Soil Compaction

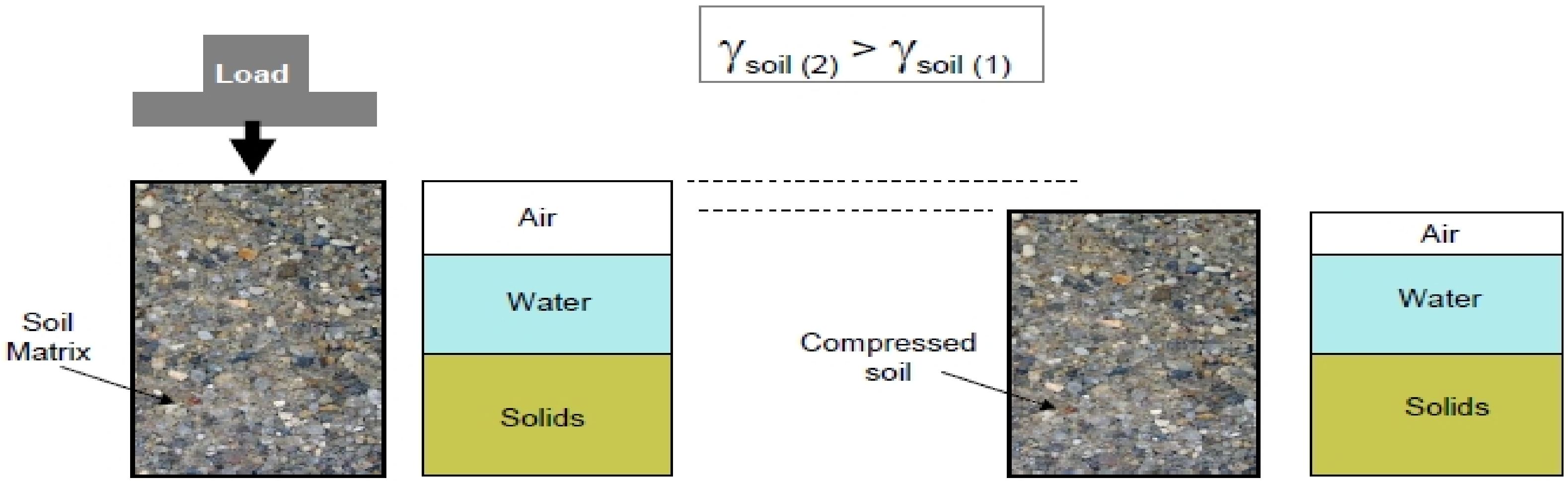
Topics

- General Principles
- Soil Compaction in the Lab:
- Factors affecting Compaction
- Structure of Compacted Clay Soil
- Field Compaction
- Specification for Field Compaction
- Determination of Field Unit Weight of Compaction

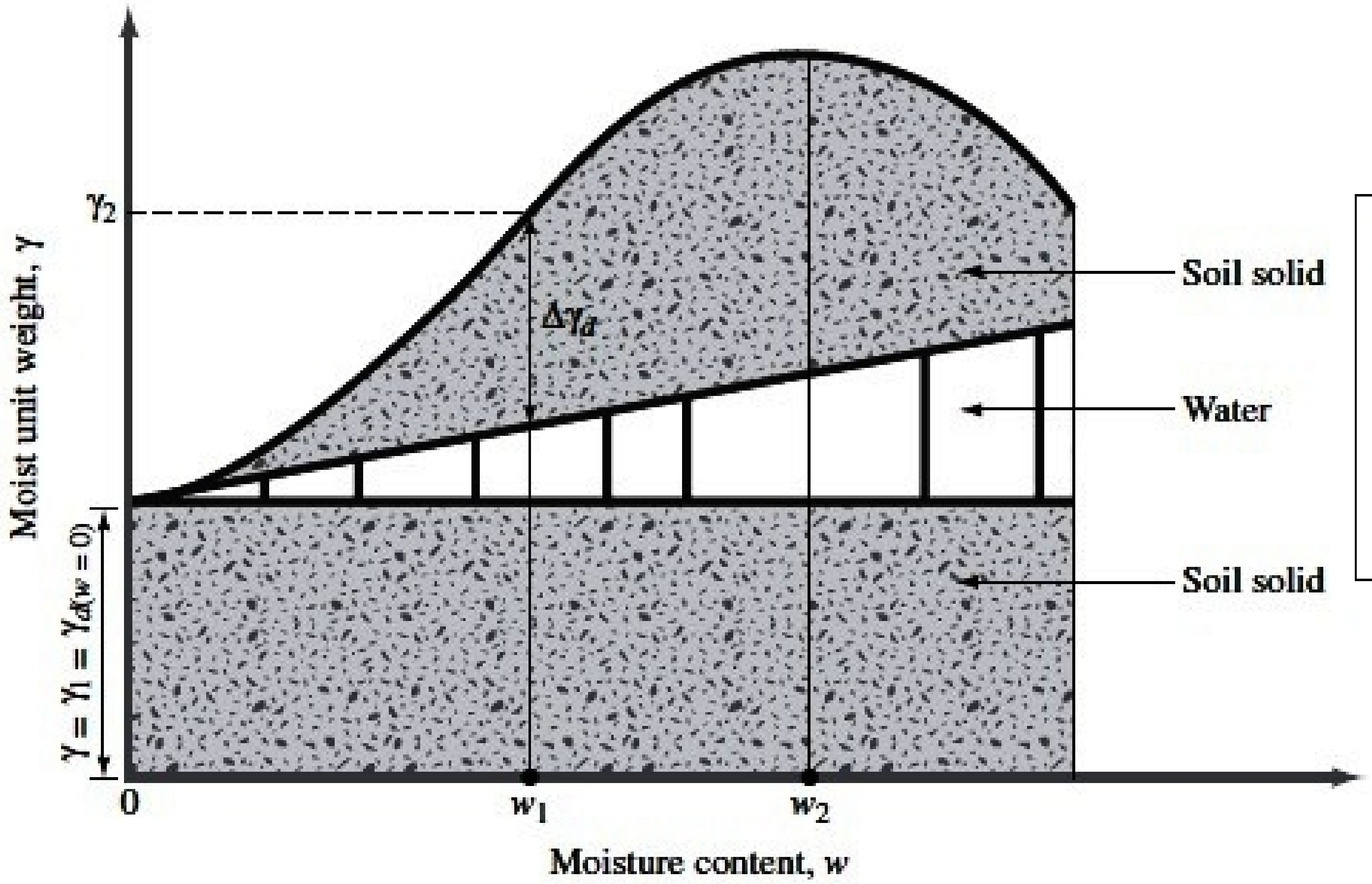
♦ ***General Principles***

Definition:

Soil compaction is defined as the method of mechanically increasing the density of soil by reducing volume of air.



$$\gamma_{soil\ (1)} = \frac{W_{T1}}{V_{T1}} \qquad \gamma_{soil\ (2)} = \frac{W_{T1}}{V_{T2}}$$

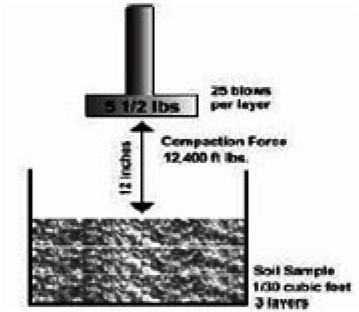


Water is added to lubricate the contact surfaces of soil particles and improve the compressibility of the soil matrix

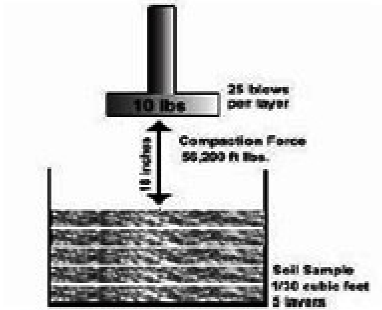
Principles of compaction

♦ *Soil Compaction in the Lab:*

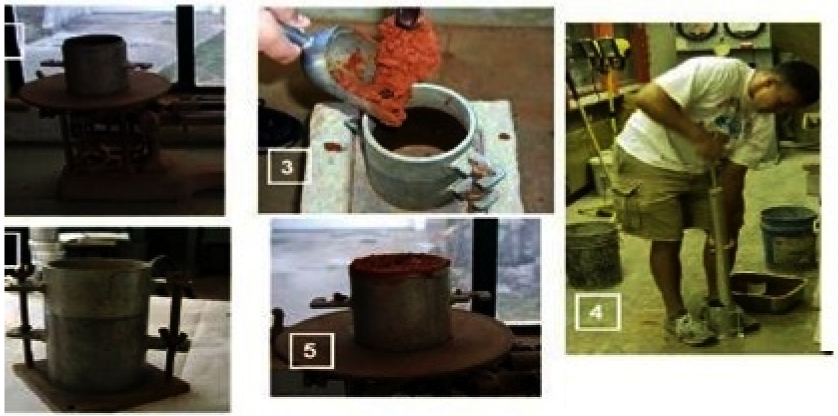
1- Standard Proctor Test
2- Modified Proctor Test



Standard Proctor Test



Modified Proctor Test



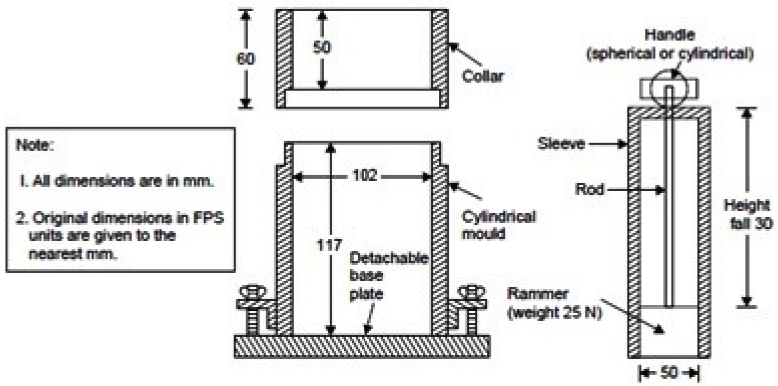
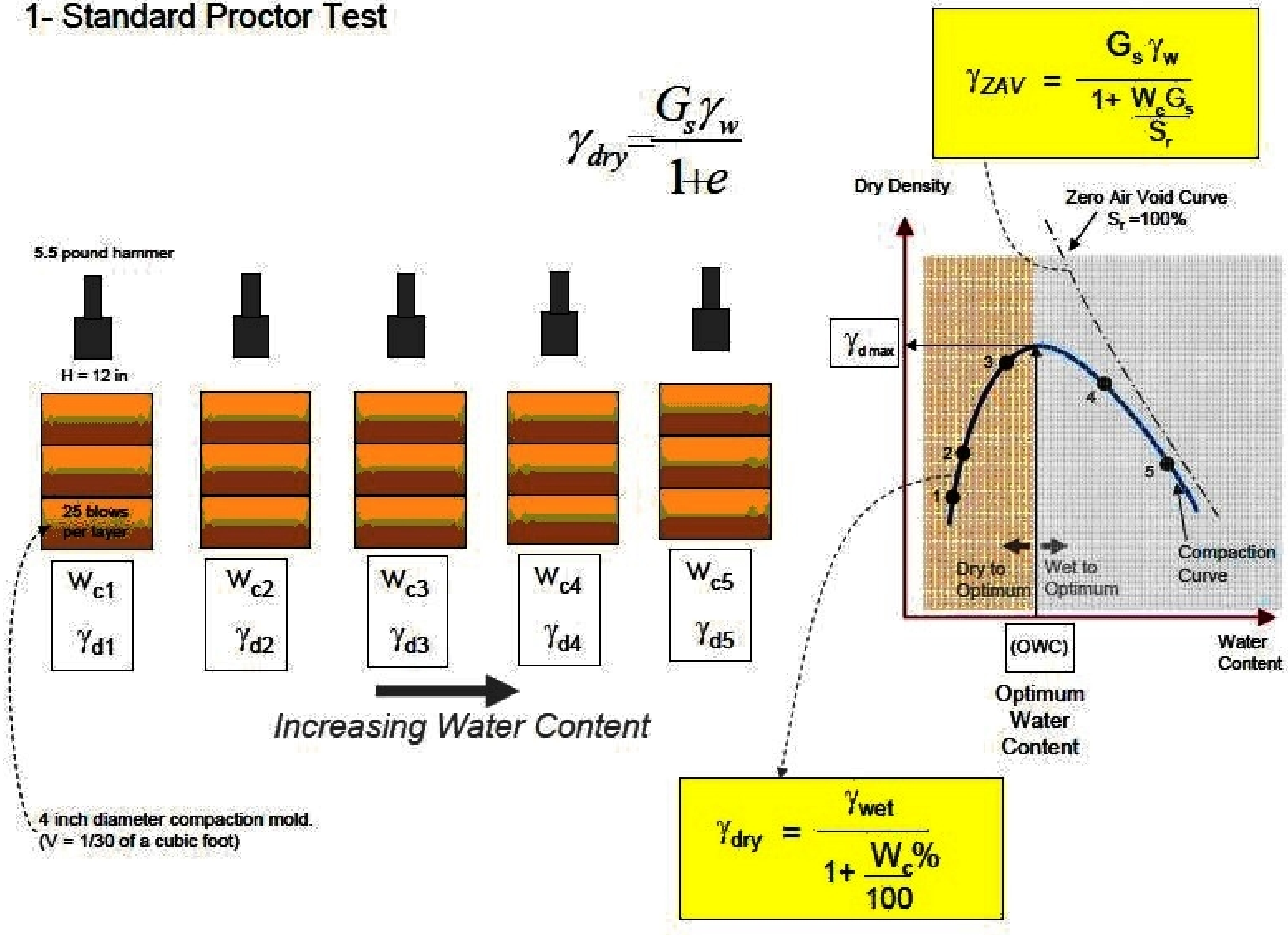


Fig. 12.4 Apparatus for standard proctor test

1- Standard Proctor Test

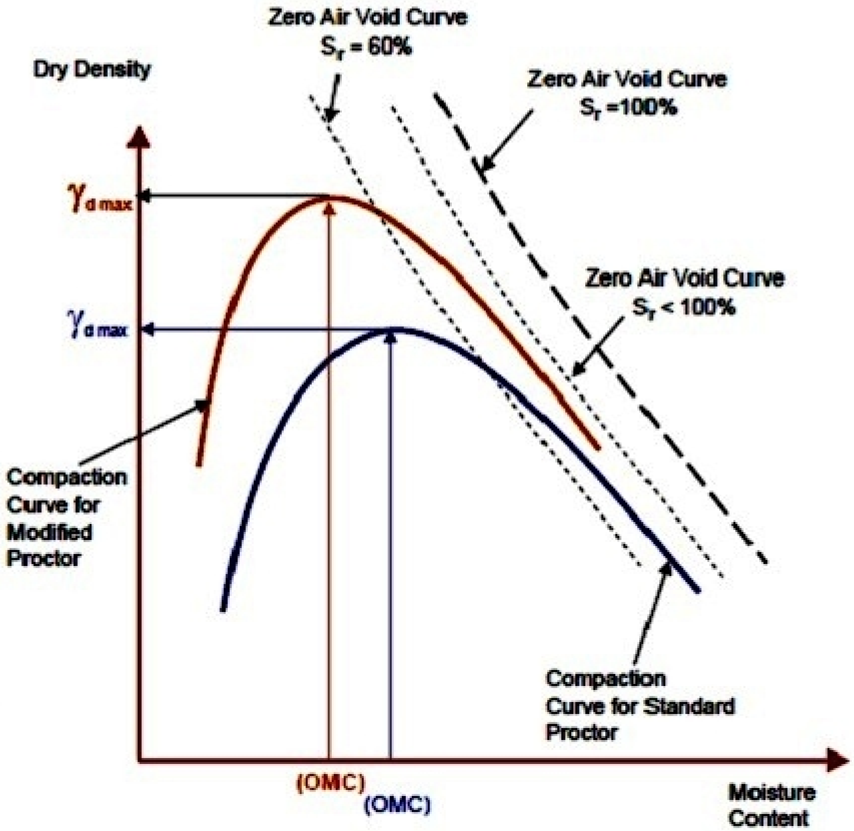


1- Standard Proctor Test
ASTM D-698 or AASHTO T-99

Energy = 12,375 foot-pounds per cubic foot

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

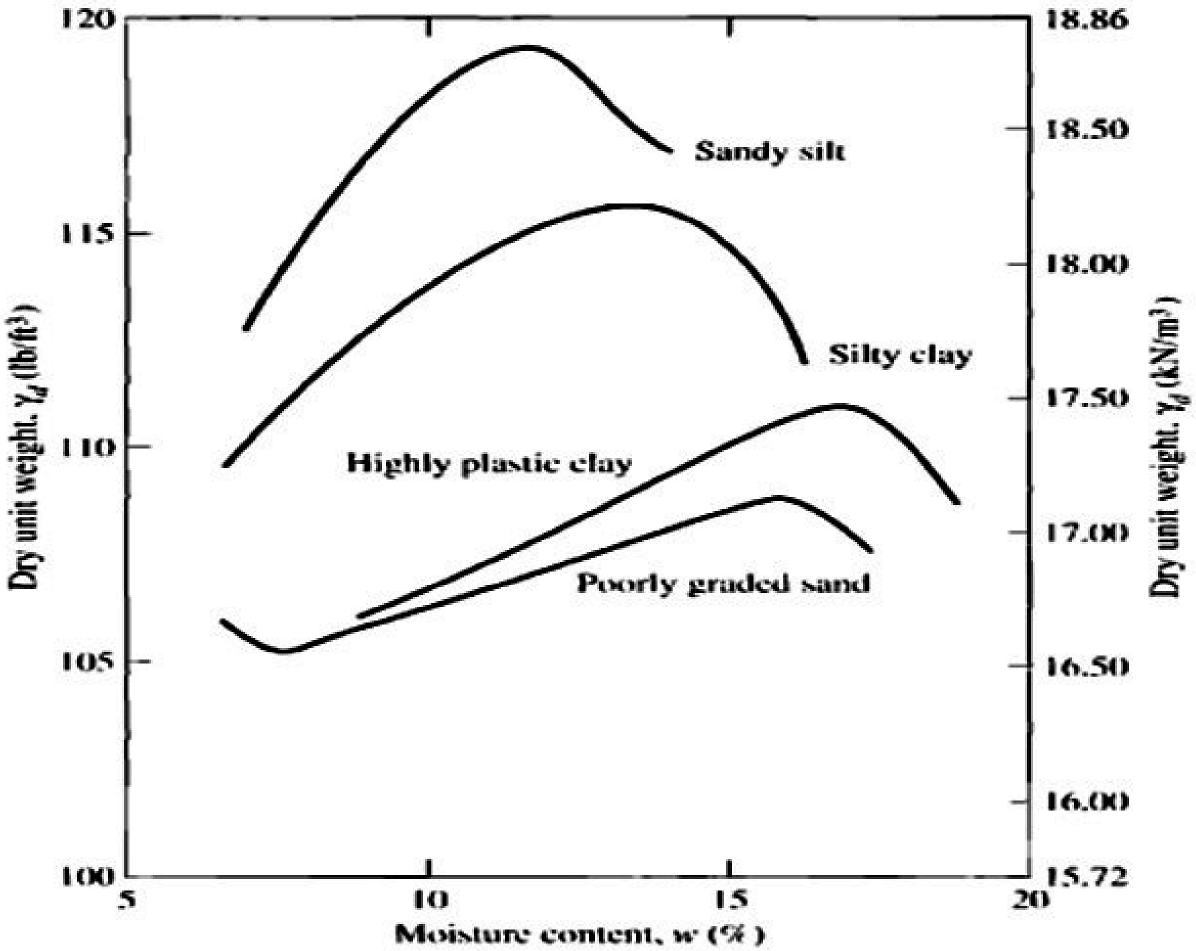
Energy = 56,520 foot-pounds per cubic foot



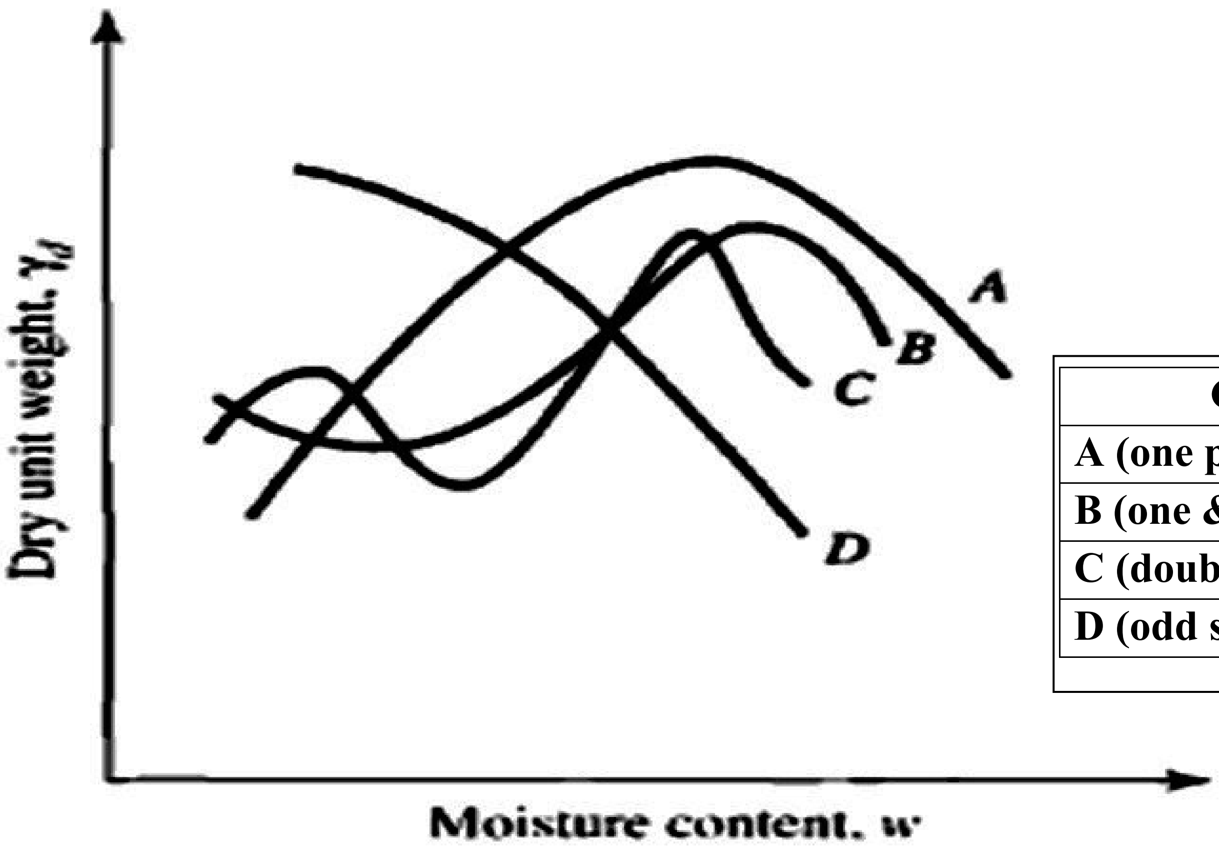
$$\text{Energy} = \frac{\text{Number of blows per layer} \times \text{Number of layers} \times \text{Weight of hammer} \times \text{Height of drop hammer}}{\text{Volume of mold}}$$

♦ ***Factors affecting Compaction***

1- Soil Type
2- Water Content (w_c)
3- Compaction Effort Required (Energy)



Typical compaction curves for four soils (ASTM D-698)



Types of compaction curve

Curve type	Soil properties
A (one peak)	Soil with liquid limit 30-70
B (one & half Peak)	Soil with liquid limit < 30
C (double peak)	Soil with liquid limit >70
D (odd shape)	

Effect of compaction effort

$$\text{ergy} = \frac{\text{Number of blows per layer x Number of layers x Weight of hammer x Height of drop hamme}}{\text{Volume of mold}}$$

in SI units.

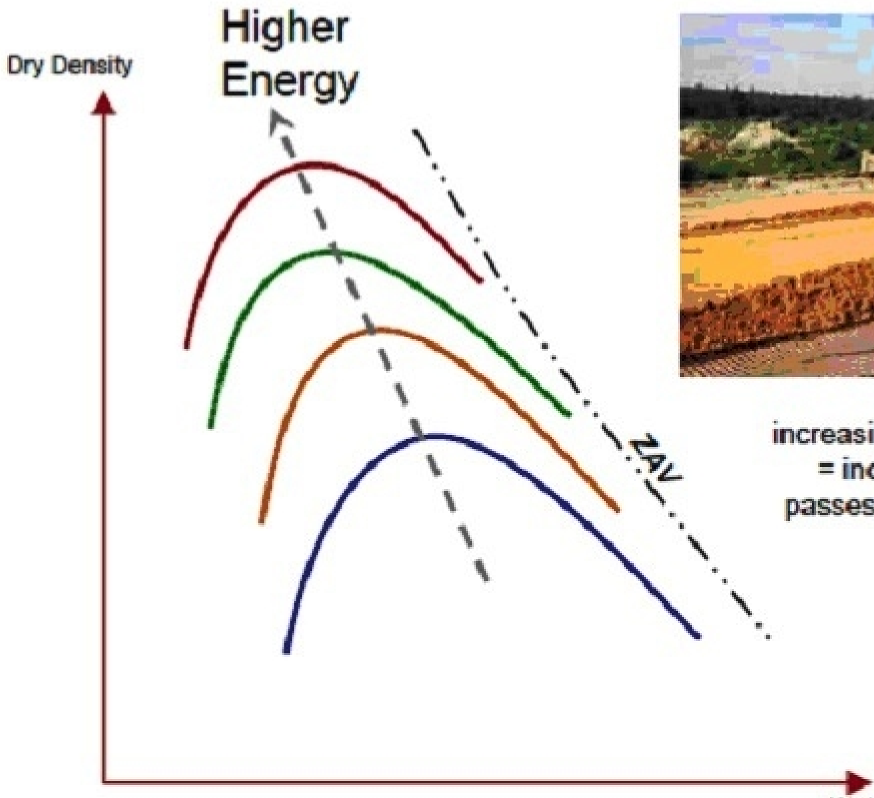
$$E = \frac{(25)(3)\left(\frac{2.5 \times 9.81}{1000}\ \text{kN}\right)(0.305\ \text{m})}{944 \times 10^{-6}\ \text{m}^3} = 594\ \text{kN-m/m}^3 \approx 600\ \text{kN-m/m}^3$$

In English units,

$$E = \frac{(25)(3)(5.5)(1)}{\left(\frac{1}{30}\right)} = 12{,}375\ \text{ft-lb/ft}^3 \approx 12{,}400\ \text{ft-lb/ft}^3$$

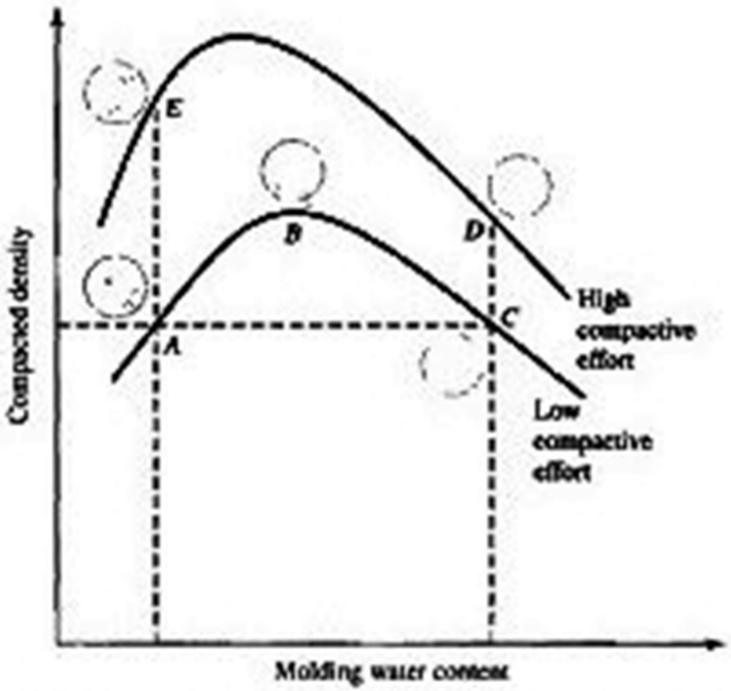
Increasing compaction energy → Lower OWC and higher dry density

In the lab
ncreasing compaction energy
= increasing number of blows

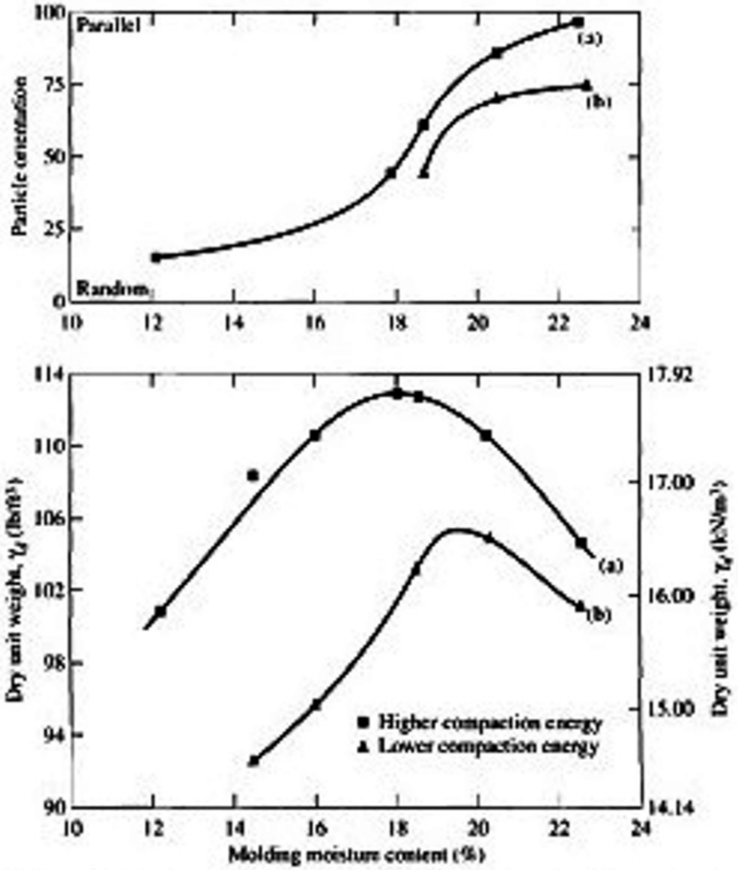


In the field
increasing compaction energy
= increasing number of
passes or reducing lift depth

♦ ***Structure of Compacted Clay Soil***



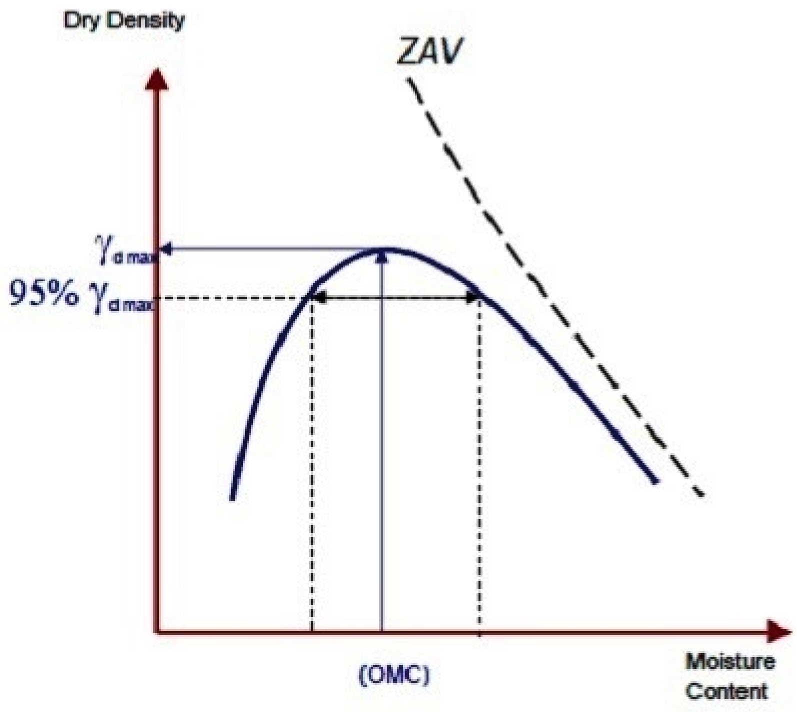
Effect of compaction on structure of clay soils (redrawn after Lambe, 1958)



Orientation against moisture content for Boston blue clay (after Lambe, 1958)

♦ ***Field Compaction***

Because of the differences between lab and field compaction methods, the maximum dry density in the field may reach 90% to 95%.



1- Rammers

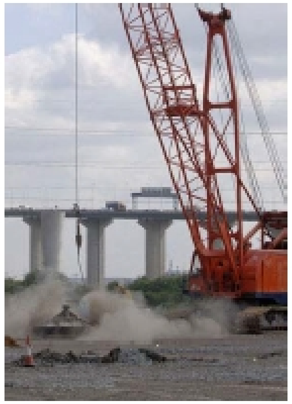
2- Vibratory Plates

3- Smooth Rollers

4- Rubber-Tire

5- Sheep foot Roller

6- Dynamic Compaction



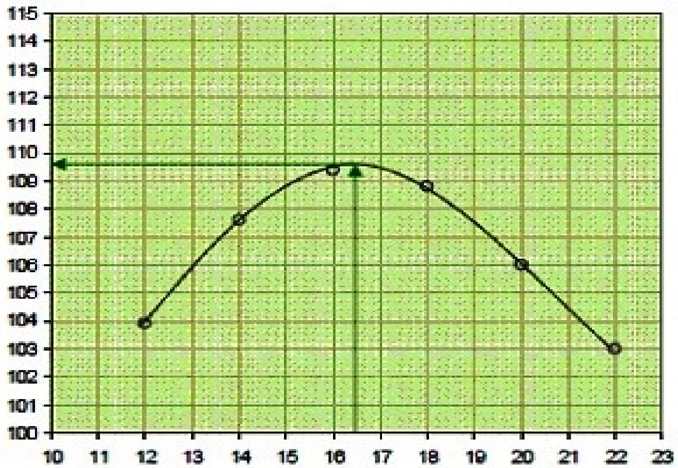
Example:

The laboratory test for a standard proctor is shown below. Determine the optimum water content and maximum dry density. If the G_s of the soil is **2.70**, draw the ZAV curve.

Volume of Proctor Mold (ft³)	Weight of wet soil in the mold (lb)	Water Content (%)
1/30	3.88	12
1/30	4.09	14
1/30	4.23	16
1/30	4.28	18
1/30	4.24	20
1/30	4.19	22

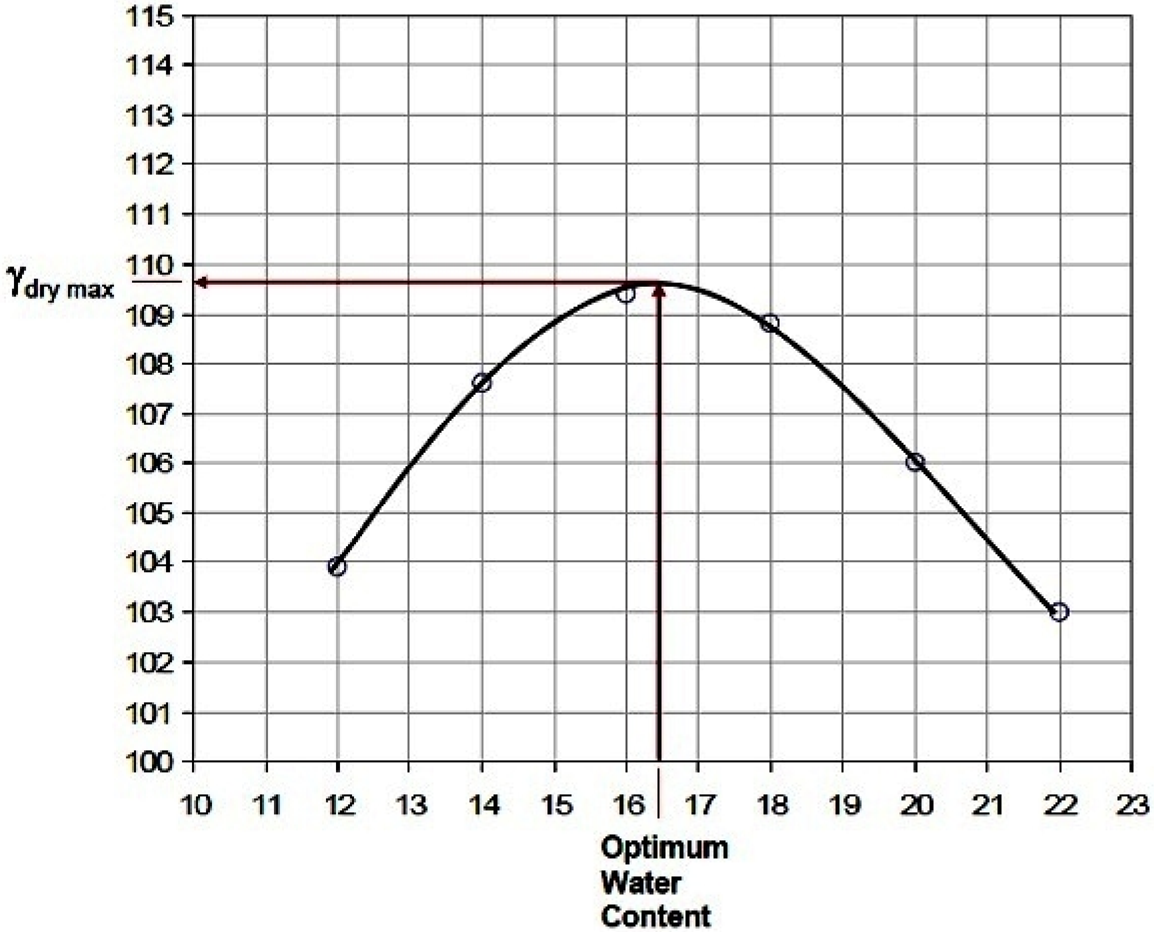
Solution:

Volume of Mold (ft³)	Weight of wet soil in the mold (lb)	Wet Unit Weight (lb/ft³)	Water Content (%)	Dry Unit Weight (lb/ft³)
1/30	3.88	116.4	12	103.9
1/30	4.09	122.7	14	107.6
1/30	4.23	126.9	16	109.4
1/30	4.28	128.4	18	108.8
1/30	4.24	127.2	20	106.0
1/30	4.19	125.7	22	103.0



$$\gamma_{dry} = \frac{\gamma_{wet}}{1 + \frac{W_c\%}{100}}$$

$$\gamma_{ZAV} = \frac{G_s \gamma_w}{1 + \frac{W_c G_s}{S_r}}$$


115
114
113
112
111
110
$\gamma_{dry\ max}$
109
108
107
106
105
104
103
102
101
100
10 11 12 13 14 15 16 17 18 19 20 21 22 23
Optimum
Water
Content

♦ ***Specification for Field Compaction***

Compaction performance parameters are given on a construction project in one of two ways:

1- Method Specification

detailed instructions specify machine type, lift depths, number of passes, machine speed and moisture content. A "recipe" is given as part of the job specifications to accomplish the compaction needed.

2- End-result Specification

Only final compaction requirements are specified (95% modified or standard Proctor). This method, gives the contractor much more flexibility in determining the best, most economical method of meeting the required specs.

RELATIVE DESIRABILITY OF SOILS AS COMPACTED FILL

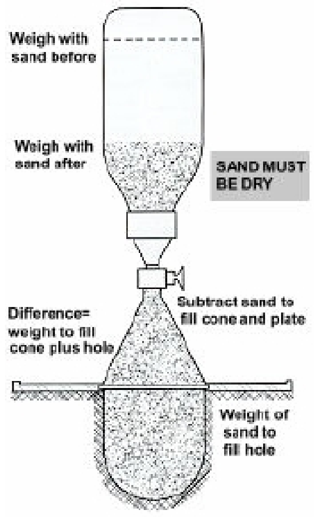
* if gravelly
** erosion critical
*** volume change critical
\- not appropriate for this type of use

			Relative Desirability for Various Uses (1=best; 14=least desirability)									
			Rolled Earth Fill Dams			Canal Sections		Foundations		Roadways		
										Fills		
Group Symbol		Soil Type	Homogeneous Embankment	Core	Shell	Erosion Resistance	Compacted Earth Lining	Seepage Important	Seepage Not Important	Frost Heave Not Possible	Frost Heave Possible	Surfacing
GRAVELS	GW	Well-graded gravels, gravel/ sand mixes, little or no fines	-	-	1	1	-	-	1	1	1	3
GRAVELS	GP sand	Poorly-graded gravels, gravel/ mixtures, little or no fines	-	-	2	2	-	-	3	3	3	-
GRAVELS	GM	Silty gravels, poorly-graded gravel/sand/silt mixtures	2	4	-	4	4	1	4	4	9	5
GRAVELS	GC	Clay-like gravels, poorly graded gravel/sand/clay mixtures	1	1	-	3	1	2	6	5	5	1
SANDS	SW	Well-graded sands, gravelly sands, little or no fines	-	-	3*	6	-	-	2	2	2	4
SANDS	SP	Poorly-graded sands, gravelly sands, little or no fines	-	-	4*	7*	-	-	5	6	4	-
SANDS	SM	Silty sands, poorly-graded sand/ silt mixtures	4	5	-	8*	5**	3	7	6	10	6
SANDS	SC	Clay-like sands, poorly-graded sand/clay mixtures	3	2	-	5	2	4	8	7	6	2
CLAYS & SILTS — LEAN	ML	Inorganic silts and very fine sands, rock flour, silty or clay-like fine sands with slight plasticity	6	5	-	-	6**	6	9	10	11	-
CLAYS & SILTS — LEAN	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	5	3	-	9	3	5	10	9	7	7
CLAYS & SILTS — LEAN	OL	Organic silts and organic silt-clays of low plasticity	8	8	-	-	7**	7	11	11	12	-
CLAYS & SILTS — FAT	MN	Organic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	9	9	-	-	-	8	12	12	13	-
CLAYS & SILTS — FAT	CH	Inorganic clays of high plasticity, fat clays	7	7	-	10	8**	9	13	13	8	-
CLAYS & SILTS — FAT	OH	Organic clays of medium high plasticity	10	10	-	-	-	10	14	14	14	-

♦ ***Determination of Field Unit Weight of Compaction***

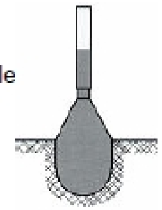
1- Sand Cone (ASTM D1556-90)

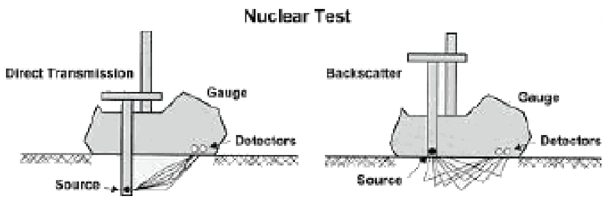
A small hole (6" x 6" deep) is dug in the compacted material to be tested. The soil is removed and weighed, then dried and weighed again to determine its moisture content. A soil's moisture is figured as a percentage. The specific volume of the hole is determined by filling it with calibrated dry sand from a jar and cone device. The dry weight of the soil removed is divided by the volume of sand needed to fill the hole. This gives us the density of the compacted soil in lbs per cubic foot. This density is compared to the maximum Proctor density obtained earlier, which gives us the relative density of the soil that was just compacted.



2- Balloon Dens meter

The same as the sand cone, except a rubber balloon is used to determine the volume of the hole





Nuclear Density

Sand Cone

3- Nuclear Density (ASTM D2292-91)

Nuclear Density meters are a quick and fairly accurate way of determining density and moisture content. The meter uses a radioactive isotope source (Cesium 137) at the soil surface (backscatter) or from a probe placed into the soil (direct transmission). The isotope source gives off photons (usually Gamma rays) which radiate back to the mater's detectors on the bottom of the unit. Dense soil absorbs more radiation than loose soil and the readings reflect overall density. Water content (ASTM D3017) can also be read, all within a few minutes.