Compaction

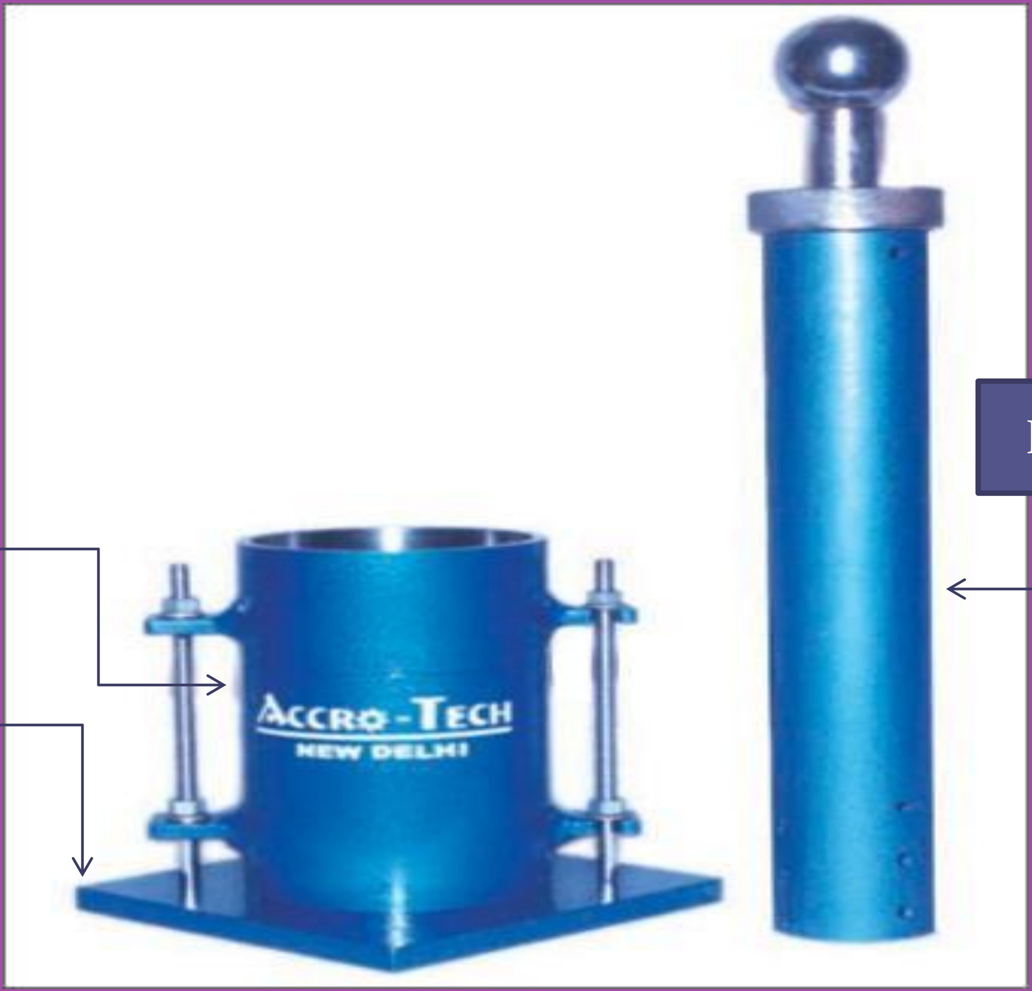
By mechanical means such as rolling, tamping and vibration
Loading of short duration
Rapid process of volume reduction
Volume reduces due to expulsion of air from the voids
Artificial process done to increase the density of soil

Compaction mould and rammer

Collar

Mould

Base Plate



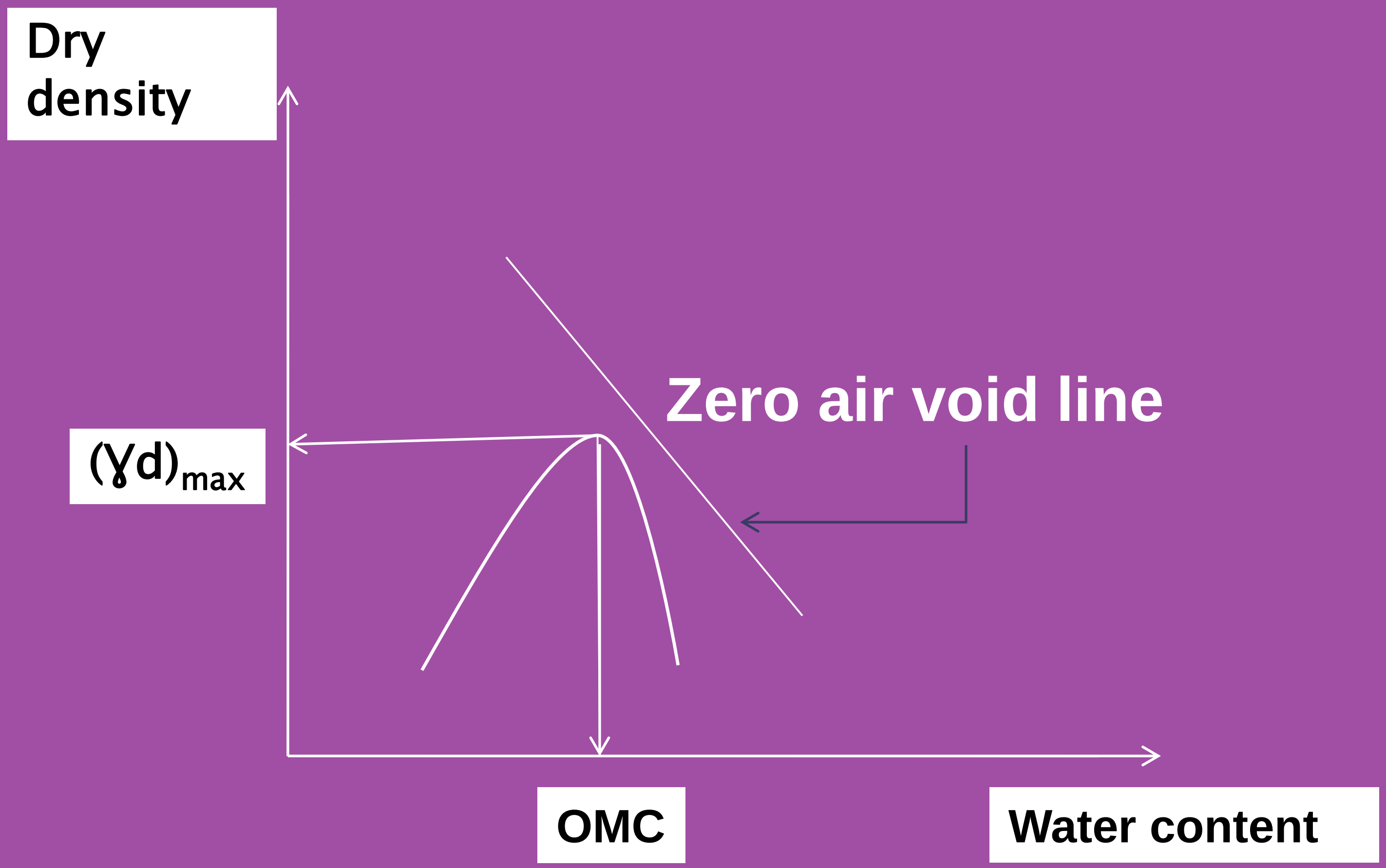
Rammer

Standard Proctor Test

- soil sample passing 19- mm sieve
- d= 4"   h = 4.6"   V= 1/30 cu. ft
- W = 5.5 lbs ; h = 12" ; No. of layers = 3
- No of blows per layer = 25

- **Blows are evenly distributed over the surface**
- **Soil surface is scratched with spatula before the second layer is placed**
- **The third layer should project above the top of the mould into the collar by not more than 6mm**
- **Collar is rotated to break the bond between the soil in the mould and that in collar**
- **Collar is then removed and soil is trimmed off flush with the top of the mould**

Compaction curve



dry density

$$\gamma_d = \frac{G\gamma_w}{1+e} = \frac{G\gamma_w}{1+ {wG}/{Sr}}$$

Theoretical maximum dry density

- $$\left(\gamma_d\right)_{theoretical.\ \max.} = \frac{G\gamma_w}{1+wG}$$

Zero air void curve OR 100% saturation line
---- line indicating the theoretical maximum dry density

Theoretical maximum dry density - hypothetical

- **Standard Proctor Test:** Adequate to represent compaction of fills in retaining wall, earth dams, highways etc… where light rollers are used.

- **Modified Proctor Test:** Used to represent heavy compaction such as in runways and modern highways

Test	Standard Proctor	Modified Proctor (Modified AASHTO test)
Type of compaction	Light	Heavy
Weight of rammer (kg)	5.5 lbs	10 lbs
Height of free drop (mm)	12”	18”
No. of layers	3	5

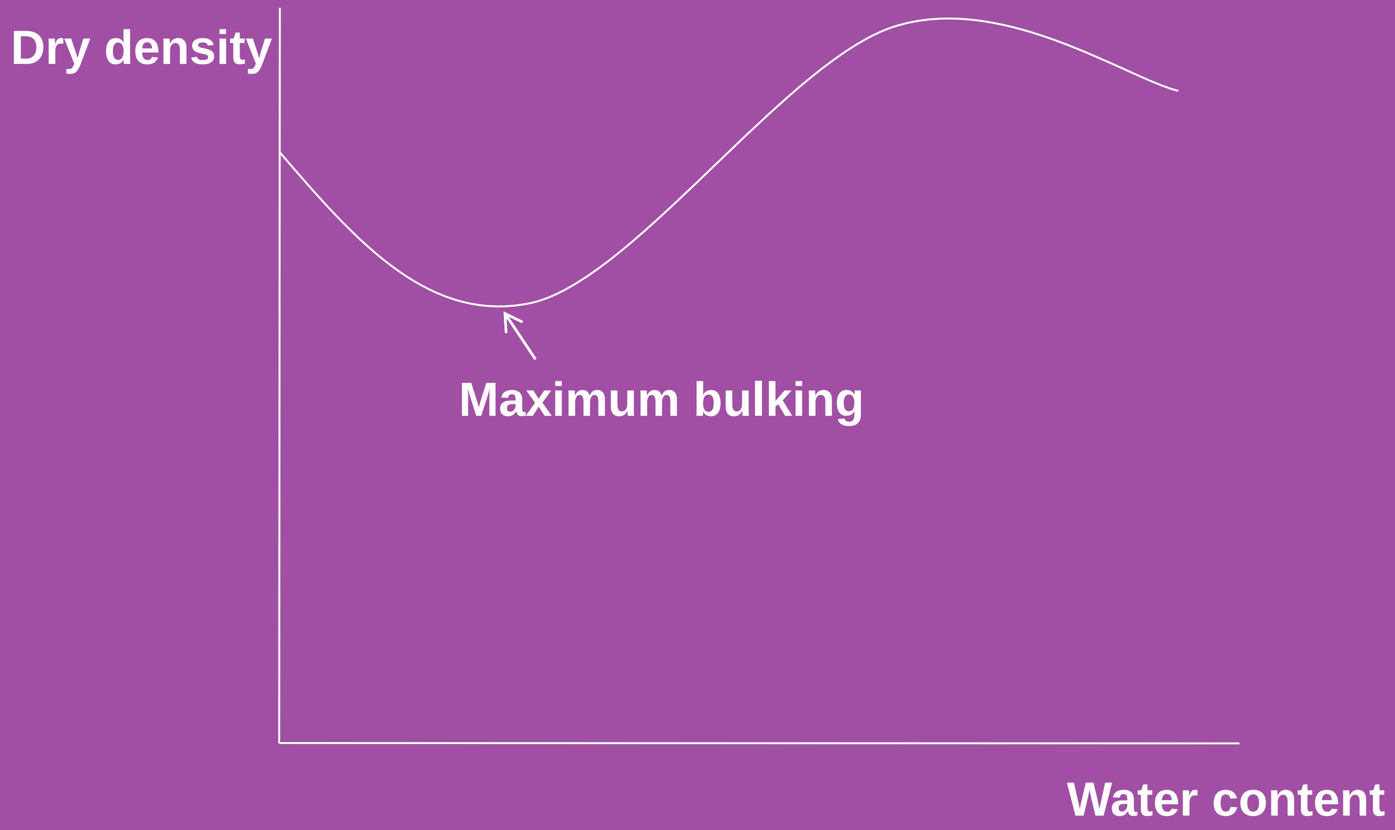
Test	Standard Proctor	I.S Light Compaction Test		
Type of compaction	Light	Light		
Weight of rammer (kg)	5.5 lbs	2.6 Kg		
Height of free drop (mm)	12"	310 mm		
No. of layers	3	3		
Compactive effort (kJ/m^3)		592 KJ/m^3		

Test	Standard Proctor	I.S Light Compaction Test	Modified Proctor (Modified AASHO test)	I.S Heavy Compaction Test
Type of compaction	Light	Light	Heavy	Heavy
Weight of rammer (kg)	5.5 lbs	2.6 Kg	10 lbs	4.9 Kg
Height of free drop (mm)	12”	310 mm	18”	450 mm
No. of layers	3	3	5	5
Compactive effort (kJ/m^3)		592 KJ/m^3		2700 KJ/m^3 (4.56 times)

Moulds used for Compaction Test

Diameter	Height	Volume	No. of Blows/ layer
100 mm	127.3 mm	1000 cm^3	25
150 mm	127.3 mm	2250 cm^3	55

Compaction curve for cohesionless soil



Factors affecting compaction

- **1. Water content**
  - **At higher water contents < OMC**
    - **Soil particles get lubricated**
    - **Closer packing**

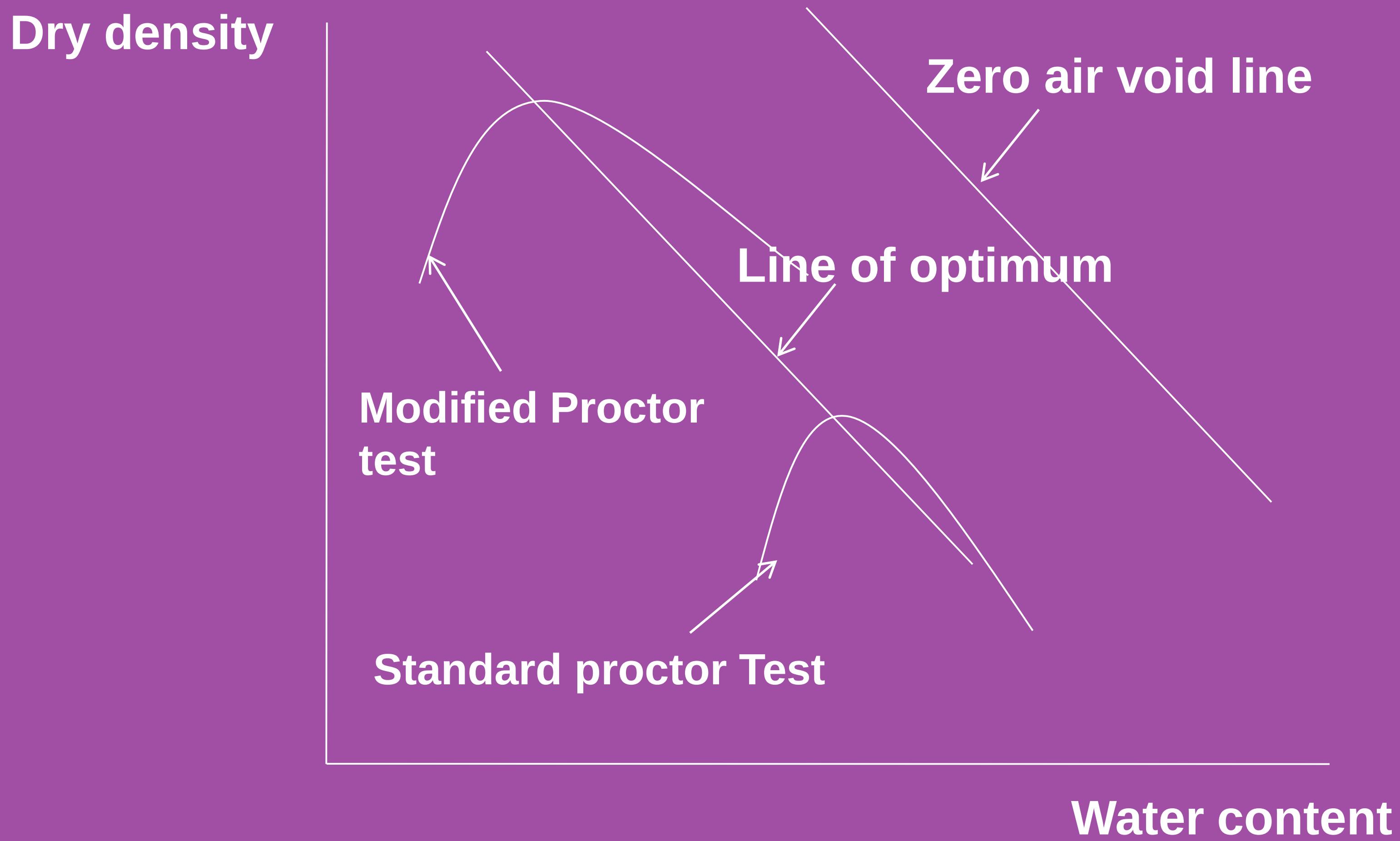
      -- resulting in reduction in volume of soil mass
    - **Dry density increases**

Factors affecting compaction

- **1. Water content**
  - **At water contents > OMC**
    - **Air voids attain constant volume**
    - **Further increase in water --– total volume increases**
    - **Dry density decreases**

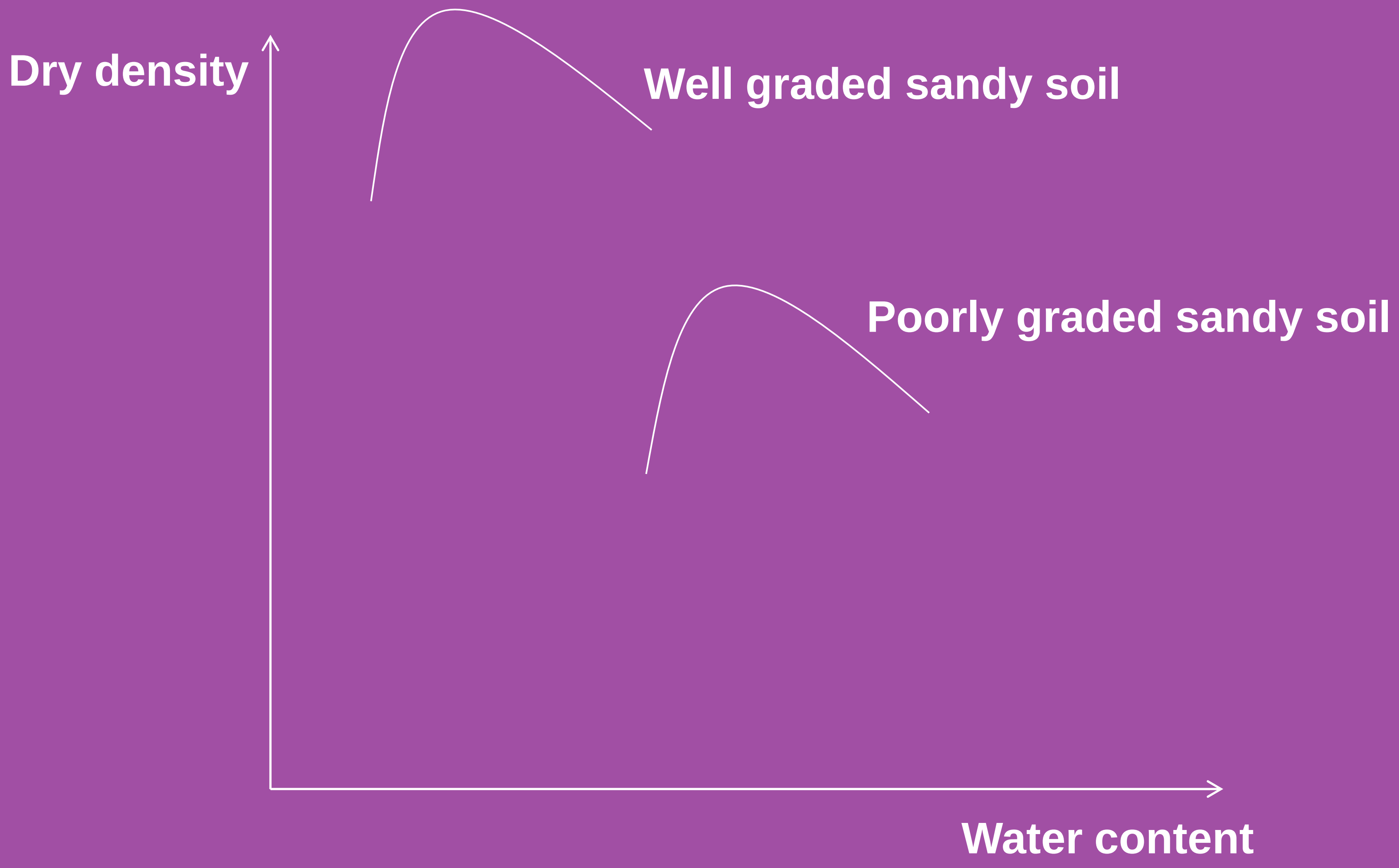
Factors affecting compaction

2. Amount of compaction



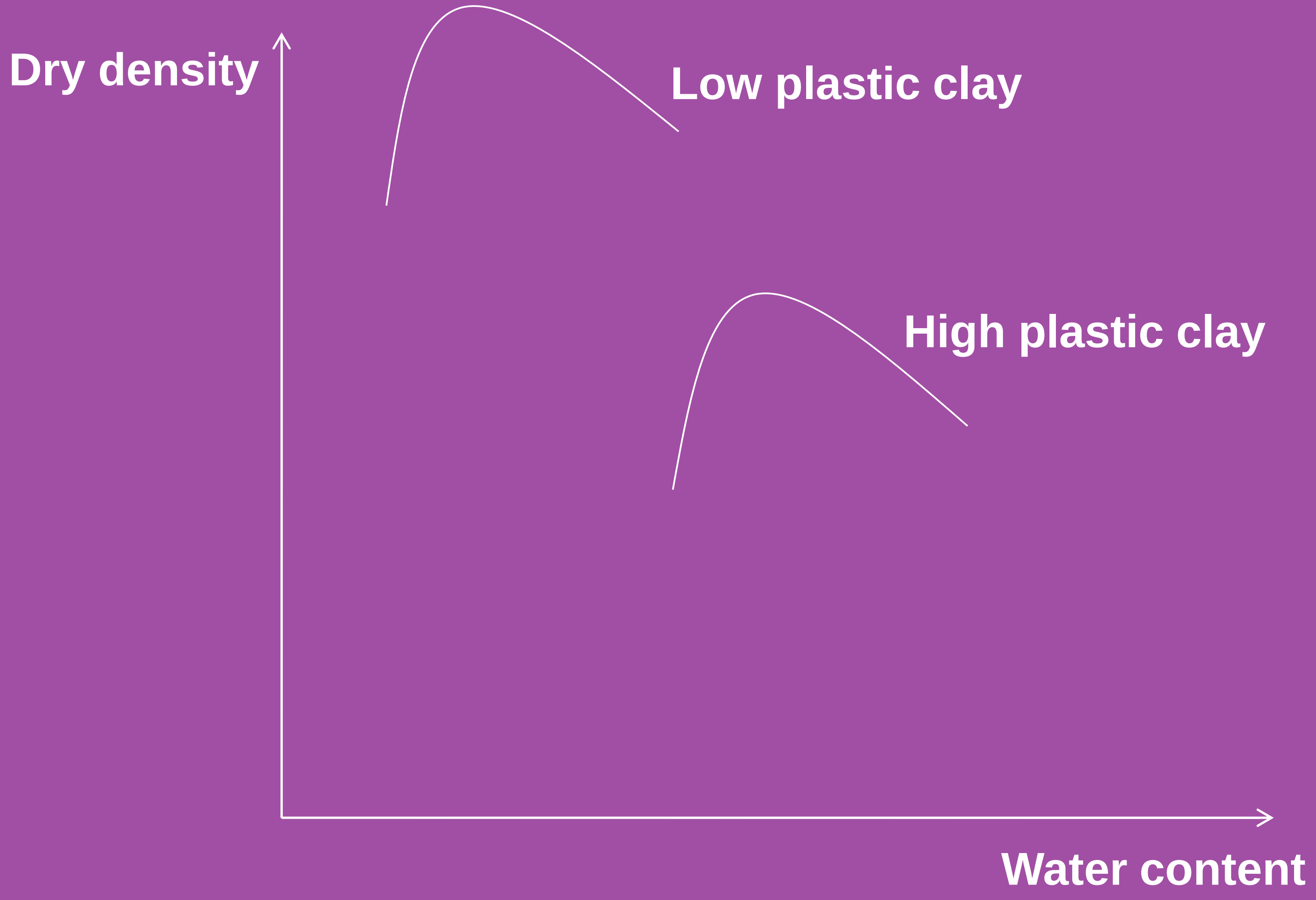
Factors affecting compaction

- **3. Type of soil**



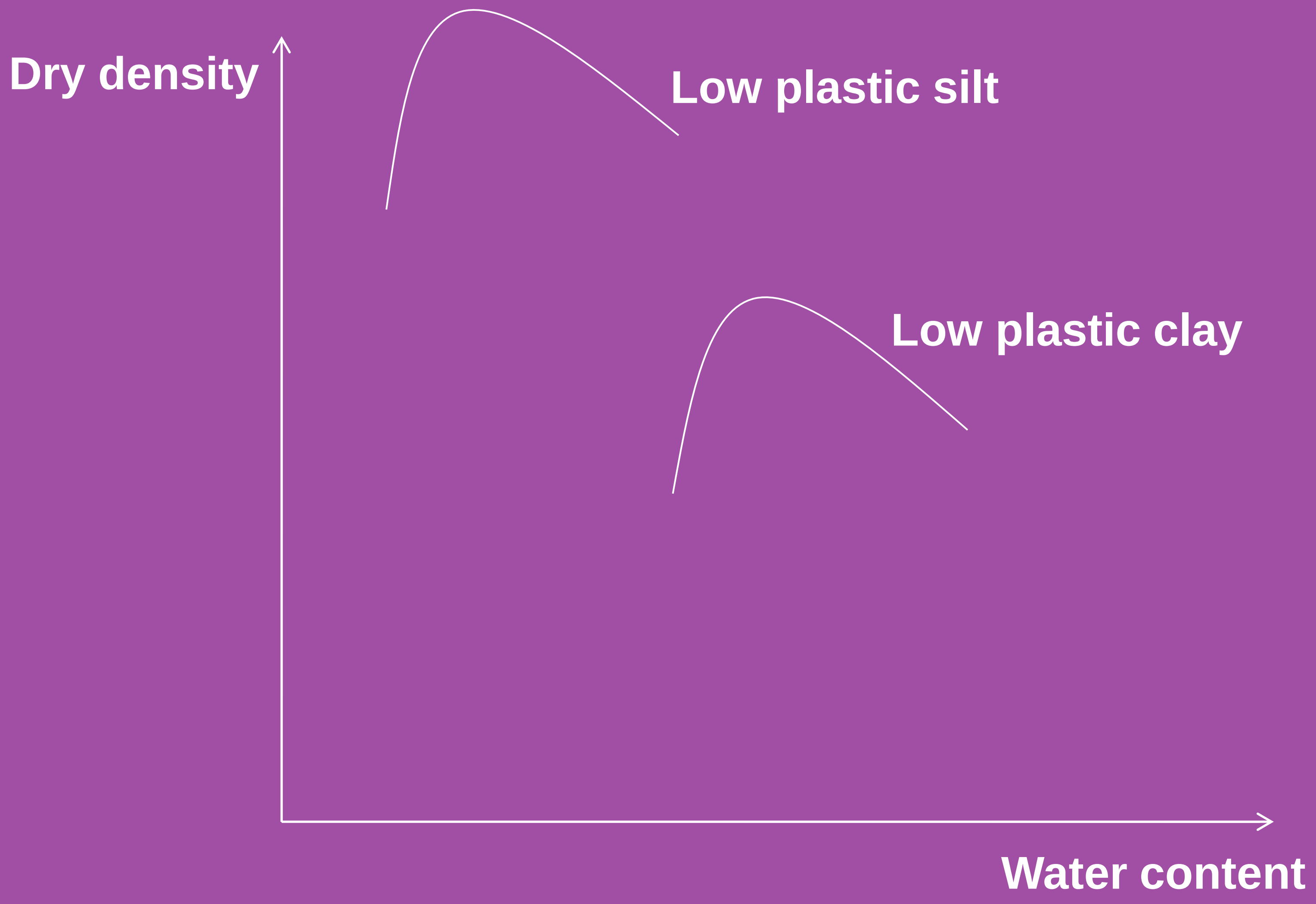
Factors affecting compaction

- **3. Type of soil**



Factors affecting compaction

- **3. Type of soil**



Factors affecting compaction

- **4. Method of Compaction**
  - **kneading action, dynamic action or static action**

- **5. Admixture**
  - **Lime, cement and bitumen**

Effect of compaction on soil structure

- Depends on – type of soil

  - moulding water content

  - amount of compaction

Coarse grained soil – maintain a single grained structure

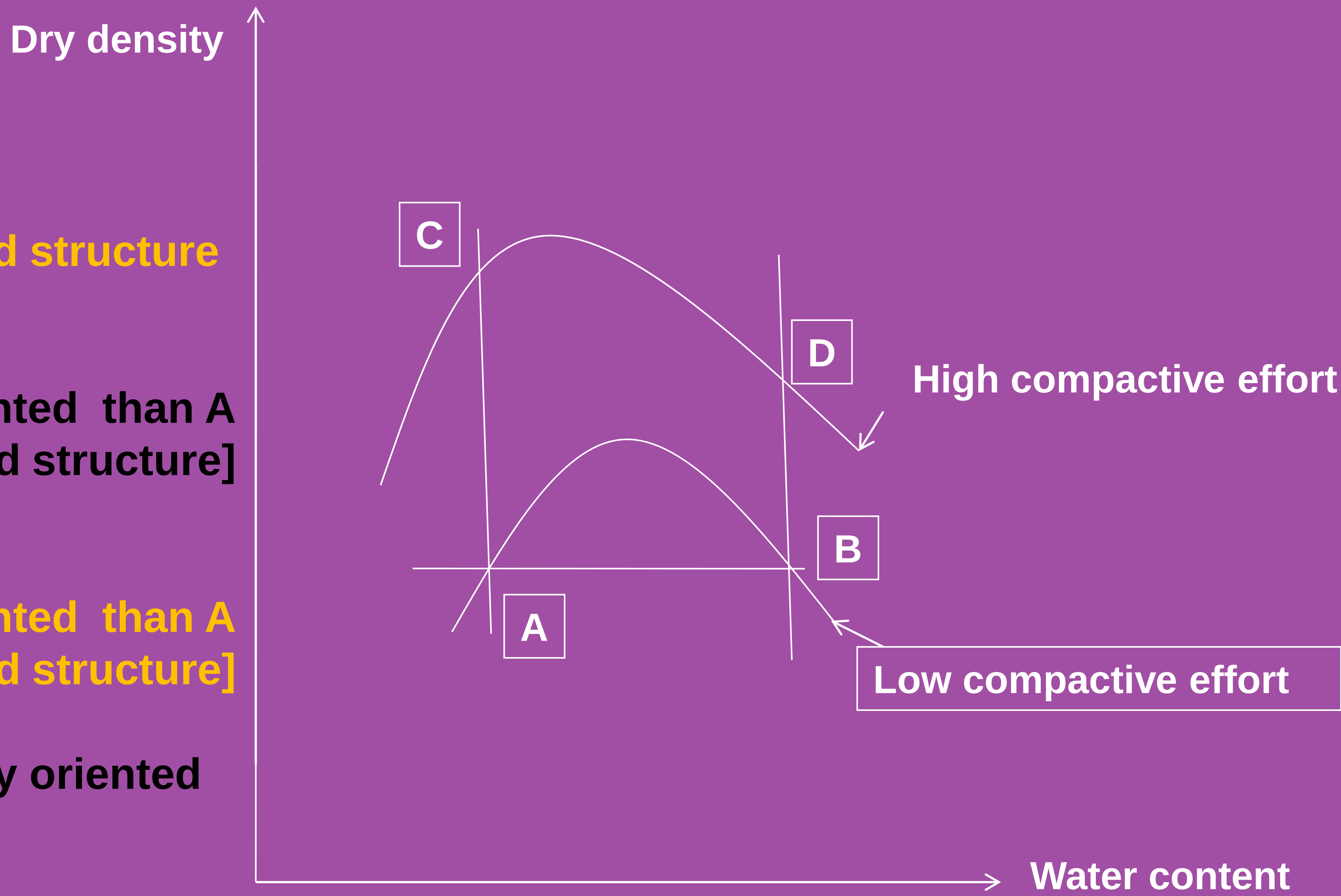
Effect of compaction on soil structure

A ----
flocculated structure

C ----
more oriented than A
[dispersed structure]

B ----
more oriented than A
[dispersed structure]

D---- highly oriented



Effect of compaction on permeability

fine grained soil, for same density :

dry of optimum (flocculated structure)

more permeable than

wet of optimum (dispersed structure)

- greater compactive effort- lesser permeability

Effect of compaction on shrinkage and swelling of fine grained soils

Shrinkage

- soil compacted dry of optimum shrinks less than sample compacted wet of optimum

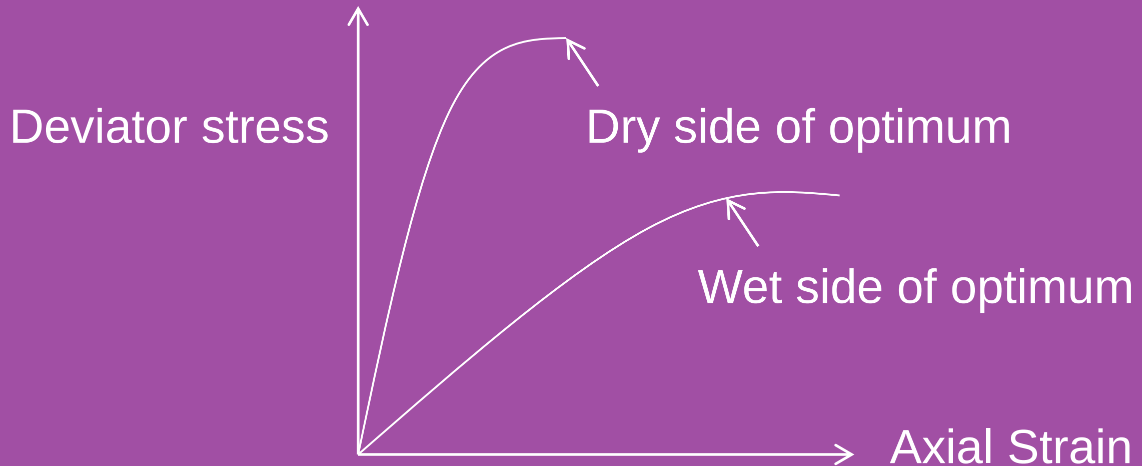
Swelling

- compacted dry of optimum has greater swelling

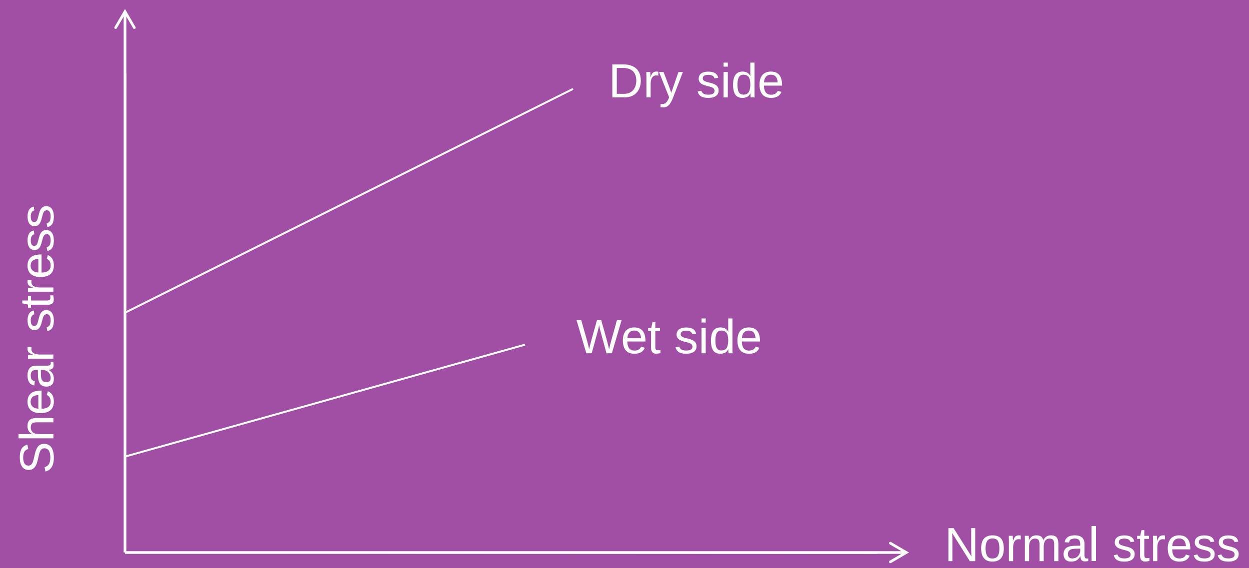
Effect of compaction on Compressibility

- **If compacted dry of optimum – less compressible**
- **[flocculated structure- Therefore, requires extra pressure to cause parallel orientation]**

Effect of compaction on σ-ε behaviour



Effect of compaction on shear strength of soil



Field Compaction

- **Tampers:** for all type of soils
  block of iron (3-5 kg) made to fall from
  about 0.3m height on soil to be compacted

Field Compaction

- **Rollers:** **compaction depends on**

  - contact pressure

  - number of passes

  - layer thickness

  - speed of roller

Smooth wheel roller

– **for finishing operations**

- **for compacting granular base courses**

Sheep foot roller

-

most suited for **cohesive soils**

Both Tamping and kneading action

Pneumatic tyred roller:

compressed air used to develop the required inflation pressure

kneading action

cohesive and cohesionless soil

Vibratory roller

suitable for
granular soils

Field Compaction Control

- **Done by measuring the dry density and water content of compacted soil in the field & by comparing with the lab. values**

- **Dry density – core cutter method**

  - sand replacement method

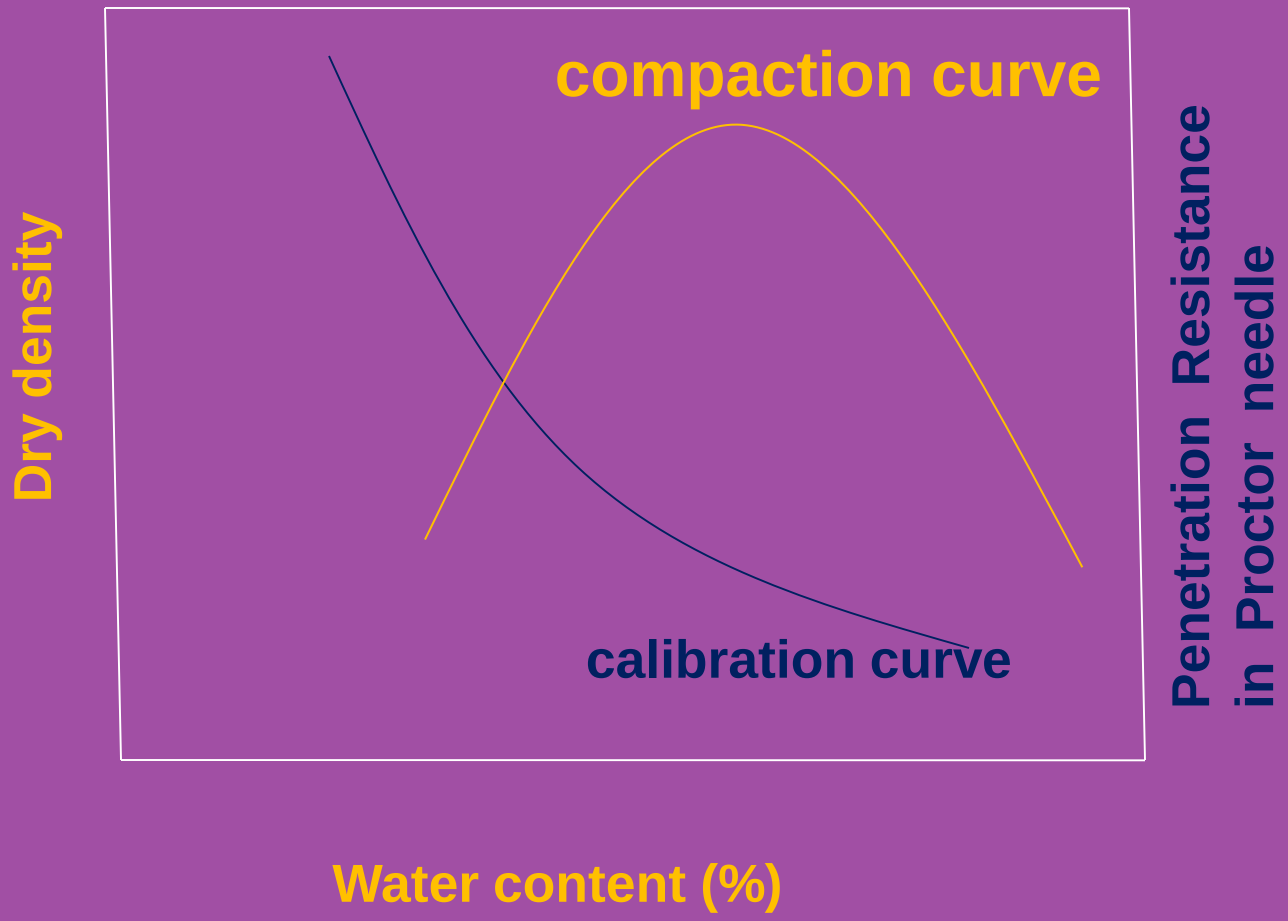
- **water content - Proctor needle**

  - calcium carbide method

Proctor Needle Method

Proctor needle is forced into the compacted soil in the mould at the rate of 1.25cm/sec. to a depth of 7.5cm. Penetration resistance per unit area is noted.

Calibration curve



FIELD COMPACTION CONTROL

- **RELATIVE COMPACTION** = $$\frac{\gamma_{d(field)}}{\gamma_{d-\max(lab)}} \times 100\%$$

- **COMPACTION REQUIREMENTS FOR EMBANKMENT AND SUBGRADE**

Type of work	Relative Compaction (Min.)
Subgrade and earthen shoulders	97
Embankment	95

- frequency of control tests as per IRC for embankments [Take at least one measurement for each <u>1000 m²</u> of compacted area.]
- Minimum no: of tests in one set of measurement (5 to 10)

- <u>Acceptance criteria</u>

Mean Dry density >= $\left[1.65-\frac{1.65}{(No.\,of\;\;samples)^{0.5}}\right]$ times the standard deviation $+\left[Specified\quad density\right]$

Let $(\gamma_{d\text{-}max})_{lab}$ = 1.63 t/m^3 and

Relative compaction (required) = 95%

Let $(\gamma_{d\text{-}max})_{lab}$ = 1.63 t/m³ and

Relative compaction (required) = 95%

Let measured Values of $(\gamma_d)_{field}$ be

1.50, 1.57, 1.63, 1.64 and 1.70 t/m³

Let $(\gamma_{d\text{-}max})_{lab}$ = 1.63 t/m^3 and
Relative compaction (required) = 95%

Let measured Values of $(\gamma_d)_{field}$ be
1.50, 1.57, 1.63, 1.64 and 1.70 t/m^3

Mean dry density = 1.61 t/m3;
Standard deviation = 0.068

$$\text{Mean Dry density} >= \left[1.65 - \frac{1.65}{(No.\,of\ \ samples)^{0.5}}\right] \text{times the standard deviation} + [Specified \quad density]$$

$$1.61 \geq \left[1.65 - \frac{1.65}{\sqrt{5}}\right] \times \ 0.068 \ + [0.95 \times 1.63]$$

Other methods of compaction

- Vibroflotation method
- Compaction by explosives
- Precompression
- Compaction piles