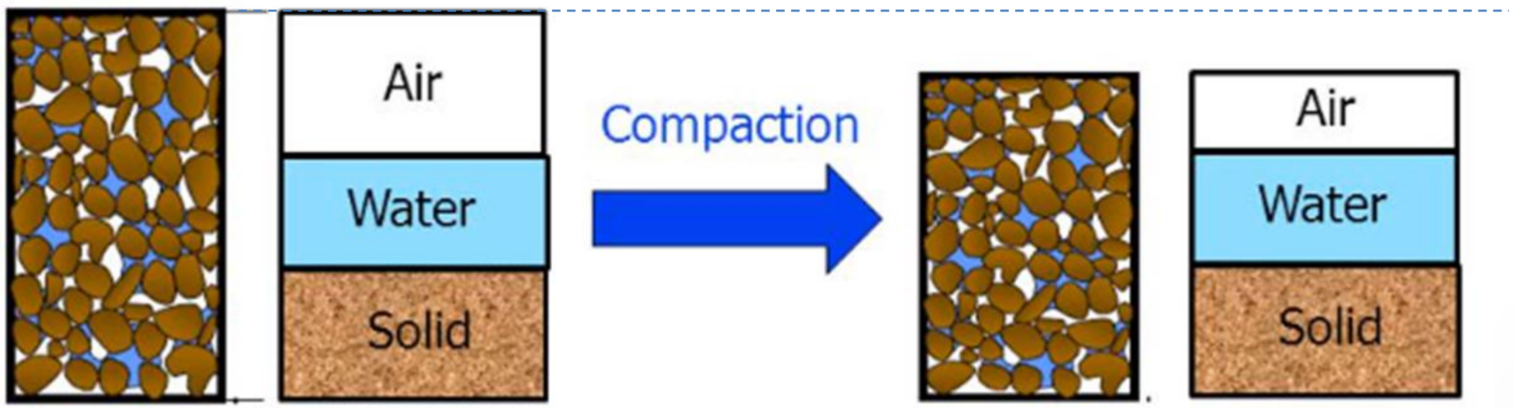
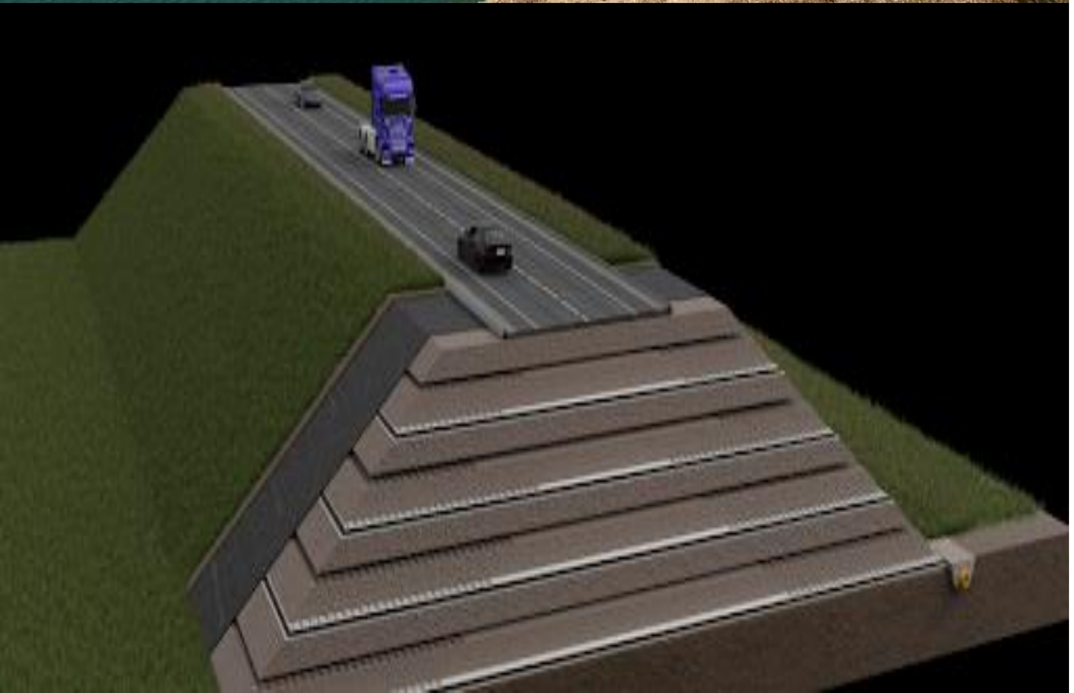
COMPACTION OF SOIL

Compaction is the process of packing of soil particles close to each other due to the expulsion of air from its voids by mechanical methods.





Compaction required for constructing

- Earth dams
- Highways
- Embankments
- Runways

OBJECTIVES OF COMPACTION

ENHANCE

- Shear Strength
- Stability
- Mass density
- Bearing Capacity

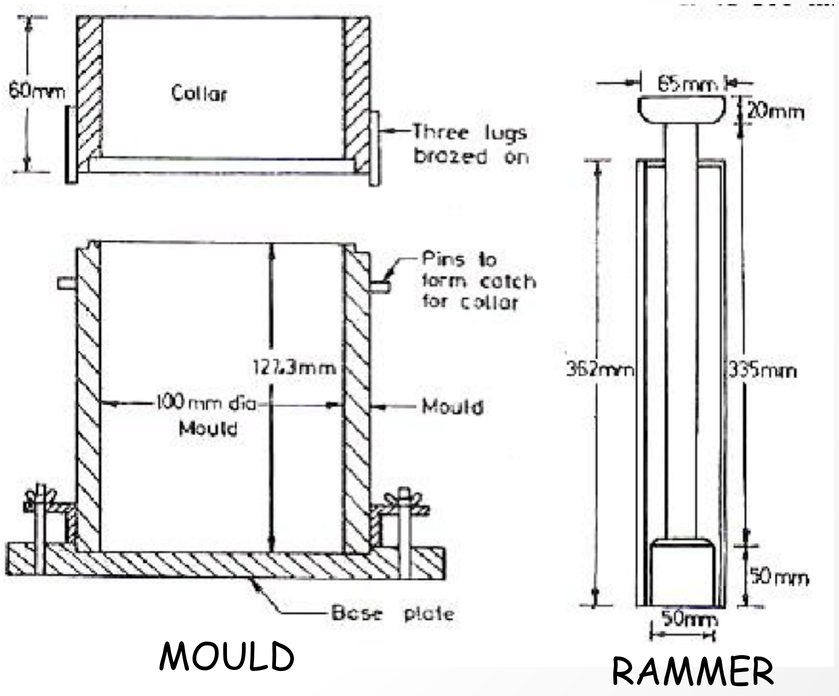
REDUCE

- Permeability
- Compressibility
- Void Ratio

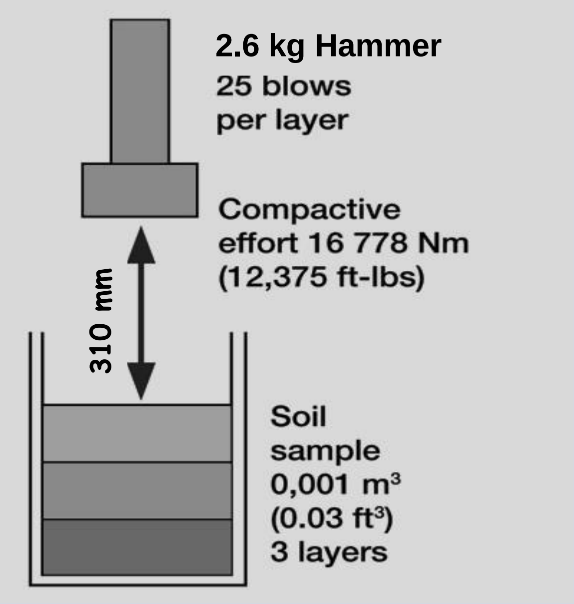
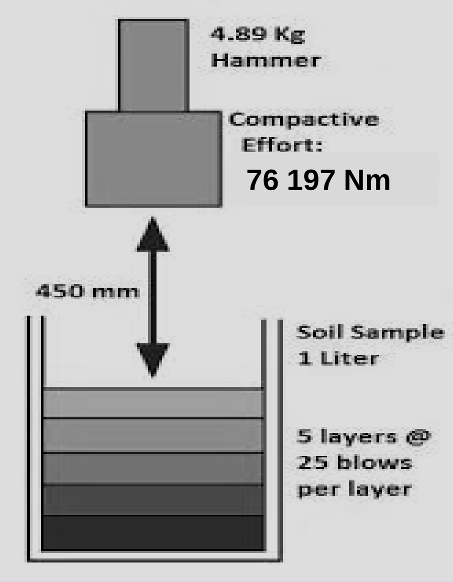
PROCTOR COMPACTION TESTS

Laboratory Tests → To assess amount of compaction and water content required in field

1. Standard Proctor Test/ Light Compaction Test
2. Modified Proctor Test/ Heavy Compaction Test



COMPARISON OF THE PROCTOR TESTS

PARTICULARS	STANDARD PROCTOR TEST	MODIFIED PROCTOR TEST
BIS NOMENCLATURE	Light Compaction	Heavy Compaction
WEIGHT OF RAMMER	2.6 kg	4.89 kg
HEIGHT OF FALL	310 mm	450 mm
NUMBER OF LAYERS	3	5
ILLUSTRATION		

LABORATORY TEST PROCEDURE

1

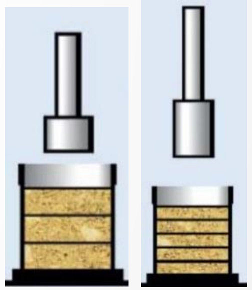
- About 3 kg of air dried soil sample passing through 4.75 mm sieve is taken.

2

- Water is added to soil so that the water content is about 4% if the soil sample is coarse grained and 8% if fine grained.

3

- Soil is filled in layers into the mould and compacted as specified in table for the particular test.



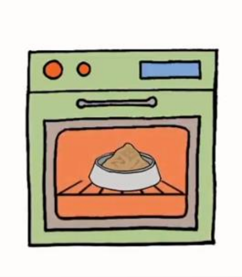
4

- Mass of the compacted soil is taken (M) and with the volume (v) of the mould bulk density (ρ) is calculated.

$$\rho = \frac{M}{V}$$

5

- Samples are taken from top, middle and bottom of compacted specimen for water content determination



6

- From field density (ρ) and water content (w), dry density (ρ_d) is calculated.

$$\rho_d = \frac{\rho}{1 + w}$$

7

- The compaction test is repeated for different water contents and corresponding dry densities are calculated.

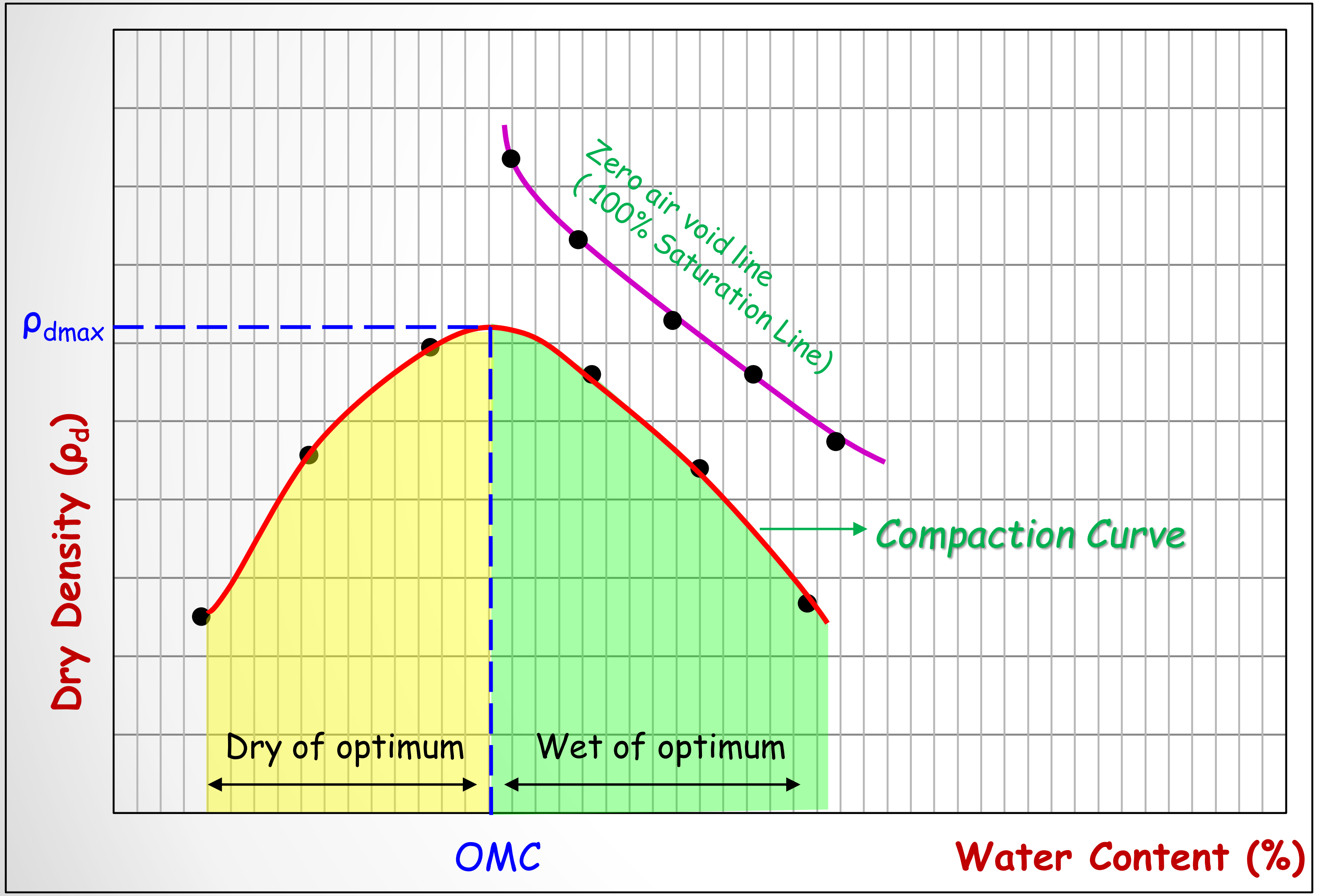
Sl. No.	Water Content	Dry Density
1	w1	ρd1
2	w2	ρd2
3	w3	ρd3
4	w4	ρd4
5	……..	……..
6	……..	……..

Plot water content v/s dry density curve

COMPACTION CURVE

COMPACTION CURVE

The curve plotted with **water content in x axis** and **dry density in y axis** is the compaction curve.



Dry Density, $\rho_d = \frac{G\rho_w}{1+(\frac{wG}{S})}$

Theoretically maximum dry density possible when fully saturated, (S = 1)

$$\boxed{\rho_{d(theomax)} = \frac{G\rho_w}{1+wG}}$$

Plot of $\rho_{d(theomax)}$ v/s water content

Zero air void line/ 100% Saturation line

ρ_{dmax} : Maximum Dry Density

OMC : Optimum Moisture Content

MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT

- Dry density initially increases with the increase in water content till maximum dry density (ρ_{dmax}) is attained.
- With the further increase in water content dry density decreases.
- The water content corresponding to maximum dry density is known as optimum water content or optimum moisture content (OMC).

DRY OF OPTIMUM

- Initially soil is stiff with lot of voids and hence have lesser dry density.
- As water content is increased soil particles get lubricated and slip over each other and move to densely packed positions.
- Dry density increases and maximum dry density is reached.

WET OF OPTIMUM

- After OMC is reached air voids attains a constant volume.
- Further increase in water content does not decrease air voids but increases the total volume of voids (air + water).
- As total volume increases. the dry density decreases.

ZERO AIR VOID LINE

$$\rho_{d(theomax)} = \frac{G\rho_w}{1+wG}$$

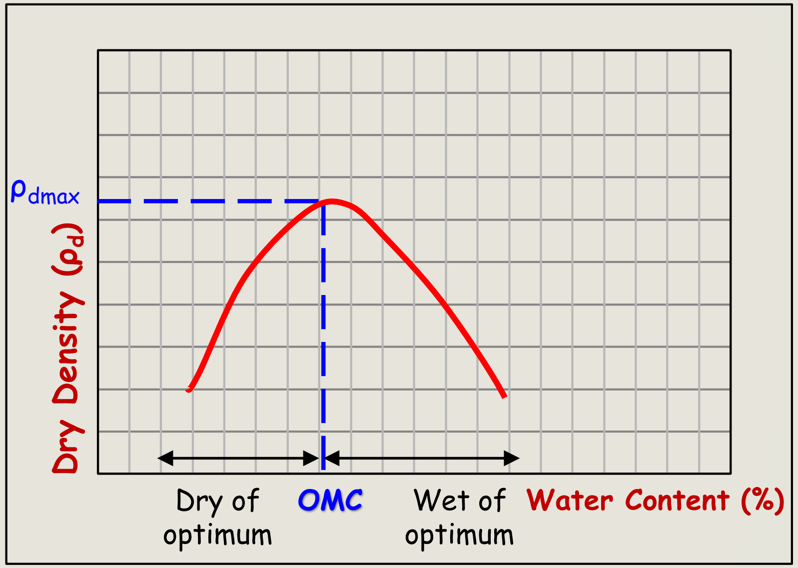
- Theoretically maximum dry density is reached when soil is fully saturated (S=100%).
- The line showing theoretical maximum dry density for different water content plotted along with compaction curve is called zero air void line or 100% saturation line.

FACTORS AFFECTING COMPACTION

1. WATER CONTENT

- Below OMC, As water content is increased soil particles get lubricated and slip over each other and move to densely packed positions. Hence dry density increases.

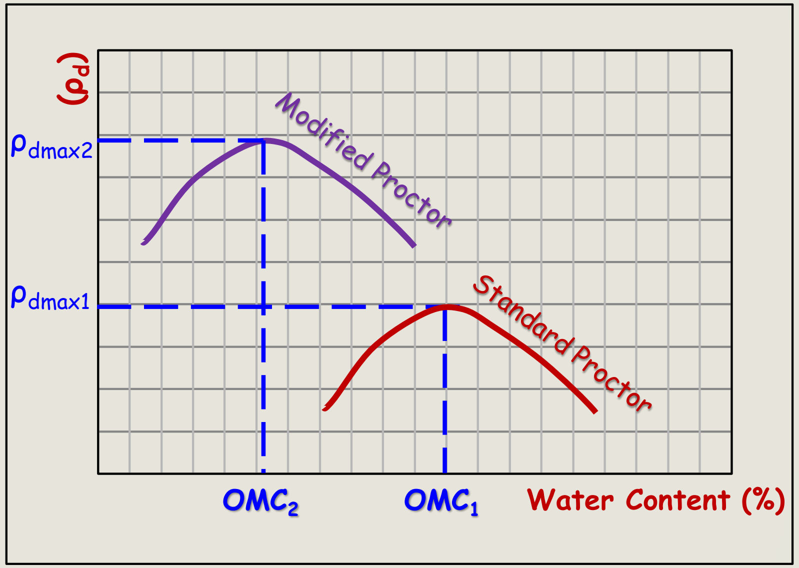
- Beyond OMC, increase in water content does not decrease air voids but increases the total volume of voids (air + water) . Hence dry density decreases.



2. AMOUNT OF COMPACTION

Increasing Compactive Effort

- Increases dry density (MDD)
- Decreases optimum moisture content (OMC)



↑ OMC

↓ MDD

STANDARD PROCTOR

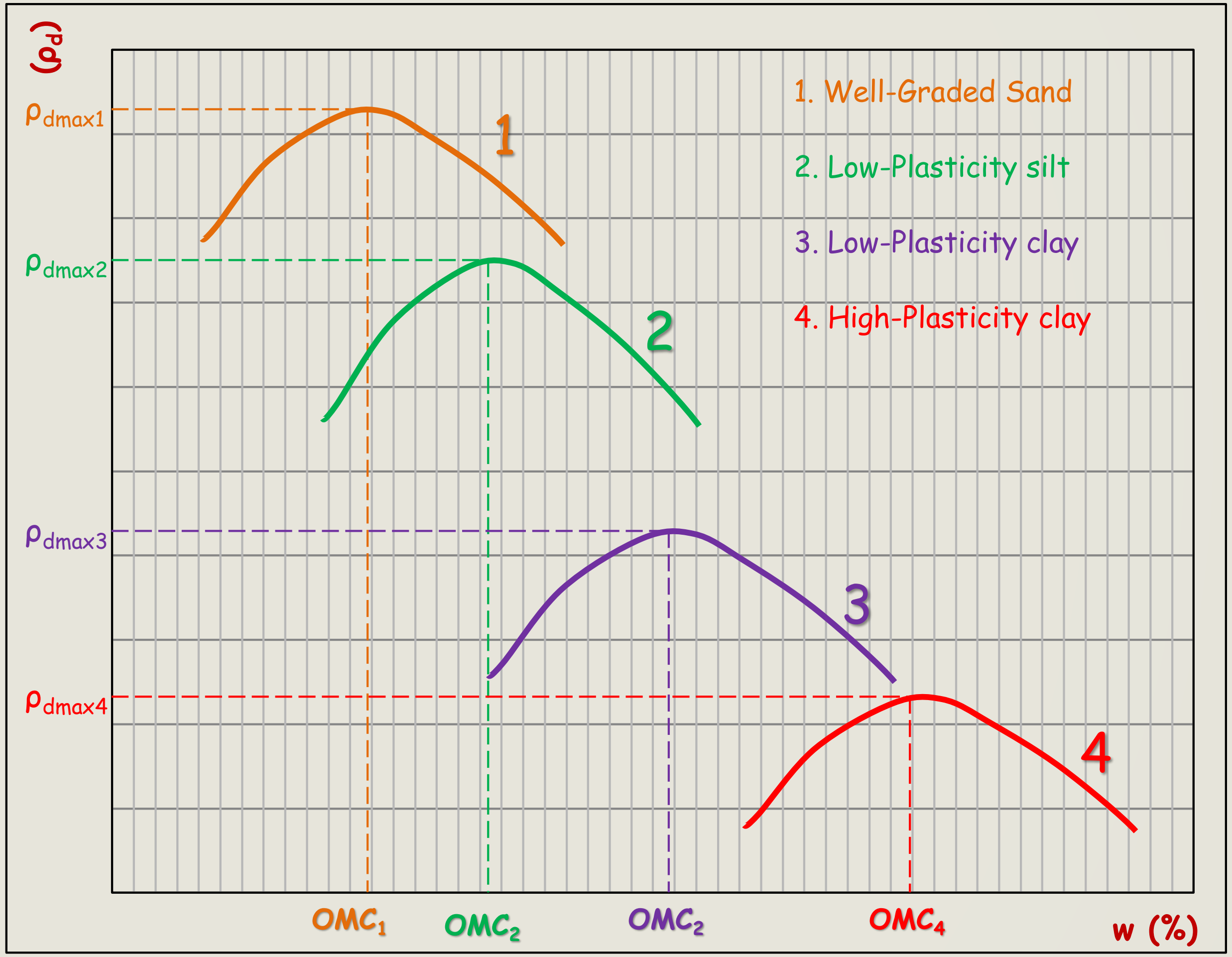
↑ MDD

↓ OMC

MODIFIED PROCTOR

3. TYPE OF SOIL

- Coarse grained soil can be compacted to higher dry density than fine grained soil.
- Well graded soil can be compacted to higher dry density than poorly graded soil.
- Cohesive soils has more air voids and require more water than cohesion less soil. Hence has lesser dry density and higher OMC.



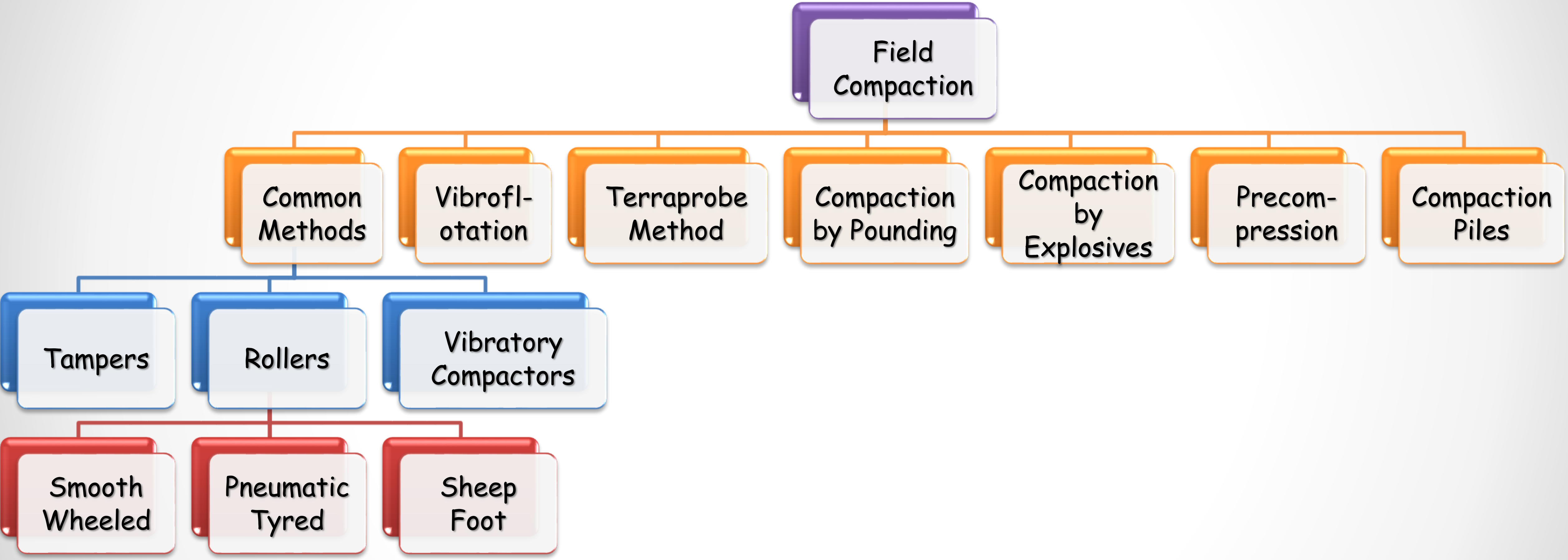
4. METHOD OF COMPACTION

- Compaction curve obtained for different methods are different.
- For same compactive effort, the curve obtained for compaction by kneading and by applying dynamic force are different.

5. ADMIXTURES

- The compaction characteristics of soil can be improved by addition of admixtures like lime, cement and bitumen.
- Admixtures holds/binds the soil particles together – Soil stabilisation.

METHODS OF FIELD COMPACTION



1. TAMPERS

- Used to compact soils adjacent to buildings or confined areas.
- Conventional rammers are with block of iron attached to a wooden rod and operated with hands.
- Mechanical rammers are operated by compressed air or gasoline power.
- Not economical when large quantity of soil is involved.

2. ROLLERS

SMOOTH WHEELED ROLLER

- Drum shaped wheels two in rear side and one in front side.
- Compaction by tamping action.
- Used for finishing operations.
- Not useful for compacting deep layers.

PNEUMATIC TYRED ROLLER

- 9-11 tyres in two axles.
- Soil compacted by contact pressure between tyre and soil.
- Compaction by kneading.
- Used for all types of soil.
- Best equipment for general use.

SHEEP FOOT ROLLER

- Has hollow drum with small projections.
- Compaction by kneading and tamping.
- Projections penetrates and compacts lower portion.
- Next passes compacts top and middle.
- Useful for cohesive soils.

3. VIBRATORY COMPACTORS

- Vibrations are induced on soil during compaction.
- Vibratory Rollers : When vibrators are mount to a drum.
- Vibrating Plate Compactors : Vibrators are mount on plate.
- Useful for compacting granular (cohesion less soils).

4. VIBROFLOTATION METHOD

- Useful for compacting thick deposits of loose soil (cohesion less).

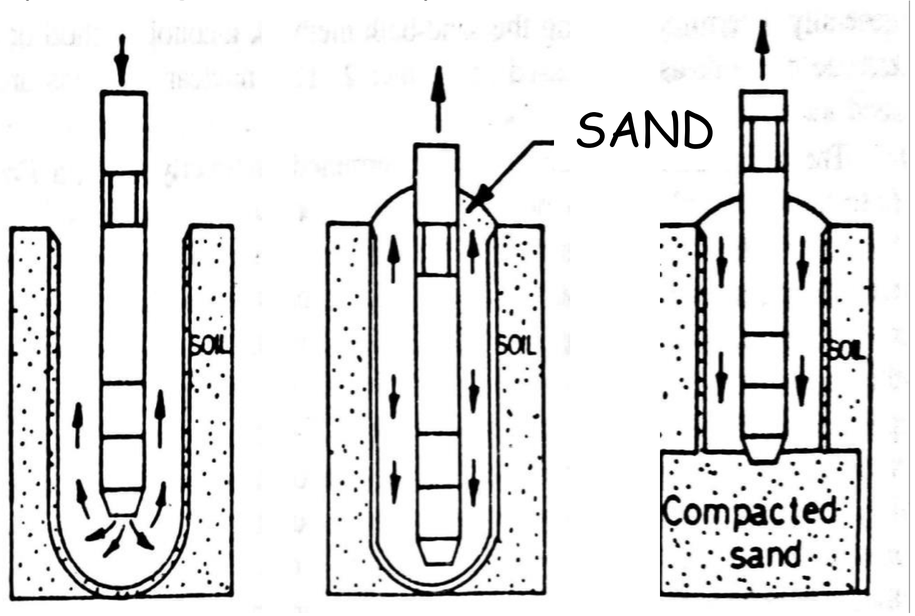
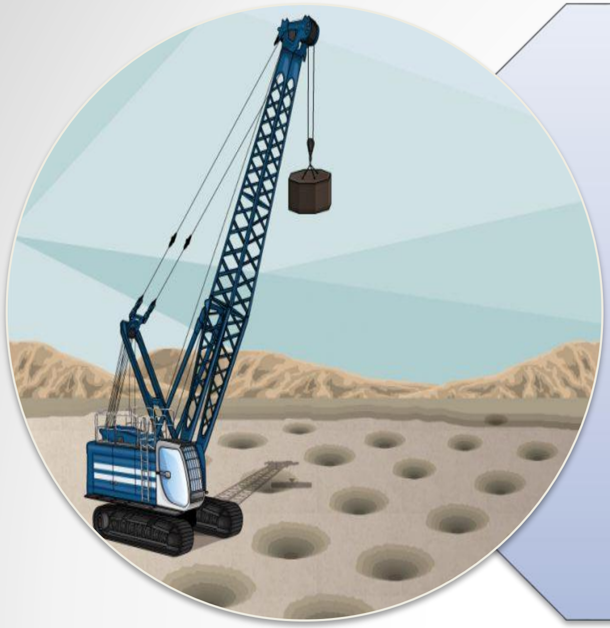


Image Source : Soil Mechanics by Dr.K.R. Arora

- The vibroflot penetrates to desired depth by waterjet - PENETRATION
- Vibrator is activated and soil is compacted horizontally - COMPACTION
- Sand is backfilled in the gap and the vibroflot is raised - BACKFILLING

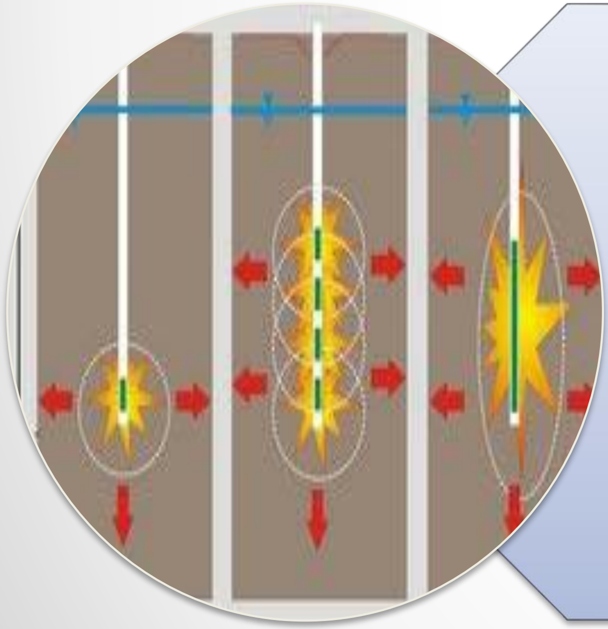
5. TERRAPROBE METHOD

- Similar to vibrofloatation in many aspects.
- A vibratory pile drive gives vibrations to terraprobe and it penetrates into soil.
- After reaching the depth the probe is raised back.
- Penetrated into soil at 1.5 m intervals.
- No need of backfill
- Faster but less efficient compared to vibrofloatation method.



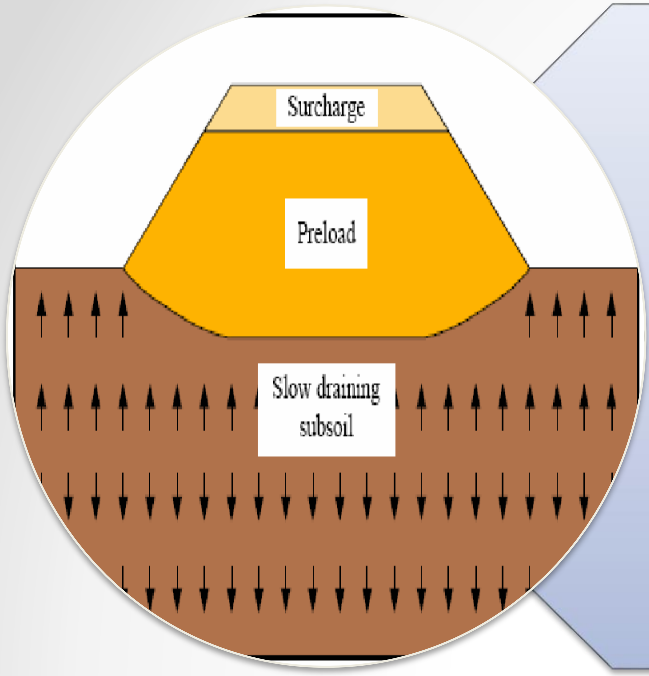
6. COMPACTION BY POUNDING

- Also known as dynamic compaction.
- A heavy mass (2 to 50Mg) is dropped from a height of (7 to 35m) from ground surface.
- At each location 5-10 poundings are given.
- Useful for compacting loose soil to greater depth.



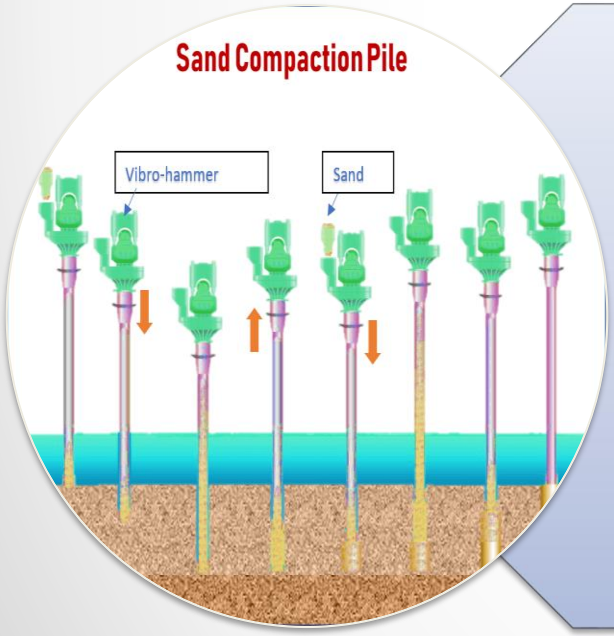
7. COMPACTION BY EXPLOSIVES

- Used for fully saturated cohesion less soil.
- The buried explosives while blasting, generates shockwaves and vibration.
- Vibrations and shockwaves transfers through particles makes them closer and thus compacts.



8. PRECOMPRESSION

- Used for cohesive soils.
- Before the application of actual design load the soil is preloaded with earth fill.
- Settlement takes place due to the applied preload.
- After required compression is achieved, the fill is removed.



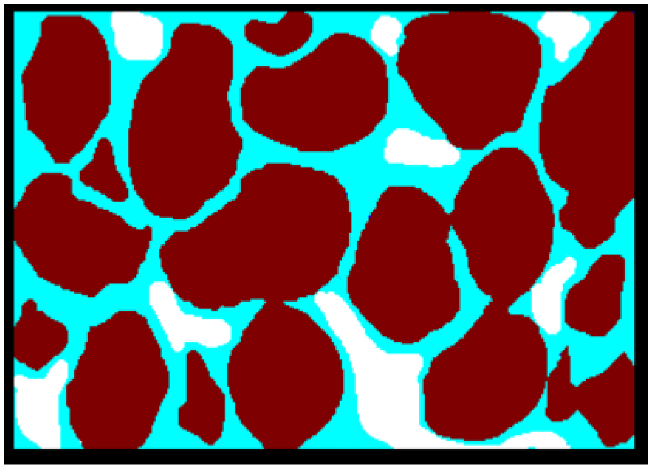
9. COMPACTION PILES

- Used for cohesion less soils.
- A pipe pile is driven into the soil.
- Due to driving of pile, surrounding soil is compacted.
- Pipe is removed and the hole is backfilled with sand.

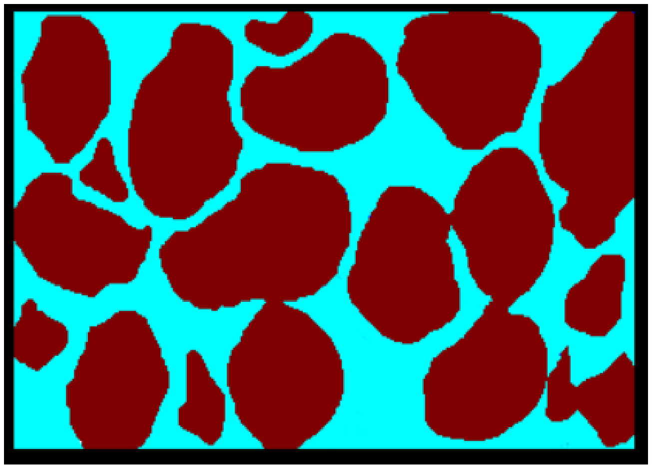
Consolidation of soil

Compaction - Consolidation

- **Compaction means the removal of air-filled porosity.**



- **Consolidation means the removal of water-filled porosity.**



Compressibility Of soils

- When a soil mass is subjected to a compressive force, it's volume decreases.
- The property of the soil due to which a decrease in volume occurs under compressive force is known as – Compressibility of soil

- The compression of soil can occur due to

1. Compression of solid particles and water in the voids
2. Compression and expulsion of air in the voids
3. Expulsion of water in the voids.

Consolidation Of soils

- The compression of saturated soil under a steady static pressure is known as consolidation.
- It is entirely due to expulsion of water from the voids.

Stages of consolidation

1. Initial consolidation
2. Primary consolidation
3. Secondary consolidation

Initial consolidation

- When a load is applied to a partially saturated soil, a decrease in volume occurs due to expulsion and compression of air in the voids.
- A small decrease in volume occurs due to compression of solid particles.
- *The reduction in volume of the soil just after the application of the load is known as initial consolidation or initial compression.*
- For saturated soils, the initial consolidation is mainly due to compression of solid particles.

Primary consolidation

- After initial consolidation., further reduction in volume occurs due to expulsion of water from the voids.
- When a saturated soil is subjected to a pressure, initially all the applied pressure is taken up by the water. A hydraulic gradient will develop and the water starts flowing out and a decrease in volume occurs.
- This reduction in volume is called as the primary consolidation of soil

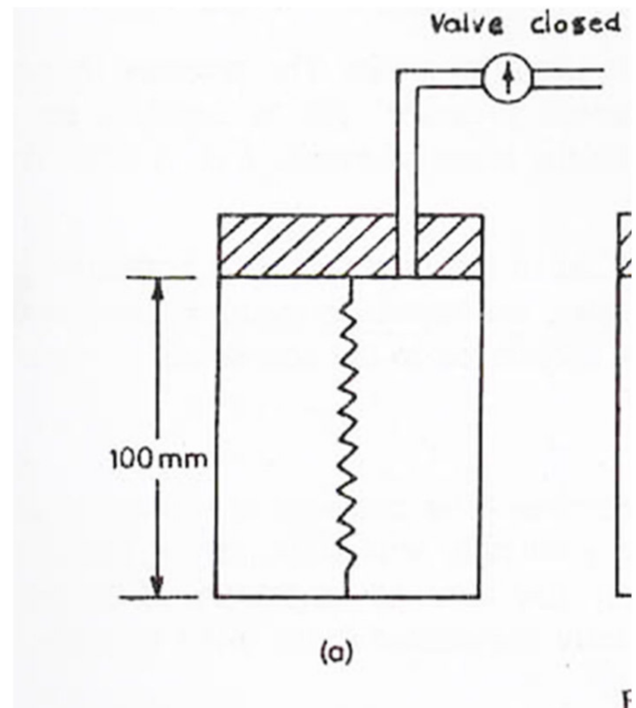
Secondary consolidation

- The reduction in volume continues at a very slow rate even after the excess pressure is fully dissipated and the primary consolidation is complete.
- The additional reduction in the volume is called as the secondary consolidation.

Spring analogy for primary consolidation

- Given by Terzaghi
- Consider a cylinder with a tight fitting piston having a valve.
- The cylinder is filled with water and have a

spring of specified stiffness.



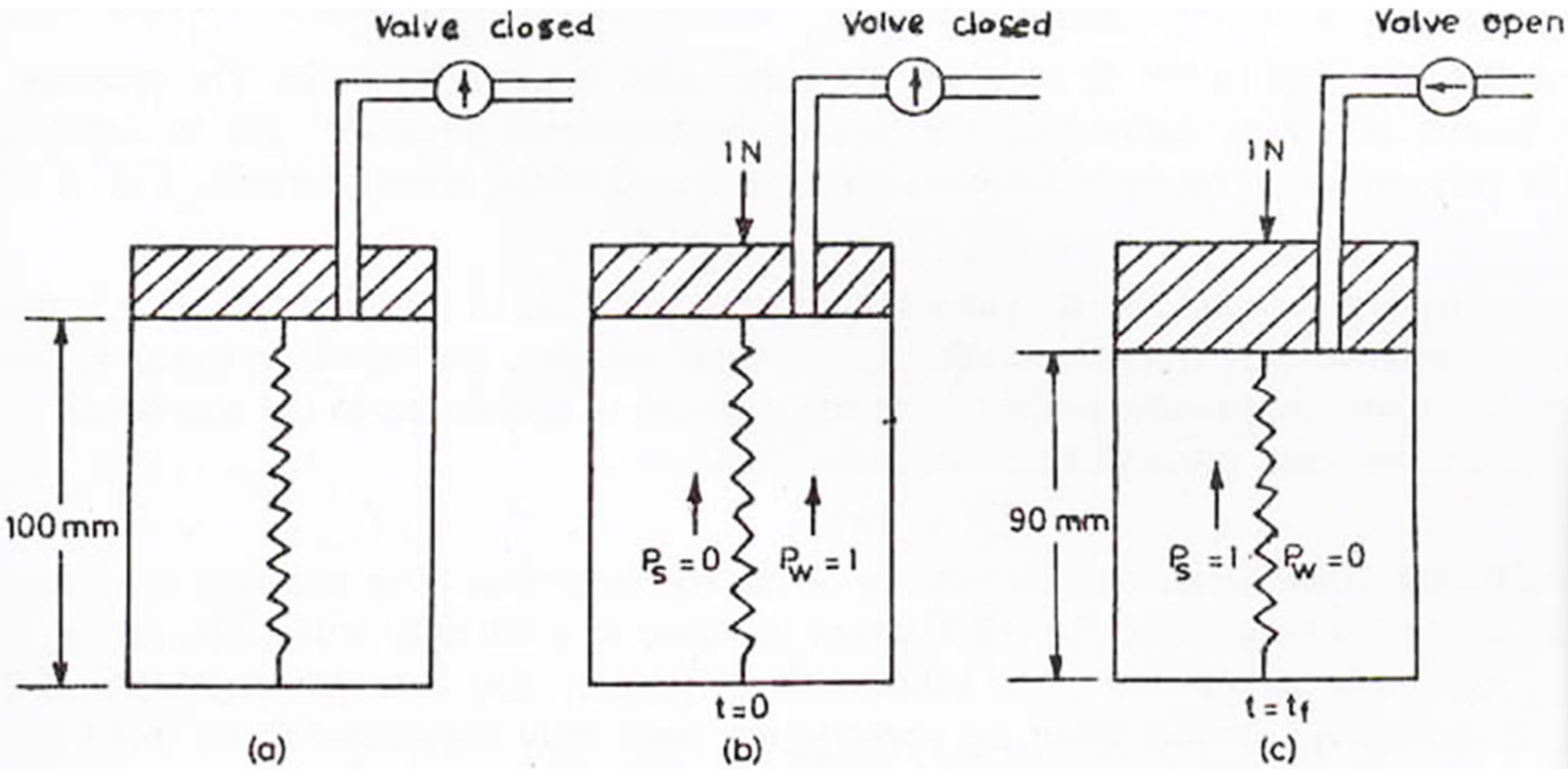
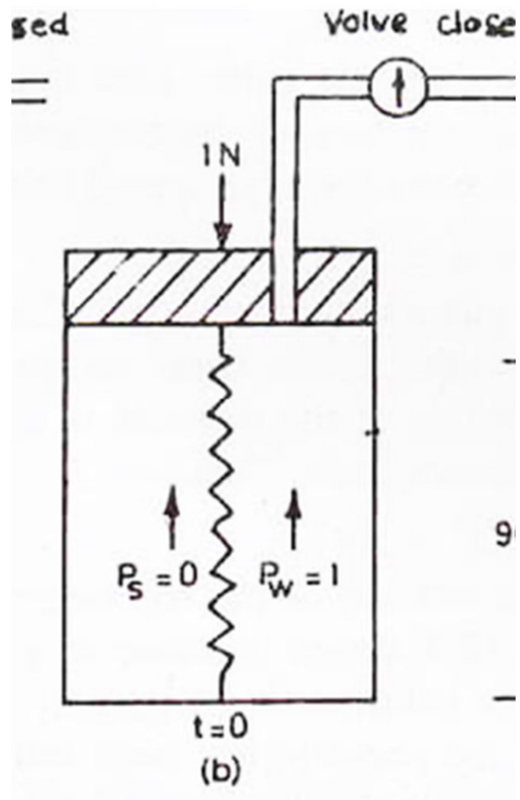


Fig. 12.1. Spring Analogy.

- Let the initial length of the spring = 100mm
- Stiffness of the spring = 10mm/N
- Assume piston is weightless and the spring and the water are free of stress.

- When a load P (Say I N) is applied to the piston, with it's valve entirely closed, the entire load is taken by water.
- The stiffness of the spring is negligible compared to that of water , consequently no load is taken by the spring.



- For equilibrium

$$P_w + P_s = P \qquad \ldots(12.1)$$

where P_w = load taken by water, P_s = load taken by spring, and P = total load.

For P = 1 N, Eq. 12.1 becomes

$$P_w + P_s = 1.0 \qquad \ldots(12.2)$$

Initially (t = 0) when valve is closed, P_s = 0.00. Therefore, $P_w = 1.0$

- If the valve is now gradually opened, water starts escaping from the cylinder.
- The spring starts sharing the load and a decrease in length occurs.
- As more and more water escapes, the load carried by the spring increases.
- Eventually when the steady conditions are established, the water starts escaping.
- Finally the entire load will be taken by the spring.
- Spring gets compressed by 10mm.

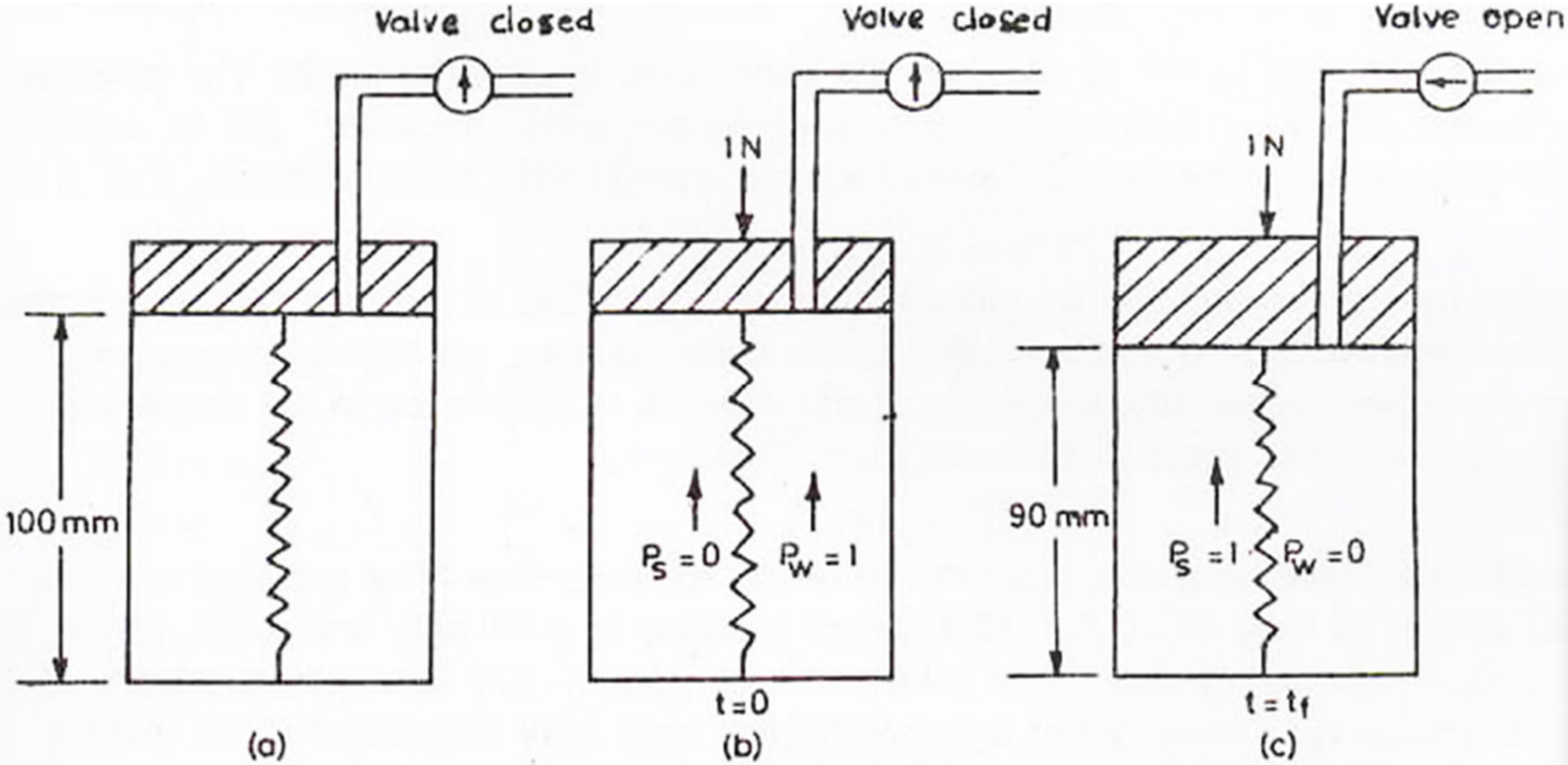
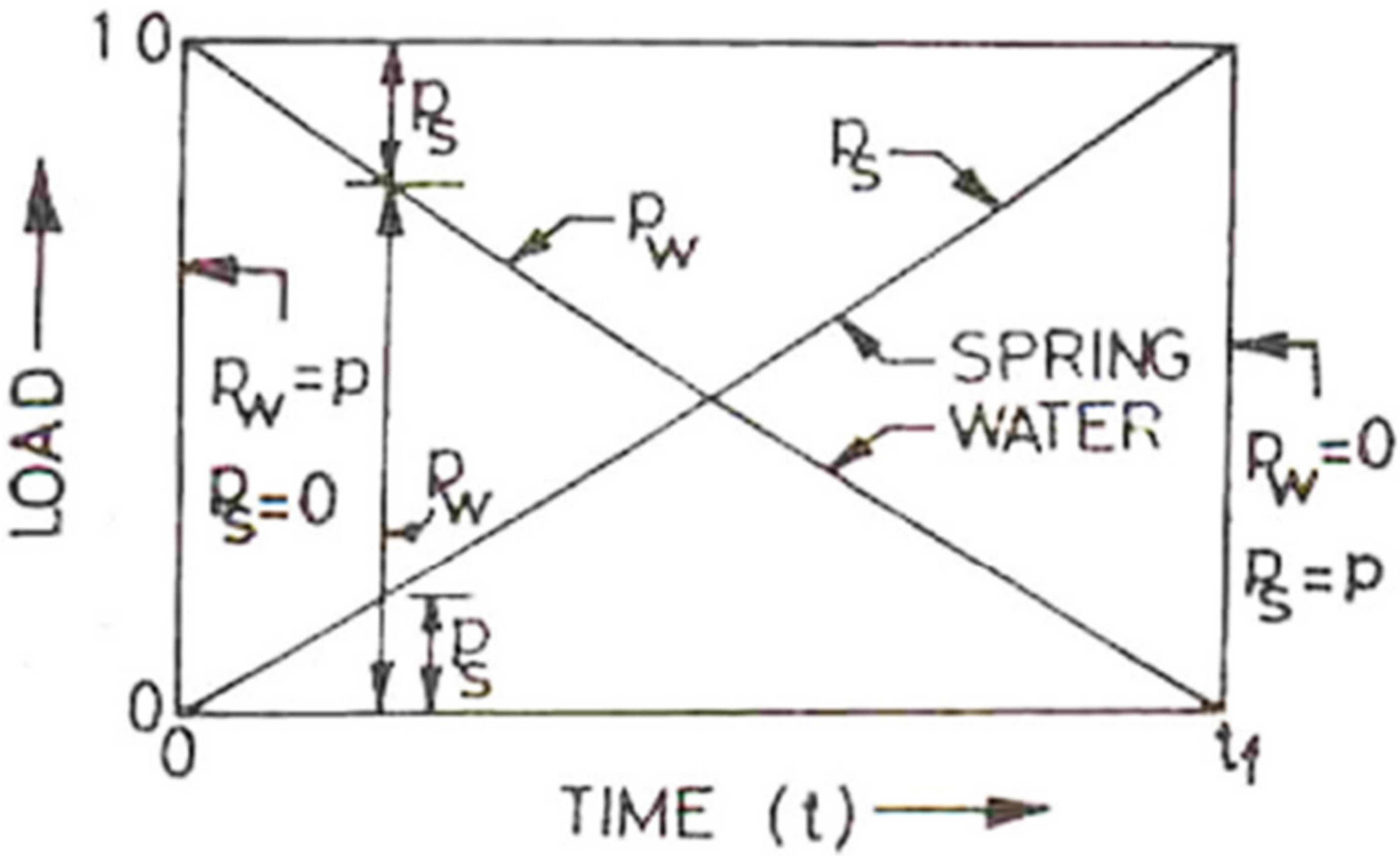


Fig. 12.1. Spring Analogy.



10
0
0
LOAD
TIME (t)
t_f
P_S
P_W
$P_W = P$
$P_S = 0$
P_W
P_S
P_S
SPRING
WATER
$P_W = 0$
$P_S = P$

- As the load carried by the water is zero, it is again free of excess pressure.
- Now if the valve is closed and the load P is increased to 2N, the process of transfer of load repeats.
- Likewise the process is repeated till the final increment of load has been applied.