PAVEMENT MATERIALS

Lecture 7

Sequence

- SUBGRADE

- Investigation
- Material Classification/Identification
- Material Evaluation
- Material Selection
- Construction of Subgrade
- QA/QC
- Post Construction Investigation

Subgrade Construction

- <u>**Sequence**</u>

- **Construction Principles**
- **Construction Equipment**
- **Construction Processes**

Subgrade Construction

- <u>**Sequence**</u>

- **What is SUBGRADE Construction ?**
- **Compaction**
  - **Objectives**
  - **Factors**
  - **Mechanism**
  - **Created Fabric and Structure**
  - **Effect on Engineering Properties**
    - **Strength**
    - **Stiffness**
    - **Stability**

Subgrade Construction

- 1. Establishment of Grade Line
  - Natural Ground (Cut)
  - Embankment (Fill)
- 2. Compaction

Subgrade Construction

- <u>**1. Establishment of Grade Line**</u>
- The subgrade line should be established
  - to obtain the optimum natural support for the pavement
  - consistent with economic utilization of available materials
  - traffic requirements
- <u>**a . Balancing Cut and Fill:**</u> Optimizing subgrade support and drainage should take precedence over balancing cut and fill.
- <u>**b . Ground Water:**</u> The subgrade line will be above the flood plain and a minimum of 2 feet above wet season ground water level . Where not practicable, provide for permanent lowering of water table by drainage.
- <u>**c . Rock:**</u> Rock excavation is to be avoided for economic reasons . Where excavation of rock is unavoidable, undercut to provide for full depth of base course under surface courses .

Subgrade Construction

- **2. COMPACTION**

- **PURPOSE:**
- In engineering practice the soils at a given site do not often meet the ideal requirements or the intended purpose.
- They may be weak, highly compressible, or have a higher/lower permeability than desirable from an engineering or economic point of view.
- It would seem reasonable in such instances to simply relocate the structure or facility. However, considerations other than geotechnical often govern the location of a structure, and the engineer is forced to design for the site at hand.
- One possibility is to adapt and design according to the geotechnical conditions at the site.

Subgrade Construction

- **2. COMPACTION**

- **PURPOSE:**
- Another possibility is to try to stabilize or improve the engineering properties of the soils at the site. Depending on the circumstances, this second approach may be the most economical solution to the problem.

Subgrade Construction

- Stabilization Methods are generally classified as:

- **Mechanical** ← **COMPACTION**
- **Physical**
- **Chemical**
- **Thermal**
- **Electrical**

Equipment Required

Clearing & Grubbing	Tractor Dozer, Rooter/Ripper
Excavation	Shovels, Dozers, Draglines, Scrapers
Transportation	Scrapers, Trucks, Dumpers
Spreading	Grader, Dozer
Watering	Tankers, Sprinklers
Compaction	Rollers of Different Types

Compaction

- **Objectives of Compaction**

- **Detrimental settlements can be reduced or prevented.**

- **Soil strength increases and slope stability can be improved.**

- **Bearing capacity of pavement subgrades can be improved.**

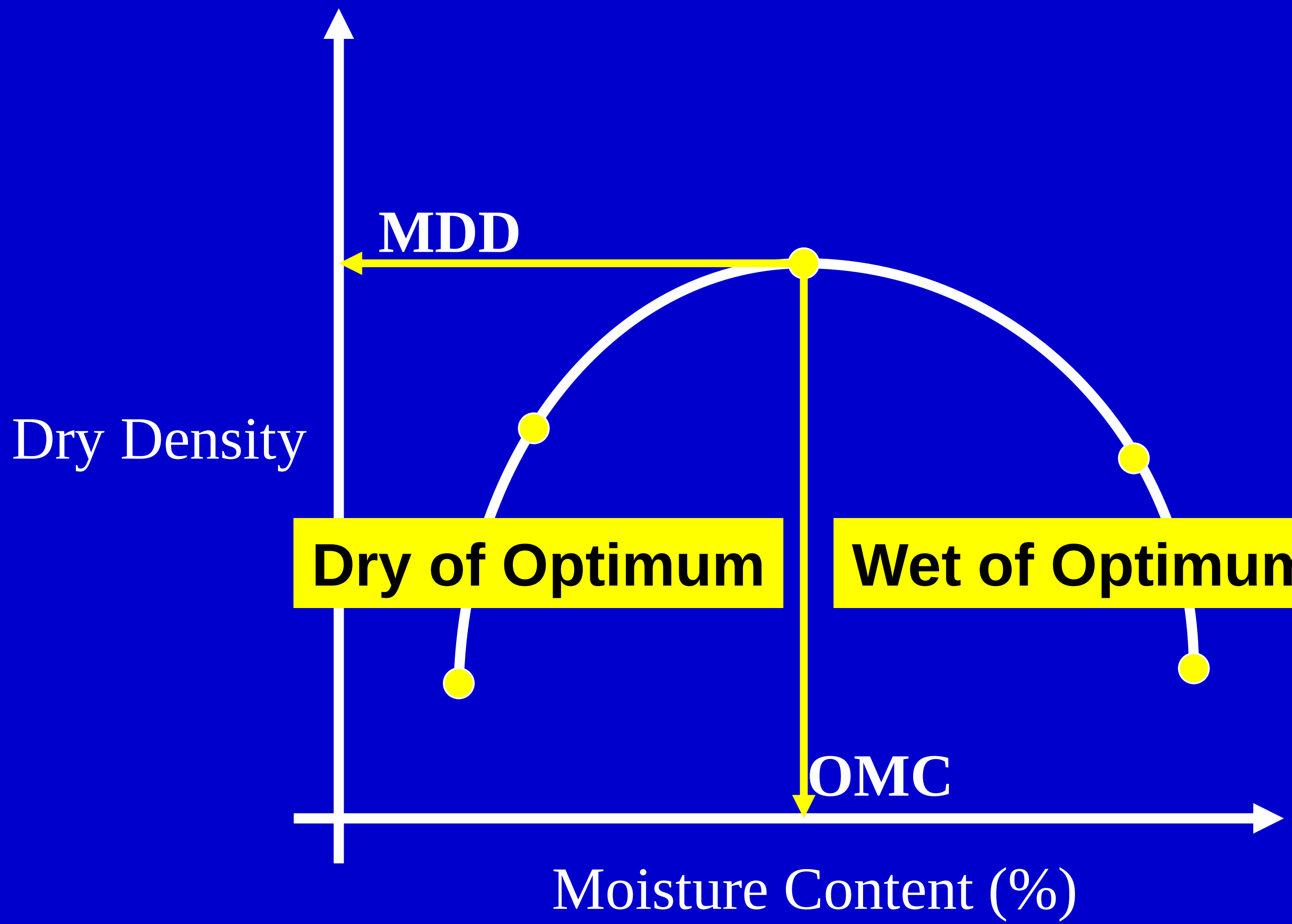
- **Undesirable volume changes, for example, caused by frost action, swelling, and shrinkage may be controlled.**

Compaction

- **Compaction is a function of four variables:**

- **Dry Density**
- **Water Content**
- **Compactive Effort/Type**
- **Soil Type**
  - ***gradation, presence of clay minerals, etc.***

PROCTOR Compaction Test



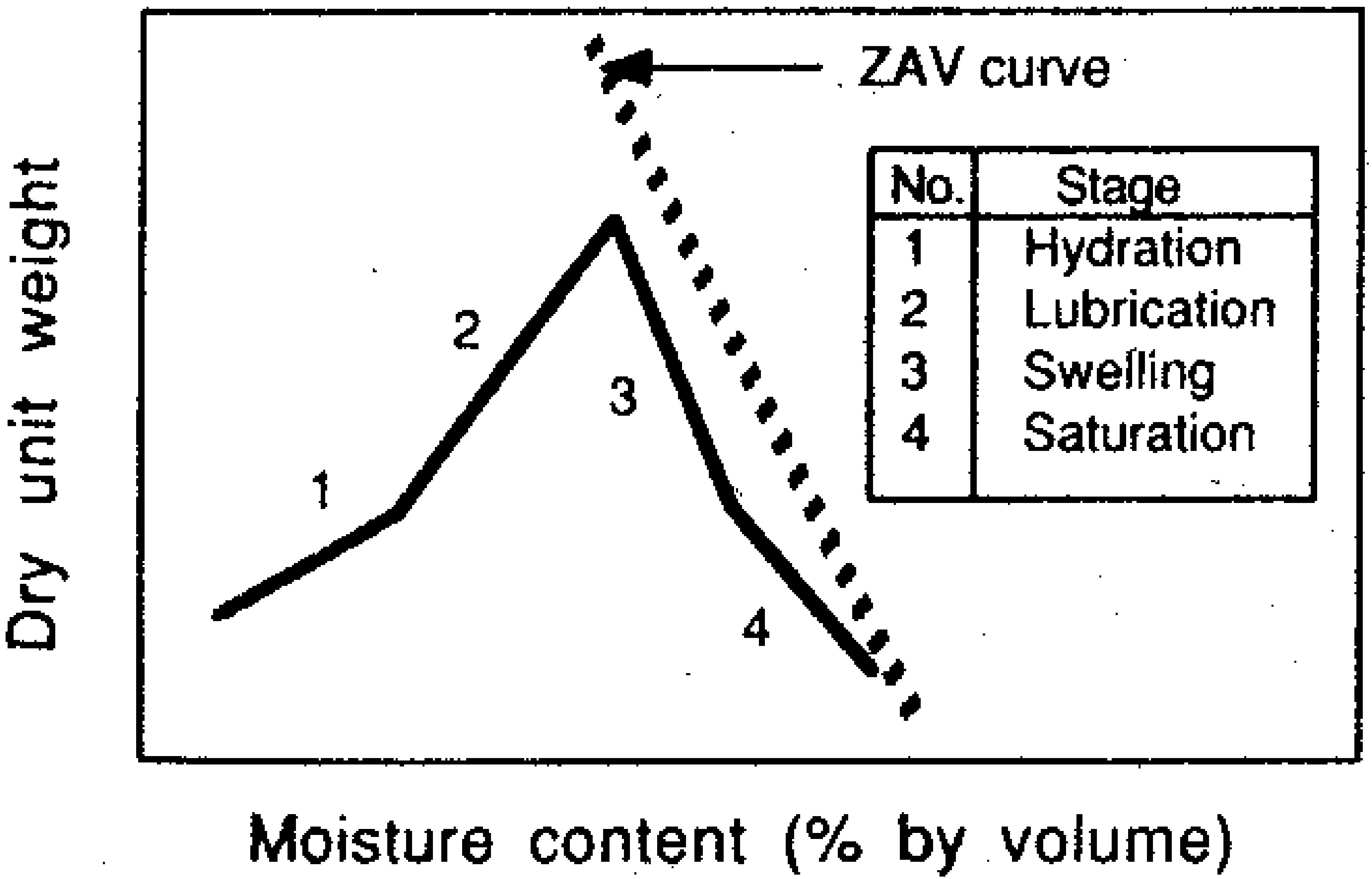
PROCTOR Compaction Test

- **MECHANISM**

- **Soil Failure ?**
- Starting at low water contents, as the water content increases, the particles develop larger and larger water films around them, which tend to "lubricate" the particles and make them easier to be moved about and reoriented into a denser configuration.
- However we eventually reach a water content where the density does not increase any further.
- At this point, water starts to replace soil particles in the mold, and the dry density curve starts to fall off.

- ***No matter how much water is added, the soil never becomes completely saturated by compaction.***

PROCTOR Compaction Test



PROCTOR Compaction Test

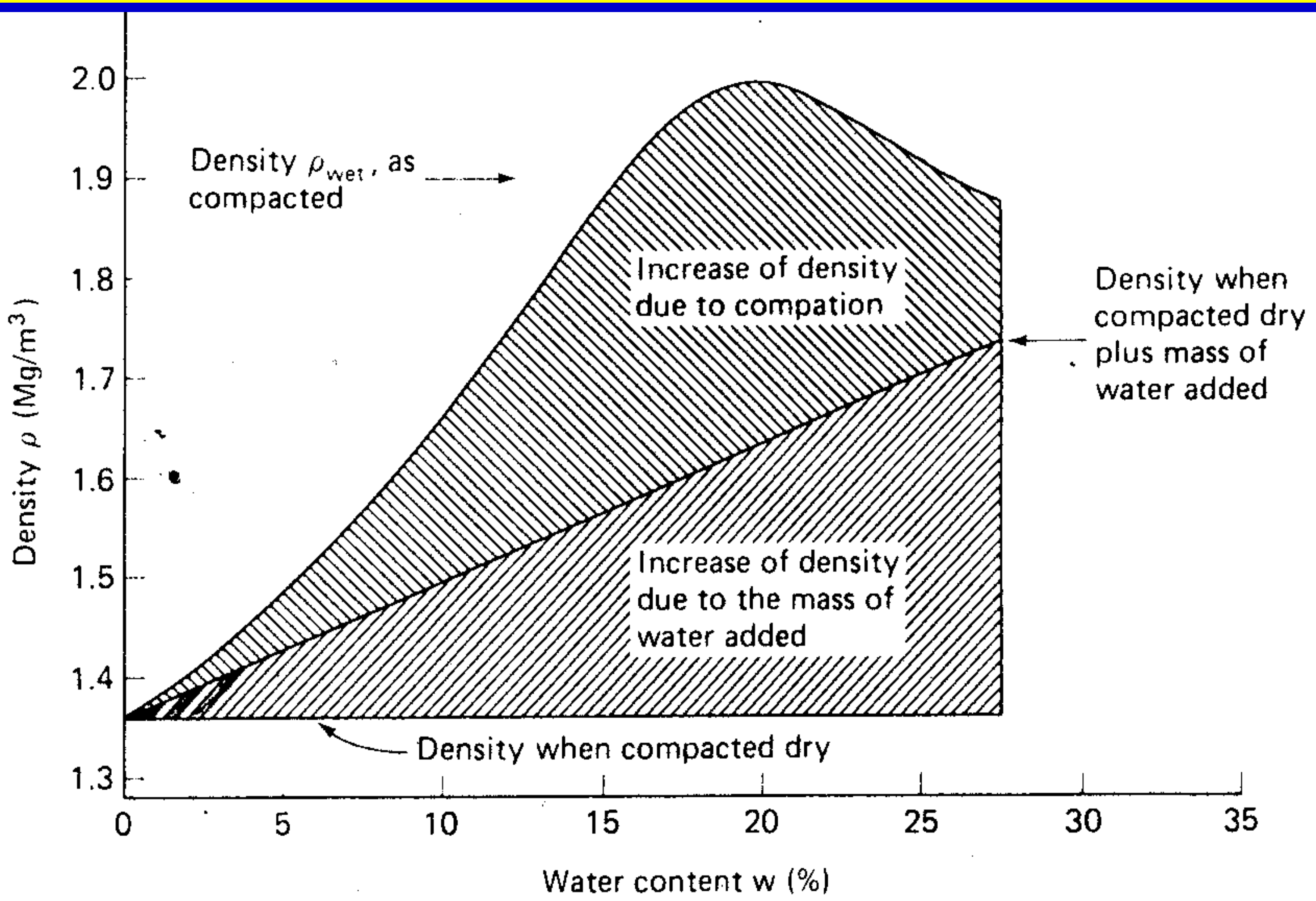


Fig. 5.3 The water content-density relationship indicating the increased density resulting from the addition of water and that due to the applied compaction effort. Soil is a silty clay, LL = 37, PI = 14, standard Proctor compaction (after Johnson and Sallberg, 1960).

PROCTOR Compaction Test

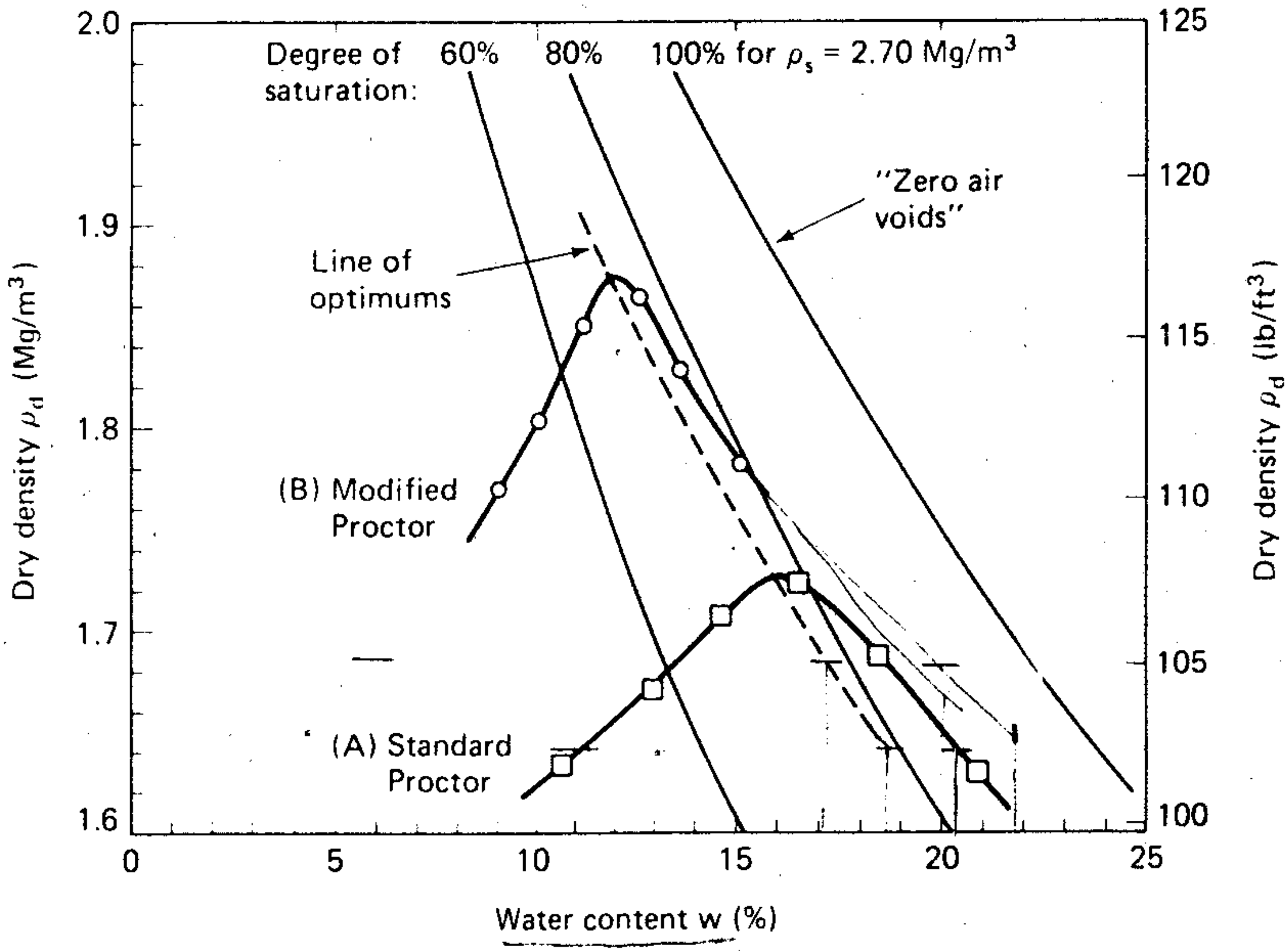


Fig. 5.1 Standard and modified Proctor compaction curves for Crosby B till.

PROCTOR Compaction Test

Soil texture and plasticity data

No.	Description	Sand	Silt	Clay	LL	PI
1	Well-graded loamy sand	88	10	2	16	N.P.
2	Well-graded sandy loam	72	15	13	16	N.P.
3	Med-graded sandy loam	73	9	18	22	4
4	Lean sandy silty clay	32	33	35	28	9
5	Lean silty clay	5	64	31	36	15
6	Loessial silt	5	85	10	26	2
7	Heavy clay	6	22	72	67	40
8	Poorly graded sand	94	— 6 —		N.P.	—

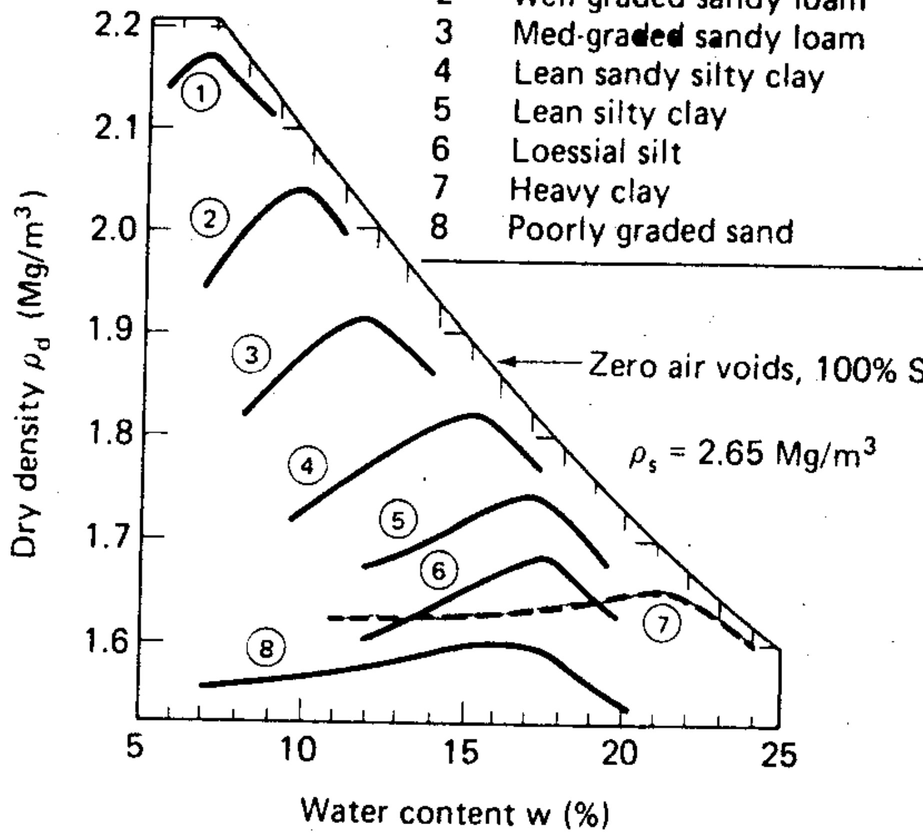


Fig. 5.2 Water content-dry density relationships for eight soils compacted according to the standard Proctor method (after Johnson and Sallberg, 1960).

PROCTOR Compaction Test

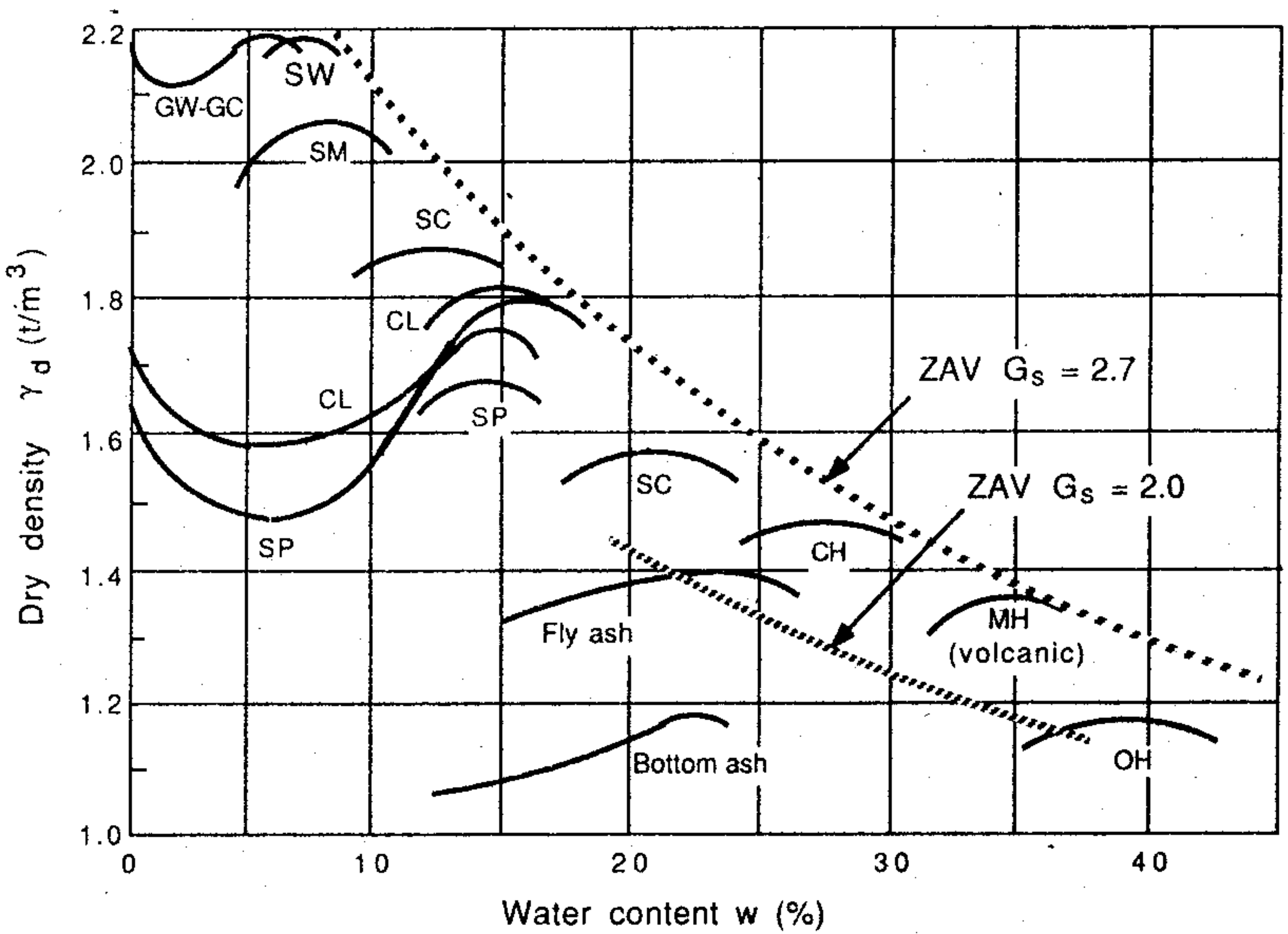


FIGURE 3.7
Arbitrarily selected examples of laboratory test results.

PROCTOR Compaction Test

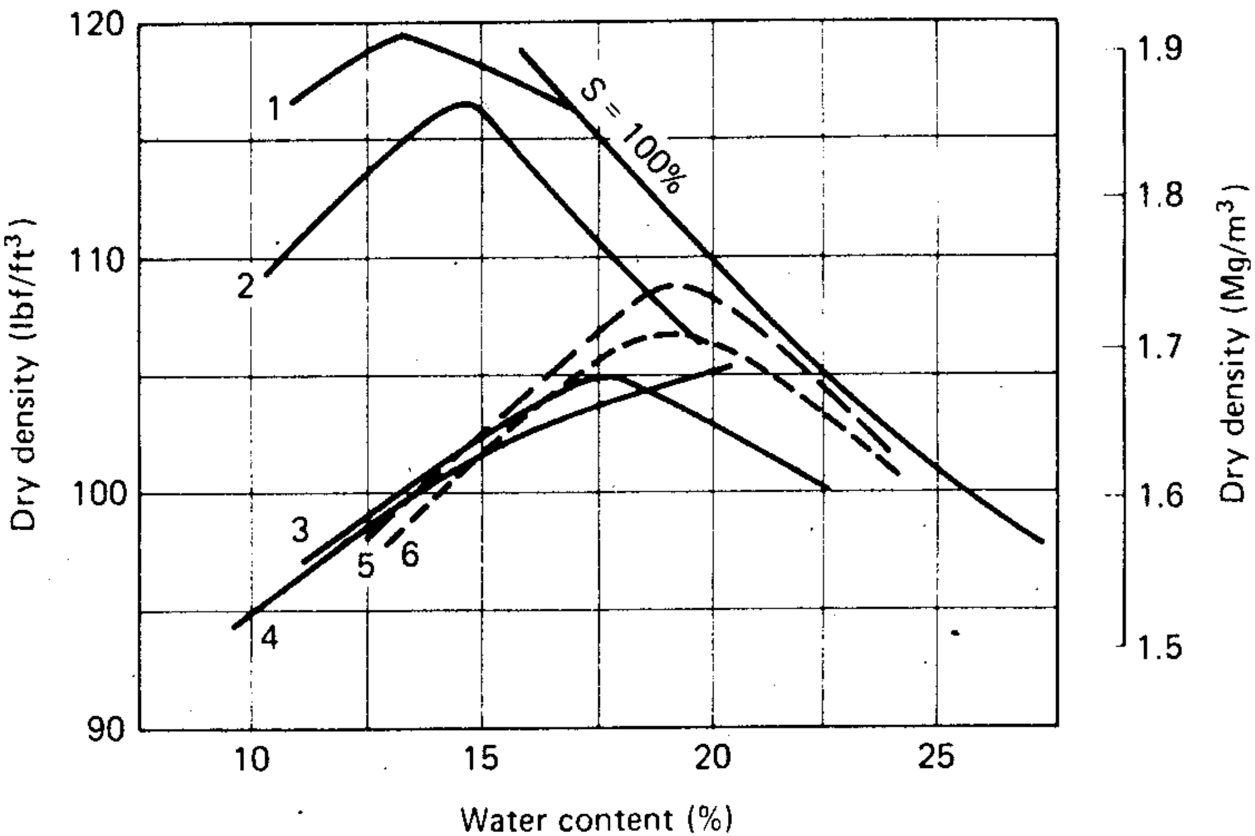


Fig. 5.4 Comparison of field and laboratory compaction. (1) Laboratory static compaction, 2000 psi; (2) modified Proctor; (3) standard Proctor; (4) laboratory static compaction, 200 psi; (5) field compaction, rubber-tired load, 6 coverages; (6) field compaction, sheepsfoot roller, 6 passes. Note: Static compaction from top and bottom of soil sample. (After Turnbull, 1950, and as cited by Lambe and Whitman, 1969.)

PROCTOR Compaction Test

- Properties and Structure of Compacted Soils

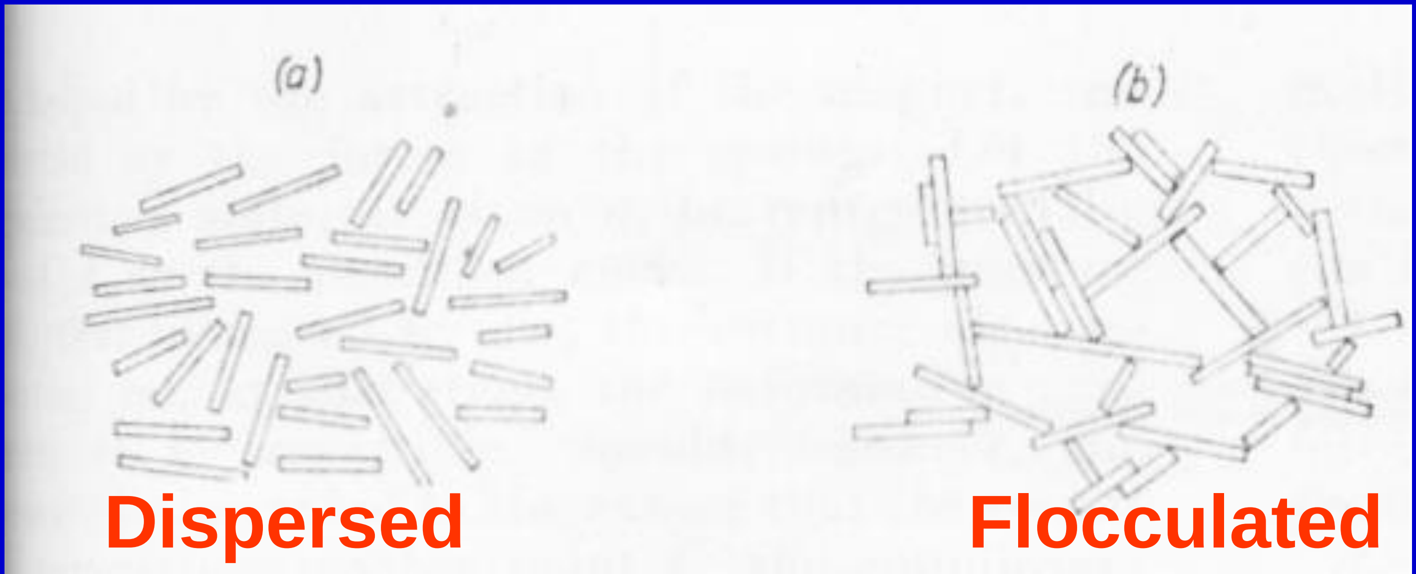
- Usually the water content of compacted soils is referenced to the optimum water content for a given type of compaction, depending on their position, soils are called

- **dry of optimum,**
- **near or at optimum, or**
- **wet of optimum.**

PROCTOR Compaction Test

- Properties and Structure of Compacted Soils

- ***Dry of optimum** the soils are always flocculated,*
- ***Wet of optimum** the fabric becomes more oriented or dispersed.*
- ***At the same compactive effort, with increasing water content, the soil fabric becomes increasingly oriented.***



Effect on Structure

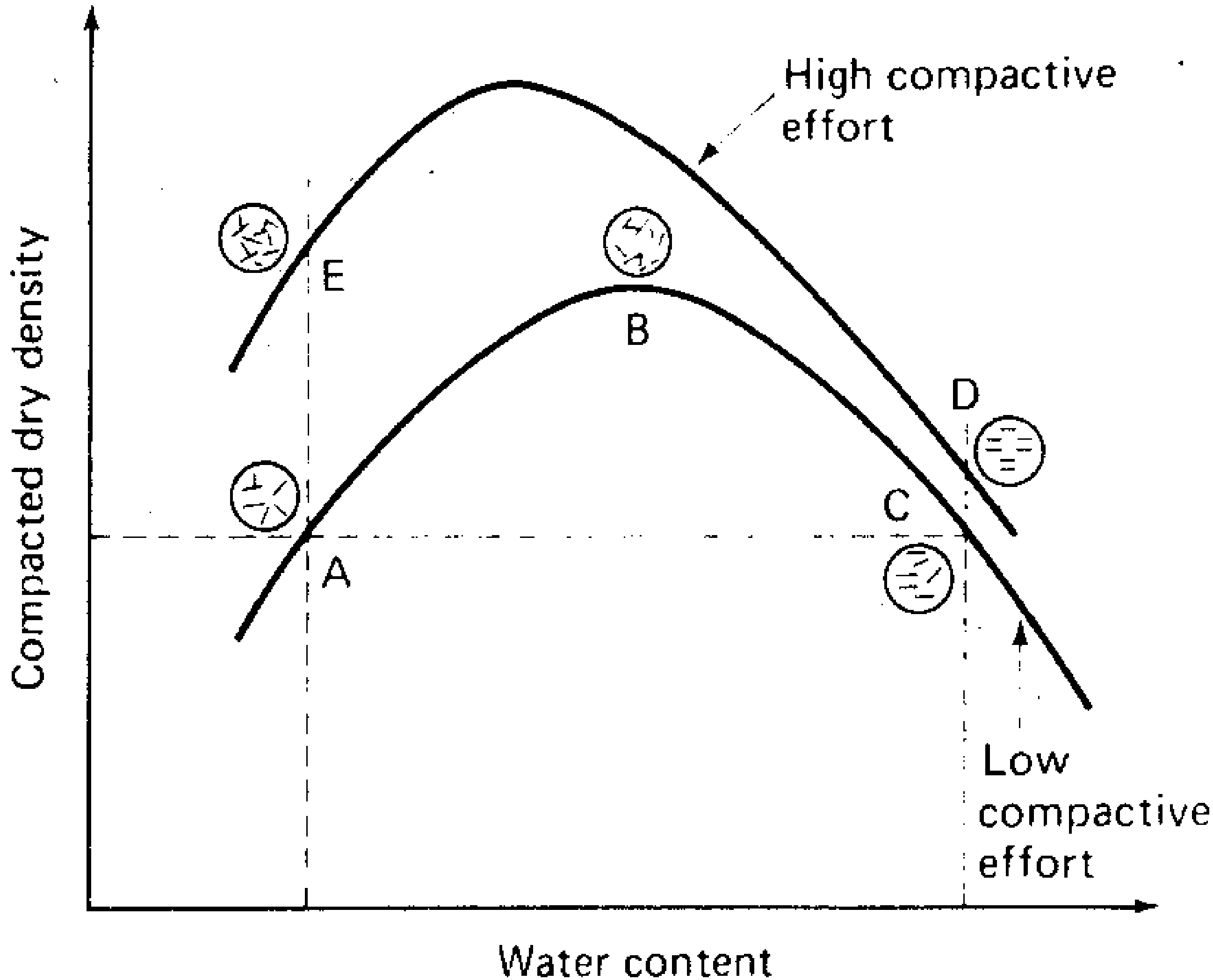


Fig. 5.5 Effect of compaction on soil structure (after Lambe, 1958a).

STRUCTURE of COMPACTED SOILS

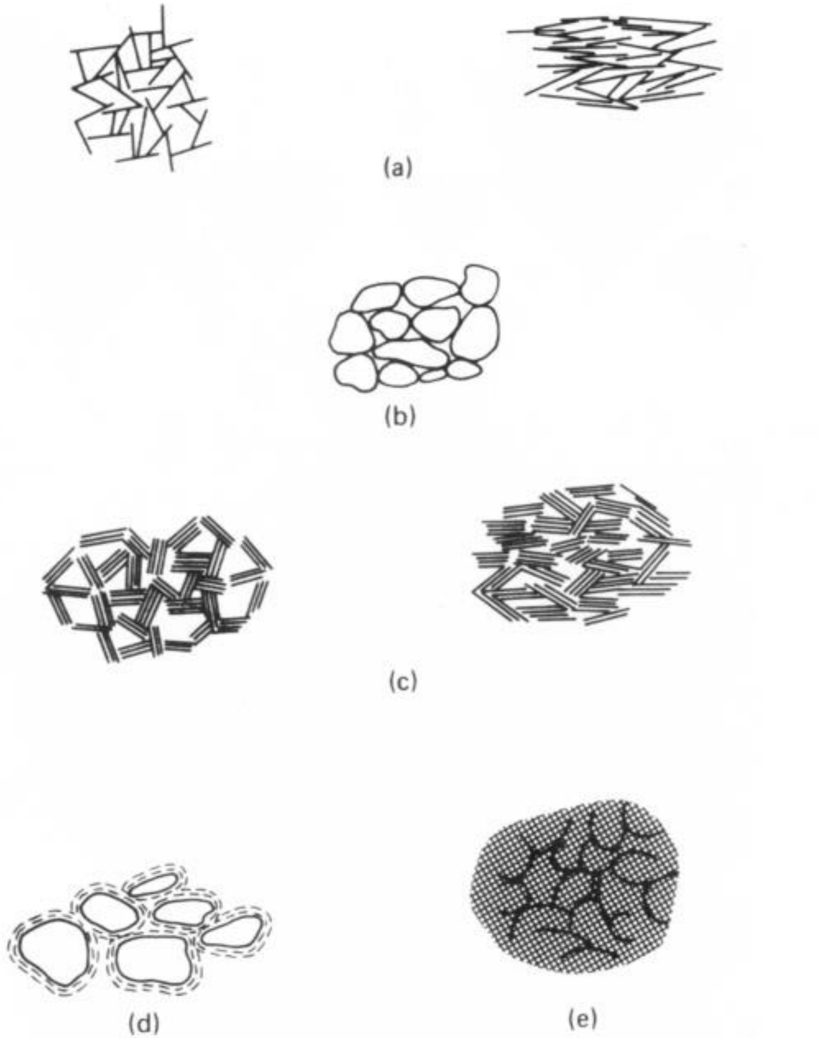
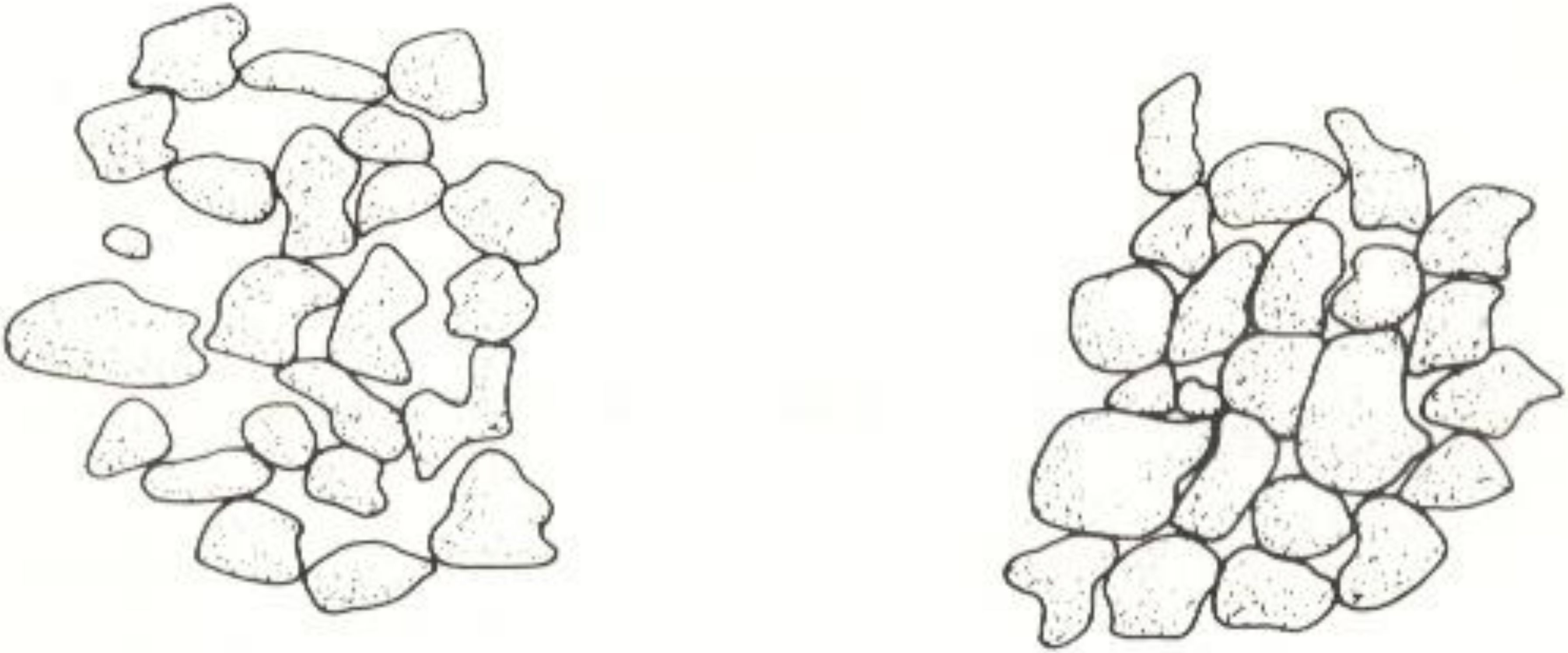


Fig. 4.20 Schematic representations of elementary particle arrangements: (a) individual clay platelet interaction; (b) individual silt or sand particle interaction; (c) clay platelet group interaction; (d) clothed silt or sand particle interaction; (e) partly discernible particle interaction (after Collins and McGown, 1974).

STRUCTURE of COMPACTED SOILS



(a) Loose

(b) Dense

Fig. 4.24 Single grained soil structures.

Effect on Engineering Properties

- Strength
- Compressibility
- Stability
  - Swelling
  - Permeability

Effect on Strength

- The strength of compacted clays is rather complex.
- Samples compacted dry of optimum have higher strengths than those compacted wet of optimum.
- The strength wet of optimum also depends somewhat on the type of compaction because of differences in soil structure.
- If the samples are soaked, the picture changes ?
- CBR ?

Effect on CBR

- CBR ?

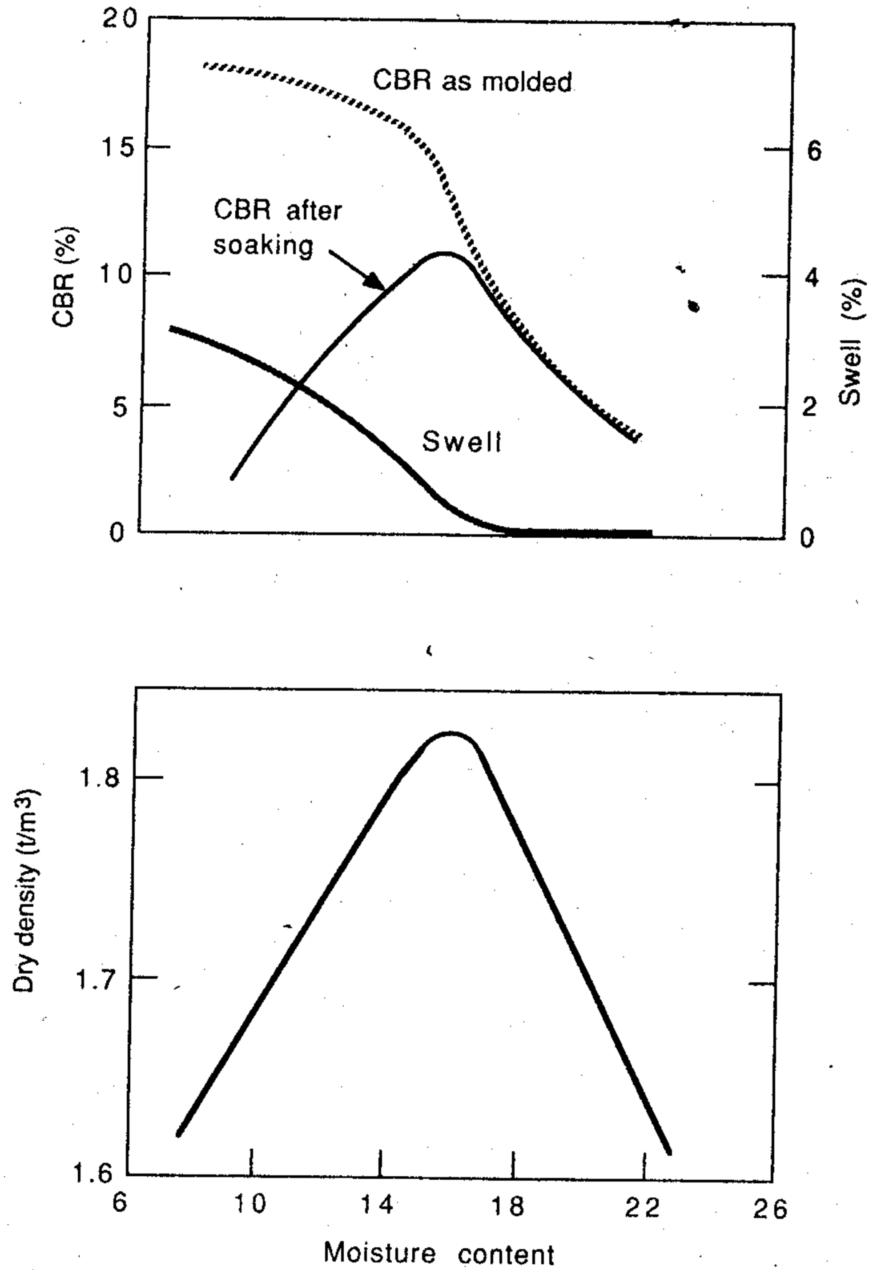


FIGURE 4.2
Density and CBR as a function of initial water content for a typical silty clay (CL). [*After Yoder (1959). Copyright John Wiley & Sons.*]

Effect on CBR

- CBR ?

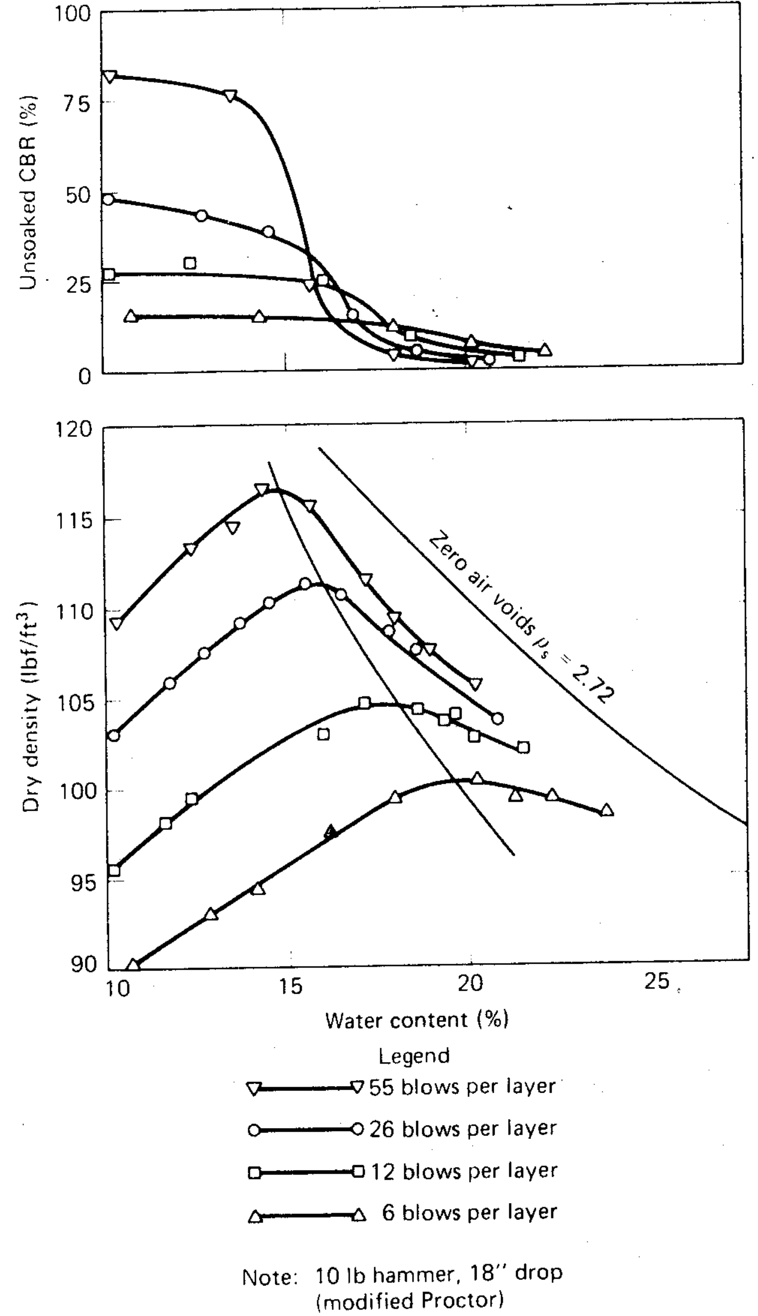


Fig. 5.8 Strength as measured by the CBR and the dry density versus water content for laboratory impact compaction (after Turnbull and Foster, 1956).

Effect on Compressibility

- Compressibility of compacted clays is a function of the stress level imposed on the soil mass. At relatively, low stress levels, clays compacted wet of optimum are more compressible.

- At high stress levels, the opposite is true. In Fig. it can be seen that a larger change in void ratio (a decrease) takes place in the soil compacted wet of optimum for a given change (increase) in applied pressure.

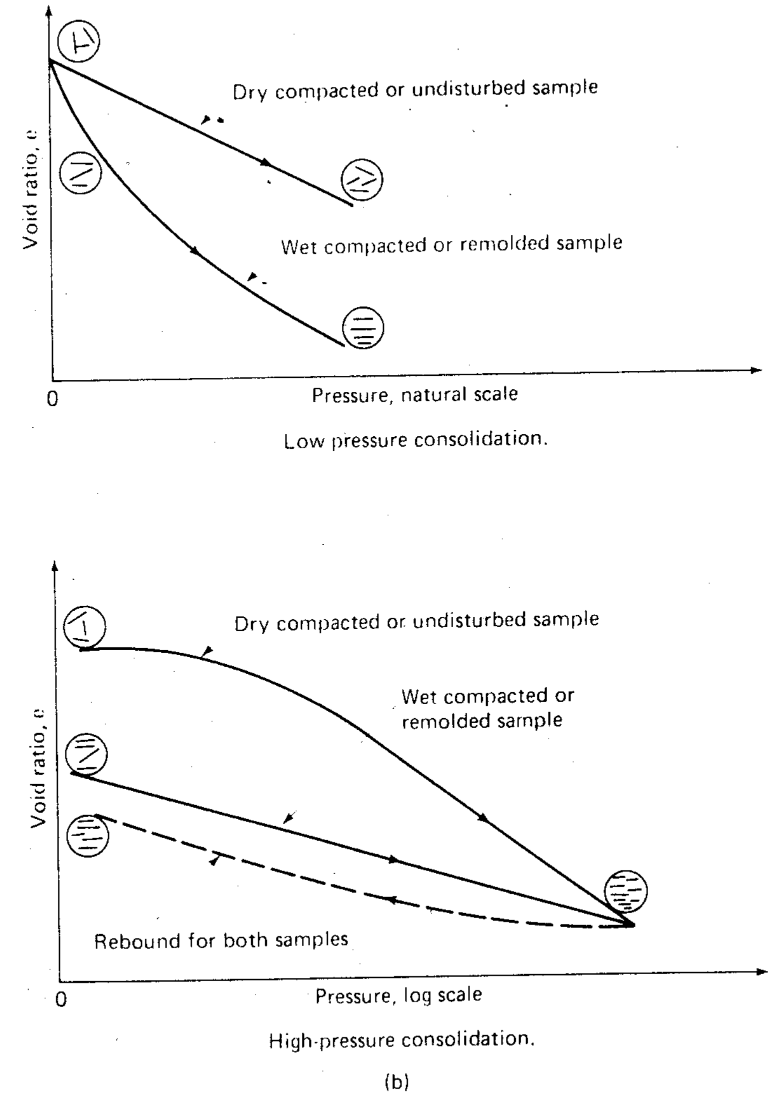


Fig. 5.6(b) Change in compressibility with molding water content (after Lambe, 1958b).

Effect on Swelling

- Swelling of compacted clays is greater for those compacted dry of optimum. They have a relatively greater deficiency of water and therefore have a greater tendency to adsorb water and thus swell more. Soils dry of optimum are in general more sensitive to environmental changes such as changes in water content.

- This is just the opposite for shrinkage as shown in Fig., where samples compacted wet of optimum have the highest shrinkage. Also illustrated in the upper part of this figure is the effect of different methods of compacting the samples.

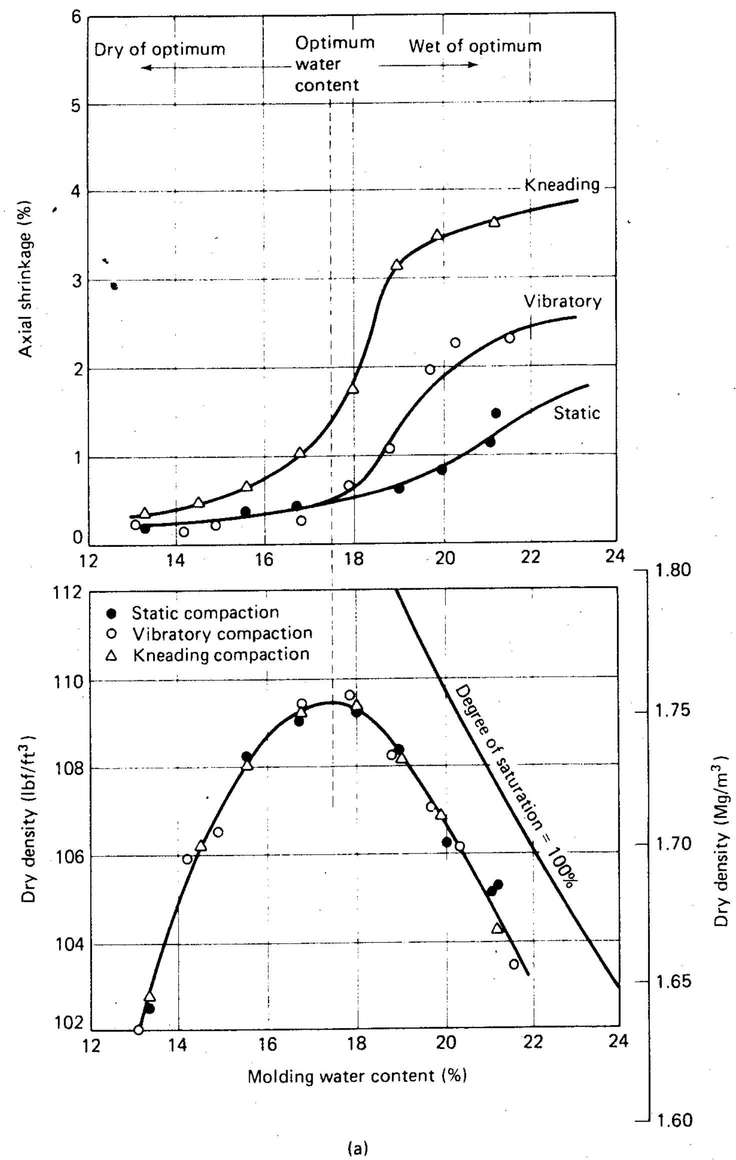
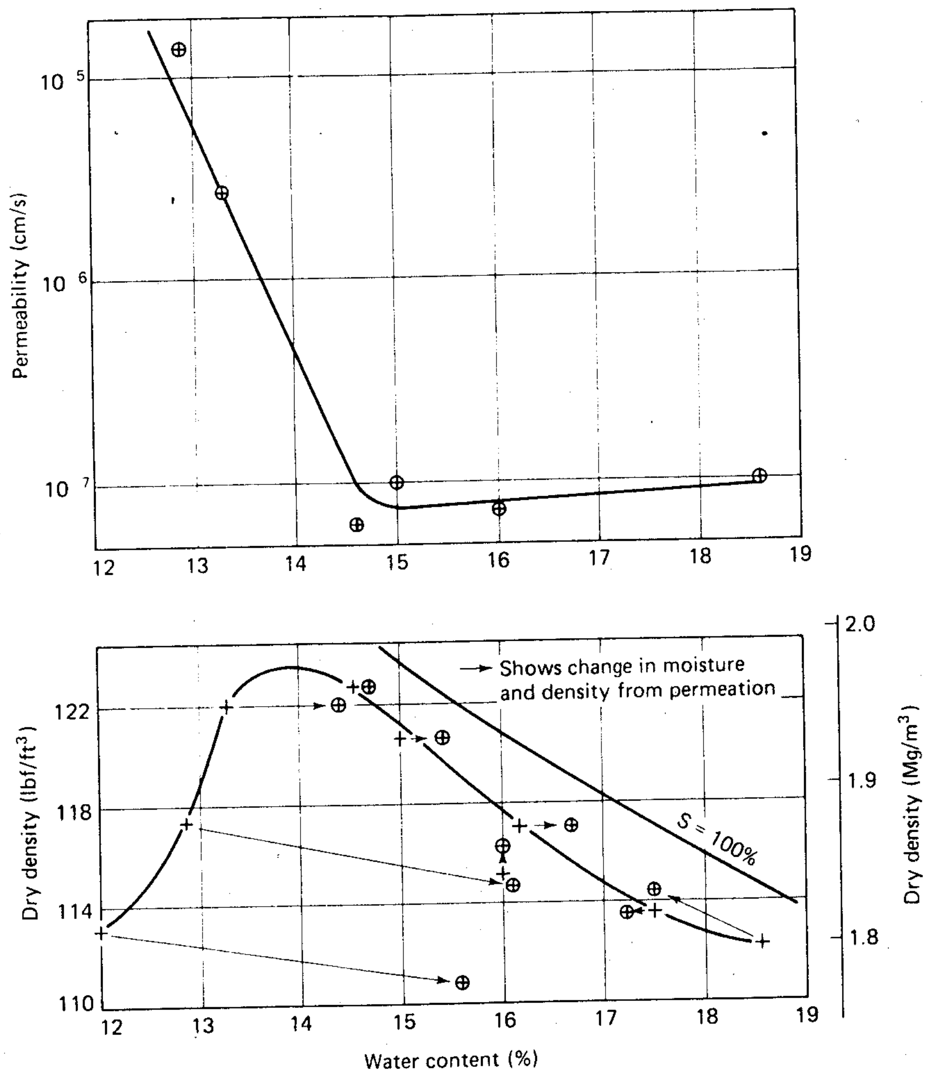


Fig. 5.7(a) Shrinkage as a function of water content and type of compaction (after Seed and Chan, 1959).

Effect on Permeability

- Permeability at constant compactive effort decreases with increasing water content and reaches a minimum at about the optimum. If the compactive effort is increased, the coefficient of permeability decreases because the void ratio decreases (increasing dry unit weight).
- In Fig., where it can be seen that the permeability is about an order of magnitude higher when this soil is compacted dry of optimum than when it is compacted wet of optimum.
- After Permeation?



(a) Compaction-permeability tests on Jamaica sandy clay.

Fig. 5.6(a) Change in permeability with molding water content (after Lambe, 1958b).

TABLE 5-1 Comparison of Soil Properties between Dry of Optimum and Wet of Optimum Compaction*

Property	Comparison
1. Structure:	
A. Particle arrangement	Dry side more random
B. Water deficiency	Dry side more deficient; thus imbibes more water, swells more, has lower pore pressure
C. Permanence	Dry side structure sensitive to change
2. Permeability:	
A. Magnitude	Dry side more permeable
B. Permanence	Dry side permeability reduced much more by permeation
3. Compressibility:	
A. Magnitude	Wet side more compressible in low pressure range, dry side in high pressure range
B. Rate	Dry side consolidates more rapidly
4. Strength:	
A. As molded:	
(a) Undrained	Dry side much higher
(b) Drained	Dry side somewhat higher
B. After saturation:	
(a) Undrained	Dry side somewhat higher if swelling prevented; wet side can be higher if swelling permitted
(b) Drained	Dry side about the same or slightly greater
C. Pore water pressure at failure	Wet side higher
D. Stress-strain modulus	Dry side much greater
E. Sensitivity	Dry side more apt to be sensitive

*After Lambe (1958b).

Thank You