GEO TECHNICAL ENGINEERING

DIPLOMA WALLAH

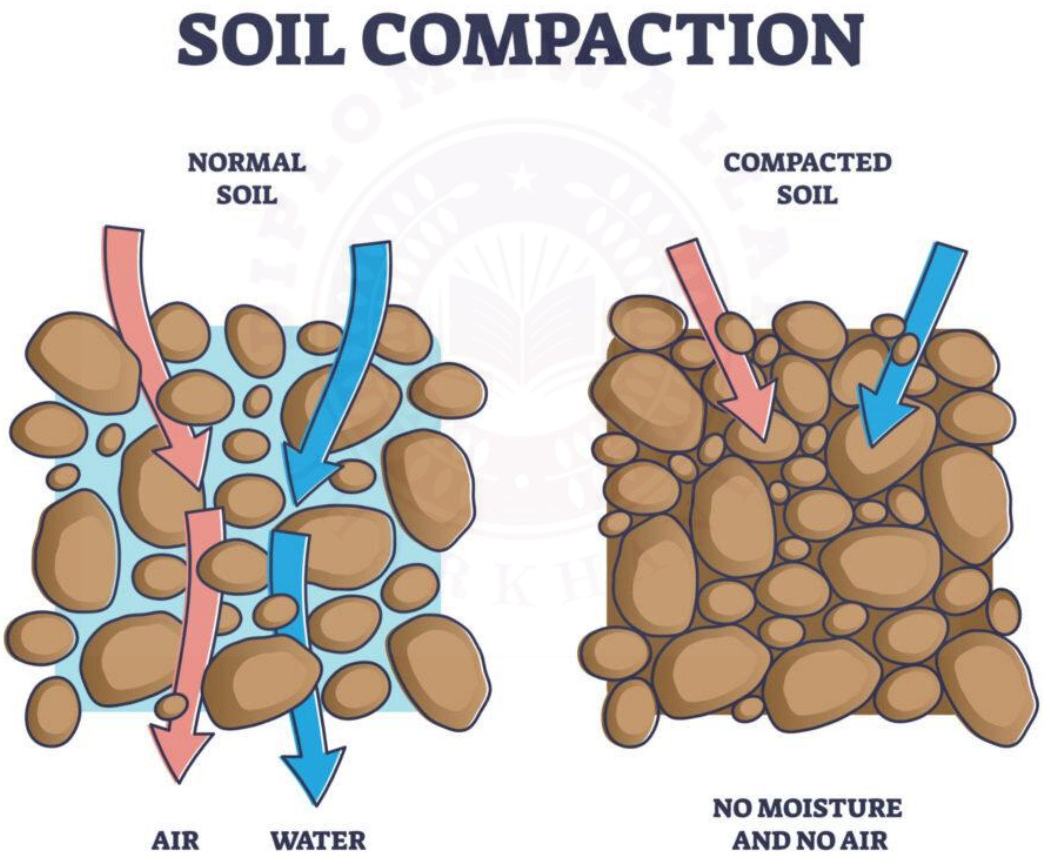
CIVIL

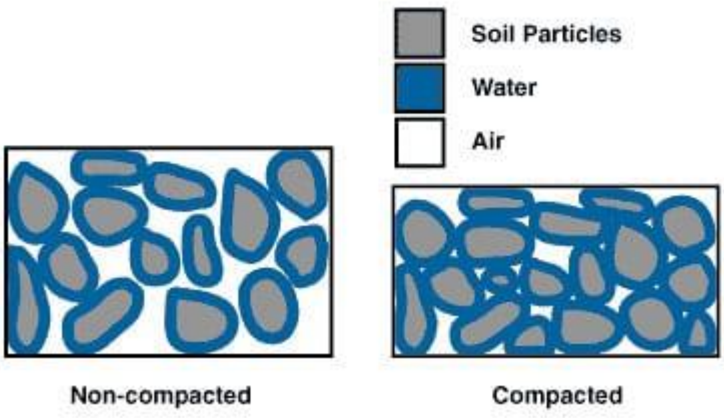
Jharkhand University Of Technology (JUT)

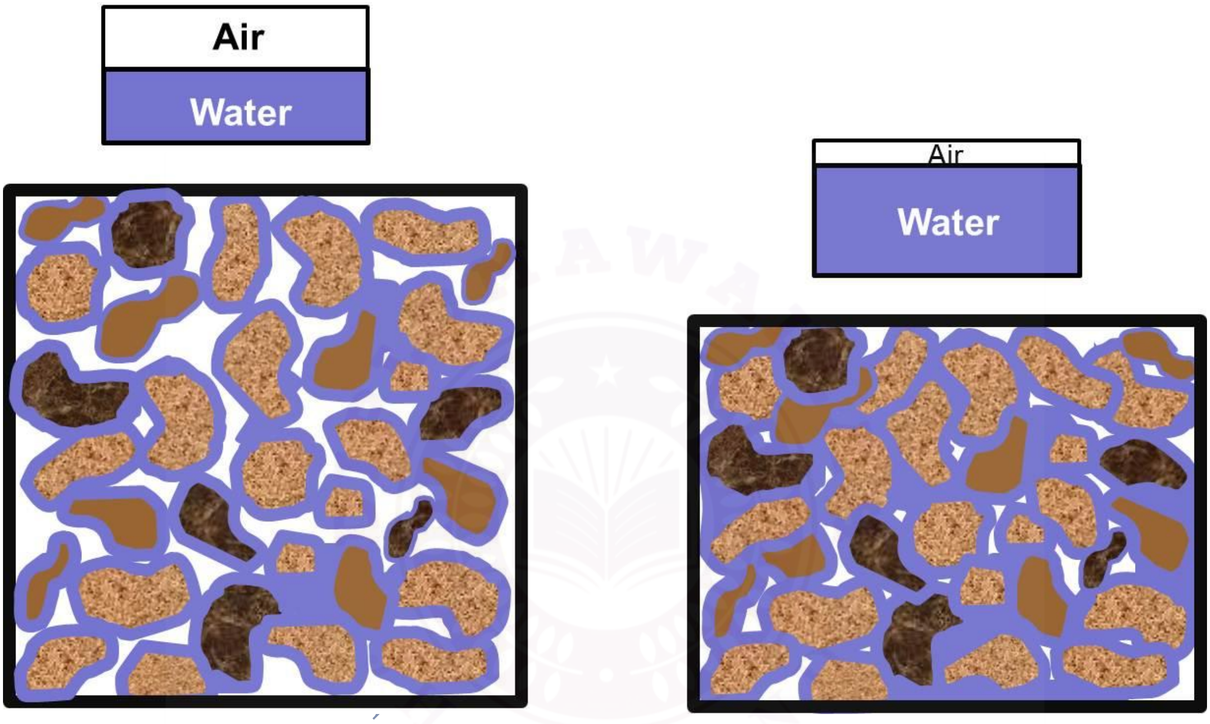
Unit - IV Compaction and Stabilization of soil

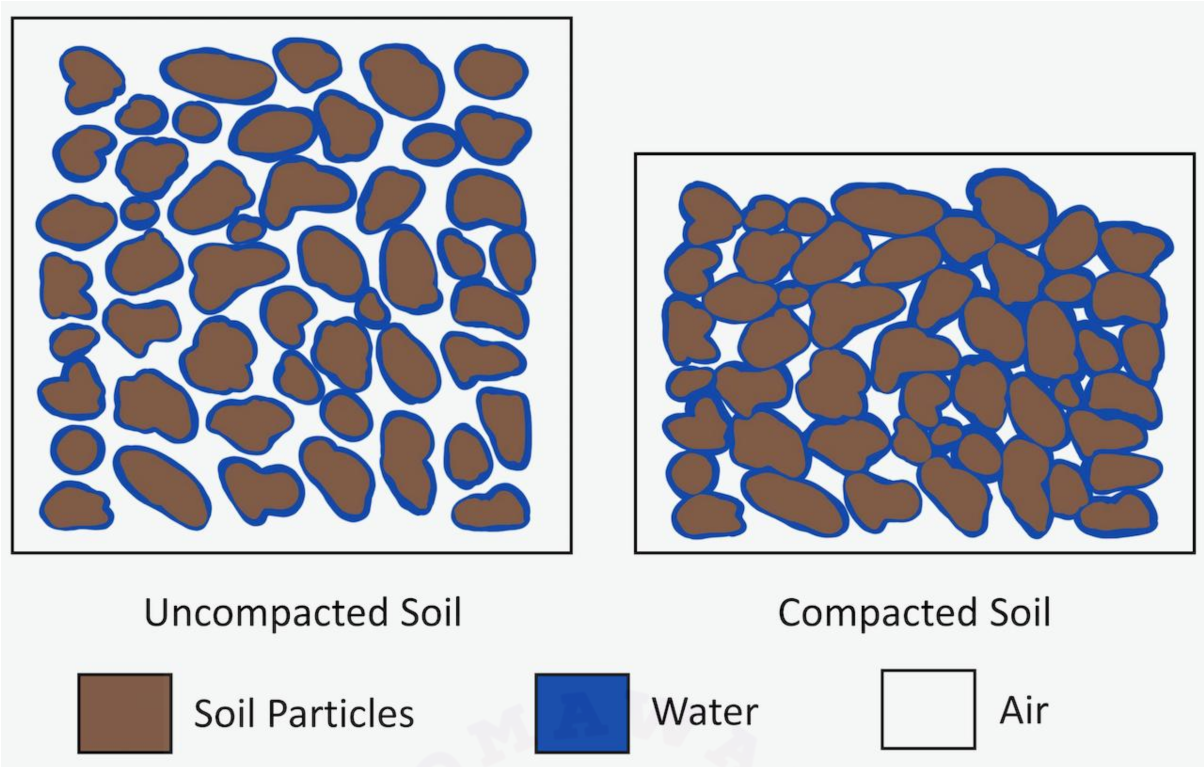
.

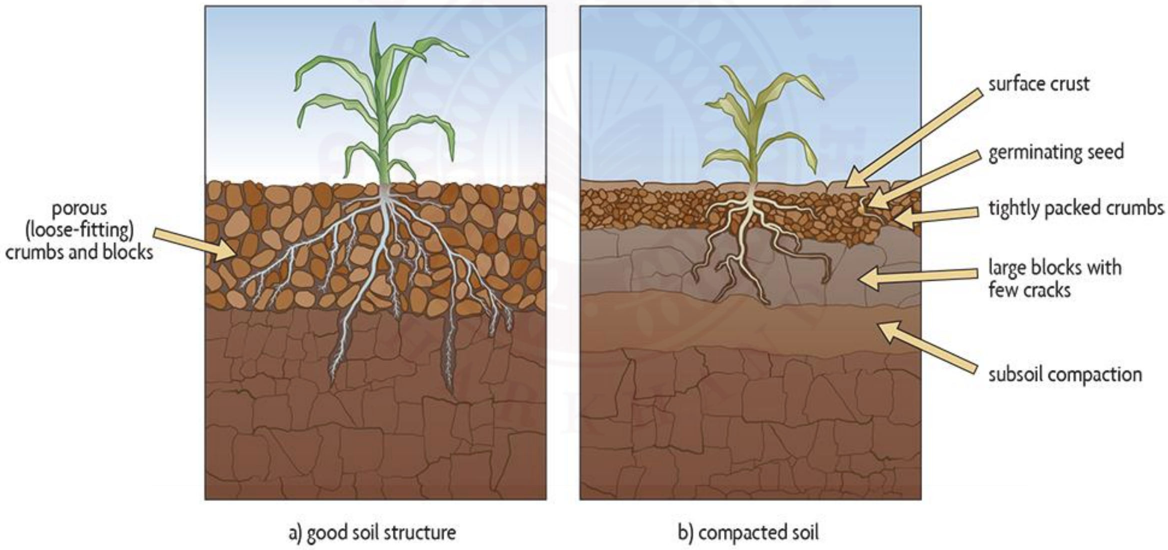
4.1 Concept of compaction

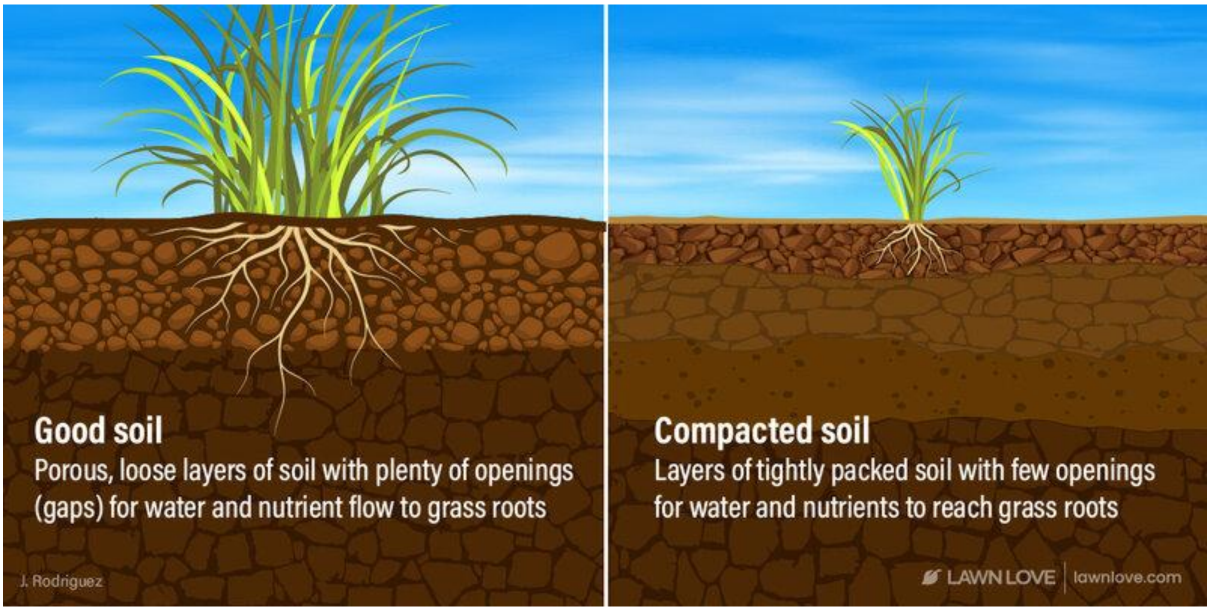



Soil Particles
Water
Air
Non-compacted
Compacted


Air
Water
Air
Water


Uncompacted Soil
Compacted Soil
Soil Particles
Water
Air


porous (loose-fitting) crumbs and blocks
surface crust
germinating seed
tightly packed crumbs
large blocks with few cracks
subsoil compaction
a) good soil structure
b) compacted soil



Definition & Explanation:

Compaction is the mechanical process of densifying soil by applying external mechanical energy (roller, rammer, vibration) so as to reduce the volume of air voids between soil particles and rearrange particles into a closer packing. (Soil Management India)

Through compaction:

- The soil's void ratio and porosity drop, bulk (and dry) unit weight increases. (extension.umn.edu)
- The internal structure becomes more stable (particles interlock more closely), which improves strength and stiffness while reducing compressibility and permeability. (Mintek Resources)

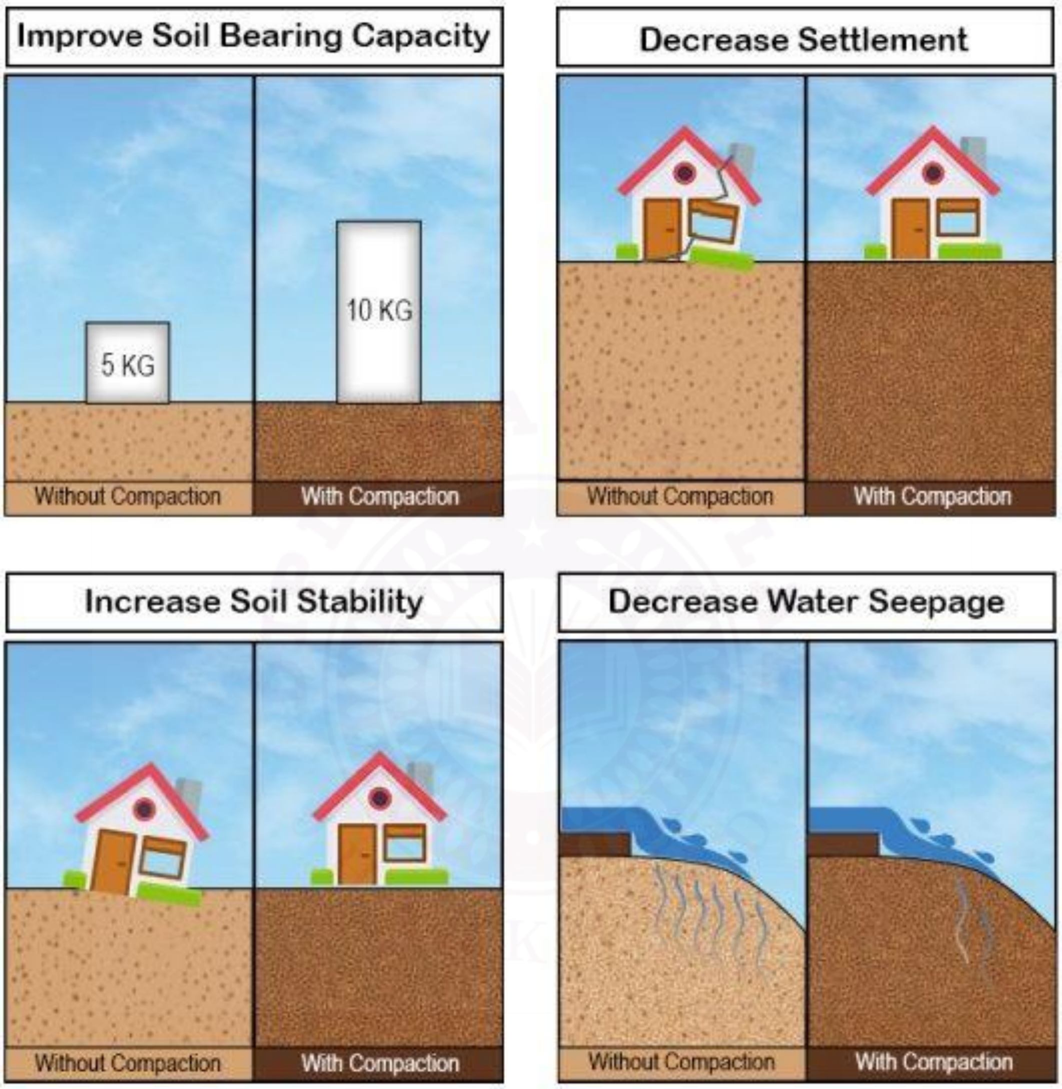
Key Points to Include for Exams:

- Distinguish compaction vs natural densification (consolidation). Compaction is short-term, mechanical; consolidation is long-term, due to expulsion of water under sustained load. (Soil Management India)
- Mention that compaction is applied to **partially saturated soils** (air + water present) since air is expelled; water may act as lubricant to assist particle rearrangement. (Soil Management India)
- State engineering objectives: improve bearing capacity, reduce settlement, reduce permeability/ seepage, control volume changes (shrink/swell). (Mikasa Sangyo Co.,Ltd.)

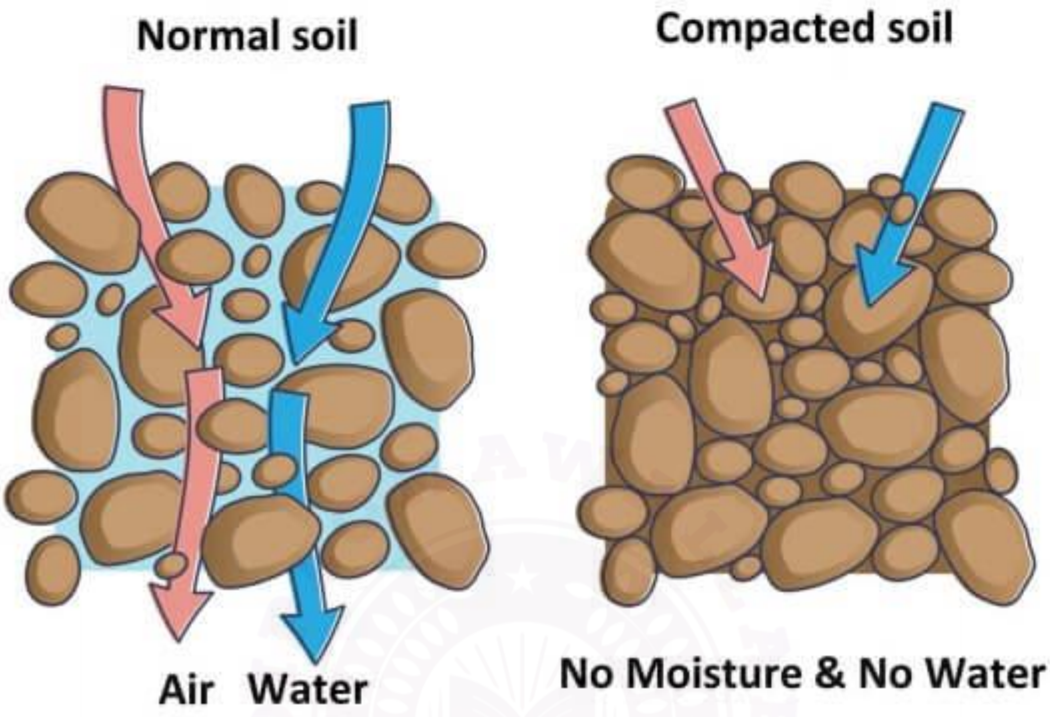
Exam-style answer snippet:

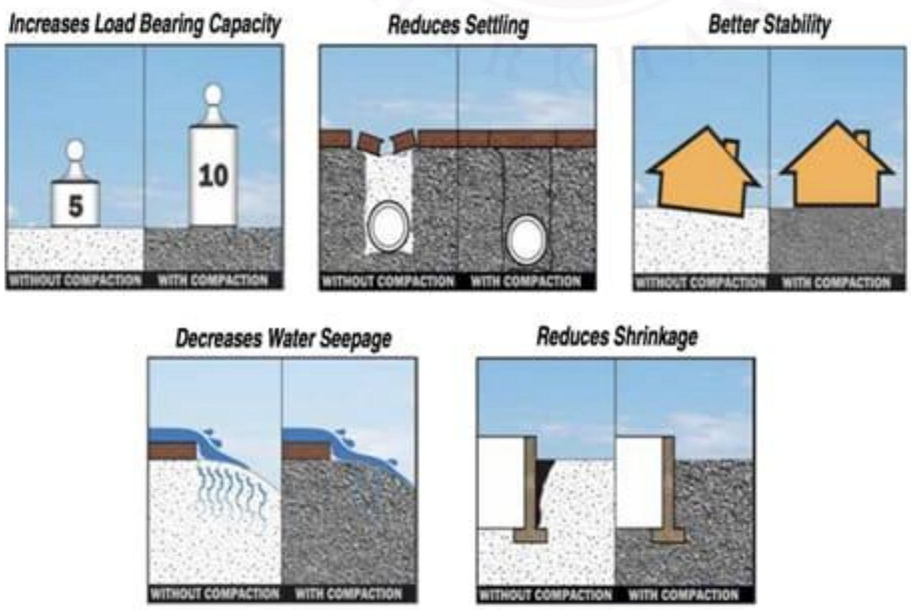
"Compaction is the artificial mechanical densification of soil by expulsion of air voids and rearrangement of particles, resulting in increased density and improved engineering behaviour (e.g., strength, stiffness, bearing capacity). In construction it is essential for providing a stable platform under roads, pavements, embankments and foundations."

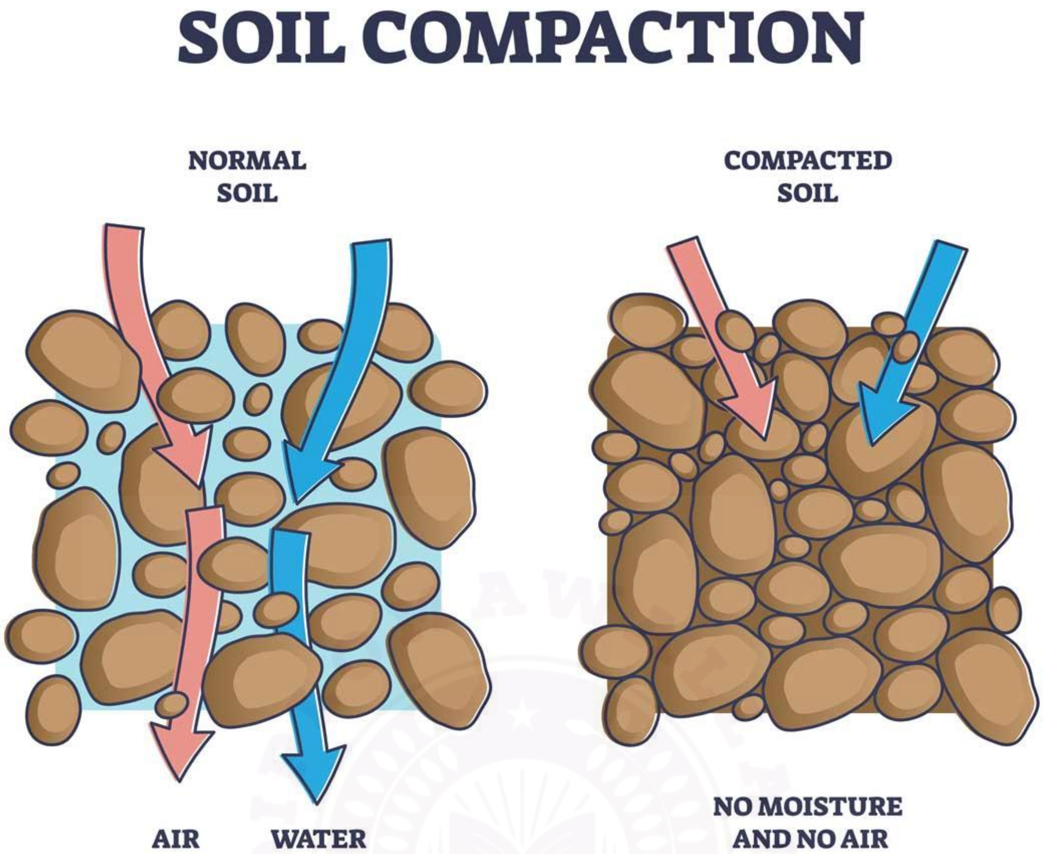
4.1 Purpose of compaction



SOIL COMPACTION







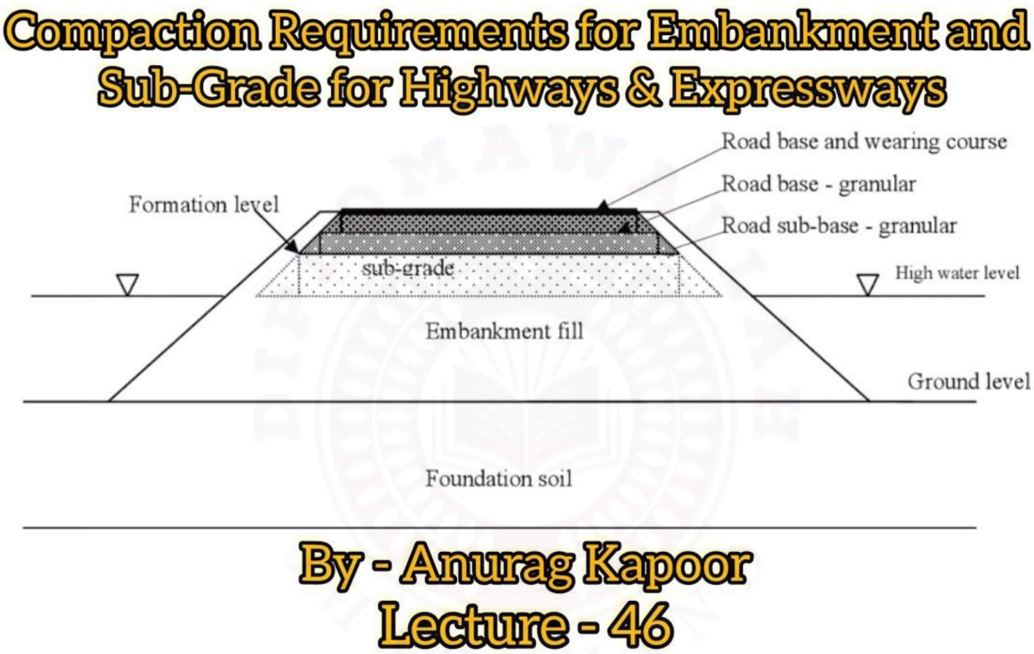
Purpose:

- **Increase bearing capacity & strength**: Denser soil provides greater support for foundations, embankments and heavy loads. (Mintek Resources)
- **Reduce settlement and volume change**: By eliminating large voids and providing more inter-particle contact, subsequent settlement is minimized. (Mikasa Sangyo Co.,Ltd.)
- **Reduce permeability and seepage**: A compacted soil has fewer and smaller voids for water to pass through, which is critical for dams, embankments or slopes. (Mikasa Sangyo Co.,Ltd.)
- **Provide a stable and uniform foundation**: For pavements, roads, slabs — compaction ensures uniform substrate, minimal differential movement.

- **Control swelling/shrinkage**: Particularly in fine-grained soils, achieving correct compaction reduces susceptibility to volume changes with moisture variation.

Exam Tip:
List 4-5 bullet points, each beginning with "Increase …", "Reduce …", "Provide …", etc. Provide a short example: e.g., "In a road base, compaction ensures that the subgrade doesn't deform under traffic loads, thus increasing pavement life."

4.1 Field situations where compaction is required



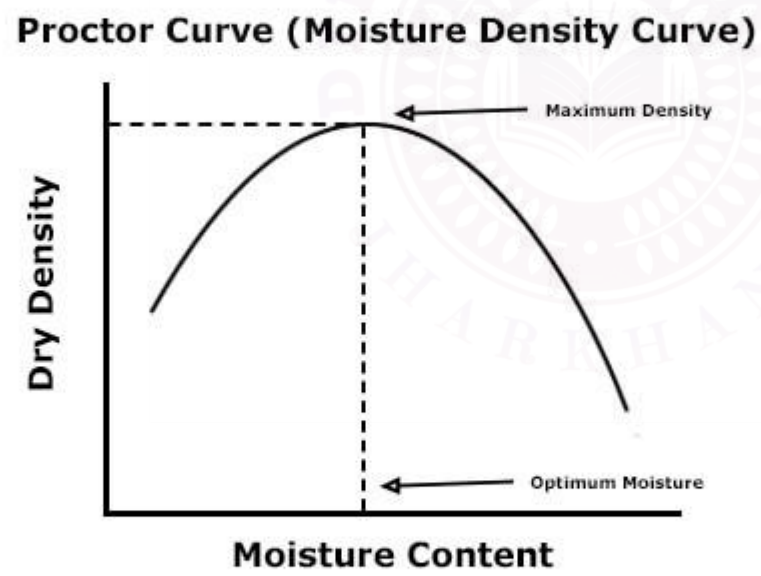
Typical Field Situations:

- Construction of **embankments and earth dams**: fill material must be compacted to specified density to avoid settlement, piping and instability.

- **Pavement subgrades and bases**: To support traffic loads, poor compaction can lead to rutting, failure, maintenance issues.
- **Backfilling around foundations or retaining walls**: Controlled compaction avoids differential settlement, lateral pressures and ensures stability.
- **Structural fills and slabs-on-grade**: For building pads, warehouses etc., compaction ensures uniform support and minimises post-construction settlement.
- **Utility trench backfill**: To avoid sagging/settlement influencing surface features.

Note for exam: You can mention 2-3 situations and link each to the purpose (strength, settlement control, permeability). That shows depth.

4.1 Standard Proctor test – test procedure as per IS code



Definition & Background:
The standard Proctor test (named after R. R. Proctor, 1933) is a laboratory compaction test used to determine the maximum dry density (MDD) and corresponding optimum moisture content (OMC) for a given soil under a specified compactive effort. (Wikipedia)

Test Procedure (IS/International Standard – summary):

1. Prepare the soil sample, air-dry and then sieve (typical specification e.g., 20 mm sieve removed).
2. Select several moisture contents (say 4-6) around expected range.
3. For each moisture content: mix soil with water, then compact into a standard mould of known volume in layers — each layer receives specified number of

blows by a standard hammer of defined weight and drop height (in standard Proctor: 2.5 kg hammer, 305 mm drop, 25 blows each of 3 lifts in ASTM; Indian IS code similar).

4. After compaction, the specimen's wet mass is measured, then water content determined by oven-drying; dry density computed.
5. Plot dry density vs moisture content curve (compaction curve). The peak of curve is the MDD and the corresponding moisture content is OMC.
6. Also plot zero-air-voids line for reference.

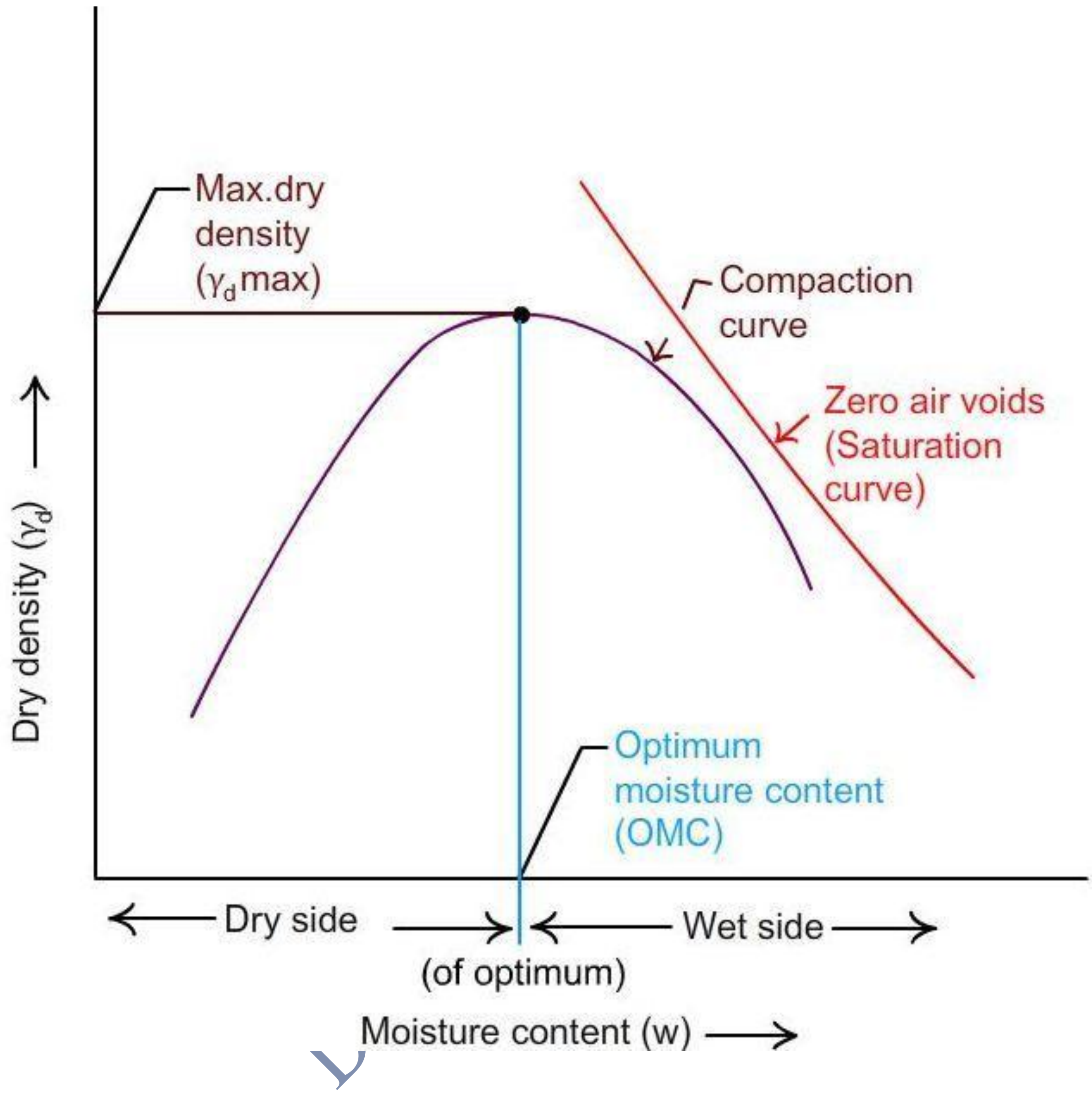
Key Outputs:

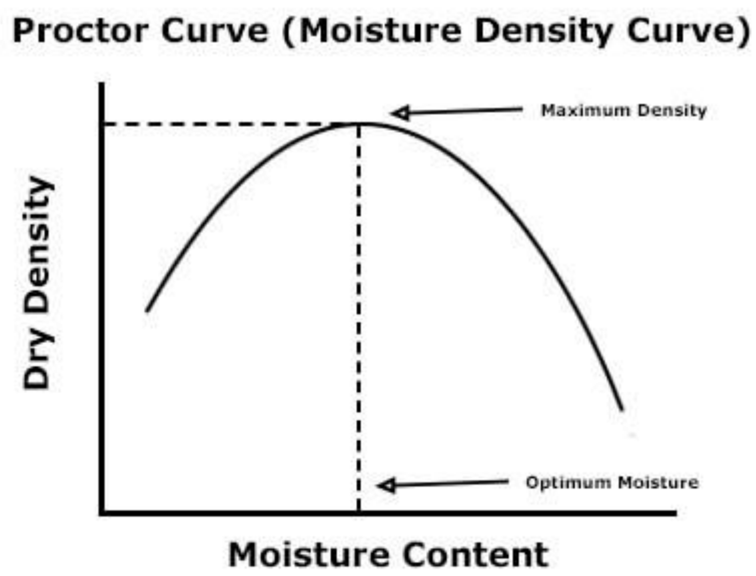
- **Maximum Dry Density ($\gamma_{d(max)}$)**: the highest value of dry unit weight achieved.
- **Optimum Moisture Content (OMC)**: the water content at which MDD occurs.
- Zero Air Voids Line: theoretical line representing 100% saturation; actual compaction curve lies below this line.

Significance:
Using MDD & OMC, field compaction quality control can specify e.g., achieve ≥ 95% of MDD at moisture within ±2% of OMC.

Exam Tip:
When answering: define test, list step-by-step (3-4 bullet points), define MDD & OMC, explain significance, sketch or describe curve (peak, falling on both sides) and mention zero air voids line. Use proper units and symbols (γ_d, w % etc).

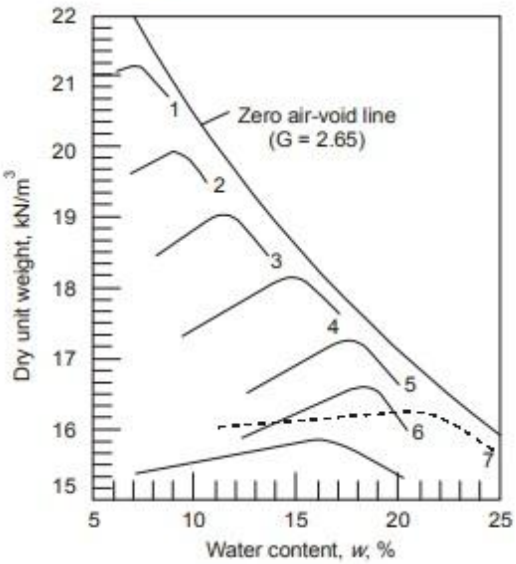
4.1 Compaction curve, optimum moisture content, maximum dry density, Zero air voids line


Max.dry
density
($\gamma_d$max)
Compaction
curve
Zero air voids
(Saturation
curve)
Dry density (γ_d)
Optimum
moisture content
(OMC)
Dry side
Wet side
(of optimum)
Moisture content (w)


Proctor Curve (Moisture Density Curve)
Maximum Density
Dry Density
Optimum Moisture
Moisture Content

$$\gamma_d = \frac{G_s \gamma_w}{1+e} \qquad \text{...(i)}$$

For any degree of saturation, $$e = \frac{wG_s}{S}$$



Compaction Curve:
A plot of **dry unit weight ($\gamma_{(d)}$)** on vertical axis vs **moisture content (w)** on horizontal axis. It typically rises with increasing moisture content (due to lubrication effect) until a peak (MDD at OMC) and then decreases (because excess water reduces inter-particle contact and creates pore water pressures). (Soil Management India)

Optimum Moisture Content (OMC):
The moisture content at which the soil attains its maximum dry density under the given compactive effort. Below OMC, there is insufficient moisture (lubrication), above OMC there is too much water (reduces compaction). (Mintek Resources)

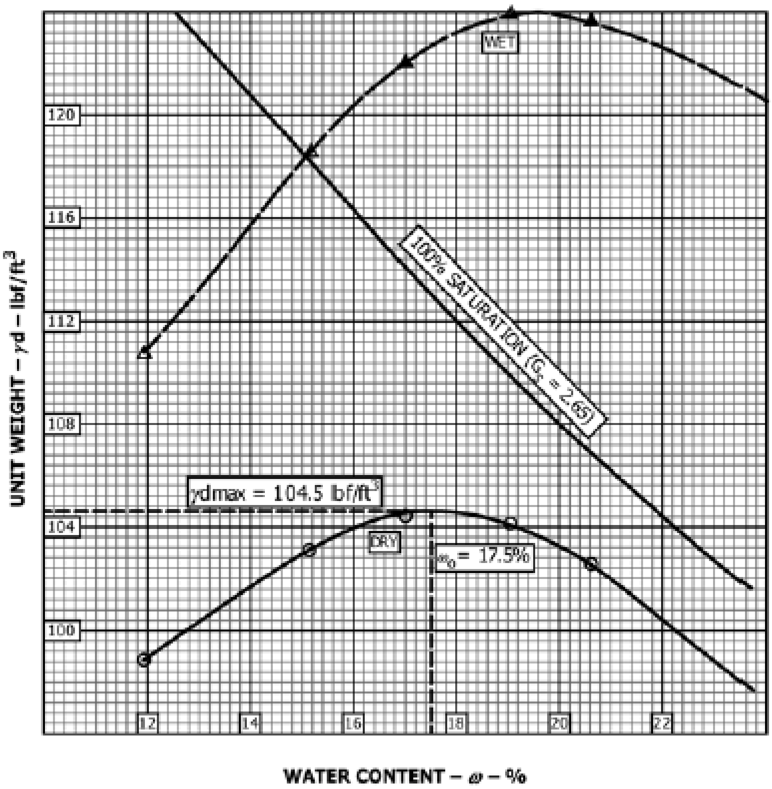
Maximum Dry Density (MDD):
The peak dry unit weight value on the compaction curve. It indicates the densest state attainable under the specified effort.

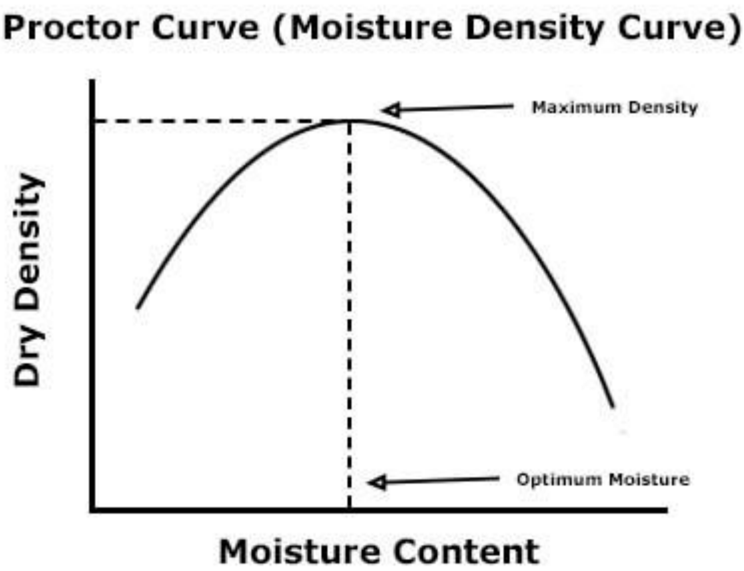
Zero Air Voids Line:
A theoretical line plotted on the same graph representing the dry unit weight corresponding to 100% saturation (i.e., no air voids) for varying moisture contents. Actual compaction curve will lie below this line because achieving 100% saturation by compaction alone is impractical.

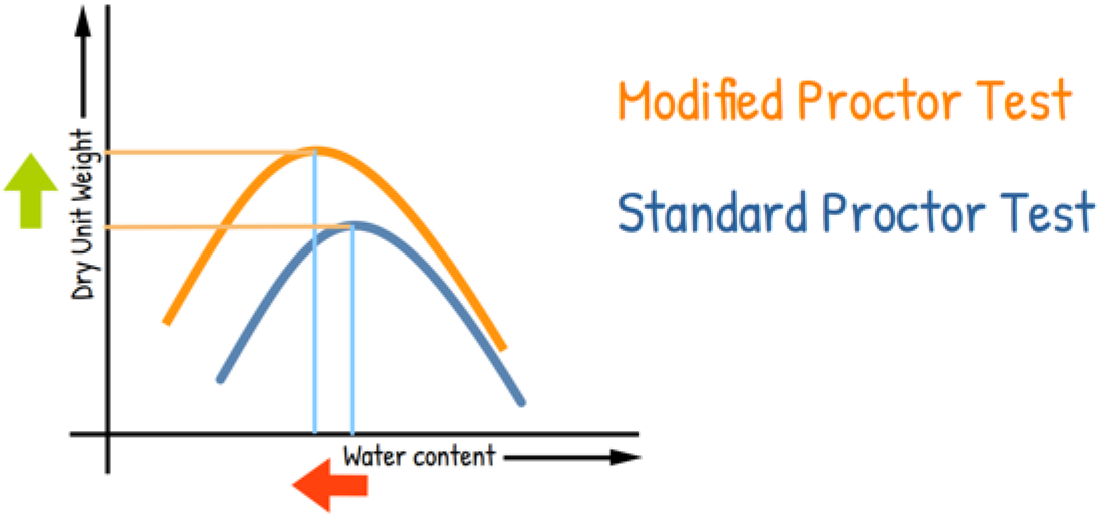
Exam Tip:
Include a small sketch of the compaction curve showing MDD, OMC, and Zero Air

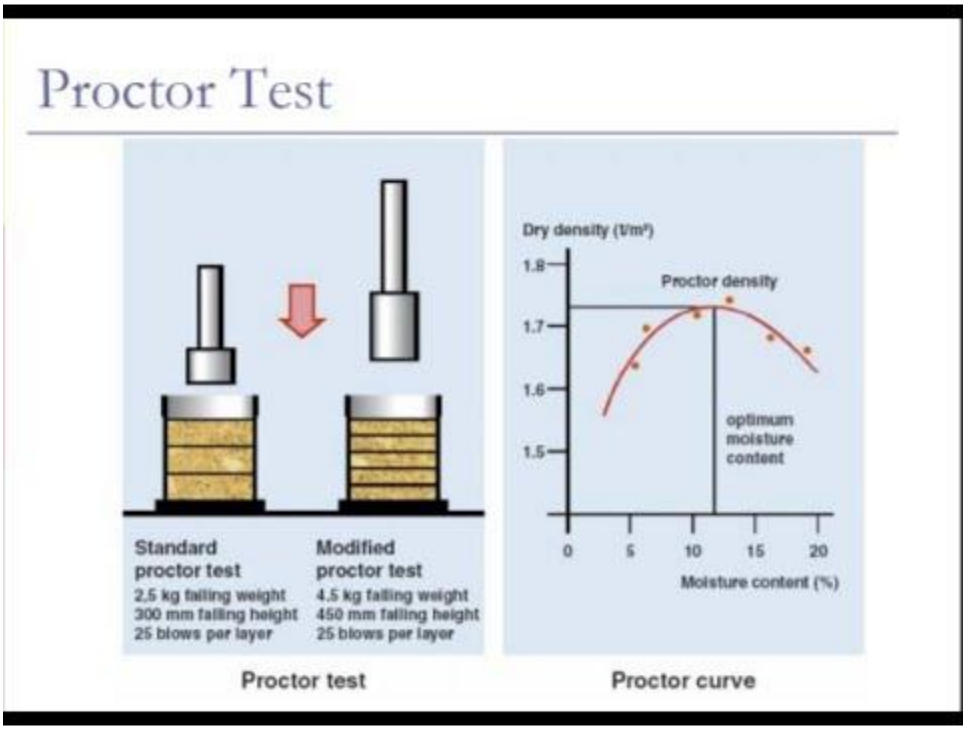
Voids Line labelled. Explain why curve behaves the way it does (lubrication effect, then excessive water effect). Mention significance of these terms.

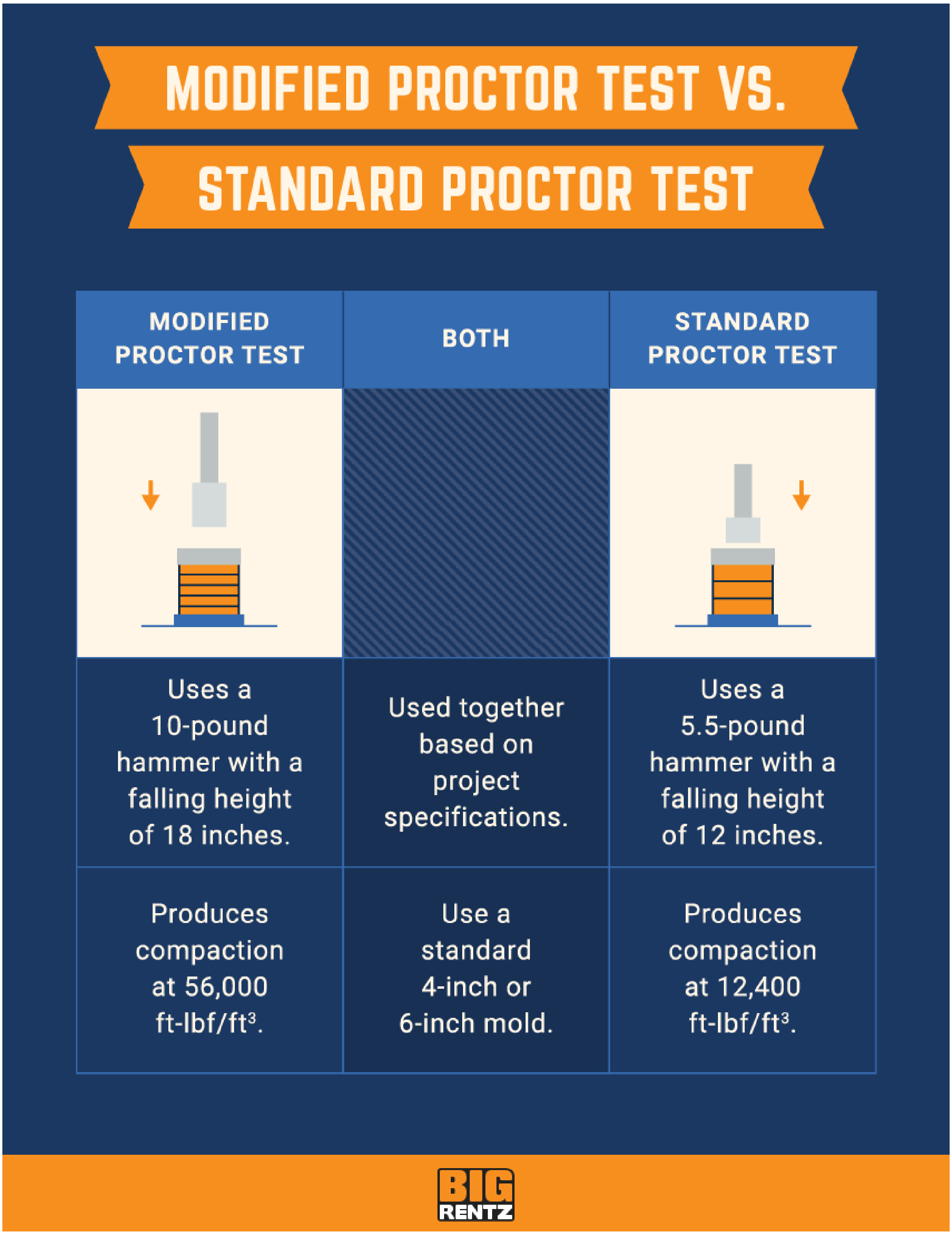
4.1 Modified Proctor test






Modified Proctor Test
Standard Proctor Test
Dry Unit Weight
Water content


Proctor Test
Standard
proctor test
2.5 kg falling weight
300 mm falling height
25 blows per layer
Modified
proctor test
4.5 kg falling weight
450 mm falling height
25 blows per layer
Proctor test
Dry density (t/m³)
1.8
1.7
1.6
1.5
Proctor density
optimum
moisture
content
0
5
10
15
20
Moisture content (%)
Proctor curve



Definition & Purpose:

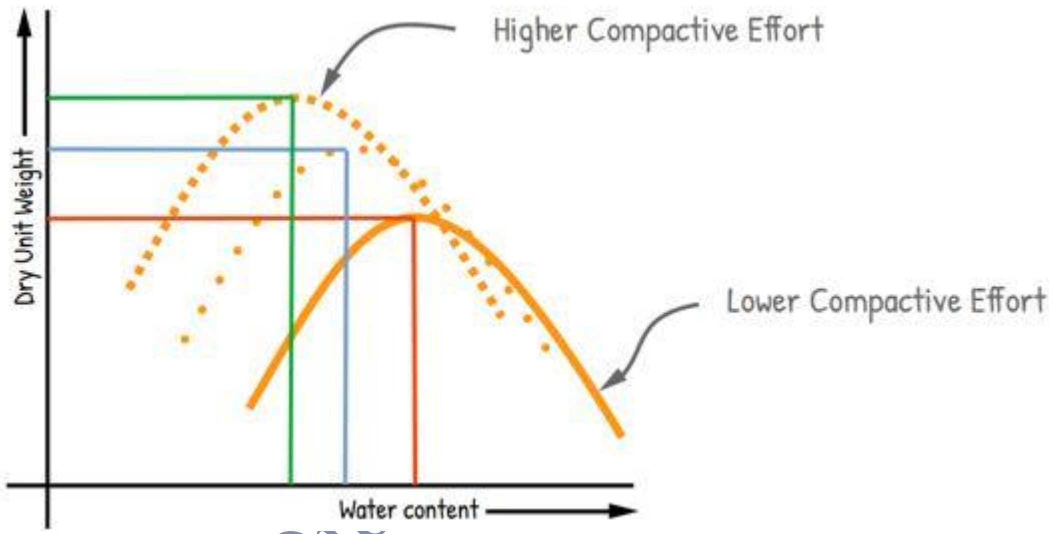
The Modified Proctor test is a laboratory compaction test similar to the standard Proctor but uses a higher compactive effort (heavier hammer, greater drop height or more layers) to simulate heavier field compaction equipment (e.g., vibratory rollers) and thus often results in higher MDD and lower OMC compared to standard. (Wikipedia)

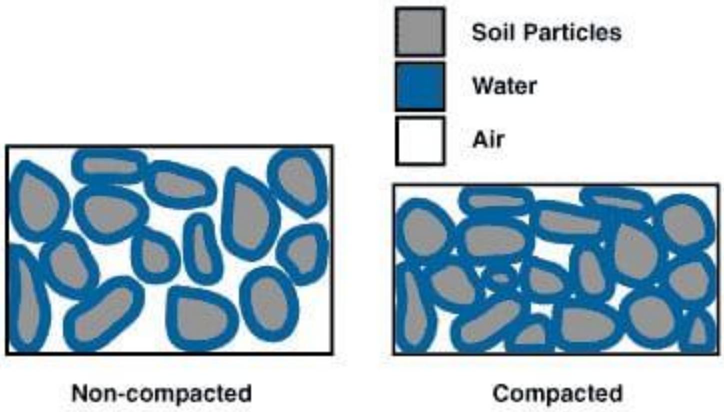
Key Differences vs Standard:

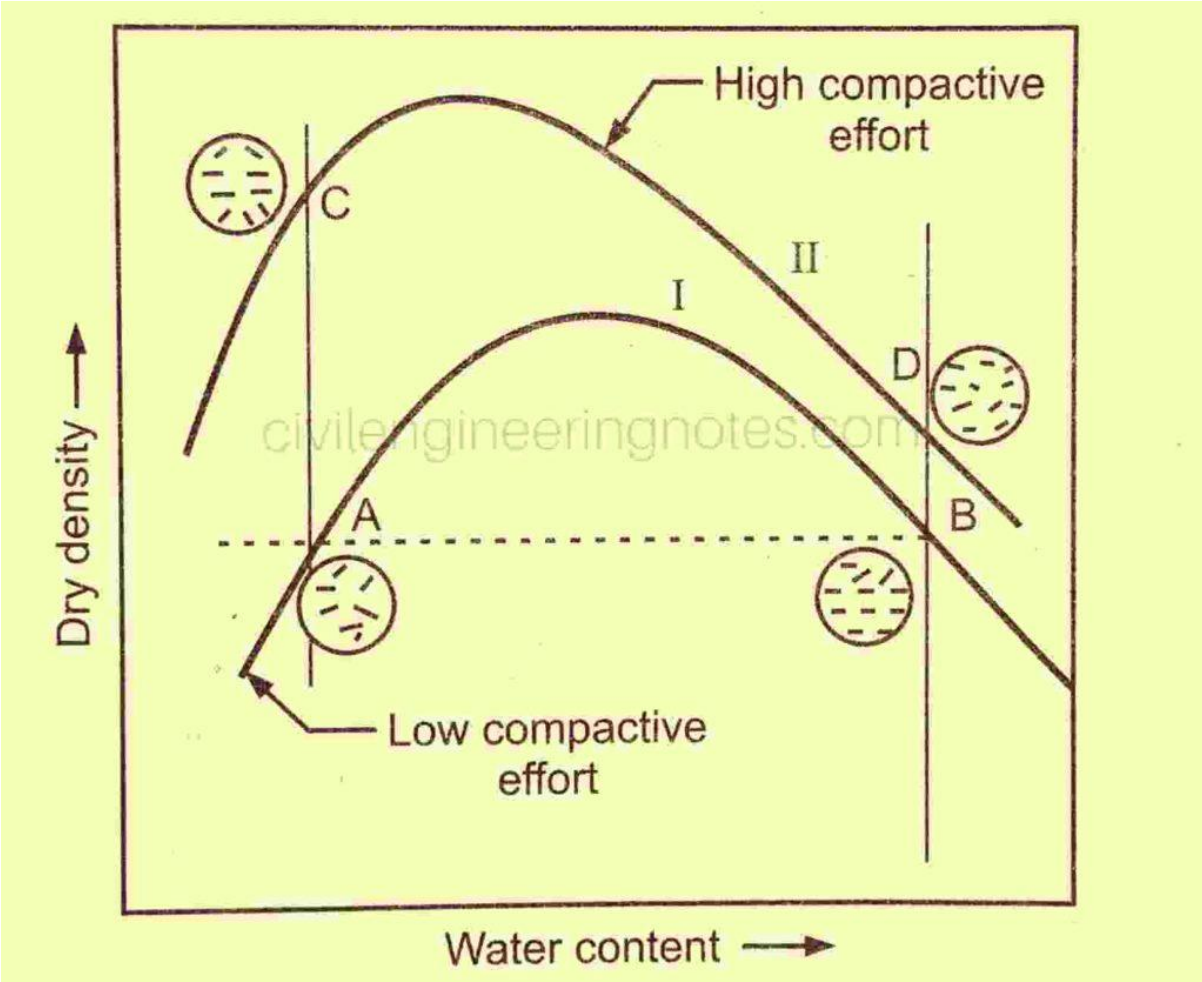
- Higher compactive energy → denser soil achievable.
- Displays separate curve (modified) with higher $\gamma_{d(max)}$ and lower w_{opt}.
- Field specification may say: "Compacted to ≥ 100% modified Proctor" for major earthworks.

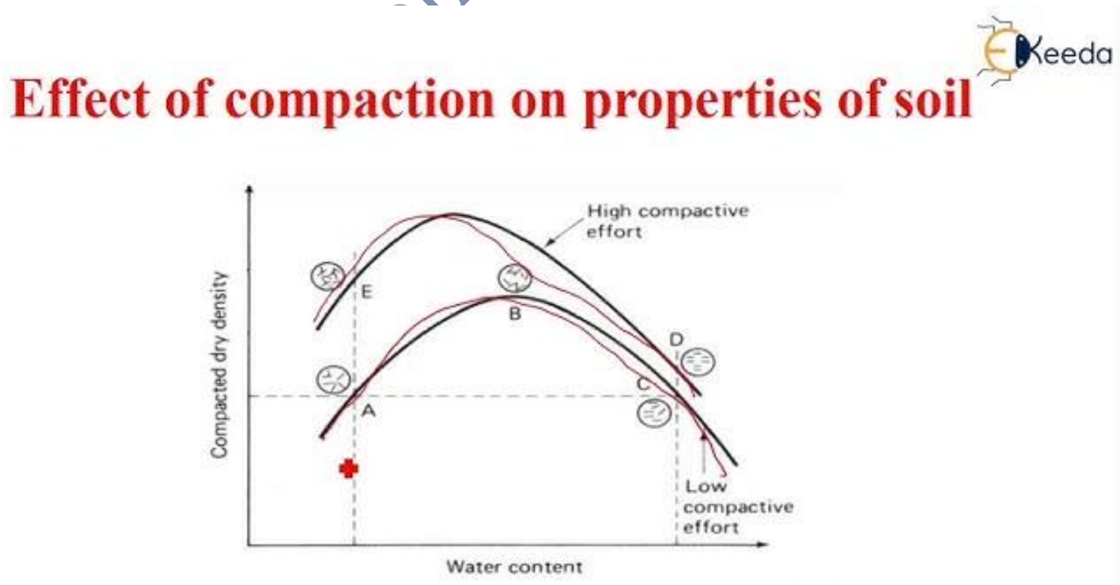
Exam Note:
Mention when modified is used (e.g., high-traffic pavements/subgrades), list parameters (hammer weight, drop height) if known, and state result differences.

4.1 Factors affecting compaction









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

Major Factors:

1. **Moisture content:** At low water content, particles stick and resist rearrangement; at optimum moisture, lubrication plus enough water to fill

small voids; above optimum, pore water pressure builds and reduces compaction. (Soil Management India)

2. **Compactive effort (energy):** More energy (heavier machines, more blows) results in higher dry density; hence modified Proctor uses higher effort. (Elementary Engineering)
3. **Soil gradation/particle size distribution:** Well-graded soils compact better due to good packing of different sizes; uniformly graded soils less efficient.
4. **Soil type & mineralogy:** Clays, silts respond differently than sands; high plasticity soils require special attention.
5. **Initial void ratio & structure:** Loose soils with high voids have more scope for densification; pre-compacted or stiff clays less.
6. **Layer thickness and field method:** Thicker layers, fewer compaction passes reduce effectiveness; proper equipment and passes needed.
7. **Moisture and weather/temperature conditions:** Cold/hot, frozen surface, water table, drainage state influence compaction.

Exam Tip:
List factors with one line each explaining influence. Often a 4-5 point list is enough. If asked "Explain factors affecting maximum dry density" you could tie factor to outcome (e.g., more compactive effort → higher γ_d).

4.1 Field methods of compaction: rolling, ramming and vibration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CATERPILLAR
Duncan


Duncan

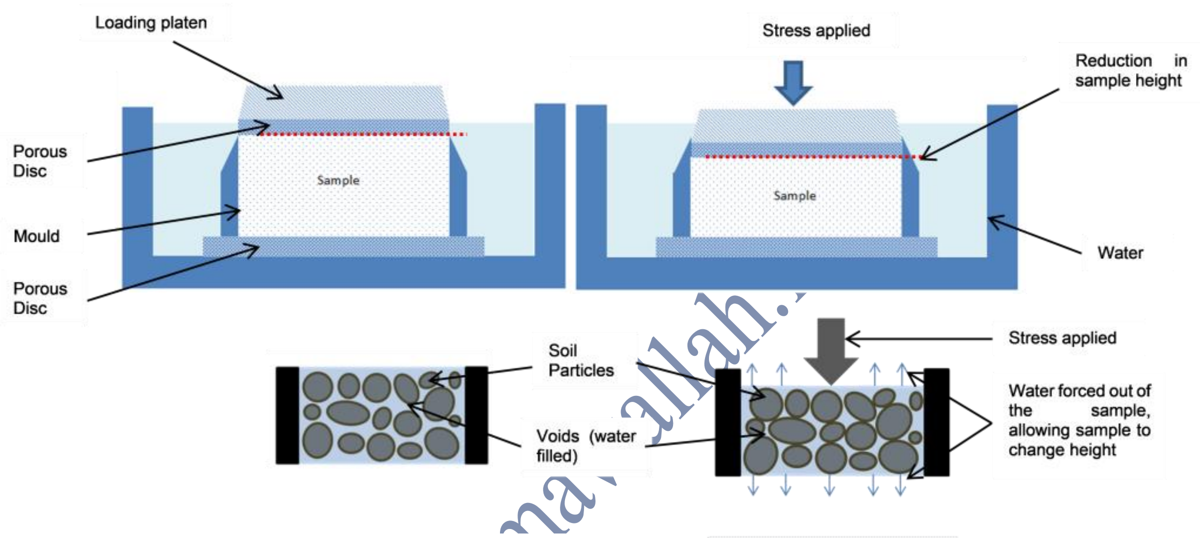
Descriptions & Applications:

- **Rolling:** Use of heavy rollers (smooth-wheel, pneumatic-tyre, padfoot, vibratory) across surface of fill. Effective for granular soils and embankments; large areas, continuous coverage.
- **Ramming (Tamping):** Impact compaction using rammers or tampers (handheld or machine) compact small areas or trenches/backfills. Good for confined spaces.
- **Vibration:** Vibratory plates or rollers impart dynamic energy (vibration) that rearranges particles and reduces voids. Very effective for granular soils; less so for cohesive soils unless combined.

Key Notes for Exam:

- Mention suitability: vibration for granular/clean soils; ramming for backfill/trenches; rolling for large areas.
- Show that choice depends on soil type, layer thickness, equipment available, accessibility.
- Include that field compaction quality control uses in-situ density tests (e.g., sand replacement, nuclear gauge) to confirm % of Proctor density.

4.1 Concept of consolidation



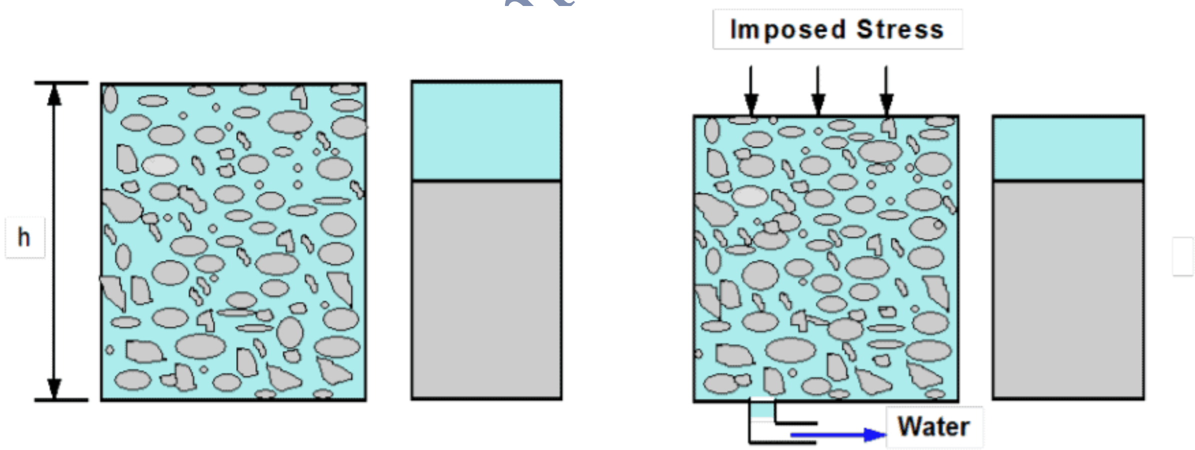
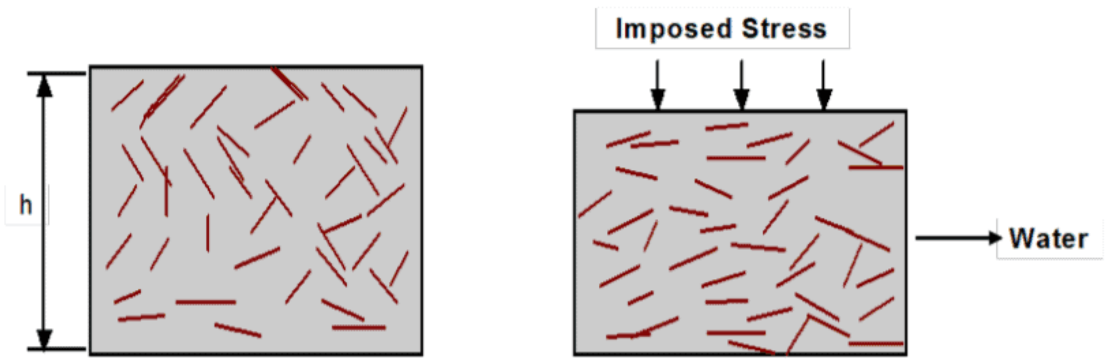


Figure 1.1



For values of U less than 60%: $$T = \frac{\pi}{4} U^2 \tag{3.56}$$

For values of U between 60% and 99%:

$$T = 1.781 - 0.933 \log(100 - U\%) \tag{3.57}$$

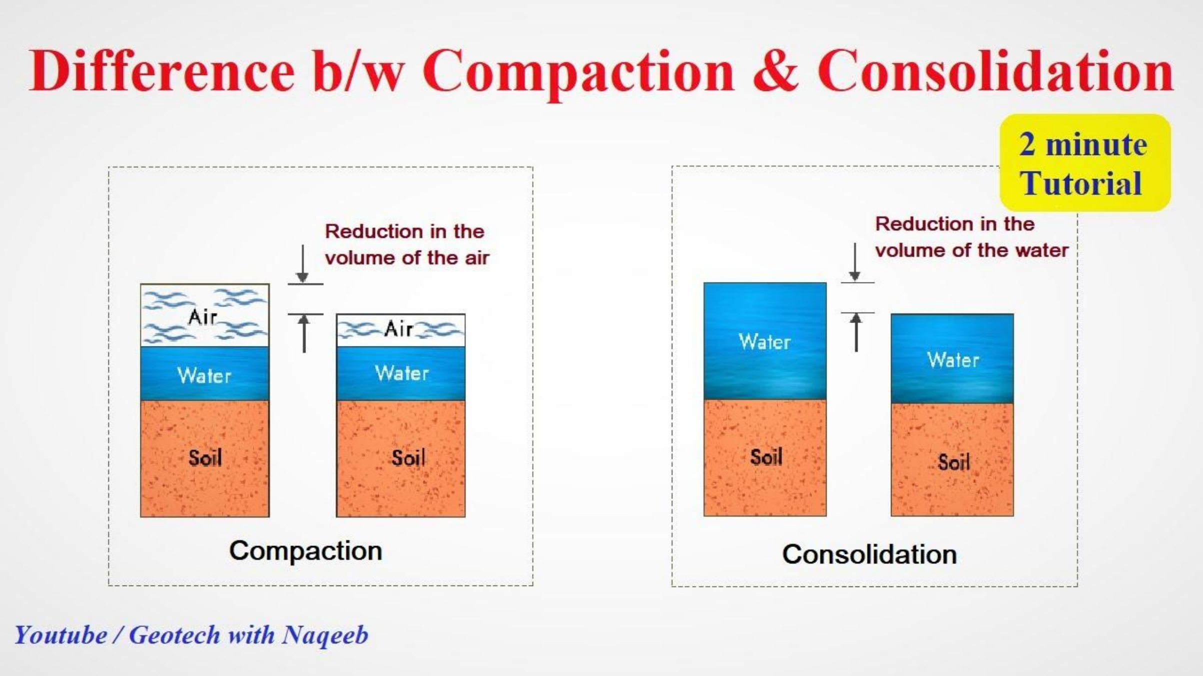
The easiest way to calculate a complete S-t curve is to use Table 3.3 to calculate values of S and t for given values of U. For example, if $U = 50\%$, then $T = 0.197$ and the settlement is (from Eq. 3.49)

$$S = US_u = (0.50)(9.5 \text{ in.}) = 4.75 \text{ in.}$$

and the corresponding time is (from Eq. 3.52)

$$t = \frac{TH^2}{c_v n} = \frac{(0.197)(10 \text{ ft})^2}{(0.05 \text{ ft}^2/\text{day})(2)^2} = 98.5 \text{ days}$$

	Compaction	Consolidation
Aspect	Mechanical densification by expelling air	Time-dependent settlement by expeiling water
Primary Mechanism	Air void reduction	Pore water expulsion
Time Frame	Immediate (seconds to minutes)	Long-term (months to years)
Soil Type	All soil types (granular and cohesive)	Primarily fine-grained saturated solls
Water Content	Remains relatively constant	Decreases significantly
Process Control	Human-controlled mechanical process	Natural process governed by soll properties
Reversibility	Partially reversible	Generally irreversible
Energy Source	External mechanical energy	Applied structural loads
Permeability Effect	Generally decreases permeability	Rate controlled by permeability
Settlement Prediction	Based on compaction tests	Based on consolidation theory



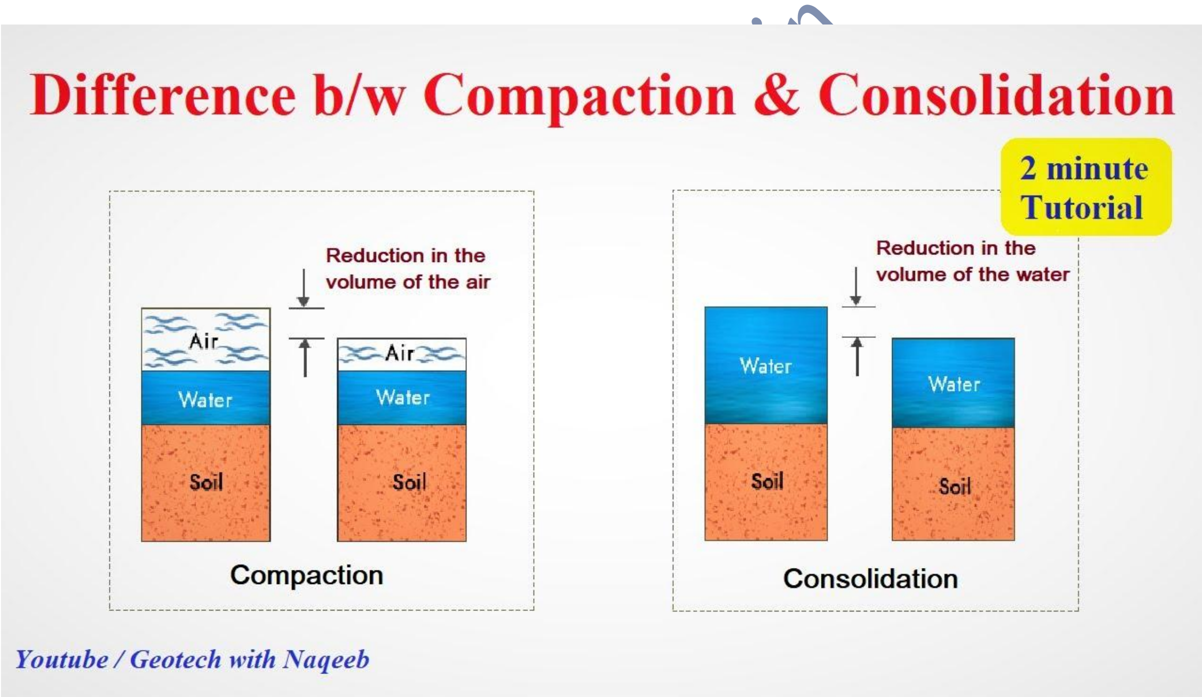
Definition & Explanation:
Consolidation is the process of **volume reduction** of a saturated soil mass due to expulsion of pore water from voids under a sustained (static) load over time. Unlike compaction (which is mechanical and rapid), consolidation involves changes in water pressure and soil skeleton adjustment over long durations. (Soil Management India)

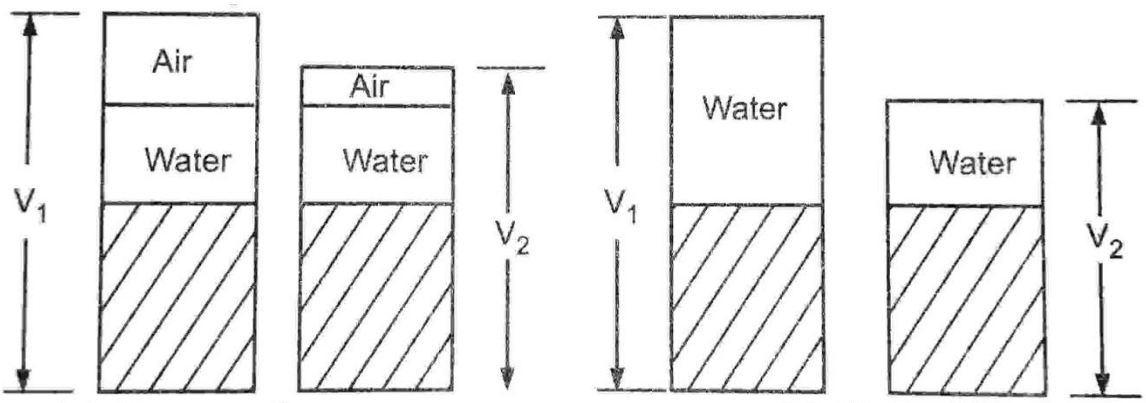
Key aspects:

- Begins when load applied → pore-water pressure increases → over time water flows out, effective stress increases → soil skeleton compresses.
- Occurs chiefly in saturated fine-grained soils (clays) with low permeability.
- Has phases: primary consolidation (major volume change) and secondary consolidation (creep, very slow).

4.1 Difference between compaction and consolidation

Sr. no.	Compaction	Consolidation
1.	It is a instant process, it can be used for all type of soil.	It is a slow process, it can be used for only clayey type of soil.
2.	It is an artificial process.	It is a natural process.
3.	Dynamic loads by rapid mechanical methods like tamping, rolling and vibration are applied for a small interval in soil compaction.	Static and sustained loading is applied for a long interval in soil consolidation.
4.	In compaction, soil changes from partially to fully saturation condition.	In consolidation, soil remains in fully saturation condition.
5.	Compaction is due to expulsion and compression of air in soil mass under short duration by moving or vibratory loads.	Consolidation is due to expulsion of pore water from voids under steady, static, long term load.
6.	Dry density of soil increases but water content will remains same.	Dry density of soil increases but water content will decreases.





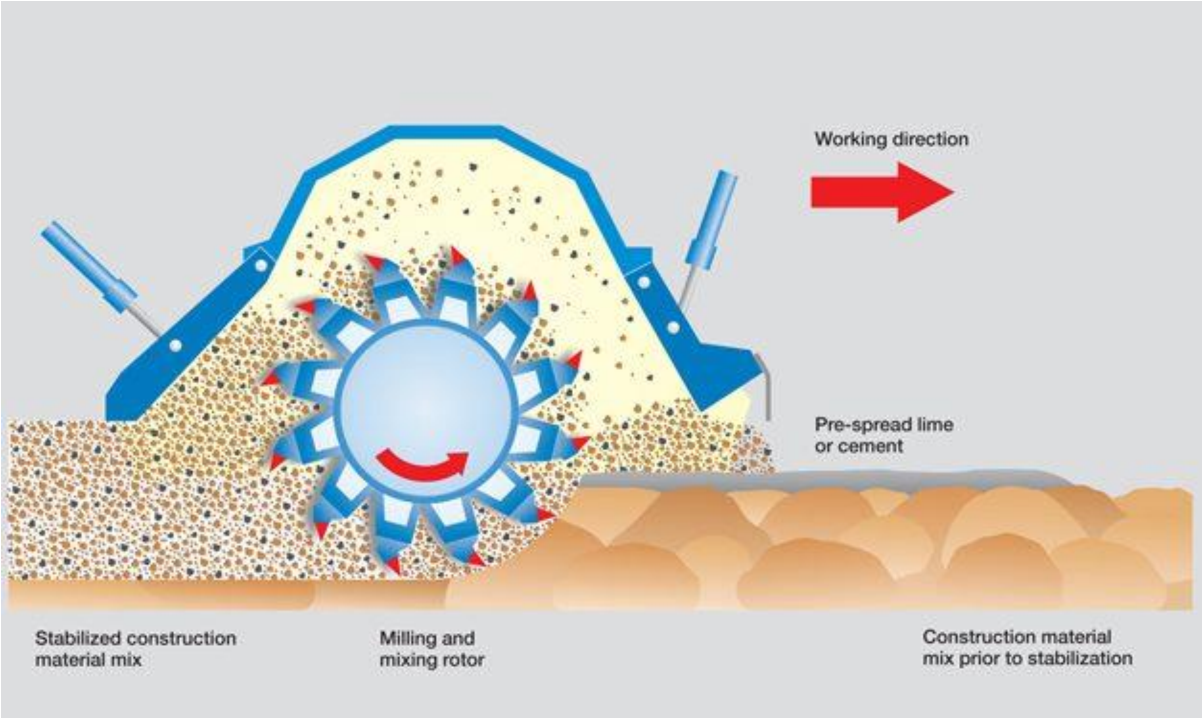
(a) Compaction (b) Consolidation

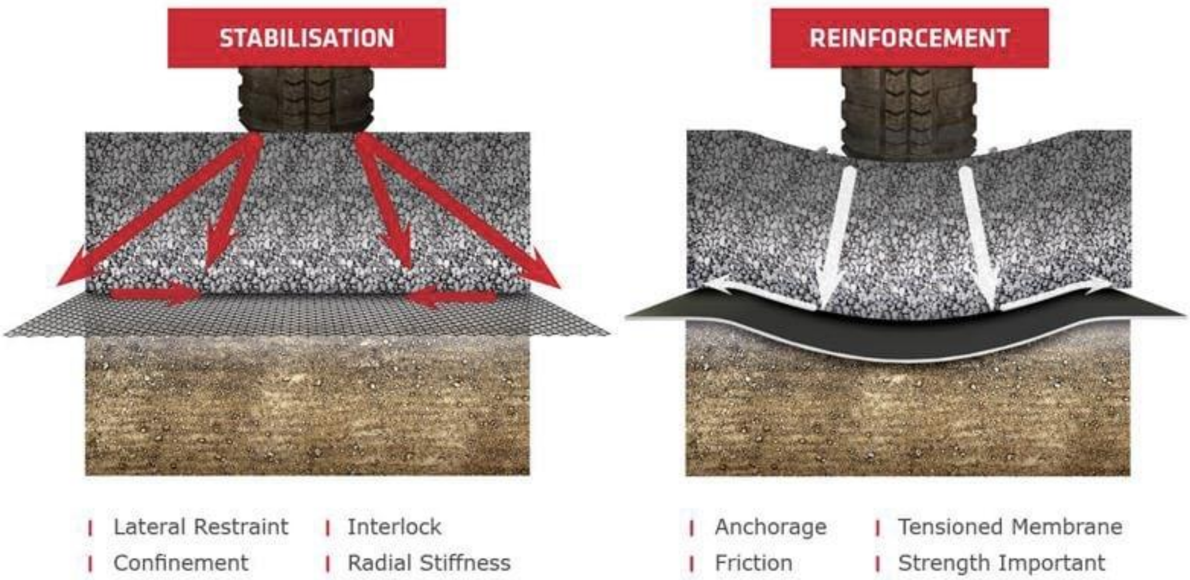
Comparison Table (Important for Exam):

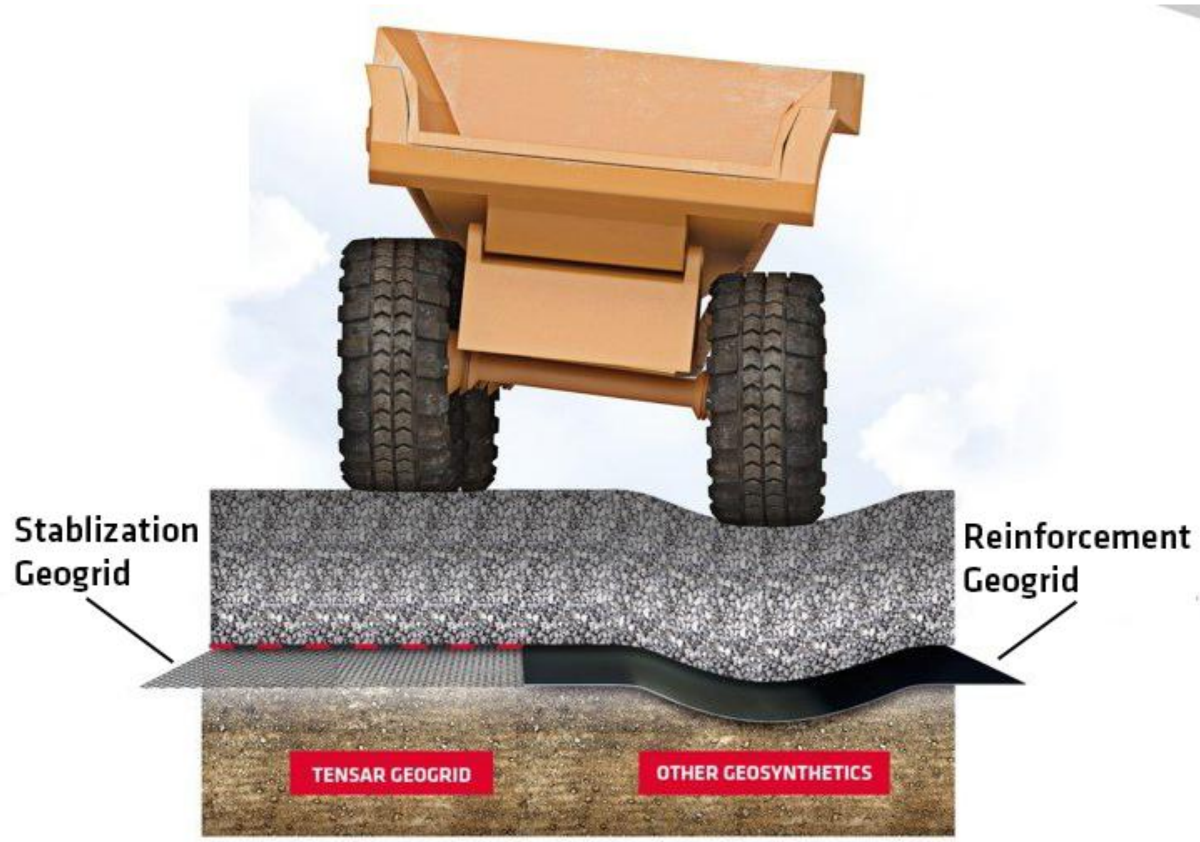
Feature	Compaction	Consolidation
Cause	External mechanical energy/effort (rollers, rammers)	Sustained load, pore-water pressure dissipation under load
Material state	Usually partially saturated soils (air + water)	Saturated soils (voids filled by water)
Mechanism	Expulsion of air voids + rearrangement of particles	Expulsion of water from voids + compression of skeleton
Time scale	Instantaneous to short-term (minutes-hours)	Long-term (days to years)
Typical soils	Coarse and some fine soils being compacted for construction	Fine grained clays, saturated soils under foundations
Purpose	Construction densification, immediate load support	Settlement prediction and rate under loads

Exam Tip:
You may be asked "Distinguish between compaction and consolidation." Use table or bullet list, mention each difference, and conclude with significance (why it matters).

4.2 ***Concept of soil stabilization, necessity of soil stabilization***


Working direction
Pre-spread lime
or cement
Stabilized construction
material mix
Milling and
mixing rotor
Construction material
mix prior to stabilization


STABILISATION
REINFORCEMENT
Lateral Restraint
Interlock
Confinement
Radial Stiffness
Anchorage
Tensioned Membrane
Friction
Strength Important



Definition & Concept:
Soil stabilization is the process by which the properties of soil are improved or modified — by mechanical, chemical, or physical means — so that the soil becomes more suitable for engineering purposes (higher load-bearing capacity, less compressibility, better durability). (GRT)
It may involve adding stabilizing agents (lime, cement, fly ash, polymers), mixing with geosynthetics, or mechanically improving the soil by compaction, replacement, or reinforcement. (Wikipedia)

Necessity / Why we need stabilization:

- When the in-situ soils have **inadequate strength** (e.g., weak clays, swampy soils) and cannot support anticipated loads. (tensarcorp.com)
- When soils exhibit **excessive settlement, volume change, or poor durability** (e.g., expansive clays, high plasticity soils) which would cause problems for pavements, foundations, or earthworks. (substrata.us)
- When better materials are unavailable or replacement is too expensive, so in-situ improvement via stabilization is more economical.
- For instance in road construction: a stabilized subgrade or base may allow thinner pavement sections, reducing cost and material usage. (Mintek Resources)

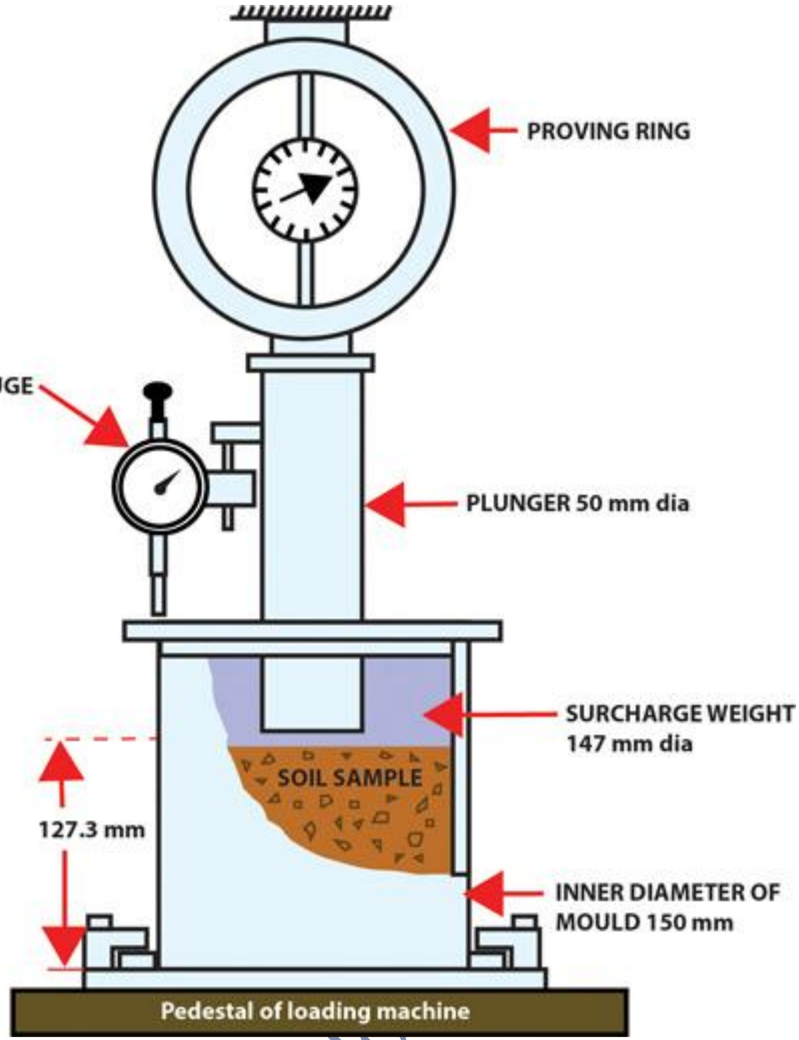
Methods Overview (brief):

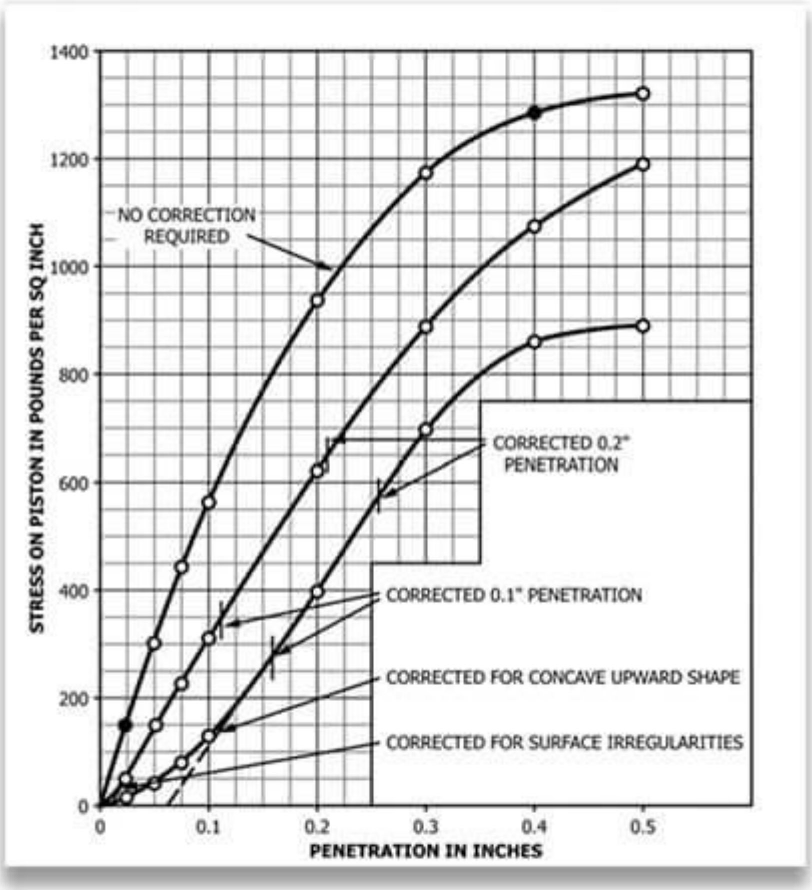
- **Mechanical stabilization**: e.g., mixing soil with gravel or sand, adding geogrids or geotextiles, reinforcing the soil mass.
- **Chemical stabilization**: adding binders like lime, cement, fly ash, bitumen; these change the soil structure, improve particle bonding and reduce plasticity/permeability.
- **Physical/Geosynthetic stabilization**: use of geosynthetics (geogrids, geocells) or mechanical devices to provide confinement and improved load distribution. (tensarcorp.com)

Key points for exam:

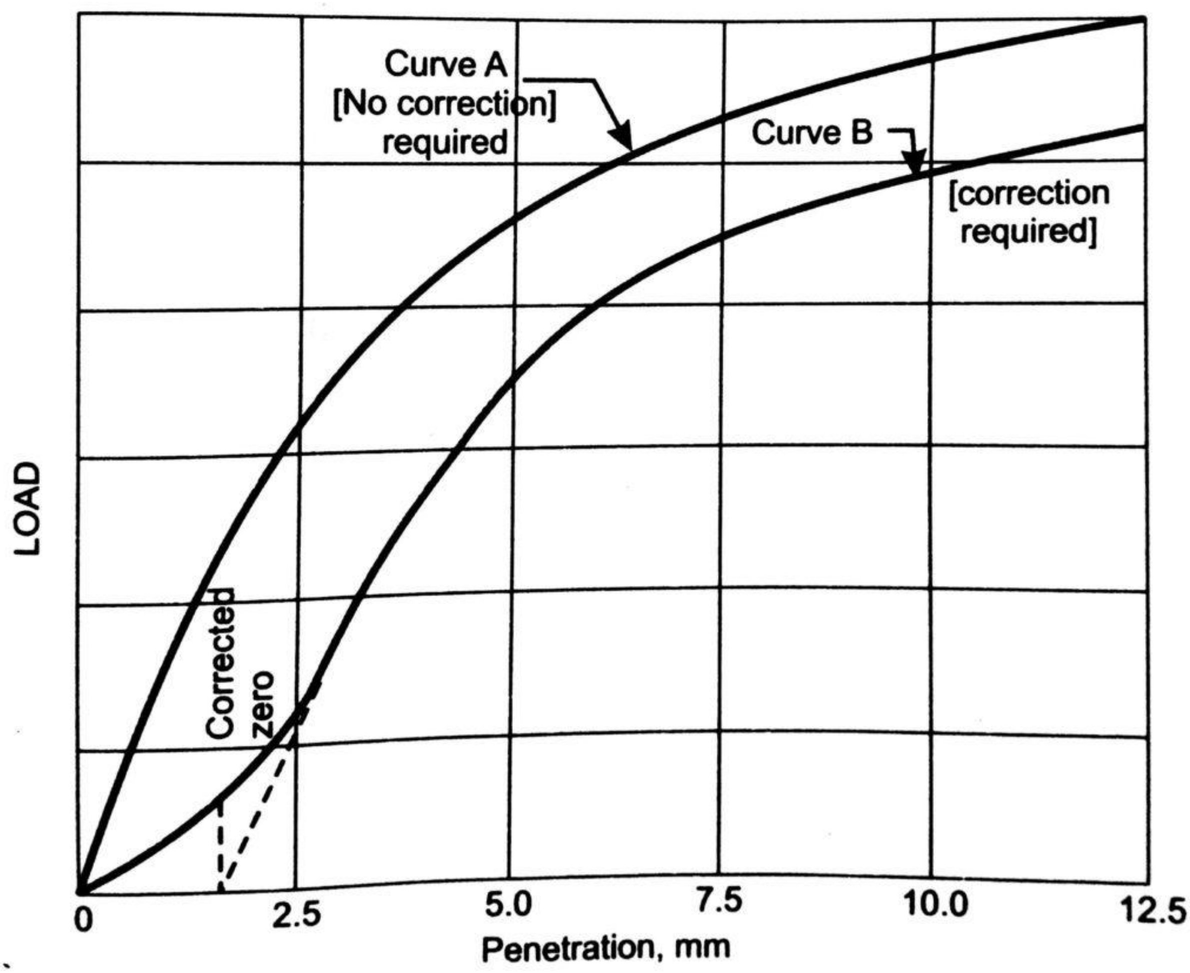
- Define "soil stabilization" clearly.
- Explain **why** it's needed—link to engineering problems (weak soil, high settlement, etc).
- Give at least two methods (mechanical & chemical) and mention what they improve (strength, bearing capacity, durability).
- You can include a small sketch or diagram of mixing lime into soil or geogrid reinforcement.
- Mention typical applications: road subgrades, foundation improvement, embankments.

4.3 ***California Bearing Ratio (C.B.R.) test, interpretation of C.B.R. values***


PROVING RING
DIAL GAUGE
PLUNGER 50 mm dia
SURCHARGE WEIGHT
147 mm dia
SOIL SAMPLE
127.3 mm
INNER DIAMETER OF
MOULD 150 mm
Pedestal of loading machine



1400
1200
1000
800
600
400
200
0
STRESS ON PISTON IN POUNDS PER SQ INCH
0
0.1
0.2
0.3
0.4
0.5
PENETRATION IN INCHES
NO CORRECTION REQUIRED
CORRECTED 0.2" PENETRATION
CORRECTED 0.1" PENETRATION
CORRECTED FOR CONCAVE UPWARD SHAPE
CORRECTED FOR SURFACE IRREGULARITIES



Typical CBR Values Table			
USCS Soil Class	Soil Type	Laboratory CBR Range	Field CBR Range
GW	Well graded sandy gravel	20 – 60	60 – 80
SW	Well graded sand	15 – 40	20 – 40
SC	Sandy clay	4 – 7	10 – 20
CL	Clay	1 – 3	5 – 15

Note: *The CBR value of the standard sample is assumed to be 100*

TABLE C 1

Equilibrium suction-index CBR values

TYPE OF SOIL	PLASTICITY INDEX	HIGH WATER TABLE – CONSTRUCTION CONDITIONS: POOR THIN	POOR THICK	AVERAGE THIN	AVERAGE THICK	GOOD THIN	GOOD THICK	LOW WATER TABLE – CONSTRUCTION CONDITIONS: POOR THIN	POOR THICK	AVERAGE THIN	AVERAGE THICK	GOOD THIN	GOOD THICK
HEAVY CLAY	70	1.5	2	2	2	2	2	1.5	2	2	2	2	2.5
	60	1.5	2	2	2	2	2.5	1.5	2	2	2	2	2.5
	50	1.5	2	2	2.5	2	2.5	2	2	2	2.5	2	2.5
	40	2	2.5	2.5	3	2.5	3	2.5	2.5	3	3	3	3.5
SILTY CLAY	30	2.5	3.5	3	4	3.5	5	3	3.5	4	4	4	6
SANDY CLAY	20	2.5	4	4	5	4.5	7	3	4	5	6	6	8
	10	1.5	3.5	3	6	3.5	7	2.5	4	4.5	7	6	>8
SILT *	–	1	1	1	1	2	2	1	1	2	2	2	2
SAND (POORLY GRADED)	–	← 20 →											
SAND (WELL GRADED)	–	← 40 →											
SANDY GRAVEL (WELL GRADED)	–	← 60 →											

* estimated assuming some probability of material saturating

Definition:
The California Bearing Ratio (CBR) is a penetration-type index test used to evaluate the strength of subgrade soils and base course materials, especially for road and pavement design. It is the ratio (expressed in percent) of the load required to penetrate a soil sample to a standard penetration load of a reference crushed stone under the same conditions. (Wikipedia)

Test Procedure (summary):

- Soil sample is prepared (often compacted to a specified density/moisture) in a mould.
- A standard plunger (usually 50 mm diameter) is pressed into the sample at a rate of 1.25 mm/min. (tensarinternational.com)
- Loads required for penetrations of 2.5 mm and/or 5.0 mm are recorded.
- The CBR value is calculated as:
  [
  \text{CBR (%)} = \frac{\text{Load on test soil at specific penetration}}{\text{Load on standard crushed stone at same penetration}} \times 100%
  ]
  (Wikipedia)

- The higher of the values at 2.5 mm or 5.0 mm penetration is typically used. (iricen.gov.in)

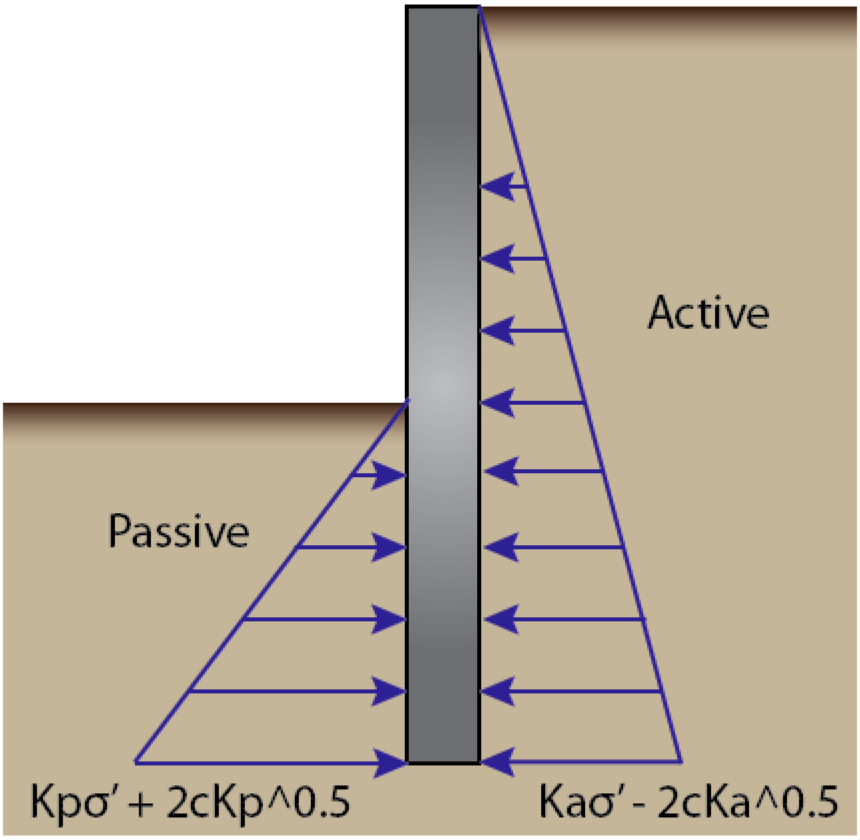
Interpretation of CBR Values:

- A high CBR (%) means the soil has a high bearing capacity and can support greater structural loads; a low CBR means weak subgrade requiring improvement or thicker pavement design. (tensarcorp.com)
- Typical approximate CBR values:
  - Soft clay sub-grade: ~2-5%
  - Typical sand/loam: ~5-15%
  - Well-graded gravel: may be 30-60% or more. (Wikipedia)
- In pavement design, CBR is used to determine required thickness of sub-base and base layers: higher CBR → thinner layers required.
- Lower CBR may signal need for stabilization, improved compaction, or different material selection.

Exam Tip:

- Define CBR, state formula, describe procedure briefly.
- Give typical ranges of values and what they imply (weak vs good subgrade).
- Mention application: pavement design, subgrade evaluation.
- Optionally draw a small graph of penetration load vs depth or show plunger apparatus.

4.4 ***Definition of earth pressure, lateral earth pressure at rest, active earth pressure and passive earth pressure with no surcharge condition, coefficient of earth pressure, Rankine's theory and its assumptions***



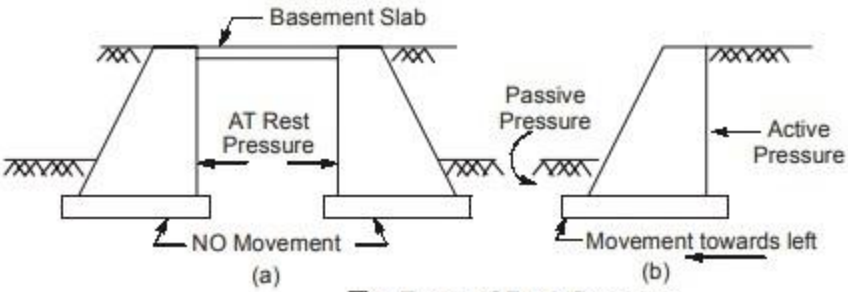
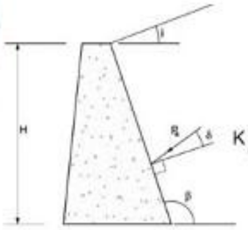


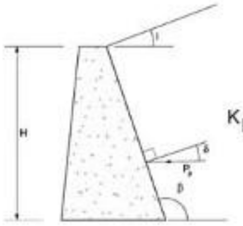
Fig: Types of Earth Pressure

Active and passive earth coefficients

Coulomb



$$K_A = \left[\frac{\operatorname{cosec}\beta \cdot \operatorname{sen}(\beta - \phi')}{\sqrt{\operatorname{sen}(\beta+\delta)} + \sqrt{\dfrac{\operatorname{sen}(\delta+\phi')\cdot \operatorname{sen}(\phi'-i)}{\operatorname{sen}(\beta - i)}}} \right]^2$$

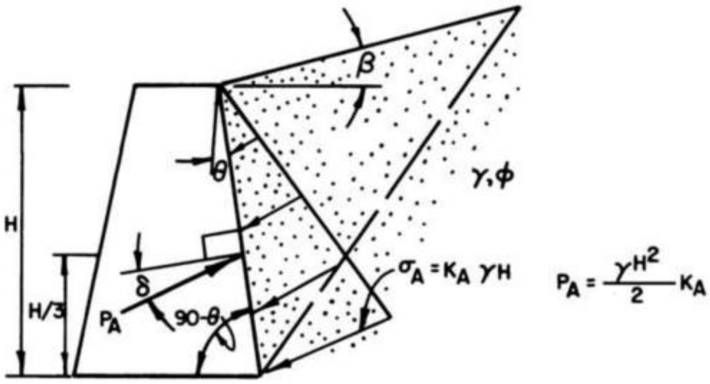


$$K_P = \left[\frac{\operatorname{cosec}\beta \cdot \operatorname{sen}(\beta + \phi')}{\sqrt{\operatorname{sen}(\beta-\delta)} - \sqrt{\dfrac{\operatorname{sen}(\delta+\phi')\cdot \operatorname{sen}(\phi'+i)}{\operatorname{sen}(\beta - i)}}} \right]^2$$

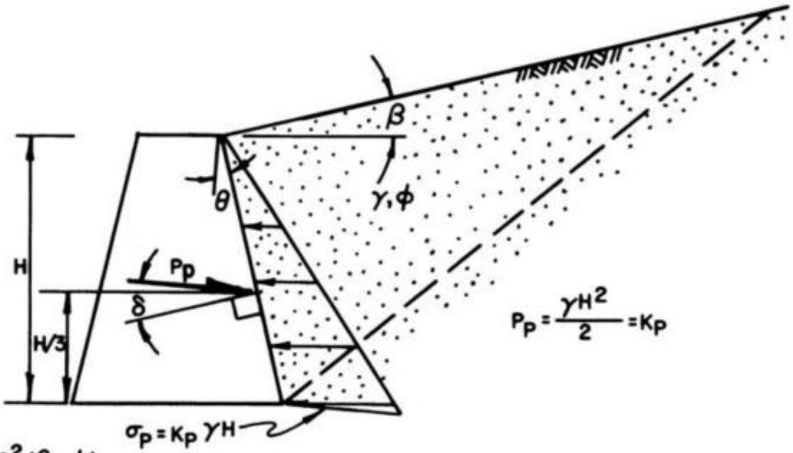
Rankine

$$K_a = \cos i \cdot \left[\frac{\cos i - \sqrt{\cos^2 i - \cos^2 \emptyset'}}{\cos i + \sqrt{\cos^2 i - \cos^2 \emptyset'}} \right]$$

$$K_p = \cos i \cdot \left[\frac{\cos i + \sqrt{\cos^2 i - \cos^2 \emptyset'}}{\cos i - \sqrt{\cos^2 i - \cos^2 \emptyset'}} \right]$$



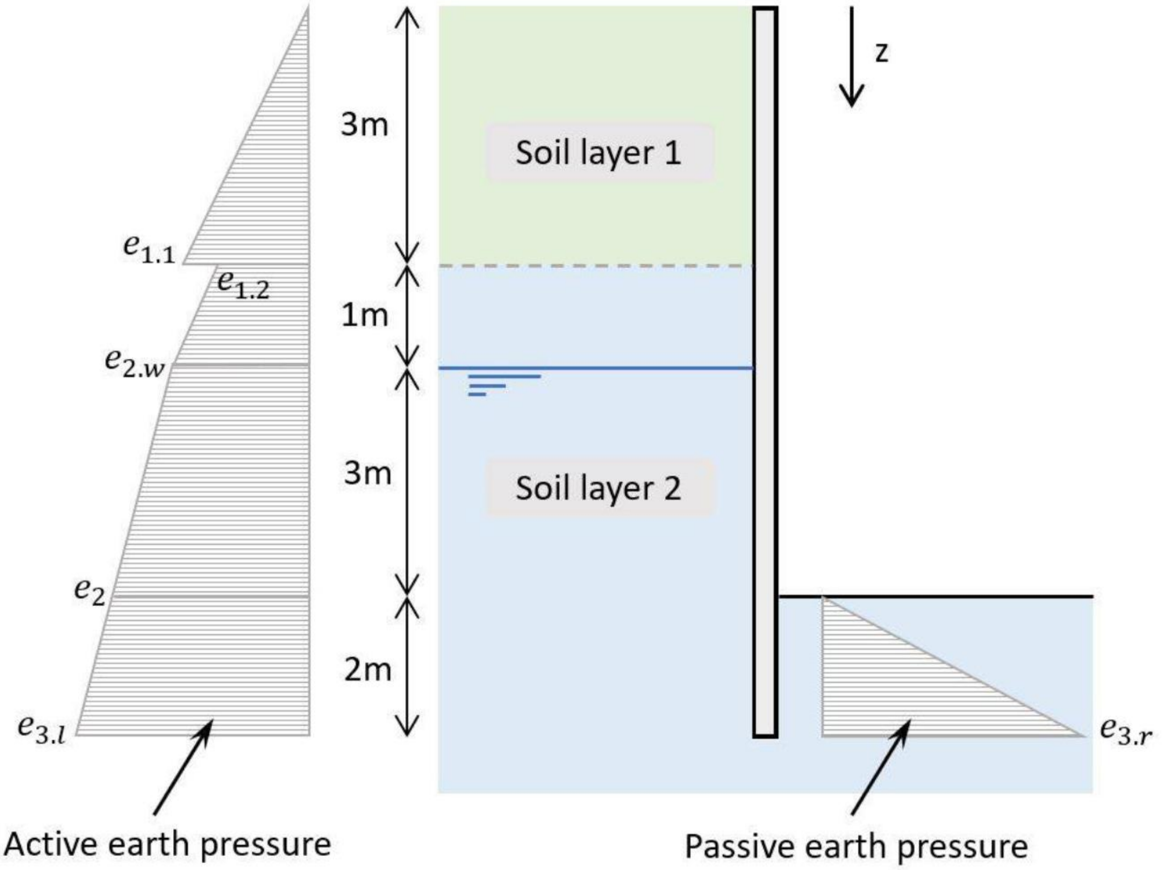
$$K_A = \frac{\cos^2(\phi-\theta)}{\cos^2\theta \cos(\theta+\delta)\left[1+\sqrt{\frac{\sin(\phi+\delta)\sin(\phi-\beta)}{\cos(\theta+\delta)\cos(\theta-\beta)}}\right]^2}$$



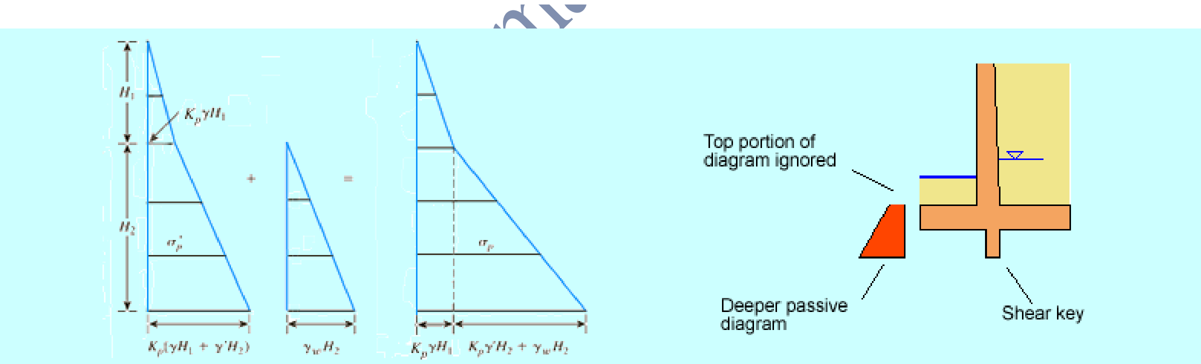
$$K_P = \frac{\cos^2(\theta+\phi)}{\cos^2\theta \cos(\theta-\delta)\left[1-\sqrt{\frac{\sin(\phi+\delta)\sin(\phi+\beta)}{\cos(\theta-\delta)\cos(\theta-\beta)}}\right]^2}$$

K_P VALUES ARE SATISFACTORY FOR $\delta \leq \phi/3$ BUT ARE UNCONSERVATIVE FOR $\delta > \phi/3$ AND THEREFORE SHOULD NOT BE USED.

FIGURE 8
Coefficients K_A and K_p for Walls with Sloping Wall and Friction, and Sloping Backfill



Active and passive earth pressure on retaining wall.



Definition of Earth Pressure:
Earth pressure is the pressure exerted by the soil mass on any retaining or buried surface (such as a wall, basement, sheet-pile) due to its weight, internal stresses and any external loads. It acts laterally when considering retaining walls.

Types of Lateral Earth Pressure (No Surcharge Condition):

- **At-Rest Earth Pressure (K_0):** This is the lateral earth pressure when the soil mass is in its natural state, undeformed, and the retaining wall is rigid (no wall movement). The coefficient (K_0) relates horizontal to vertical effective stress.

- **Active Earth Pressure (K_a):** Occurs when the retaining wall moves away slightly from the soil (soil mass expands) causing mobilization of shear and reduction of lateral pressure. ($K_a < K_0 < 1$) for typical cohesionless soils.
- **Passive Earth Pressure (K_p):** Occurs when the wall moves into the soil (soil is compressed), mobilizing greater shear strength; lateral pressure can be significantly higher. ($K_p > 1$).

Coefficient of Earth Pressure ((K)):

$$K = \frac{\sigma_h'}{\sigma_v'}$$

where (σ_h') = horizontal effective stress, (σ_v') = vertical effective stress.

For active and passive conditions for a cohesionless soil (horizontal backfill, no wall friction) using Rankine's theory:

$$K_a = \tan^2\left(45° - \frac{\phi}{2}\right), \quad K_p = \tan^2\left(45° + \frac{\phi}{2}\right)$$

where (ϕ) = internal angle of friction of the soil.

Rankine's Theory & Assumptions:
Rankine's theory provides a simple method for calculating lateral earth pressures under certain conditions. Key assumptions include:

- Soil is homogeneous, isotropic and cohesionless (for the simplest form).
- Backfill surface is horizontal, wall is vertical and frictionless.
- The wall moves sufficiently to achieve active or passive state (i.e., soil wedges form uniformly).
- The resultant earth pressure acts at a proper height (often at h/3 from base). If these assumptions are relaxed (cohesion, wall friction, surcharge, inclined backfill) more advanced methods are used.

Note: Since your syllabus says "with no surcharge condition," you focus on the case where there is no external load on top of the backfill other than its self-weight.

Exam Tip:

- Define each type of pressure (at-rest, active, passive).
- Write the coefficients formulas and describe what they mean.
- Mention Rankine's theory assumptions.
- Sometimes include a small sketch of a retaining wall showing backfill, active wedge, passive wedge, direction of wall movement.

Problem 1: CBR Test

Given:
A soil sample is compacted and tested in the CBR apparatus. At 2.5 mm penetration the measured load is 1200 kgf. The standard load for 100 % CBR at 2.5 mm is 1370 kgf.
Required: Determine the CBR value.

Solution steps:

1. Write the formula:
   [
   $$\text{CBR (\%)} = \frac{\text{Load on test soil at specific penetration}}{\text{Load on standard material at same penetration}} \times 100\%$$
   ] (Calculator Academy)

2. Substitute values:
   [
   $$\text{CBR} = \frac{1200}{1370} \times 100\% \approx 87.6\%$$
   ]

3. Interpret: A CBR of ~87.6% indicates a very strong subgrade/base material—well above typical natural soils.

Exam note: Show units (kgf) cancel, write percentage, and mention typical benchmark values for context.

Problem 2: Lateral Earth Pressure (Active Condition via Rankine)

Given:
Backfill soil: unit weight ($\gamma = 18,kN/m^3$), internal friction angle ($\varphi = 30°$). Retaining wall is vertical, backfill horizontal, no surcharge, no wall friction (simplified Rankine conditions). Height of wall ($H = 4,m$).
Required: Compute the coefficient of active earth pressure (K_a) and the active lateral earth pressure at the base of the wall.

Solution steps:

1. Use Rankine's formula for cohesionless soil (horizontal backfill, vertical wall):
   [
   $$K_a = \tan^2\left(45° - \tfrac{\varphi}{2}\right) = \tan^2\left(45° - 15°\right) = \tan^2(30°) \approx (0.577)^2 \approx 0.333$$
   ] (Wikipedia)

2. Vertical stress at base:
   [
   $$\sigma\_v = \gamma \times H = 18 \times 4 = 72,kN/m^2$$
   ]

3. Horizontal active stress at base:
   [
   $$\sigma\_h = K\_a ; \sigma\_v = 0.333 \times 72 \approx 24,kN/m^2$$
   ]

4. Interpretation: This means the soil exerts ~24 kN/m^2 lateral pressure at the base in the active state under the given conditions.

Exam note: Clearly mention assumptions (no surcharge, vertical wall, horizontal backfill, frictionless wall) because Rankine's formula is under those conditions. (skdavpolytech.ac.in)

Diploma Wallah

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