Soil Stabilization and Compaction

Term description:

Soils are used extensively in and with many types of construction, they are used to support structures, to support pavement, for highway and airports, and as dams and levees to resist the passage of water. Some soils may be suitable for use in their natural state, while others must be excavated, processed, and compacted in order to serve their purposes.

Methods for soil stabilization:

i. *Mechanical methods*

- **a.** Compaction.
- **b.** Impact.
- **c.** Vibration.
- **d.** Combined.

ii. *Chemical methods*

- **a.** Stabilization by lime.

Use to stabilize soil of grain grading (fine-grained soils)

Common admixture:

- Lime-cement mixture
- Lime-fly ash mixture

Quantity used 5-10% from the soil weight.

When added to the clay soil, there are two reactions take place;

- Ionic exchange $Ca(OH)_2 + SiO_2 \rightarrow CSH$
- Sedimentation process

Method of addition:

- In situ mixing
- Mixing at plant
- Slurry

b. Stabilization by cement.

Using in:

- Stabilization of roads
- Earth dames

Soil suitable for this method

- Sandy soil
- Clay soil with L.L (45-50), and PI less than 25.
- Cement help to reduce L.L and increase P.I.

Table 1: percent of cement added to soil.

AASHTO	Unified classification	% Cement by volume
A-2 and A-3	GP, SP and SW	6-10
A-4 and A-5	CL, ML, and MH	8-12
A-6 and A-7	CL, CH	10-14

Methods of adding the cement

- In situ mixing
- Mixing at plant
- Slurry (0.5:5) (Cement: Water)

For weak soil, under foundation by injection which causes to reduce permeability and increase the strength.

c. Stabilization by Fly-Ash.

It is a pozzolanic material consists mainly $SiO_2 + AL_2O_3$

$$SiO_2 + AL_2O_3 + Ca(OH)_2 \rightarrow CSH$$

Added ratio (10-35%) fly ash, and (10-20%) lime, the soil should be compacted with a suitable moisture.

iii. *Stabilization by replacement or addition*

a. *Mixing soil.*

Mixing soil: mix different soil to get a good soil for compaction.

b. *Rock column.*

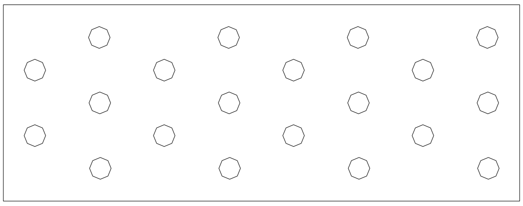
Rock column (stone column): Used to increase the bearing capacity for shallow foundation which piling on softy clay soil.

Specifications:

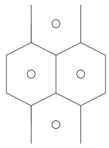
- size of the stone or aggregate used (6-40) *mm*.
- columns diameter (0.5-0.75) *m*.
- spacing between columns (1.5-3.0) *m*.

c. *Sub base.*

d. *Boulder*.



Plane



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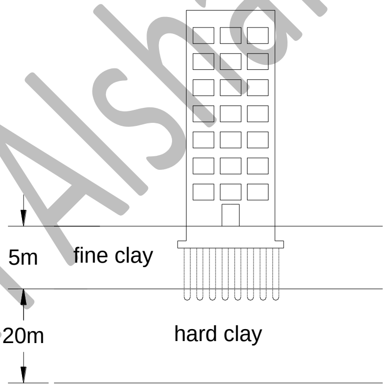
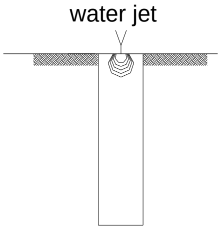
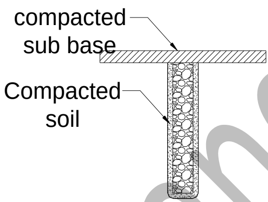
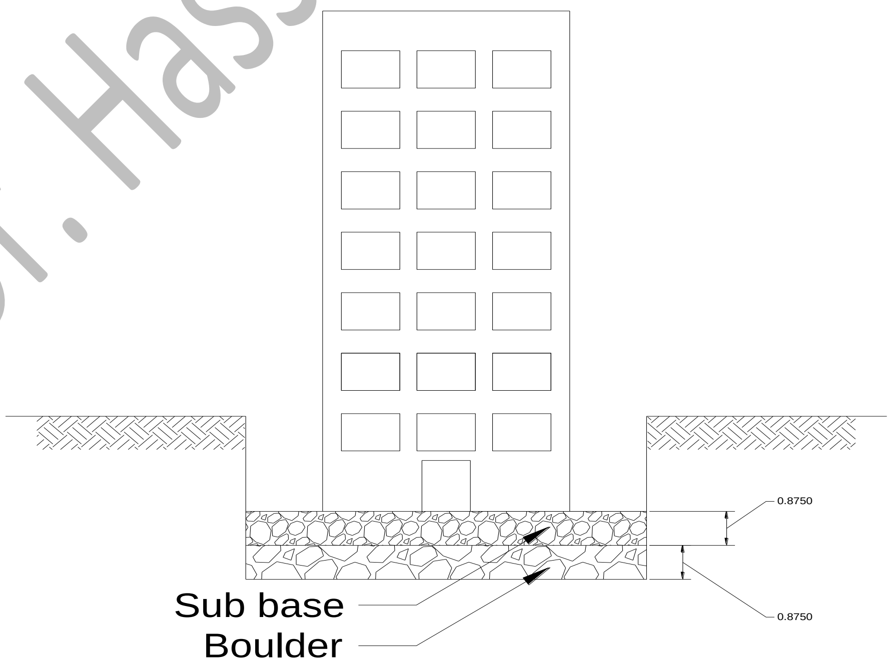






Replacement:



Swelling and Shrinkage Factors:

$$\boldsymbol{S_w}(\%) = \left(\frac{B}{L} - 1\right) * 100 \ldots\ldots\ldots (1)$$

$$\boldsymbol{S_n}(\%) = \left(1 - \frac{B}{C}\right) * 100 \ldots\ldots\ldots (2)$$

Where:

S_w: *Percentage of Swelling.*
S_n: *Percentage of Shrinkage.*
B: *Density of soil before excavation (embankment).*
L: *Density of soil after excavation (Loose).*
C: *Density of soil after excavation (compacted).*

Classification of Soil:

- Boulder > 250 mm
- Gravel > 6 mm
- Sand (0.05-6) mm
- Silt < 0.05 mm.
- Clay < 0.002 mm
- Organic material.

Laboratory Test for Soil Density:

A. Standard proctor test.
B. Modified proctor test.

Specification of Soil Compaction:

- Fix the method of compaction, thickness of each layer, moisture content, type of compactor equipment, no. of compactors passing.
- Method and end result.
- Suggest method and end result.
- Result only

Methods of compaction:

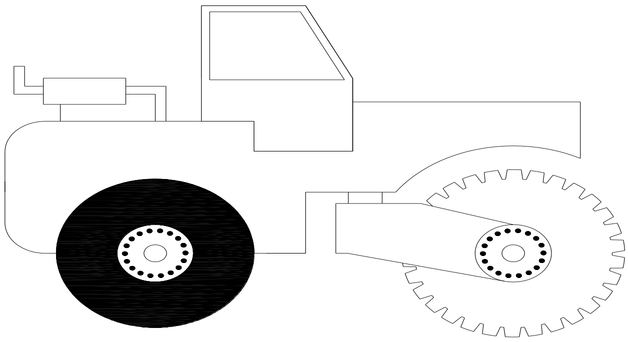
- *Kneading action.*
- *Static weight.*
- *Vibration.*
- *Impact.*

Compaction equipment:

1. ***Tamping Roller:*** It is suitable for compacting clay soil or sandy clay soil and it is not suitable for granular soil such as sand or gravel.

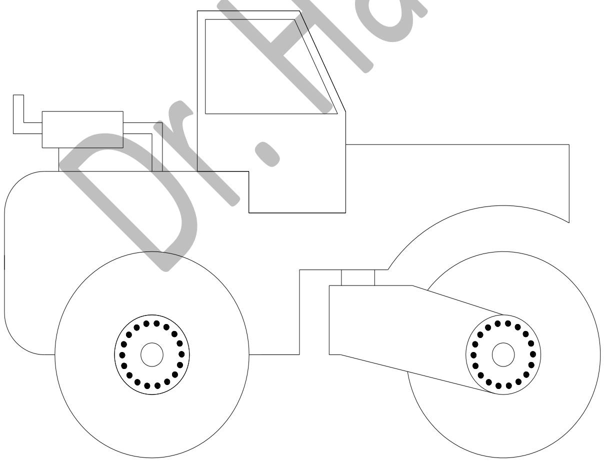
   Specification of compaction

   - No. of passing
   - Passing tamping rollers for a certain depth.
   - Repeat passing till reaching specified density.



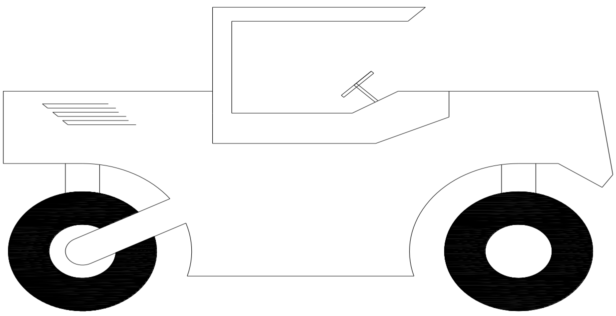
2. ***Smooth Wheel Compactor:***

- Used to compact granular soils, for surface layers of roads, and for asphalt.
- It is not suitable for clay soil.
- When compacting cohesive soils these rollers tend to form a crust over the surface, which may prevent adequate compaction in the lower portions of a lift.



3. *Pneumatic-Tire Roller:*

Used for all types of soil and asphalt, their weight can be increased by adding water or sand.



4. *Vibrating compactor:* Most compactor are supplied with vibration machine to give more compaction especially for grain soils.

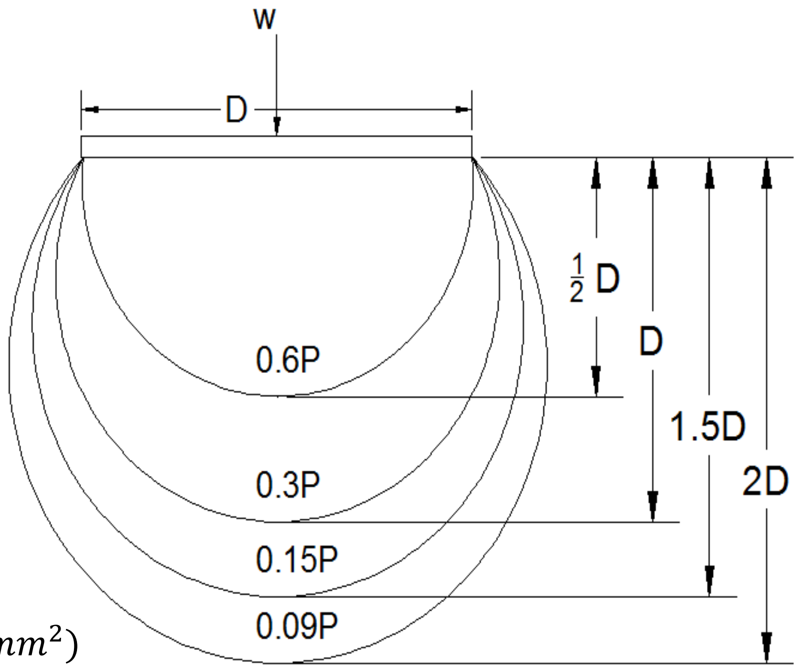
Pressure Bulb Theory of Load Distribution:

$$A = \frac{w}{P}$$

$$\frac{\pi}{4} * D^2 = \frac{w}{P}$$

$$\therefore D^2 = \frac{4w}{\pi P}$$

$$D = \sqrt{\frac{4w}{\pi P}}$$



Where:

D: diameter of circle (mm)
W: load (N)
A: area of circle (mm^2)
P: unit pressure under area (N/mm^2)

Case Study No. 9-1:

A pneumatic-tire roller was used to compact a soil, if the weight on each tire is 1500 kg and the pressure inside it = 0.6 N/mm^2. What is the maximum thickness for each lift of the soil that can be compacted, if the pressure beneath this lift is not less than 0.35 N/mm^2.

Solution:

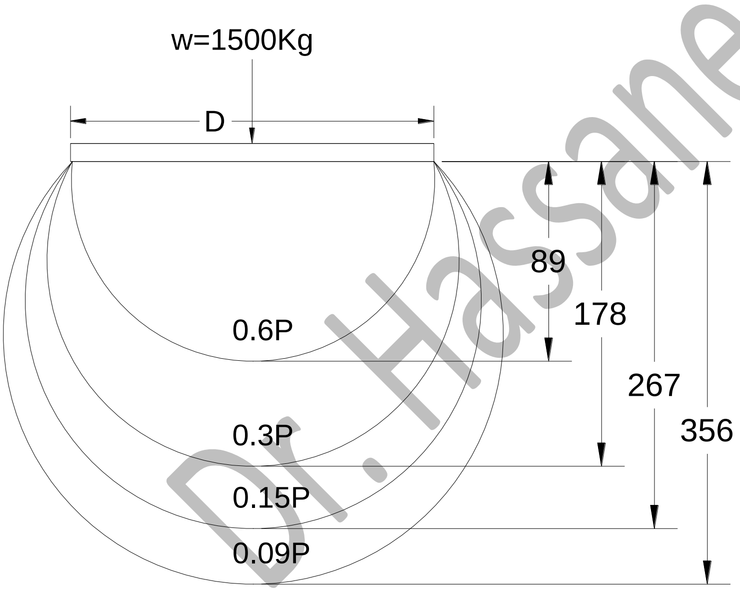
$$A = \frac{w}{P} = \frac{1500 * 10}{0.6} = 25000$$

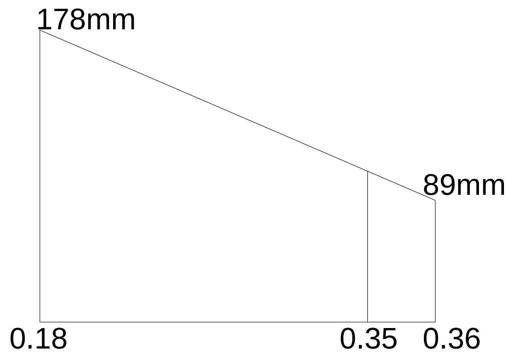
$$D = \sqrt{\frac{4 * 25000}{\pi}} = 178\,mm$$

$$\frac{y}{0.01} = \frac{89}{0.18} \rightarrow y = 4.94$$

Depth	Factor	Pressure (N/mm^2)
0	1	0.6
89	0.6	0.36
178	0.3	0.18
267	0.15	0.09
356	0.09	0.054

$$\therefore Thickness\ of\ lift = 89 + 4.94 = 94\ mm$$





Case Study No. 9-2:

If a multi-wheel pneumatic roller whose tires were inflated to **0.9 *N/mm²*** and whose empty weight =**10 *ton*** and maximum weight =**16 *ton*** and has ***8 wheel***, what is the maximum compacted depth of a layer of earth that can be compacted to a unit pressure of not less than **0.135 *N/mm²*** at the bottom of the layer?

Solution:

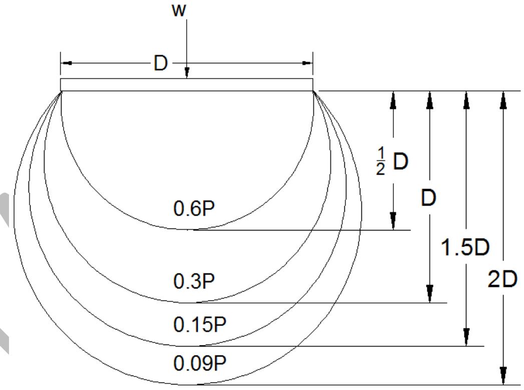
Maximum weight on each Wheel= 16/8=2 ton = 2000kg

$$A = \frac{W}{P}$$

$$\frac{\pi}{4}D^2 = \frac{W}{P}$$

$$D^2 = \frac{4\,W}{\pi\,P}$$

$$D = \sqrt{\frac{4 \times 2000 \times 10}{3.14 \times 0.9}} = 168.2\ mm$$



Depth	0	84.1	168.2	252.3	336.4
Stress (MPa)	0.9	0.54	0.27	0.135	0.081

$$\therefore\ Depth\ of\ max.compacted\ earth\ layer = 252.3\ mm$$

Case Study No. 9-3:

If earth placed in a fill area by a machine with output rate **100 *m³/hr***, and the dry weight of the earth is **1200 kg/m³**. How many liters of water must be supplied each hour to increase the moisture content of the earth from **4 to 10%** by weight of fill materials.

Solution:

Percentage of moisture added to the soil = 10% - 4% = 6 %

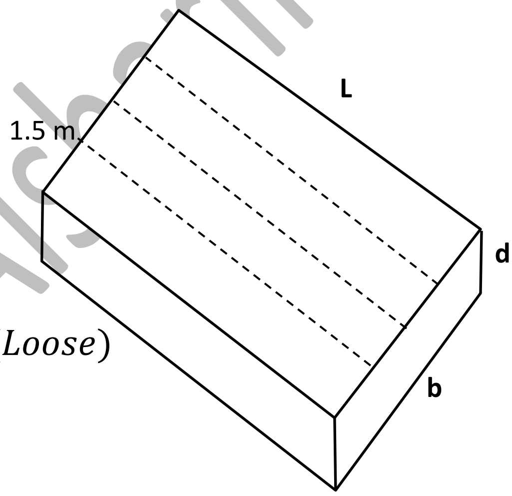
Quantities of moisture added to each 1 $m^3 = \frac{6}{100} \times 1200 = 72\ kg/m^3 \approx 72\ Liters/m^3$

Quantities of water should be supplied each hour $= 72\ l/m^3 \times 100\ m^3/hr = 7200\ l/hr$

Case Study No. 9-4:

Earth in situ weight is **1700 kg/m³**, loss weight is **1410 kg/m³**, and compacted weight is **1954 kg/m³** is placed in a fill layer at the rate of **150 m³/hr**, measured as compacted earth in layers whose compacted thickness of **150 mm**. Sheep's-foot roller drums, each **1.5 m** wide, are pulled by a tractor at a speed of **3 km/hr** with an operating factor of **80%**. Determine the number of drums required to prove the necessary compaction if **8 drums** passes are specified for each layer of earth. Width of road is **6 m**.

Solution:



$$S_w = \left(\frac{1700}{1410} - 1\right) \times 100 = 20.56\%$$

$$S_n = \left(1 - \frac{1700}{1954}\right) \times 100 = 13\%$$

$$Rate\ of\ output\ per\ day = 150 \times 8 \times 0.8 = 960\ \frac{m^3}{day} \quad (Loose)$$

$$Compacted\ volume = \frac{960}{1.13} = 850\ m^3$$

$$Volume\ of\ each\ layer\ per\ day\ (compacted) = d \times b \times L$$

$$850 = 0.15 \times 6 \times L \Rightarrow L = \frac{850}{6 \times 0.15} = 944.4\ m$$

$$Distance\ required\ to\ be\ compacted = No.of\ trips \times No.of\ lines \times length$$

$$= 8 \times 4 \times 944.4 = 30220.8\ m$$

$$Distance\ travelled\ by\ each\ roller\ per\ day = 3 \times 8 \times 0.8 = 19.2\ km$$

$$Nomber\ of\ roller = \frac{30220.8}{19200} = 1.57 \approx 2$$