EWCE 341

Principles of Soil Mechanics

Proctor Compaction Test

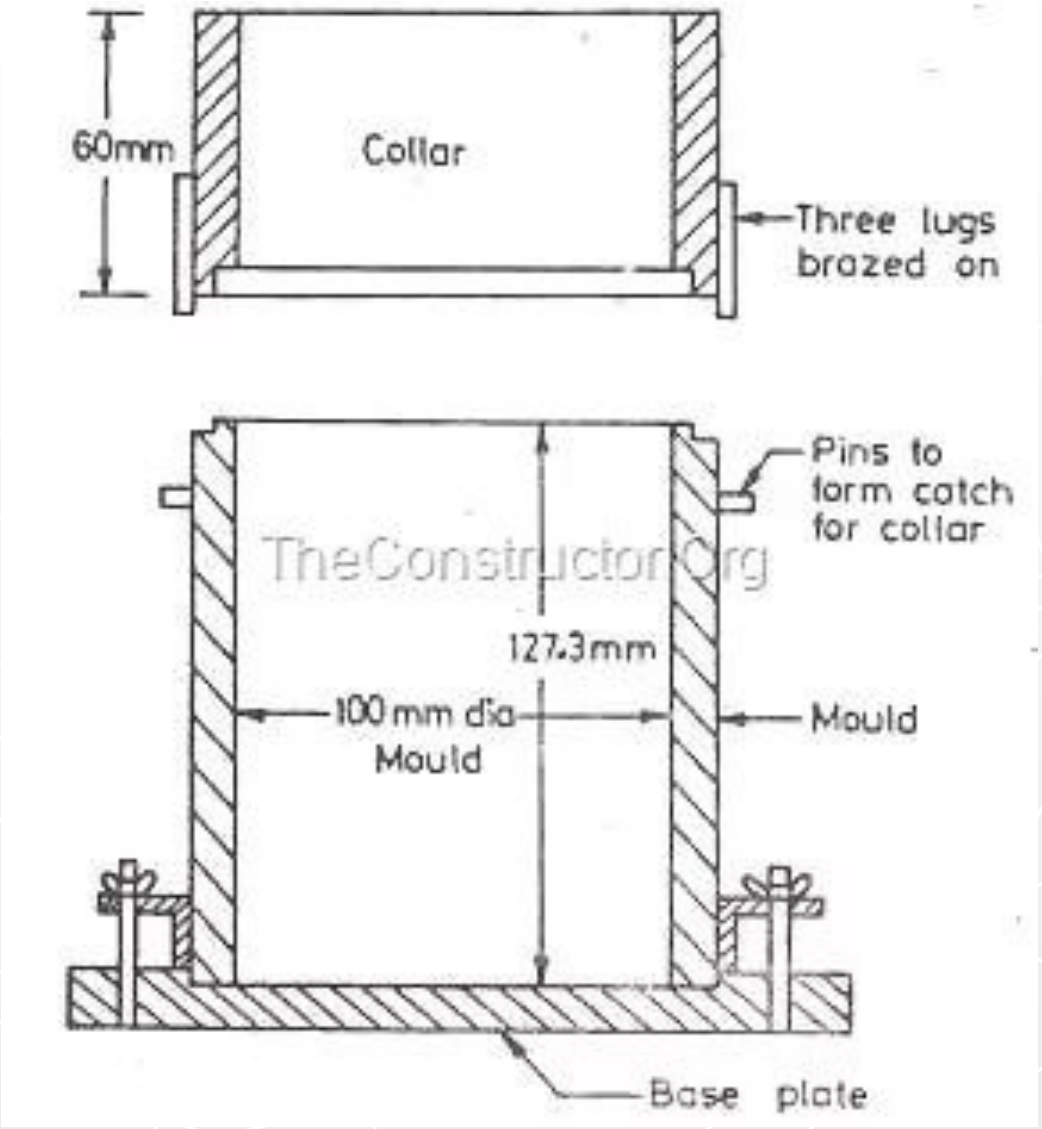
What we learned in the last class?

- What is soil Compaction?
- Purpose of soil Compaction.
- Requirements of soil compaction in Engineering works.
- Differences between consolidation and compaction of soils.
- Ensuring Proper Compaction of Fill
- History of development of compaction of fill
- Necessity of Specialize Compaction Equipment
- Methods used by the Compaction Equipment for compaction.
- Compaction improves engineering properties of fill.
- Why dry unit weight ($\gamma_d = \frac{W_s}{V}$) of soils is an important parameter for soil compaction?

Laboratory Compaction Test of Soils



Standard Proctor Test Apparatus (Mold and Rammer)


60mm
Collar
Three lugs brazed on
Pins to form catch for collar
TheConstructor.org
127.3mm
100 mm dia Mould
Mould
Base plate

Proctor Compaction Test

What is Proctor Compaction Test?

- During 1930s, **R R Proctor, an engineer** of LA City, USA developed a **method for assessing the compaction of fills**, becomes a nearly universal.

- **Method consists of :**

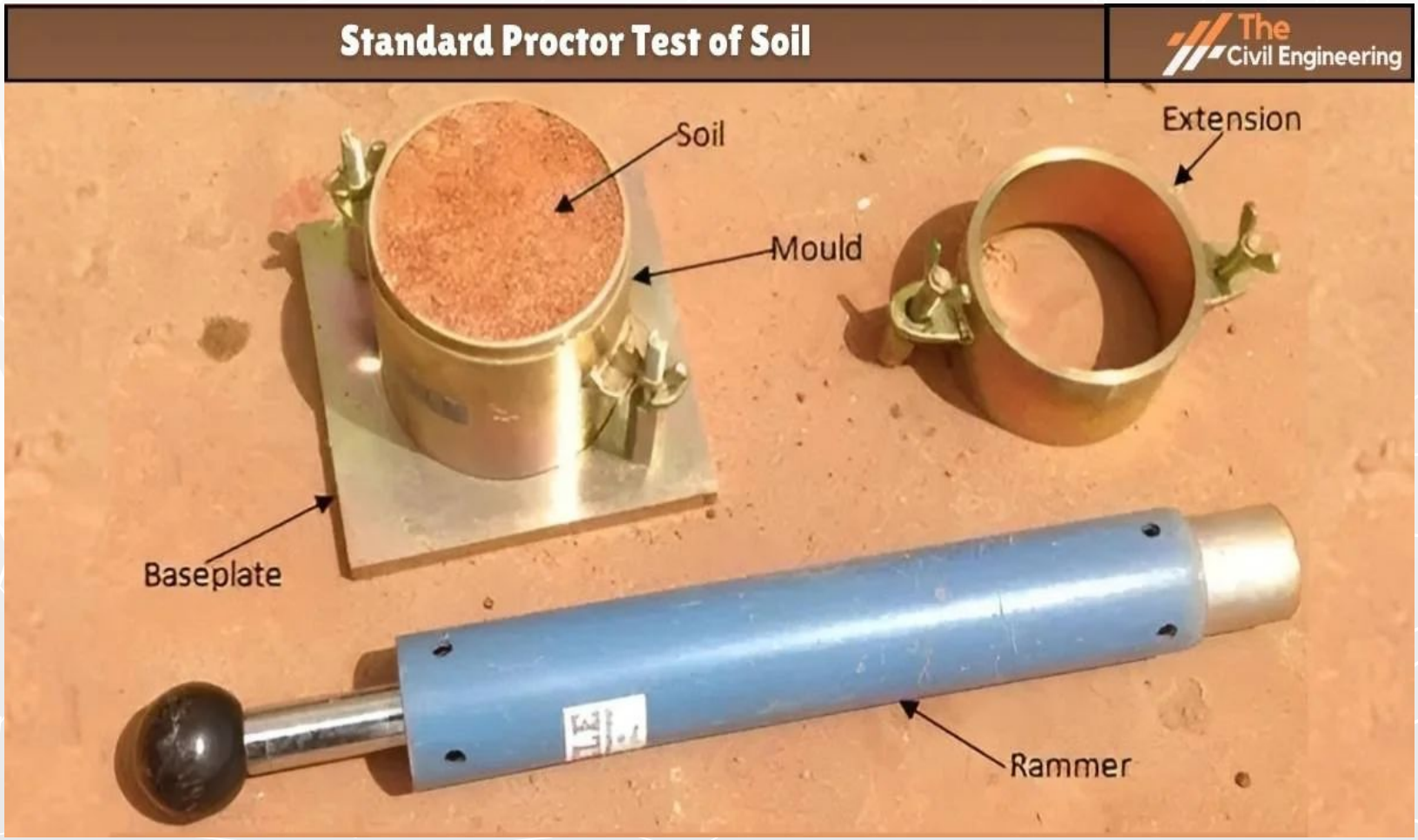
  -Compacting soils in the lab to **attain** $(\gamma_d)_{max}$

  -Requiring the contractor to **achieve some specified % of this value in the field**.

Types of Proctor Compaction Test:

- **Standard Proctor Test**: Original version of laboratory test.

- **Modified Proctor Test**: Revised version of Standard Proctor Test.



Modified Proctor Test:

- During 1940s and 1950s, geotechnical engineers found that 'Standard Proctor Test' in **no way sufficient** for airport and highways because fills were not providing adequate support for heavy trucks and aircraft.

- **US Army Corps of Engineers** addressed the problem by developing 'Modified Proctor Test' which **used greater level of compaction** and thus producing higher values of $(\gamma_d)_{max}$.



Differences between Standard Proctor Compaction Test and Modified Proctor compaction test

Events	Standard P C test	Modified P C Test
Standardised	ASTM D698, AASHTO T-99	ASTM D1557 and AASHTO T-180
Hammer Weight	5.5 lb (2.49kg)	10 lb
Hammer drop height	12” (305mm)	18” (457mm)
Number of Soil Layers	3	5
Number of hammer blows/ Layers	25	25
Energy Imparted from hammer for each sample		

Test Procedure:

- About **3.0kg of air-dried** soil sample is taken.
- Water is added to bring its **water contain 5%** if soil is coarse grained, **8% if its fine grained soils.**
- **Water content should be much less** than the expected moisture content:

  Sand - 6-10%

  Sandy silt or silty sand- 8 –12%

  Silt- 12 -16%

  Clay - 14-20%
- Soil is mixed thoroughly and covered with a **wet cloth** and left for **about 15-30mins.**
- Mold is **cleaned, dried** and **greased** lightly.

- Place some of the prepared soil into the **standard cylindrical steel mold** until it is **filled about 40% full**.

- Compact the soil by **applying 25 blows** from a special **5.5 lb (2.49 kg) hammer** that **drops from a height of 12”** (305mm).

- Place a **second layer** of prepared soil into the mold until it is **75% full.** Compact the soil by **applying 25 blows**.

- Place the **3rd layer** of the prepared soil into the mold and compact it by **applying 25 blows** in the same fashion. Thus applied a total of **75 blows of hammer**.

- **Trim the sample** so that the **volume is exactly 1/30** ft^3 **(9.44x10^{-4}**m^3 and then **weight it**.

Soil Compaction



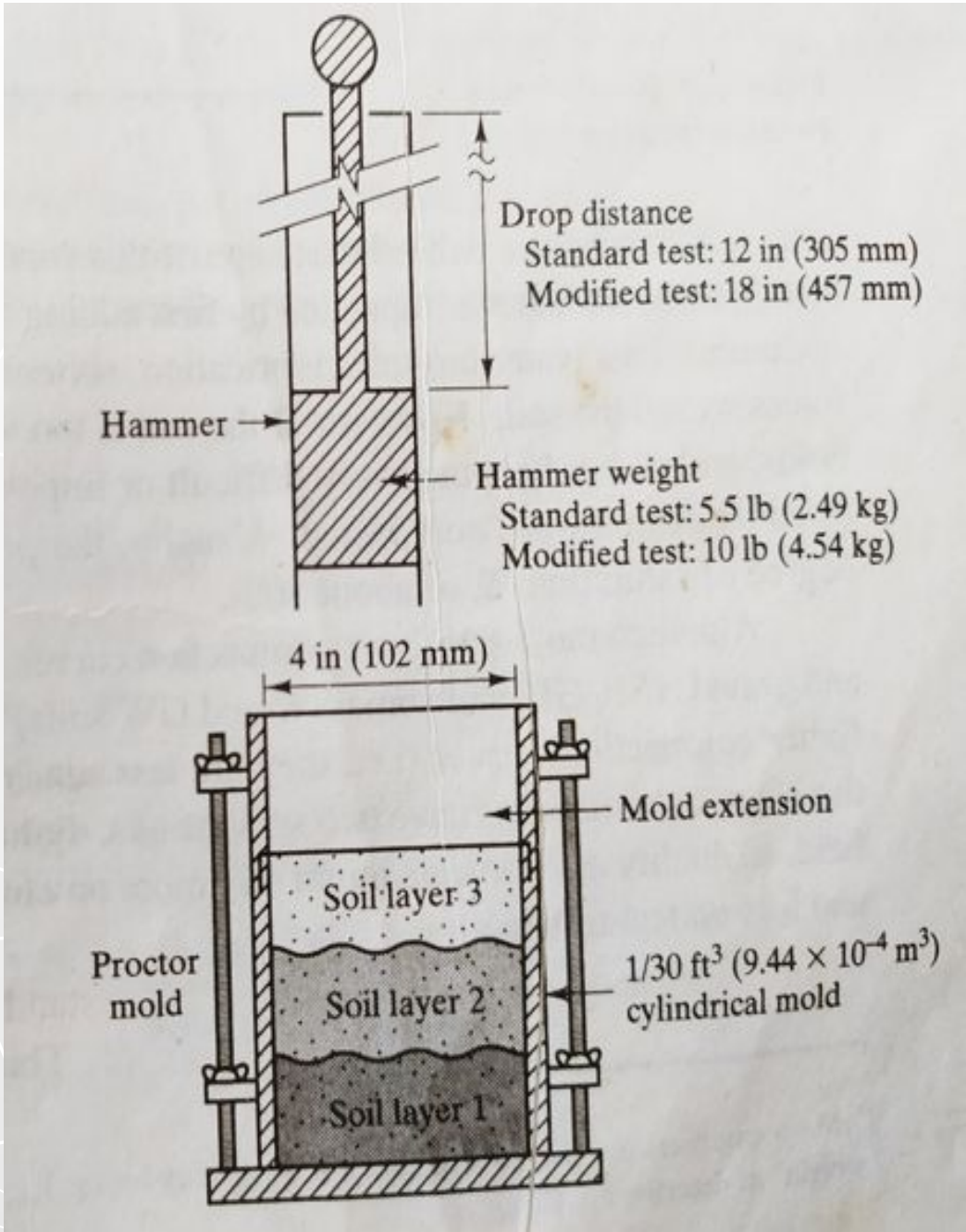


Figure: Mold and Hammer for Proctor Compaction test. Standard Test uses three layers.

- **Unit weight** $\gamma = \frac{W_{ms} - W_m}{V_m}$

where, W_{ms}= weight of mold +soil

W_m= weight of mold

V_m= volume of mold ie. $\frac{1}{30}\,ft^3$ or $9.49\text{x}10^{-4}\,m^3$

- Perform the **moisture content test** on the **representative portions of the compacted sample,**

$$\mathbf{w} = \frac{W_w}{W_s} = \frac{W_2 - W_3}{W_3 - W_1} \text{ x } 100\%$$

where, W_1= weight of can

W_2= weight of can + wet soil

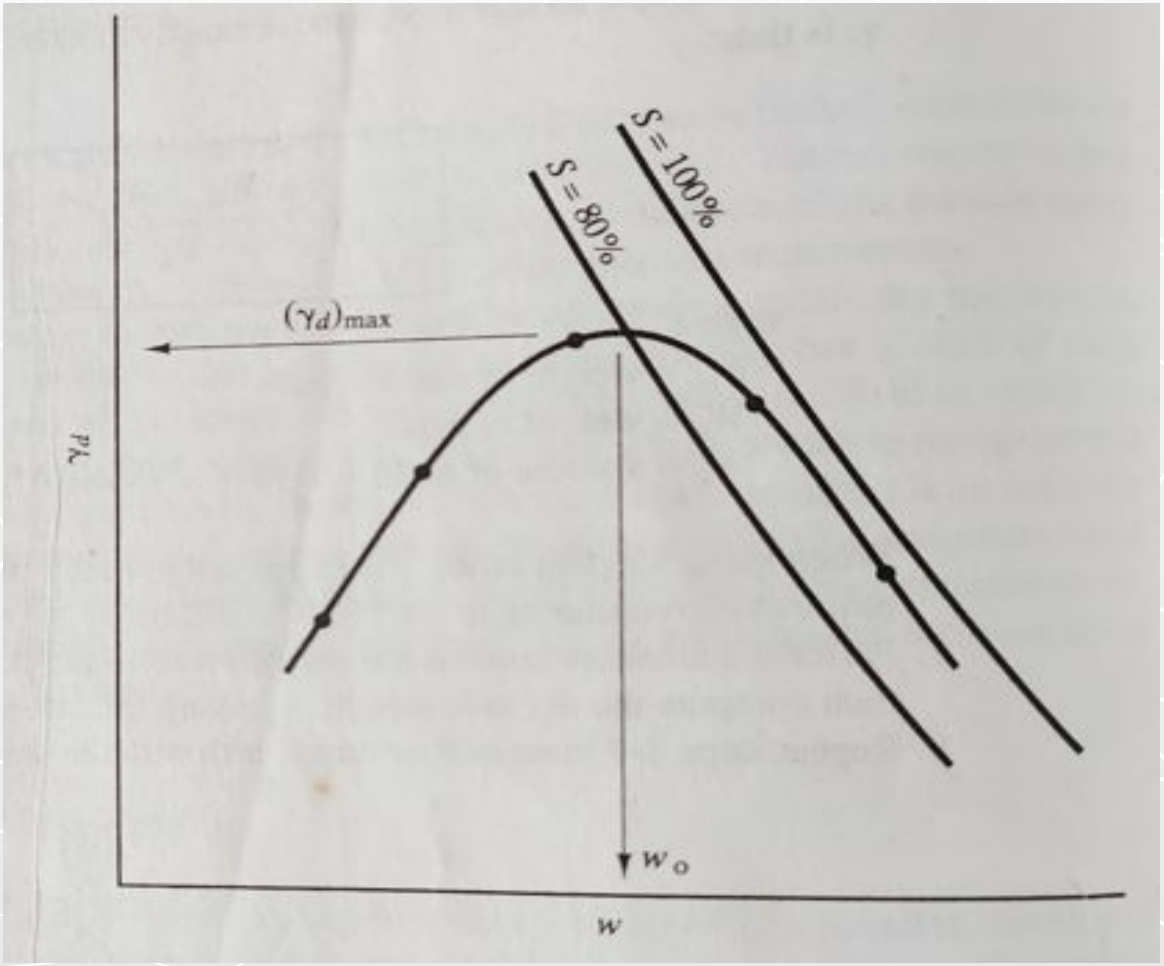
W_3= weight of can + dry soil (110±5°C for 24 hours).

- Compute the dry unit weight of the soil sample:

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

- **Repeat the test 3-4 times** with soils at a different moisture content.
- Then plot the graph in **log paper γ_d vs. w%.**

Results from Proctor Compaction Test



What is Proctor Compaction Curve?

- Plot γ_d, achieved by compacting soils at various **moisture content w.**
- Curve connecting data points is called compaction curve.
- In **dry soils, better compaction** is achieved **by adding water** to raise its moisture content to near maximum.
- Water provides **lubrication, softens clay bonds**, and **reduces surface tension forces** within the soils.

Compaction Curve

- Thereby**, expelled air to reduce volume**.
- If soils become **too wet**, no voids is left, very **difficult/impossible to compact.**
- Peak of compaction curve usually at degree of saturation **S=80%.**
- **S=100%** curve known as **zero void curve is out side** the compaction curve.
- **Most of the soils have the similar curves**, but clean sands and gravels do not show such curves.

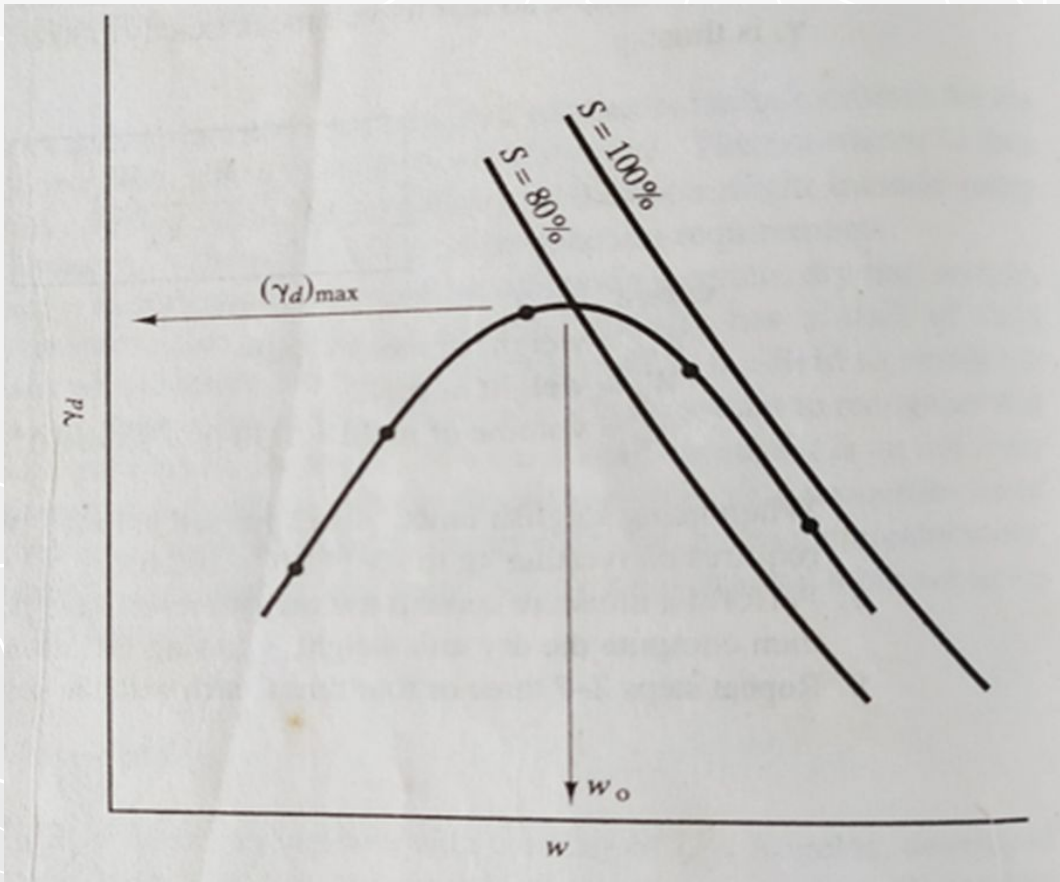
Compaction Curve

- Clean sand and gravel **have better compaction curves because they are less sensitive to moisture contents.**
- Curves of such soils have **some times two peaks** and **compacted easily in the field**.
- So quality assessment of compaction of clean sands and gravels **might rely on observation of contractor procedures** and less on test results.

How to draw saturation Curve?

From the equation, $w = S\left[\frac{\gamma_w}{\gamma_d} - \frac{1}{G_s}\right] x100\%$

- **Select γ_d in the range of test data.**
- **Compute the corresponding values of w** for S=80% and S=100%.
- Plot data point.



How the Earthwork Specification are given?

- **From the graph**, get the $\gamma_{d_{max}}$ and moisture content.
- Determine the value of γ_d **from the field after compaction**.
- Then express the degree of compaction ie **Relative compaction**

$$C_R = \frac{\gamma_d}{\gamma_{d_{max}}} \text{x } 100\%$$

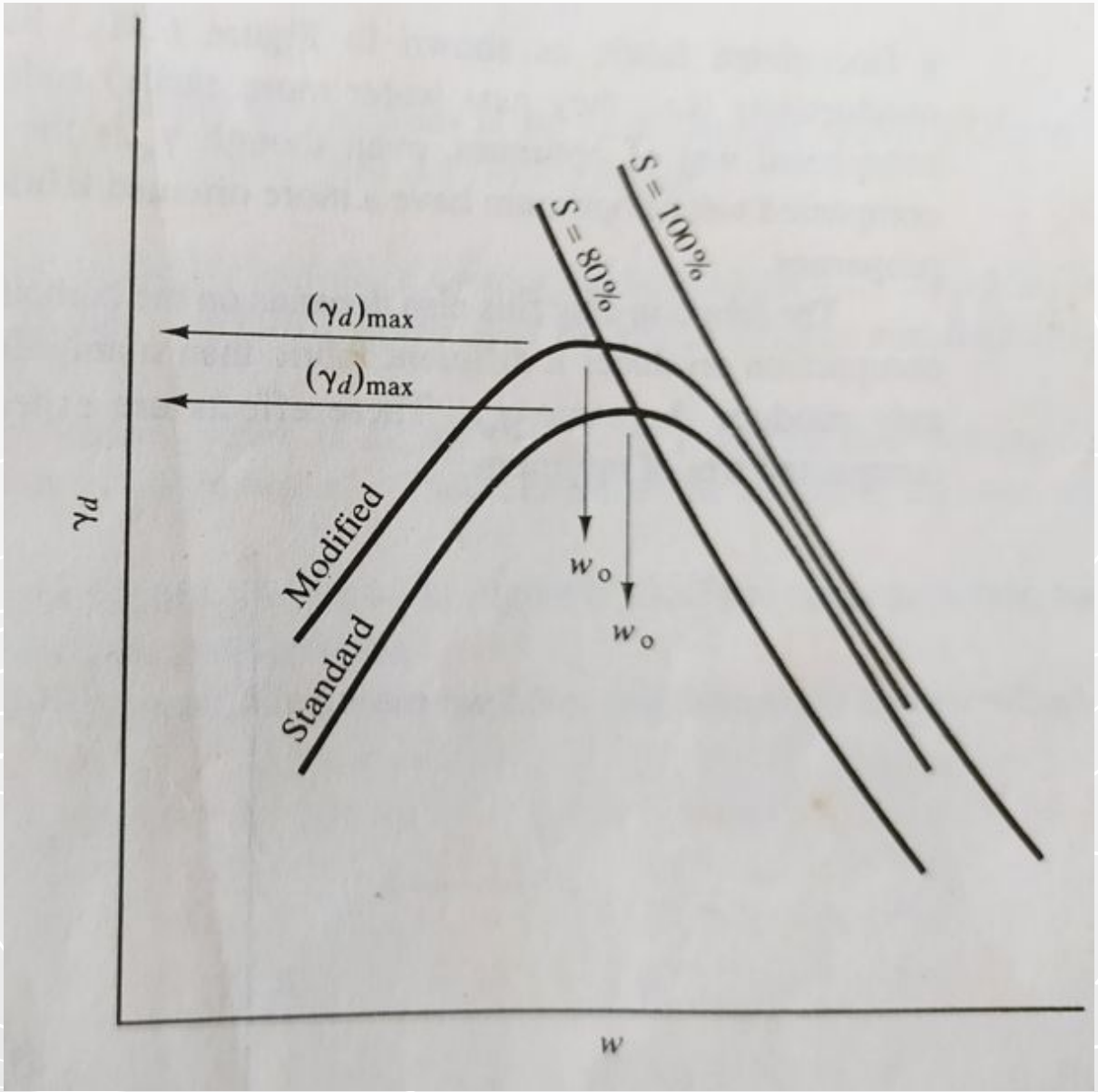
- **Most Earthwork specifications are written in terms of C_R** and require the contractor **to achieve at least certain value of C_R**.

- For example, if a certain soil has $\gamma_{d_{max}} = 120$ **lb/ft^3** and project specification is **required** $C_R \geq 90\%$, then contractor must compact the soils in the field **until** $\gamma_d \geq 108$ **lb/ft^3**.

Typical Compaction Specification

Type of project	Minimum Required Relative Compaction
Fills to support buildings or roadways	90%
Upper 150mm of subgrade below roadways	95%
Aggregate base material below road ways	95%
Earth dams	100%

Comparison Between standard Proctor test and modified Proctor test results of same soil:



- From the figure the term **maximum dry unit weight is misleading** because the standard and the modified tests have two different "maximums".
- For each test, $\gamma_{d_{max}}$ is the greatest dry unit weight achieved for the level of compaction effort (ie. For so many blows of a certain hammer).
- **Neither these values represents the largest possible dry density**.
- Figure also shows, how the optimum moisture content for the modified test is **slightly less** than that for the standard test.

Ensuring Proper Compaction in the Field:

- γ_d achieved in the field will ***generally less*** than $\gamma_{d_{max}}$, even the moisture content is exactly equal to w_0, because the **contractor usually *applies less compactive*** efforts (ie. so many passes of a certain kind of Roller).

- **This is acceptable**, so long as the project specifications permit relative compaction is less than 100%, which they usually do.

- Sometimes, contractors **applies large effort that exceeds** $\gamma_{d_{max}}$, thus producing a relative compaction of more than 100%; specially on earth dam where high level of compaction are required.

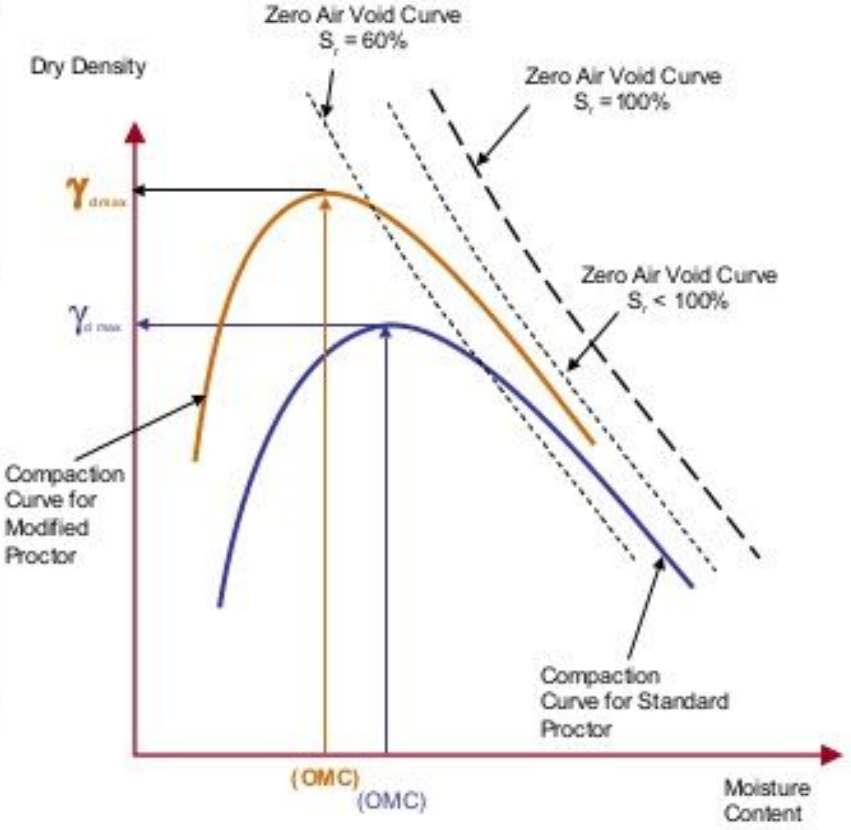
Soil Compaction in the Lab:

1- Standard Proctor Test
ASTM D-698 or AASHTO T-99

Energy = 12,375 foot-pounds per cubic foot

2- Modified Proctor Test
ASTM D-1557 or AASHTO T-180

Energy = 56,520 foot-pounds per cubic foot



$$\text{Energy} = \frac{\text{Number of blows per layer} \times \text{Number of layers} \times \text{Weight of hammer} \times \text{Height of drop hammer}}{\text{Volume of mold}}$$

S=100% and S=80% Curve

- **S=100% curve represent an upper limit** for the proctor data, because it is impossible to compact a soil having S>100%.

- At S=100% **no voids remains for air**, so it is **called zero voids curve.**

- **S=80% curve should go near through the peak** in proctor compaction curve.

- Right limb of proctor curve should **be slightly to the left of S=100% curve,** because compaction does not remove all the air.

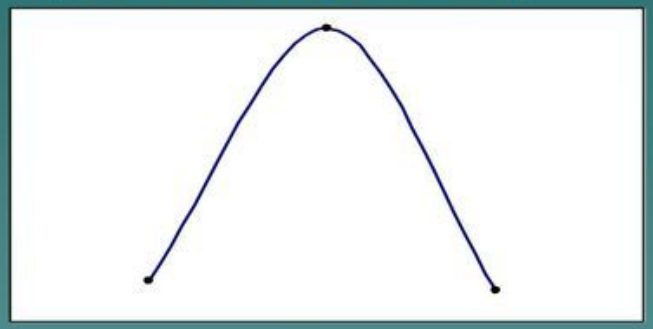
Different Shapes of Compaction Curve

- **Well graded sands** have **better compaction curves** **because they are less sensitive to moisture contents.**
- **Poorly graded sands** have **some times two peaks** and **compacted easily in the field**.
- So quality assessment of **compaction of clean sands and gravels** **might rely on observation of contractor procedures** and less on test results.
- **Silt or poorly graded sand** with silts have **odd shape curve**.
- **Clay** has one and a **half peak curve**.

Compaction Curves for Different Types of Soil

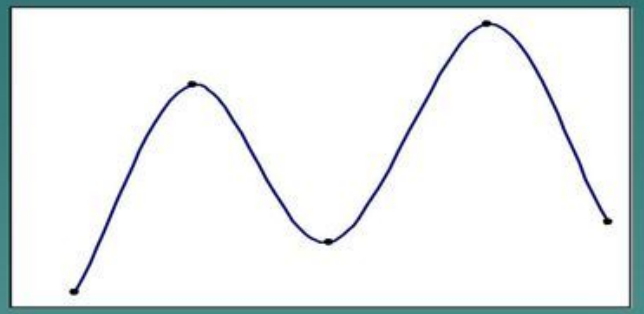
One peak

(Well Graded Sand)



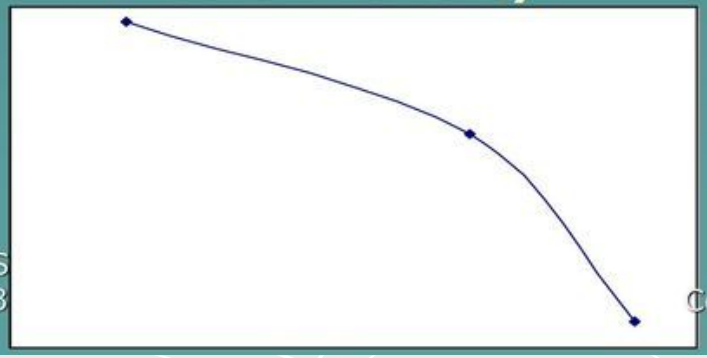
Double peak

(Poorly Graded Sand)



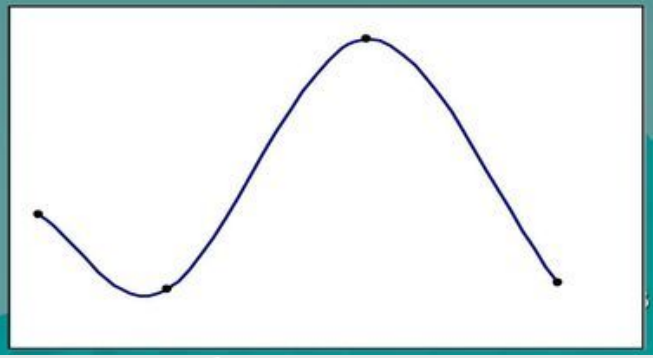
Odd Shape

(Silt OR Poorly Graded Sand with Silt)



One & half peak

(Clay)



Thanks