} = \frac{1.5}{88.3 * 10^{-6} * 9810}$$

$$= 1.73$$

EX 3: Find particle density if the soil mass is 4.5g of 5 cm^3 volume.

Sol.

$$\text{particle density} = \frac{\text{mass}}{\text{Volume}} = \frac{4.5}{5} = 0.9 \frac{g}{cm^3}$$

EX4: Determine the bulk density and particle density of a given soil, if weight of dried soil = 12.5g for 5 cm^3 soil volume, Mass of particle = 12 g for 2.5 cm^3 unit volume and Find porosity.

Sol.

$$(\gamma_b) \text{ Bulk density} = \frac{12.5}{5} = 2.5 \ g/cm^3$$

$$(\gamma_s) \text{ particle density} = \frac{12}{2.5} = 4.8 \ g/cm^3$$

$$1 - n = 1 - \frac{V_v}{V} = \frac{V - V_w}{V} = \frac{V_s}{V} = \frac{V_s / W_s}{V / W_s} = \frac{1/\gamma_s}{1/\gamma_b}$$

$$1 - n = \frac{\gamma_b}{\gamma_s} \Rightarrow n = 1 - \frac{2.5}{4.8} \approx 48 \%$$

H.W (1): Given a soil which has the following data:

$V = 120\ Cm^3$, $W = 1.5\ N$, $W_s = 1.45\ N$,

$\gamma_w = 9810\ \frac{N}{m^3}$, $G_s = 2.65$,

Find:
1. Apparent spesific gravity (G_b)
2. The porosity (n)
3. Volume of solid (V_s)

Ans.

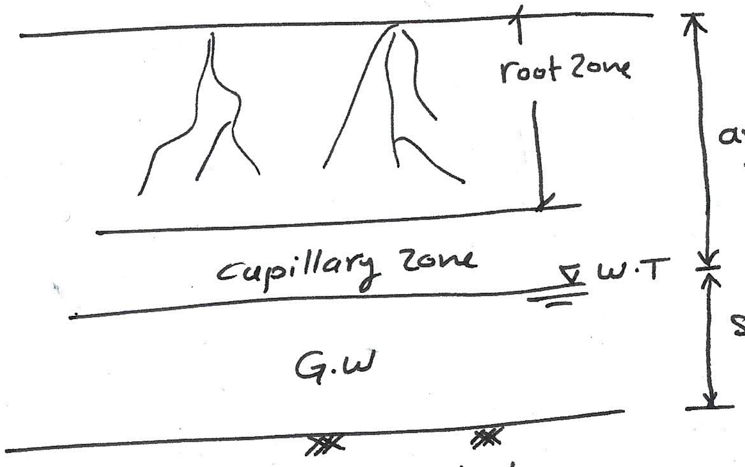
$G_b = 1.23$

$n = 54\%$

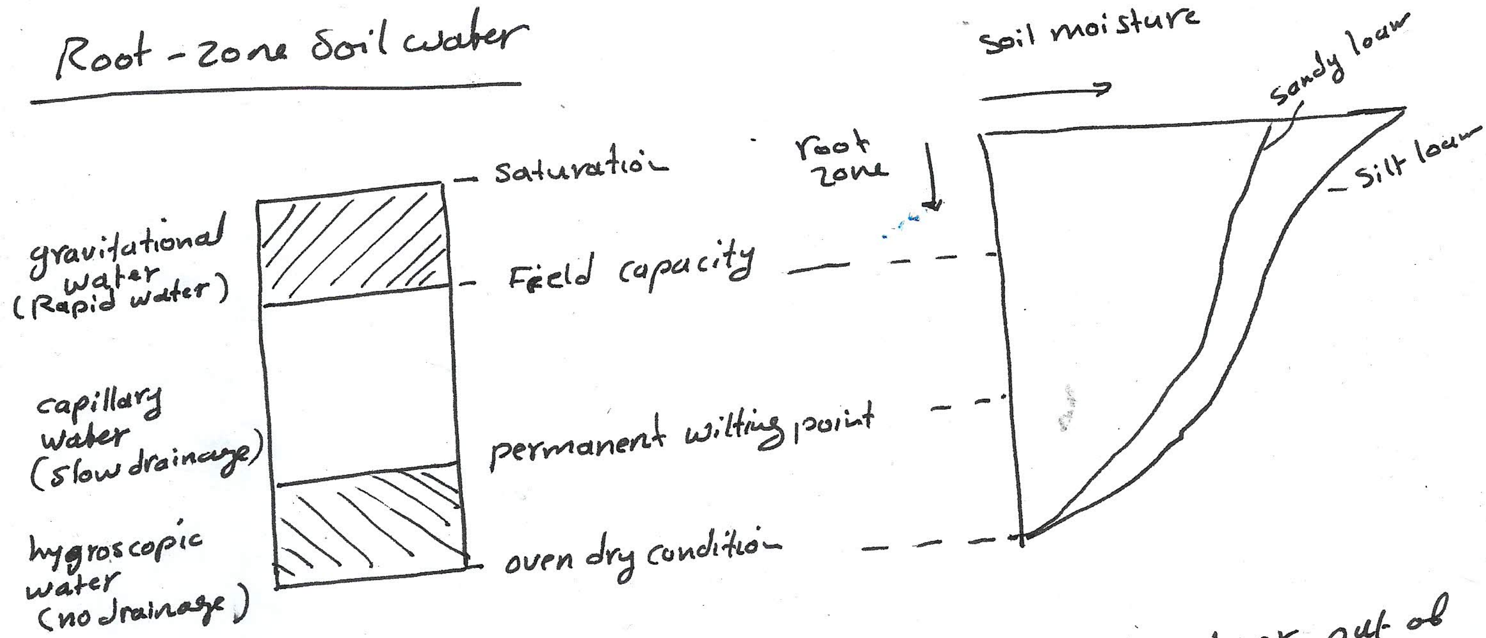
$V_s = 55.2\ cm^3$

H.W (2): A soil has Apparent spesific gravity equal to 1.45, its dry weight is 1.5N. The weight of soil sample is 1.7N, Find the percentage of water content by volume.

Subsurface water < Zone of areation / Zone of saturation



Root-zone Soil water



Gravitational water : the water that moves into, through or out of the soil by gravity مياه لا يستفاد منها النبات

Capillary water : is the water that remaines in the soil after the gravitational water drains ; it permits plants to servive through periods of drought. مياه يستفاد منها النبات

hygroscopic water : is the water held very tightly by the soil particles so that it is unavailable to the plant.

Field capacity: is the amount of soil moisture or water content held in the soil after excess water (gravitational water) drained away and the rate of downward movement has decreased. this usually takes place after 2-3 days after irrigation depending on texture & structure of soil.

هي كمية الرطوبة التي تحتفظ بها التربة بعد التخلص من المياه الزائدة (مياه الجذب الارضي) اي بعد ان تتوقف حركة المياه السائبة الى الاسفل بفعل الجاذبية حيث يقل المحتوى الرطوبي لحد السعة الحقلية بعد ٢-٣ ايام من الارواء وحسب نسجة وبنية التربة.

permanent wilting point: is the moisture content beyond which, plants can no longer extract enough moisture and remains wilted unless water is added to the soil.

هي كمية الرطوبة التي عندها يميل النبات الى حالة الذبول ما لم يتم اضافة الماء مجدداً الى التربة حيث يتعذر على النبات امتصاص هذه الرطوبة.

Available water (capillary water): (AW)

هي الرطوبة المتوفرة للنبات.

$$AW = F.C - P.W.P$$

Readily available water (RAW) (ماء ميسر): is the water which can be removed from the soil with minimal energy required.

$$RAW \approx 50\%\ AW$$

بالرغم من ان AW يعتبر ماء ممتص (قابل للامتصاص او متوفر) من قبل النبات الا ان RAW يمتص بسهولة من قبل النبات بدون جهد حيث ما بعد RAW يحتاج الى جهد اكبر وكلما اقتربنا من PWP كلما زاد جهد النبات لامتصاص الماء.

$$RAW = \%\ AW$$

Allowable depletion (AD): is the term of what is the allowable amount of water that can be withdrawn from the soil between irrigation events without stressing the crop.

نسبة استنزاف الرطوبة للدرجة المسموح بها لكي يبقى دائماً خزين من المياه يحتاج النبات اليه في اوقات القطع او الصيانة الخ.

$$RAW = AD \times AW$$

يتراوح AD (40-60)% من الماء المتوفر

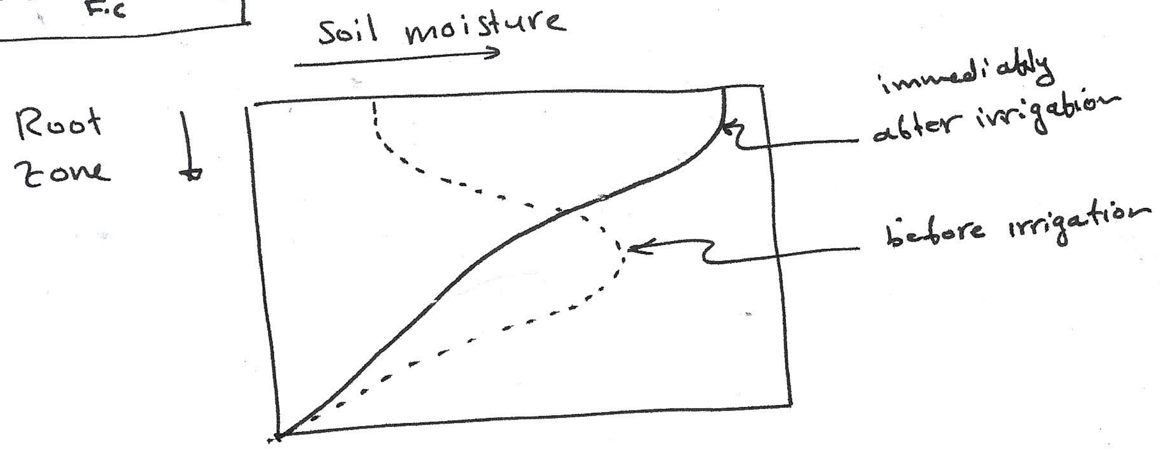
Soil moisture deficit (SMD): the amount of water needed to bring the soil moisture back to field capacity

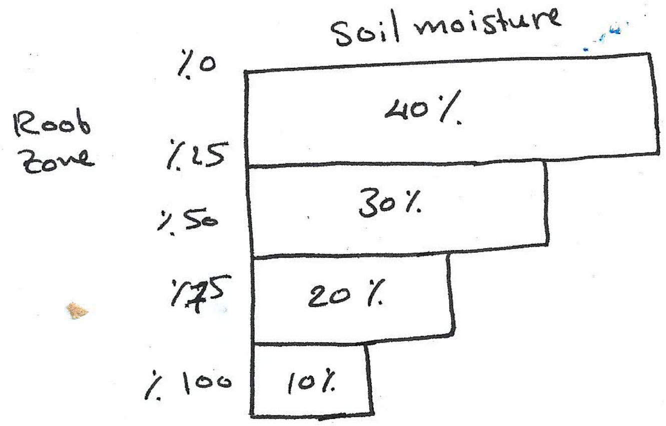
الفرق بين المحتوى الرطوبي عند السعة الحقلية و المحتوى الرطوبي الابتدائي (الذي يحصل
(iwc)
اي قياس للمحتوى الرطوبي قبل السعة الحقلية)

$$SMD_{max} = AW \quad (SMD \leq AW)$$

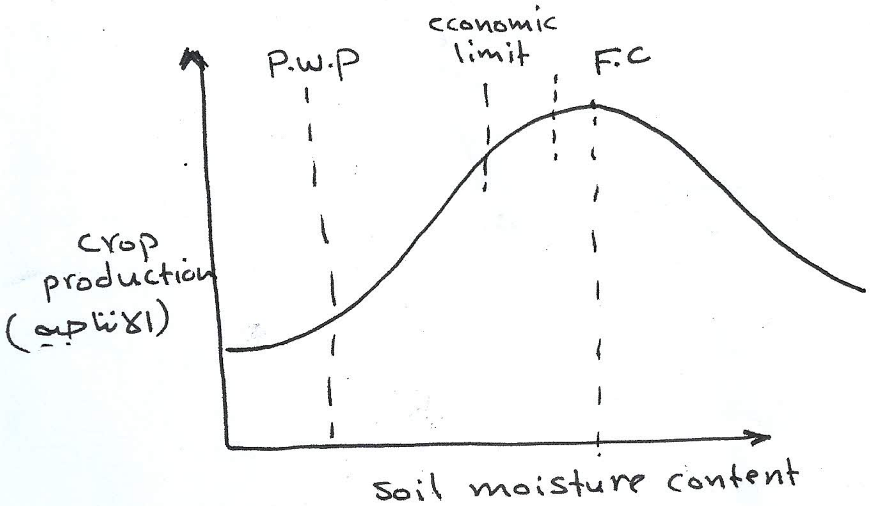
if $SMD = 0$ then the water content is at F.C

$$SMD = W_{F.C} - iwc$$





التوزيع الرطوبي بعد السقي مباشرة



العلاقة طردية لأنه بزيادة
المحتوى الرطوبي تقل الانتاجية
عند حد معين حيث تغلق المسامات

EX/ For a soil ; F.C = 28% by dry weight
PWP = 18% by volume.
AD = 50% , Find Readily available water by volume , $G_b = 1.35$ and Readily AW by weight

Sol.

$$RAW = AD * AW$$

$$= AD\,(F.C - PWP)$$

$$\boxed{W_{\text{by volume}} = W_{\text{by weight}} * G_b}$$

$$RAW = \frac{50}{100} * (28 * 1.35 - 18)\,\% = 9.9\,\%\ \text{by vol.}$$

$$RAW = 9.9 / 1.35 = 7.33\,\%\ \text{by weight}$$

EX/ For a given soil ; $G_s = 2.46$, weight = 184 g , dry weight = 153 g , Find G_b ?

Sol.

$$G_b = \frac{W_s}{V \cdot \gamma_w} \quad , \quad G_s = \frac{W_s}{V_s \cdot \gamma_w} \Rightarrow V_s = \frac{153}{2.46 * 1} = 62.5\ cm^3$$

where $\gamma_w = 1\ gm/cm^3$

$$W_w = 184 - 153 = 31\ g$$

$$V_w = \frac{31}{\gamma_w} = 31\ cm^3$$

$$V = V_s + V_w = 62.5 + 31 = 93.5\ cm^3$$

$$G_b = \frac{153}{93.5 * 1} = 1.64$$

Ex: A layered soil has the following:

Top layer : F.C = 40%

P.w.P = 18% AD = 35%

Depth of soil = 50 cm

initial water content (iwc) = 26% by vol.

bottom layer : F.c = 38%

p.wp = 20%

D = 60 cm

actual water content = 30% by vol., AD = 55%

Find the required depth of irrigation dn.

Sol.

Top layer : $Smd = F.c - iwc$

$$= \frac{40 - 26}{100} * 50 * 100 = 70 \text{ mm}$$

$$Aw = (W_{F.c} - W_{p.wp})\, AD$$

$$= \left(\frac{40 - 18}{100}\right) * 50 * 10 * 0.35 = 38.5 \text{ mm}$$

$Smd > AW$ معنى ذلك ان السقيه كانت متأخره

وتجاوز السحب الى الخزين الداخلي

Bottom layer :

$$Smd = \left(\frac{38 - 30}{100}\right) * 60 \times 10 = 48 \text{ mm}$$

$$AW = \left(\frac{38 - 20}{100}\right) * 60 * 10 * 0.55 = 59.4 \text{ mm}$$

$dn = 70 + 48 = 118 \text{ mm}$ ← العمق الواجب اضافته للتربة

$dn_{max} = 38.5 + 59.4 = 97.9 \text{ mm}$

Ex: A layered soil has the following

1st layer

F.C = 40%
P.W.P = 18%] by vol.
iWC (initial water content) = 26%

D = 50 cm

2nd layer

F.C = 38%
P.W.P = 20%] by vol.
iWC = 30%

D = 60 cm

20 cm of water added to the soil, find water content for the second layer after this addition of water.

Sol. 1st layer

Smd = F.C − iWC

= 40 − 26 = 14% by vol.

$$Smd = \frac{14}{100} * 50 \times 10 = 70 \text{ mm} \qquad (d_w = \omega \cdot D)$$

extra water = 200 − 70 = 130 mm will go to the 2nd layer

2nd layer

Smd = F.C − iWC

= 38 − 30 = 8% by vol.

$$Smd = \frac{8}{100} * 60 * 10 = 48 \text{ mm}$$

extra water = 130 − 48 = 82 mm will go as a deep percolation losses
(ضائعات التغلغل العميق)

Ex: Given a soil of 2 layers

Top layer:

$$\left.\begin{array}{l} F.C = 32\% \\ P.W.P = 10\% \\ iwc = 36\% \end{array}\right\} \text{by vol.} \qquad D = 40\ cm$$

bottom layer

$$\left.\begin{array}{l} F.C = 32\% \\ PWP = 16\% \\ iwc = 20\% \end{array}\right\} \text{by vol.} \qquad D = 60\ cm$$

Find soil water content % by volume for second layer when two layers reach a moisture balance.

Sol. نلاحظ في هذا السؤال انه للطبقة العليا من التربة iwc اعلى من F.C معنى ذلك انه تم اضافة ماء زائد سوف ينزل الى الطبقة السفلية لذا وجب حسابه كما يلي

1st layer:

extra water $= iwc - F.C$

$$= \left(\frac{36-32}{100}\right) * 40 * 10 = 16\ mm$$ will go to bottom layer

2nd layer:

$$smd = F.C - iwc$$

$$= \frac{32-20}{100} \times 60 \times 10 = 72\ mm$$

smd after extra water comes from top layer $= 72 - 16 = 56\ mm$

$$\therefore\ iwc = F.C - smd$$

$$= 32 - \frac{56}{600} \times 100 = 22.6\%\ \text{by vol.}$$

EX: Given a soil sample:

$V = 131\ cm^3$, $W = 2N$, $W_s = 1.8N$,

at full saturation $W = 2.8\ N$

after all gravity water has been drained out, $W = 2.2N$

when all capillary water has been Used, $W = 1.85$

Find: The apparent spesific gravity (G_b), Gravity water % by Vol., hygroscopic water % by vol. & AW % by vol.

Sol.

1- $G_b = \frac{W_s}{V\,\gamma_w} = \frac{1.8 * 10^6}{131 * 9810} = 1.4$

ملاحظة: عندما ذكر في السؤال ان وزن العينة كان W=2.2N بعدها تم
نزل كل ماء الجذب الارضي هنا يعني ان المحتوى الرطوبي وصل الى السعة الحقلية
(F.C) اي ان وزن العينة W=2.2N كان عند السعة الحقلية (F.C).

ملاحظة: عندما ذكر في السؤال ان وزن العينة W=1.85N بعدها تم استهلاك
كل الماء الشعري هنا يعني ان المحتوى الرطوبي وصل الى نقطة الذبول الدائمية
(P.W.P) اي ان وزن العينة W=1.85N كان عند نقطة الذبول الدائمية (P.W.P)

2- gravity water = water content at full saturation − water content at Field capacity

$$\text{gravity water} = W_{sat} - W_{F.C}$$

at saturation :-

$$W_{sat} = \frac{V_w}{V} \times 100$$

$$V_w = \frac{W_w}{\gamma_w} = \frac{(2.8-1.8)\times 10^6}{9810} = 102\ cm^3$$

$$W_{sat} = \frac{102}{131} \times 100 = 77.9\ \%\ \text{by vol.}$$

at Field capacity :-

$$W_{F.C} = \frac{V_w}{V} \times 100$$

$$V_w = \frac{W_w}{\gamma_w} = \frac{(2.2-1.8)\times 10^6}{9810} = 40.8\ cm^3$$

$$W_{F.C} = \frac{40.8}{131} \times 100 = 31.2 \% \text{ by vol.}$$

$\therefore$ gravity water $= 77.9\% - 31.2\% = 46.7\%$ by vol.

ملاحظة: الماء الهايكروسكوبي يساوي المحتوى الرطوبي عند نقطة الذبول الدائمية (p.w.p)

3- hygroscopic water $= W_{p.w.p}$

<u>at permanent wilting point p.w.p :-</u>

$$W_{p.w.p} = \frac{V_w}{V} \times 100$$

$$V_w = \frac{W_w}{\gamma_w} = \frac{1.85 - 1.8 \times 10^6}{9810} = 5.1 \text{ cm}^3$$

$$W_{p.w.p} = \frac{5.1}{131} \times 100 = 3.9 \% \text{ by vol.}$$

$\therefore$ hygroscopic water $= 3.9\%$ by vol.

4- $A_w = W_{F.C} - W_{p.w.p}$

$= 31.2 - 3.9$

$= 27.3\%$ by vol.