Main Points Of Compaction

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- **Soil Stabilization:**
    1. Chemical : Mix or injection chemical Substance into soil.(Portland Cement, Lime, Asphalt, calcium chloride, sodium chloride , paper mill)
    2. Mechanical (Densification).
    3. Dewatering: Removal Or Reduction of unwanted excess Ground water pressure.
    4. Preloading: Temporary over load so increase the strength decrease anticipated settlement.
    5. Other techniques for improving soils:
        - Removal and replacement
        - Stage construction
        - Dynamic compaction
        - Stone columns etc...
- **Compaction:**
    - ***Definition*** *:*I s densification of soil by application of mechanical energy.
    - ***Advantages:***

1. Detrimental settlement can be reduce or prevented.
2. Soil Strength Increase and slope stability can be Improved.
3. Bearing Capacity of pavement subgrade can improved.
4. Undesirable volume changes.

- **Proctor established he Compaction is Function of four Variables:**
    1. Dry Density.
    2. Water content.
    3. Compactive Efforts.

4. Soil Type.

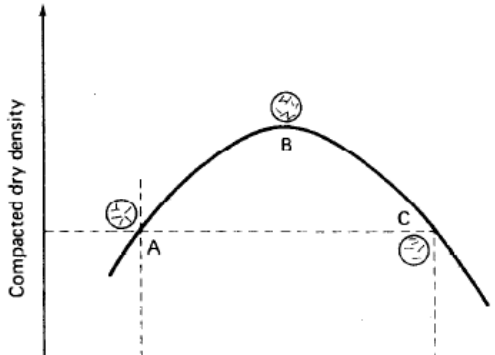
- **In the Field Compactive Effort is the Number of Passes or Coverage the roller of Certain type and weight of Given Volume of soil.**
- **Proctor Test Specifications:**

Test	Proctor Test	Modify Proctor Test
Hammer mass	2.495Kg	4.536
High fall	304.88mm	457mm
Tamped/layer	3layer tamped25	5 layer Tamped 25
$\gamma d = \frac{GS*\gamma_w}{1+\frac{GS*w_c}{S}}$		$\gamma d = \frac{\gamma_b}{1+w}$
$\gamma d = \frac{(1-na)GS*\gamma_w}{1+Wc*Gs}$		$\gamma d = \frac{(1-ac)GS*\gamma_w}{1+Wc*Gs}$
ac: Air content $\frac{Vair}{VTotal}$ **na: Percent Air Voids** $\frac{Vair}{Vvoids}$ **ac=1-S at ac=0 S=100%**		

- **The Maximum Dry density tends to decrease as plasticity increase.**
- **Why do we get compaction Curve?**

Starting at Low water content as the water content increase the particles develop longer and larger water films around them, which tend to "lubricate" the particles and make them easier to be moved about and reoriented into a denser configuration, however we eventually reach a water content where the density does not increase any further ,at this point water starting to replace soil particles in the mode and since $\rho w \leq \rho s$ thee dry density curve starts to fall. Note that no matter how much water is added the soil never becomes completely saturated by compaction.

- **Properties Structure of Cohesive Compacted Soil:**



A: Dry Of Optimum

B: Near or At Optimum

C:Wet of Optimum

1. **Type of Compaction:**

- At Dry of optimum: The structure of soil essentially independent of the type of compaction.
- At Wet of optimum: the type of compaction has significant effect on the soil structure and thus on the strength , permeability, …,etc

2. **Fabric:**

- At Dry of optimum: Soil is always flocculated.
- At Wet of optimum: the fabric become more oriented or dispersed.

3. **When Compactive effort** is increase the soil tends to become more oriented (Soil structure).
4. **Permeability:** if compaction effort is increased the coefficient of permeability decrease because the void ratio decrease.
5. **At Relatively low stress levels** clay compacted wet of optimum are more compressible at high stress level the opposite is true.
6. **Swelling** of compacted clays is greater for those compacted dry of optimum , they have greater tendency to adsorbed water and thus swell more , soils dry of optimum more sensitive to environmental changes such as change in water content, this is just the opposite for shrinkage , where the sample compacted wet of optimum have the highest shrinkage.
7. **The Strength:** The samples compacted dry of optimum have higher strength than those compacted wet of optimum the strength wet of optimum also depend on the type of compaction. if the sample soaks the picture change due to swelling ,especially dry of optimum. Note that at given wet of optimum the stress at 5% , Strain is actually use for higher energy.

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- **The depth Influence :**

  When structure are to be founded on are relatively deep deposits of a loose granular material densification by even heavy surface vibratory rollers is in sufficient and other technique must be employed , the depth of influence D in meter of the soil undergoing compacting is be conservatively given by:

$$D \cong 0.5\sqrt{wh}$$

W: mass falling weight ,ton

H:Drop High in meter

- **Compaction mechanisms :**

  Impact, kneading, static press and vibration

- **Field compaction :**

Compacter Type	Pressure	Coverage	Other
Smooth rollers	55 psi(380) kpa	100%	Proof rolling and compaction of asphalt pavements
Pneumatic or Rubber Tired	up to 100psi (700 kpa)	80%	Granular and cohesive soils, highway fill, earth dams …
Sheep Foot Roller	200-1000) psi (1400-1700) kpa	8-12%	Kneading action Suited for cohesive soils
Tamping Foot Rollers	(200-1200) psi (1400-8400) kpa	40%	Kneading action For cohesive soils
Vibratory rollers	▸ Several manufacturers attached vertical vibrators to smooth and tamping foot rollers to more efficiently density granular soils ▸ Small vibratory machines are used in areas where large rollers can not operates. Dynamic component tends to help particle rearrangement specially dry of optimum		

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Variables which control field compaction

- Characteristic of compactor: Type, Mass, size, vibration frequency
- Characteristic of the soil: Type, initial density, grain size & shape and water content
- Construction procedures :(Number of passes of rollers, Lift thickness ,Towing speed, Vibrator operation frequency)

Water for Embankments:

$$\boldsymbol{Volume\ (gal)\ for\ 100\ ft\ lenth} = \frac{\left(\boldsymbol{Dry\ Density}\left(\frac{\boldsymbol{lb}}{\boldsymbol{ft^3}}\right)\right) \times \left((\boldsymbol{O.M.C}\%) - (\boldsymbol{MC}\%)\right) \times \boldsymbol{Volume\ of\ Compacted\ Soil}(\boldsymbol{ft^3})}{\boldsymbol{8.33 lb/gal\ \times 100}}$$

Rate of Splash Water:

$$\boldsymbol{Rate\ (gal/yard^2)} = \frac{\left(\boldsymbol{Dry\ Density}\left(\frac{\boldsymbol{lb}}{\boldsymbol{ft^3}}\right)\right) \times \left((\boldsymbol{O.M.C}\%) - (\boldsymbol{MC}\%)\right) \times \boldsymbol{Thickness\ of\ Compacted\ Soil}(\boldsymbol{ft^3}) \times \boldsymbol{9}}{\boldsymbol{8.33 lb/gal\ \times 100}}$$

Field control test

- Destructive

1. Field density:
   - Balloon method
   - Sand cone
   - Oil or water method

Destructive field test elements	Problem	Alternative
Maximum dry density	M.D.D Unknown exactly .	- Time consuming and expansive proposition - Field check point of proctor test
Determination of water content	Taking times	-Pan drying or frying sample over and open flame (difficult to control temperature, gives a poor result especially for (CH) Soil)

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		-The speedy moisture meter -burning with methanol and specially alcohol hydro meter
Volume of hole	Subject to error if the compacted fills with gravel or large particles	Non destructive Test

- Non-destructive

1. Nuclear density
2. Rapid and accurate however equipment is expensive and there are some safety concerns

- **Earth work specification:**
  1. **End product Specification:**
     Relative Compaction or percent compaction is specified

$$RC = \frac{\rho field}{\rho dry\ in\ lab} \times 100$$

Note:(Over compaction occurs in the field when wet of optimum soils are proof rolled with very heavy smooth wheeled rollers or an excessive number of passes are applied to the lift , other wise a good material can become a weaker**)**

  2. **Method Specification:**
     Used for highways and building foundation as long as contractor is able to obtain the specified relative compaction how he obtains it does not matter nor does the equipments he uses**.**

- **Ref:**

1- An Introduction to Geotechnical Engineering(Holtz & Kovacs)
2- Soil Mechanic (Dr.Abd alfatah Algasabi)

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