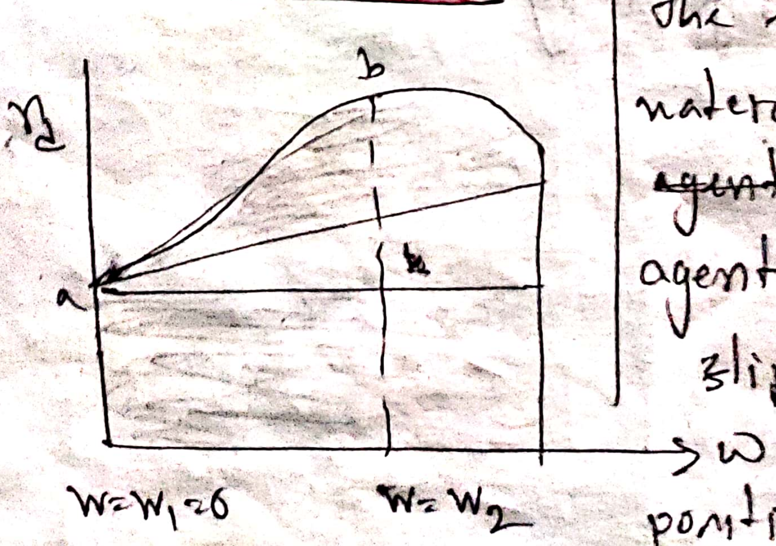
Soil compaction

[2019] **Compaction** – Compaction means densification of soil by removal of air applying mechanical energy.
Compaction increase the strength characteristics of soil, which increase the bearing of foundations constructed over them.

[15et] **Field of compaction** – (Some work side where compaction is needed)

1. Roads, highway, Railway
2. Foundation of any structure
3. Any earth structure (dam, embankment)
4. Any filling works
5. Runway

Principle of compaction



When water is added to the soil during compaction, water particle ~~lubricant agent~~ act as lubricant agent particle become slipy and move into densely packed position.

The more water is added, the more soil is compacted. ~~In this way~~ the Dry density increases. In that way maximum ~~wet~~ dry unit weight is gained. Then it is called OMC.

- If then more water is added water particle take place between the solid particle which decrease the density.

Compaction parameters

1. Max dry density
2. OMC → optimum moisture content.

[14, 7]

~~Optimum m~~ OMC → The moisture content at which the maximum dry unit weight is attained is generally reffered to as the ~~to~~ OMC

Objectives of soil compaction [2017]

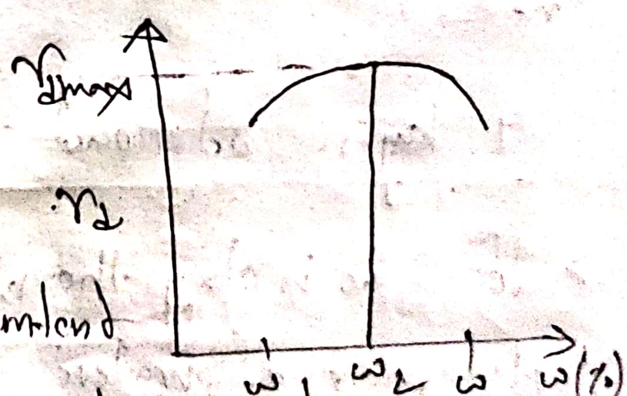
Applied to improve the properties of an existing soil or in the process of placing fill.

Main objectives are :- to -

1. increase shear ~~stress~~ strength and ~~therefore~~ bearing capacity.
2. Increase stiffness and therefore reduce future settlement.
3. decrease voids ratio and so permeability, thus reducing potential frost heave

Explain compaction curve [15]

In standard proctor test, if we plotted (γ_d) vs W in graph we can see that,



when the percentage of water content is increased, the value of dry ~~density~~ unit weight is also increased.

At one point, for a certain percentage of water content, the dry unit weight (γ_d) will be maximum.

After this water content, if we increase the percentage of water content, the value of dry unit weight (γ_d) will decreased

placement of water content

→ The water content used in field compaction is called the placement water em content.

→ It may be equal to, lower than or higher than the optimum water content determined in the laboratory.

→ Cohesive subgrades under pavement should be preferably be compacted wet of optimum so that they they may not exhi exhibit large expansions and swelling pressure on submergence.

4 layer of road →

W.S

BC

Sub base (SB)

Sub grade (SG)

→ If S.G is clay then, placement of water content > OMC

→ Highway embankment, placement of water content < OMC

→ Dam if granular soil OMC ≤ placement of water conten

→ High dam < OMC

→ Im pervious dam > OMC

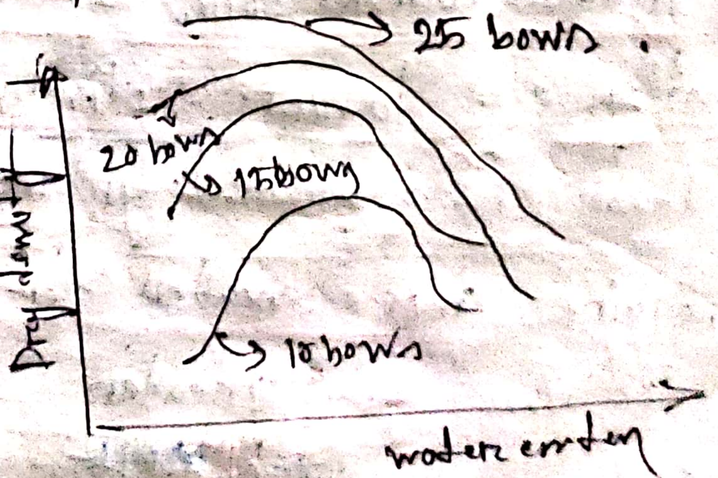
Factors Affecting compaction [ct 16]

(i) Water content - It has been seen by laboratory experiments that as the water content is increased, the compacted density goes to increasing till max. dry densities is achived. After that if water content is added more, then the dry density decreases.

(ii) Amount of compaction - The amount of compaction greatly affects the maximum dry density and optimum water content of a given soil.

⇒ increase compactive energy → increase maximum dry density

⇒ increase compactive energy → decrease optimum water content.



(5) Method of compaction – The ~~dry~~ density of soil during compaction depends on –

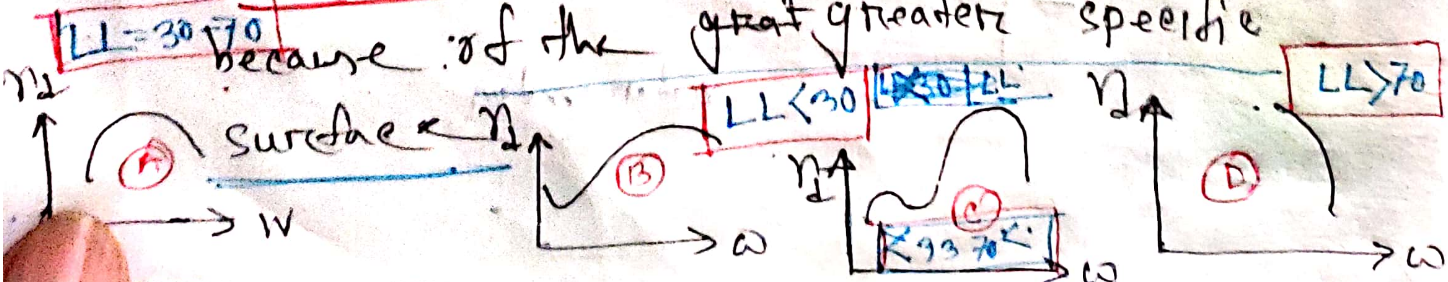
① Weight of the compacting equipment

② The manner of operation such as dynamic or impact, static, ~~kneading or ro~~ kneading or rolling

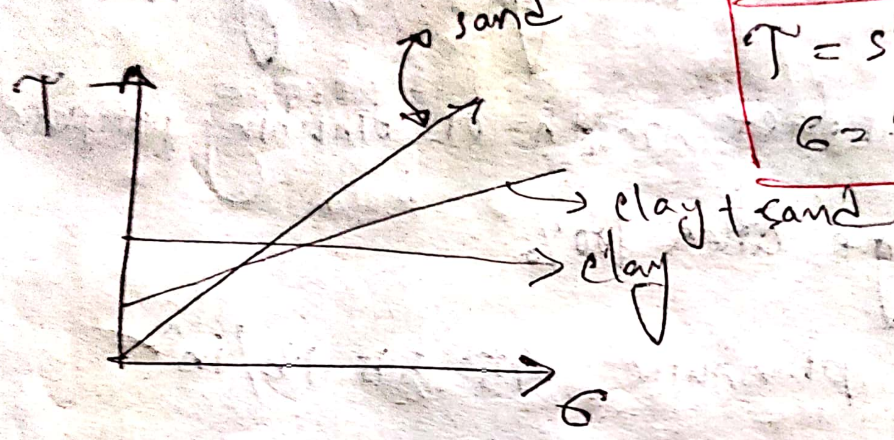
③ Time and area of contact between the compacting element and the soil.

(4) Type of soil – The ~~maximum~~ maximum dry density achieved corresponding to a given compactive energy largely depends upon the type of soil.

→ Well graded coarse soils attain a much higher density and lower optimum water content, than fine ~~graded~~ grained soils, which require more water for lubrication because of the ~~great~~ greater specific surface.



5) Addition of admixture - The compaction properties/ characteristics of a soil can be modified by the number of admixtures other than soil material.



τ = shear stress
σ = bending stress

Field compaction

i Compaction equipments [Q. short note (What are the field compaction equipment?)]

(i) Smooth-wheel rollers (Smooth drum rollers)

(ii) Pneumatic rubber-tired rollers

(iii) Sheepsfoot rollers

(iv) Vibratory rollers

(1) Smooth wheel rollers [Short note]

(i) consist with drum

(ii) Used for sandy and clay soil

(iii) for surface smooth or finishing purpose

(iv) coverage area 100%

(v) exert pressure 45-55 lb/in^2

(2) Pneumatic or rubber-tired rollers [Short note]

(i) 9-6 number of rubber tire

(ii) For compaction of sandy / clay soil

(iii) 72-80% coverage area

(iv) exert pressure 85-100 psi

(3) sheepsfoot rollers [Short note]

(i) Drum with projection

(ii) 25-85 in^2 area of projection

(iii) compaction of clayey soil

(iv) coverage area 100%

(v) Exert pressure 200-1000 psi

(9) Vibratory rollers

(i) Load should be passed through the eccentricity of the objects not to the center of gravity.

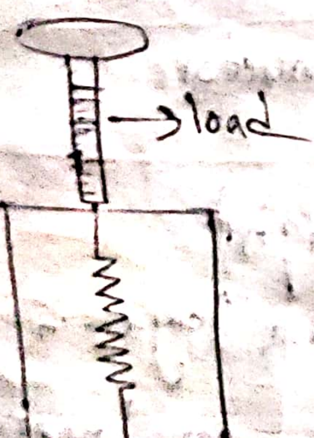
(ii) For compaction of (granular soil) sandy soil.

Field compaction control

2 method

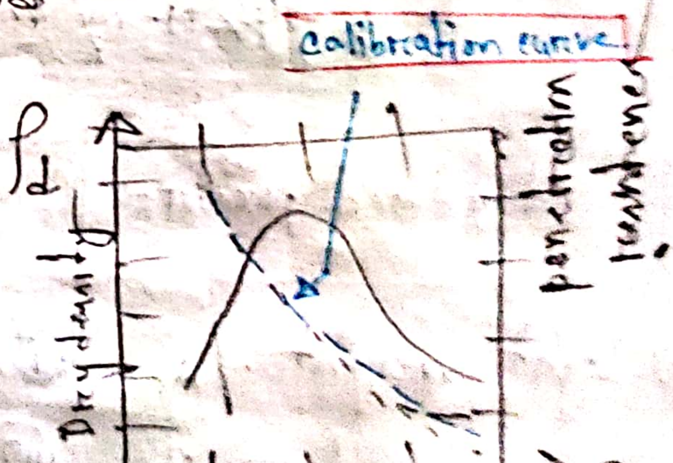
(i) ~~Calcium~~ Calcium carbide method

(ii) Proctor needle method



1 inch penetration

↳ pressure calculation



Energy of compaction

The compaction energy per unit volume

$$E = \frac{\left(\text{No of blow / layer}\right) \times \left(\text{No of layers}\right) \times \left(\text{weight of hammer}\right) \times \left(\text{Height of drop}\right)}{\text{volume of mold}}$$

For standard procedure test :

$$E = \frac{25 \times 3 \times \left(\frac{2.5 \times 9.81}{1000} kN\right) \times 0.305}{944 \times 10^{-6}\ m^3}$$

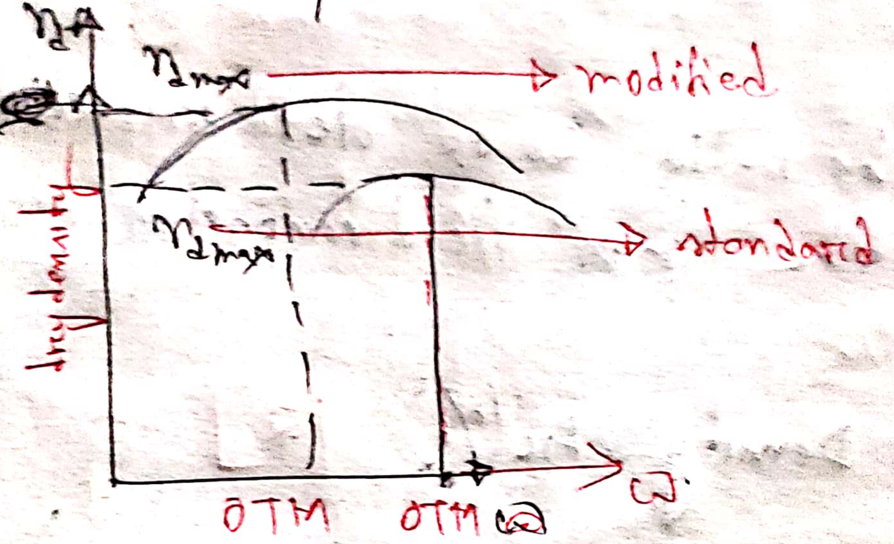
$= 2.594\ kN\text{-}m/m^3 \approx 600\ kN\text{-}m/m^3$

Standard procedure	Modified procedure
(i) Light weight	(i) Heavy weight
(ii) compaction layer 3	(ii) Compaction layer 5
(iii) blow per layer 25	(iii) 25 blow per layer
(iv) Hammer weight = 5.5 lb	(iv) Hammer weight 10 lb
(v) Drop of hammer — 12"/1 ft	(v) Drop of hammer — 18"/1.5 ft

Qualitative diagram of proctor test

→ For Modified proctor test compaction energy of 56250 lb-ft/ft³

→ For standard proctor test compaction energy 12375 lb-ft/ft³



⇒ $[(\gamma_d)_{max}]_{modified} > [\gamma_{d\,max}]_{standard}$

⇒ $[OMC]_{modified} < [OMC]_{standard}$

Specification of compaction

Relative compaction / degree of compaction

$$R(\%) = \frac{\rho_d(\text{field})}{\rho_d(\text{max})} \times 100 \quad [Q]$$

→ the ratio of field compaction to the max field compaction

Relative Density, $D_{rc}(\%)$ [Q]

$$= \left(\frac{\rho_d(\text{field}) - \rho_d(\text{min})}{\rho_d(\text{max}) - \rho_d(\text{min})} \times \frac{\rho_d(\text{max})}{\rho_d(\text{field})} \right) \times 100$$

$$\rho_d = \frac{G_s \rho_w}{1+e}$$

$$e = \frac{G_s \rho_w}{\rho_d} - 1$$

$$= \left(\frac{e_{max} - e}{e_{max} - e_{min}} \right) \times 100$$

$$R = \frac{R_0}{1 - D_{rc}(1 - R_0)} \qquad R_0 = \frac{\rho_d\ min}{\rho_d\ max}$$

$\rho_{d\,min} \rightarrow \rho_{max}$

$\rho_{d\,max} \rightarrow \rho_{min}$

Math on
→ Sand cone method
→ Core cutter method

① Relative Compaction
② Relative Density

Mould Volume	w	Bulk density
1/30	7%	1.73 g/cm3
1/30	10%	1.89 g/cm3
4/30	13%	1.95 g/cm3

① calculate compaction perrameter

(i) $\rho_d = \frac{\rho}{1+w} = \frac{1.73}{1+0.07} = \square$

② For 20% water content calculate zero air void line.

for zero void, $S=1$

$\rho_d = \frac{G_s \rho_w}{1+\frac{wG_s}{S}}$

$\rho_d = \frac{G_s \rho_w}{1+wG_s}$ → $\rho_d = $ ——

2005, 2006, 2009, 2015

Math| The relative compaction of a sand in the field is 95%. The max. and min. dry unit weight of sand are $\gamma_{d(max)} = 17\ kN/m^3$, $\gamma_{d(min)} = 15\ kN/m^3$. For the field condition, determine (i) dry unit weight (ii) relative density of compaction (iii) moist unit weight of a moisture content of 10%.

Soln:

(i)

$$R(\%) = \frac{\gamma_{d(field)}}{\gamma_{d\,max}} \times 100$$

$$\Rightarrow 95 = \frac{\gamma_{d(field)}}{17} \times 100$$

$$\Rightarrow \gamma_{d(field)} = 16.15\ kN/m^3$$

(ii) Relative density of compaction

$$D_r = \left(\frac{\gamma_{d(field)} - \gamma_{d(min)}}{\gamma_{d(max)} - \gamma_{d(min)}} \right) \times \frac{\gamma_{d(max)}}{\gamma_{d(field)}}$$

$$= \frac{16.15 - 15}{17 - 15} \times \frac{17}{16.15}$$

$$= 0.6052$$

(14)

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

$$\Rightarrow 16.15 = \frac{\gamma}{1+0.1}$$

$$\Rightarrow \gamma = 16.15 \times 1.1 = 17.765 \ kN/m^3$$

[12,14]

Math/ The weight of sand used to fill test hole and funnel of sand cone device is 8539 g and weight of sand to fill the funnel is 321.0gm. The density of sand is found to be 1.549 g/cm3. The weight of the soil from the test hole is 7399g and the moisture content is 15%. Calculate the dry ~~density~~ unit weight of the compacted soil

Soln: weigh of sand fill the hole = (8539 − 321) g
= 8218 g

$$\text{Volume of test hole} = \frac{8218}{1.549} = 5305.3582$$

Moist density of compacted soil,

$$e = \frac{7399}{5301.982} = 1.3946$$

$$\rho_d = \frac{e}{1+w} = \frac{1.3946}{1+0.15}$$

$$= 1.2126 \ g/cm^3$$

$$\gamma_d = \rho_d \times g$$

$$= 1.2126 \times \frac{1}{1000} \times 9.81$$

$$= 1.189 \times 10^{-2} \ N/cm^3$$

$$= 11.8965 \ kN/m^3$$

[2020]

[3(e)]

$\gamma_{d\,max} = 19$ kN/m3 | $D_r = 80\%$

$\gamma_{d\,min} = 17$ kN/m3 | $\omega = 15\%$

$\gamma_{field} = ?$

Sol^n:

$$R_o = \frac{\gamma_{d\,min}}{\gamma_{d\,max}} = \frac{17}{19} = 0.8947$$

$$R = \frac{R_o}{1 - D_r(1 - R_o)}$$

$$= \frac{0.8947}{1 - 0.8 \times (1 - 0.8942)} = 0.9770$$

$$R = \frac{\rho_{field}}{\rho_{max}}$$

$$0.9770 = \frac{\rho_{field}}{19}$$

$$\rho_{field} = 0.977 \times 19$$

$$= 18.563$$

Math] [CT 16]

[Q.2]

$G_s = 2.70$

$S = 90\%$

$\gamma_{d\,max} = 1.80\,g/cm^3$

$w = 15\%$

$$\gamma_d = \frac{G_s \gamma_w}{1 + \frac{G_s w}{S}}$$

$$= \frac{2.7 \times 1}{1 + \frac{2.7 \times 0.15}{0.9}}$$

$$= 1.8628$$

Math [2019]

[Q.2(c)]

$$e_{max} = \frac{G_s \gamma_w}{\gamma_{d\,max}} - 1$$

$$= \frac{2.66}{1.8} - 1$$

$$= 0.4778$$

$$S = \frac{w G_s}{e_{max}} = \frac{0.15 \times 2.66}{0.4778} = 0.835 / 82$$

$$\eta = \frac{e}{e+1}$$

$$= \frac{0.4778}{0.4778+1}$$

$$\eta = 0.3032$$