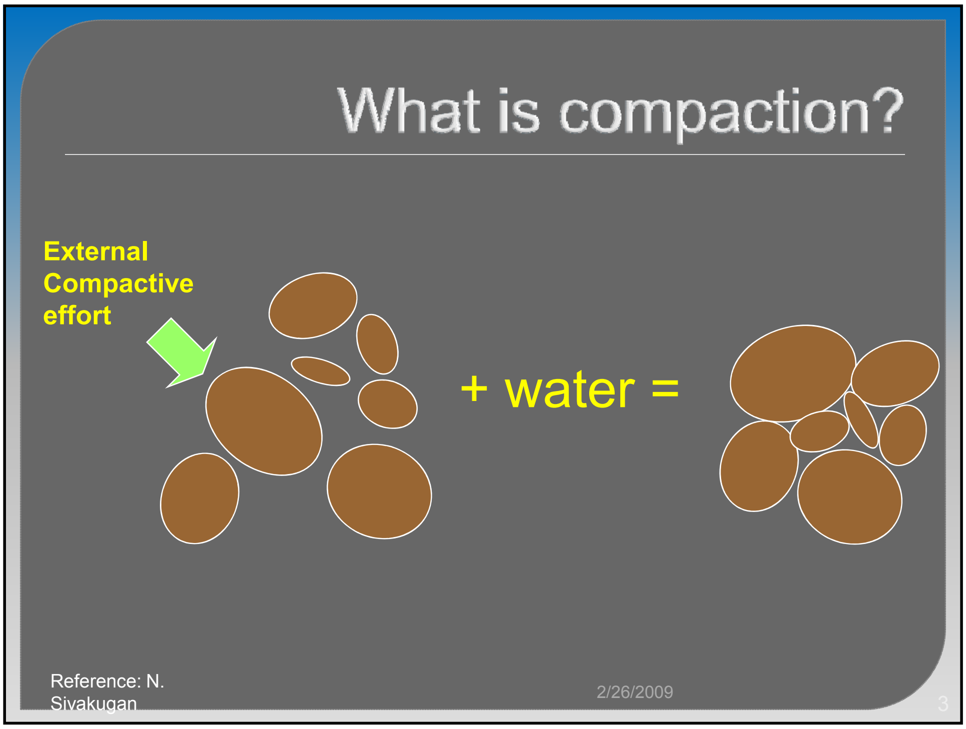
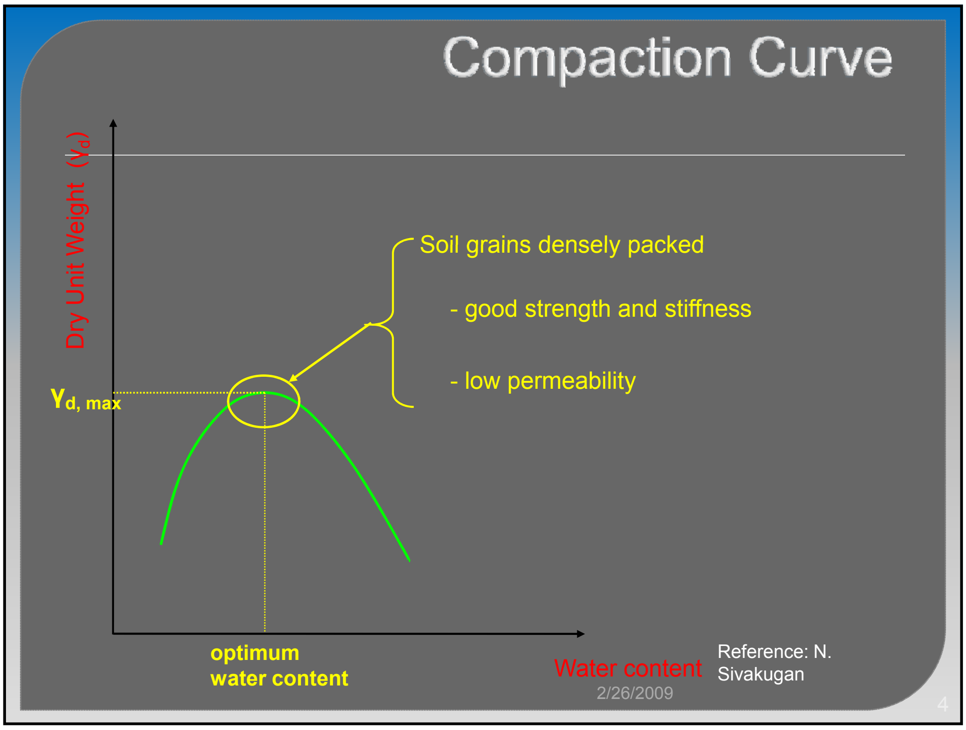
COMPACTION

Lecture Notes

What is compaction?

- A simple ground improvement technique by removal of air with an external compactive effort.
- The degree of compaction of a soil is measured in terms of its dry unit weight.


What is compaction?
External
Compactive
effort
+ water =
Reference: N.
Sivakugan
2/26/2009


Compaction Curve
Dry Unit Weight (γ_d)
Soil grains densely packed
- good strength and stiffness
- low permeability
$\gamma_{d,\ max}$
optimum
water content
Water content
Reference: N.
Sivakugan
2/26/2009

Compaction curve

What happens with addition of water?

- Water acts as a softening agent on the soil particles
- The soil particles slip over each other and move into a densely packed position
- γ_{dry} after compaction first increases as the water content increases.

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Compaction curve

- When the water content is gradually increased and the same compactive effort is applied, the weight of the soil solids in a unit volume gradually increases
- Beyond a certain water content, any increase in the water content tends to reduce the dry unit weight.

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Compaction curve

- This phenomenon occurs because the water takes up the spaces that would have been occupied by the solid particles.
- Optimum water content: is the water content at which the maximum dry unit weight is attained.

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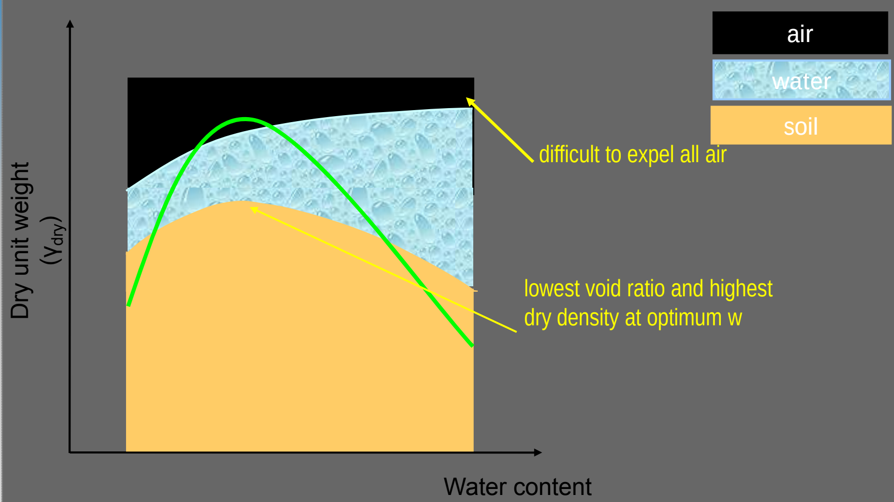
Compaction Curve



Reference: N. Sivakugan

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Laboratory Compaction Test

- to obtain the compaction curve and define the optimum water content and maximum dry density for a specific compactive effort.

Standard Proctor:

- 3 layers
- 25 blows per layer
- 2.7 kg hammer
- 300 mm drop

hammer

1000 ml compaction mould

Modified Proctor:

- 5 layers
- 25 blows per layer
- 4.9 kg hammer
- 450 mm drop

Reference: N. Sivakugan

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Standard Proctor Test

- For each test the moist unit weight can be calculated:

$$\gamma = \frac{W}{V_{mold}}$$

W= weight of the compacted soil in the mold

V = volume of the mold

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Standard Proctor Test

- For each test the water content of the compacted soil is determined in the laboratory
- With the known water content, the dry unit weight can be calculated as:

$$\gamma_{dry} = \frac{\gamma}{1 + w(\%)/100}$$

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Standard Proctor Test

- For a given water content and degree of saturation (S), the dry unit weight of compaction can be calculated as follows:

$$\gamma_{dry} = \frac{G_s \gamma_w}{1 + (G_s w) / S}$$

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Standard Proctor Test

To obtain the variation of zero air void unit weight (γ_{zav}) with water content use the following procedure:

- Determine the specific gravity of soil solids
- Know the unit weight of water (γ_w)
- Assume several values of w, such as 5%, 10%, 15%
- use the following equation :

$$\gamma_{zav} = \frac{G_s \gamma_w}{1 + (G_s w)} = \frac{\gamma_w}{w + 1/G_s}$$

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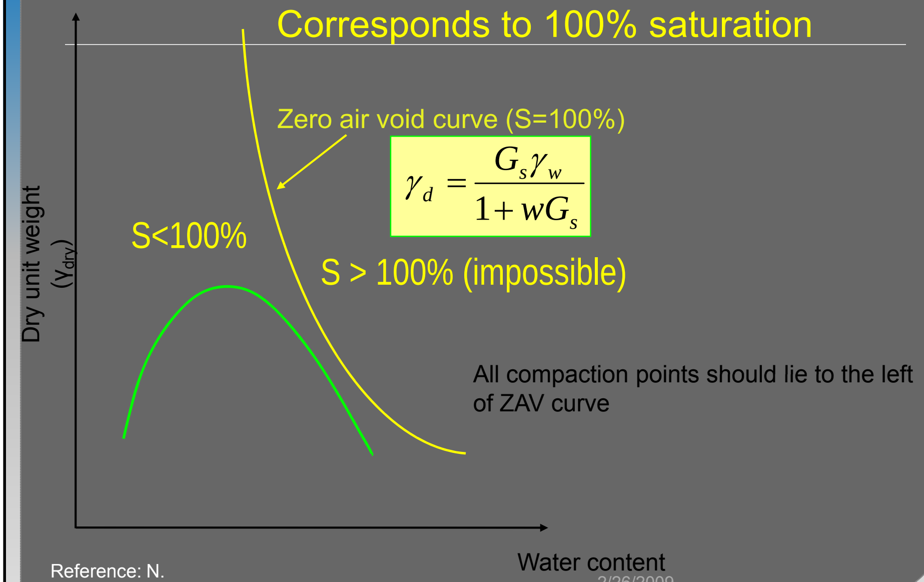
Zero Air Void Curve

Corresponds to 100% saturation



Reference: N. Sivakugan

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Factors affecting compaction

- **Effect of soil type**
  - Grain-size distribution
  - Shape of the soil grains
  - Specific gravity of soil solids
  - Amount and type of clay minerals

- **Effect of compaction effort**

$$E = \frac{(\#\text{blows/layer}) \bullet (\#\text{layers}) \bullet (W_{\text{hammer}}) \bullet (\text{drop height})}{\text{Volume of mold}}$$

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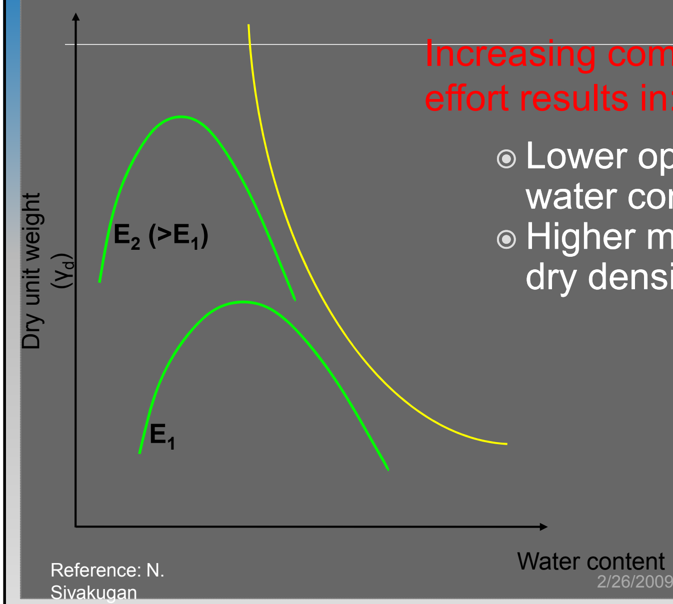
Effect of Compactive Effort



Increasing compactive effort results in:

- Lower optimum water content
- Higher maximum dry density

Reference: N. Sivakugan

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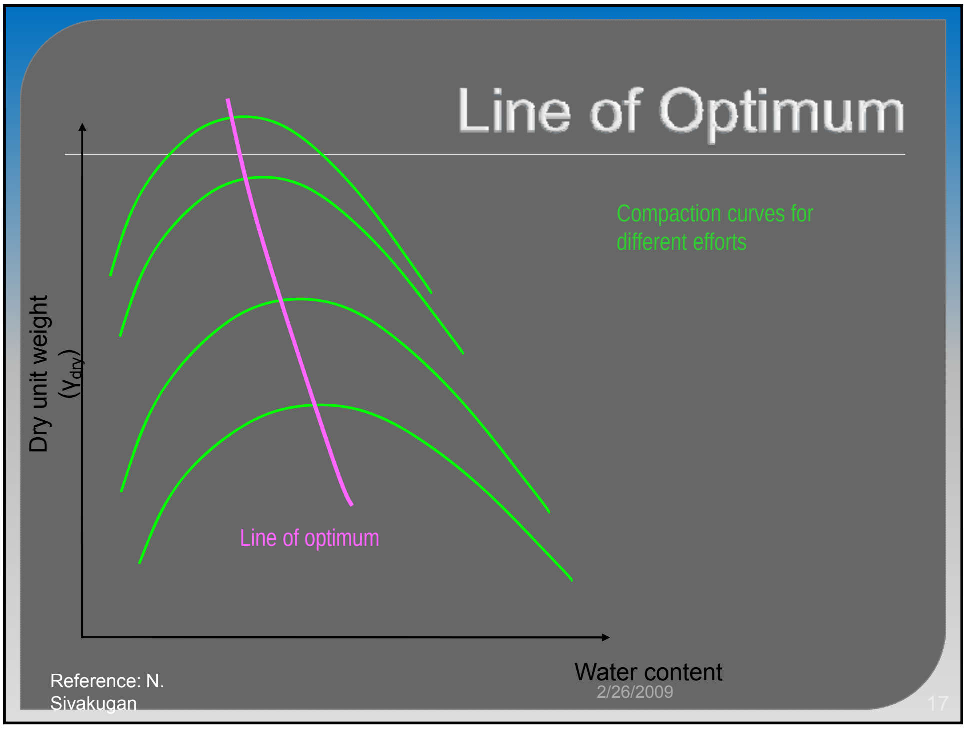
Line of Optimum
Compaction curves for different efforts
Dry unit weight (γ_{dry})
Line of optimum
Water content
Reference: N. Sivakugan
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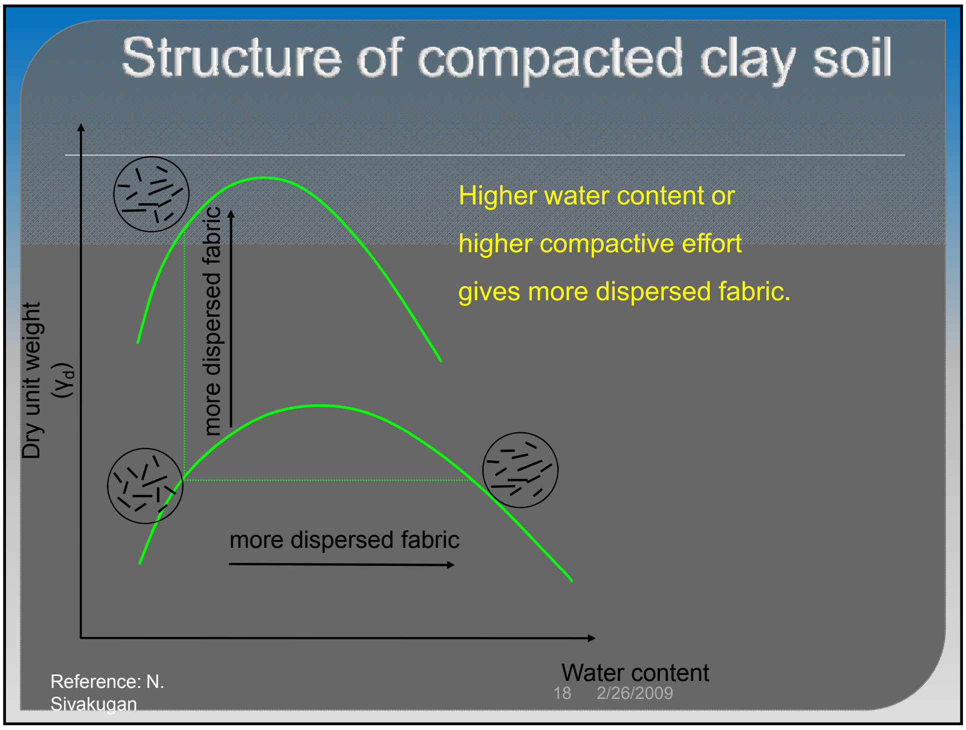
Structure of compacted clay soil
Higher water content or
higher compactive effort
gives more dispersed fabric.
Dry unit weight (γ_d)
more dispersed fabric
more dispersed fabric
Water content
Reference: N. Sivakugan
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Field compaction

- Smooth-wheel rollers
- Pneumatic rubber-tired rollers
- Sheepsfoot rollers
- Vibratory rollers




Field Compaction

Smooth Wheeled Roller

Compacts effectively only to 200-300 mm; therefore, place the soil in shallow layers

Field Compaction

Sheepsfoot Roller

- Provides kneading action; “walks out” after compaction
- Very effective on clays

Reference: N. Sivakugan

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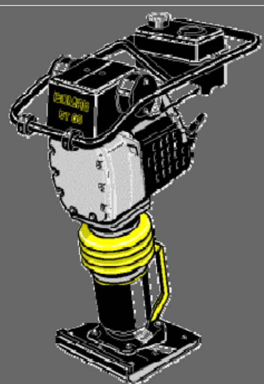
Field Compaction

Vibrating Plates



- for compacting very small areas
- effective for granular soils

Reference: N. Sivakugan

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Field Compaction

Impact Roller

- Provides deeper (2-3m) compaction. e.g., air field

Reference: N. Sivakugan

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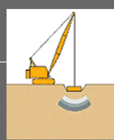
Dynamic Compaction

- pounding the ground by a heavy weight



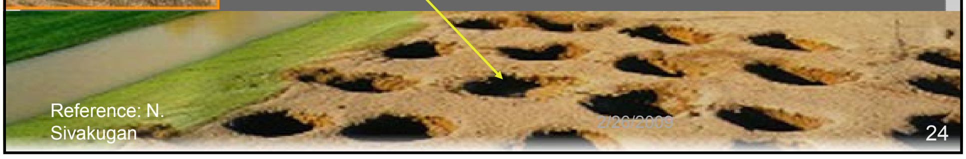
Suitable for granular soils, land fills and karst terrain with sink holes.

solution cavities in limestone

Pounder (Tamper)

Crater created by the impact

(to be backfilled)



Reference: N. Sivakugan

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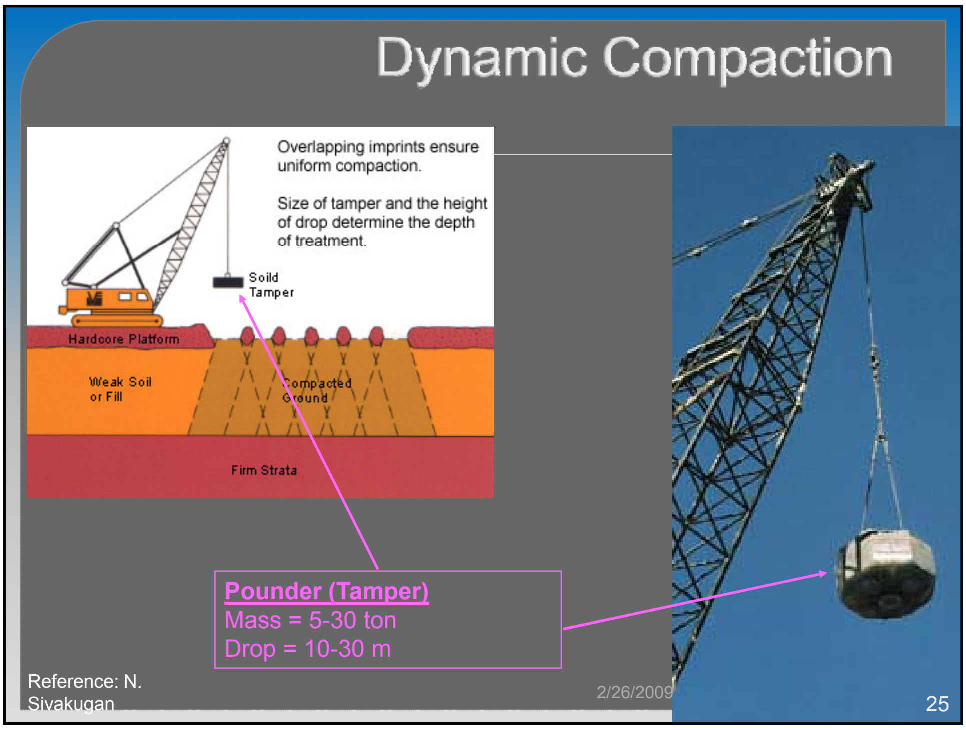
Dynamic Compaction
Overlapping imprints ensure uniform compaction.
Size of tamper and the height of drop determine the depth of treatment.
Soild Tamper
Hardcore Platform
Weak Soil or Fill
Compacted Ground
Firm Strata
Pounder (Tamper)
Mass = 5-30 ton
Drop = 10-30 m
Reference: N. Sivakugan
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Dynamic Compaction
Reference: N. Sivakugan
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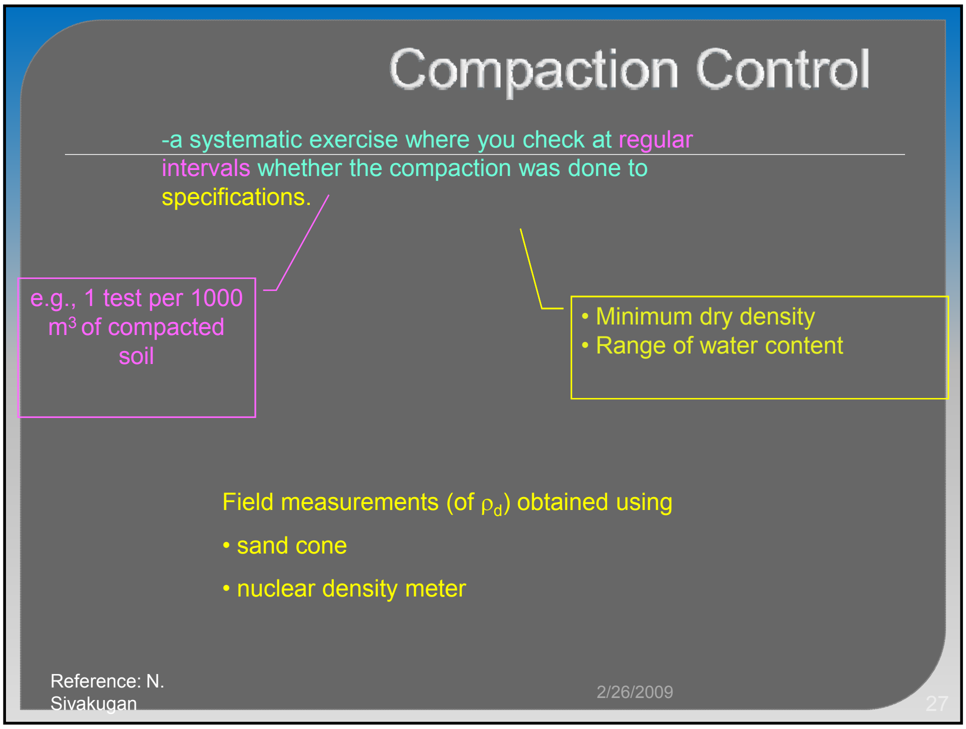
Compaction Control
-a systematic exercise where you check at regular intervals whether the compaction was done to specifications.
e.g., 1 test per 1000 m³ of compacted soil
• Minimum dry density
• Range of water content
Field measurements (of ρd) obtained using
• sand cone
• nuclear density meter
Reference: N. Sivakugan
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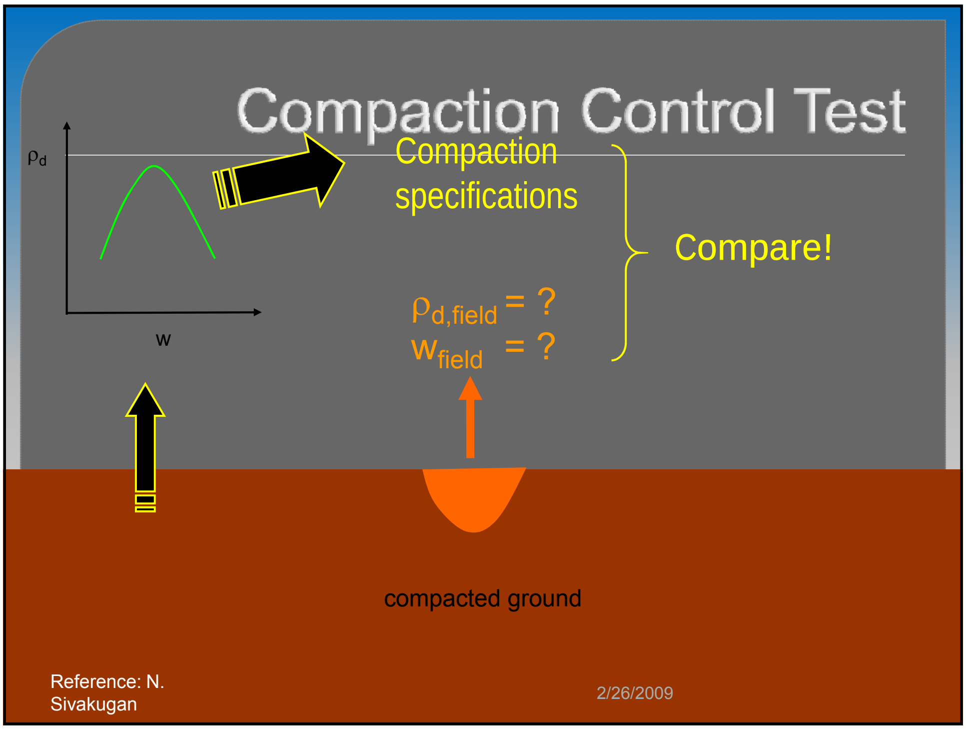
Compaction Control Test
ρd
w
Compaction specifications
Compare!
ρd,field = ?
wfield = ?
compacted ground
Reference: N. Sivakugan
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Vibroflotation

Suitable for granular soils

Practiced in several forms:

- vibro–compaction
- stone columns
- vibro-replacement

Vibroflot (vibrating unit)
Length = 2 – 3 m
Diameter = 0.3 – 0.5 m
Mass = 2 tons

(lowered into the ground and vibrated)

Reference: N. Sivakugan

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Vibroflotation

Reference: N. Sivakugan

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Vibroflotation

Reference: N. Sivakugan

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Vibroflotation

Reference: N. Sivakugan

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Vibroflotation

Reference: N. Sivakugan

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Vibroflotation

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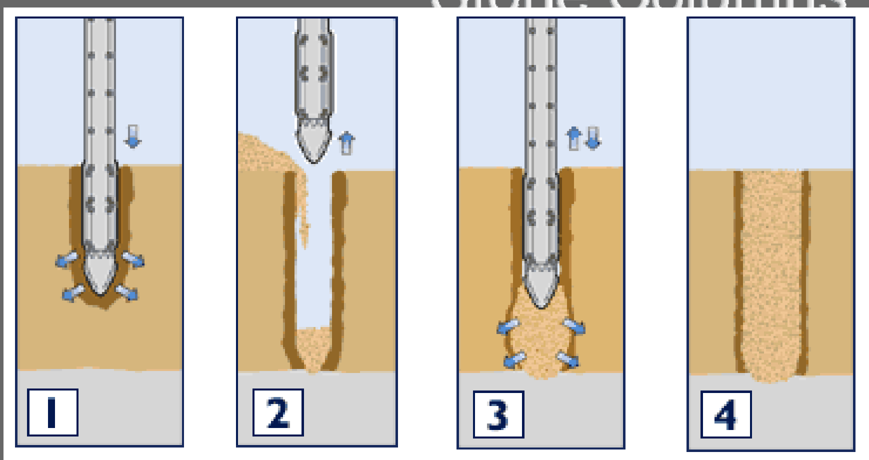
Vibroflotation

Stone Columns



vibrator makes a hole in the weak ground

hole backfilled

..and compacted

Densely compacted stone column

Reference: N. Sivakugan

Blasting

For densifying granular soils

Fireworks?

Aftermath of blasting

Reference: N. Sivakugan

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Earthmoving Equipment

Large Excavator (see minivan on left for scale)

Reference: N. Sivakugan

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Earthmoving Equipment

Grader for spreading soil

Reference: N. Sivakugan

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Earthmoving Equipment

Bulldozer for spreading soil evenly

Reference: N. Sivakugan

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Earthmoving Equipment

Loader

Reference: N. Sivakugan

Earthmoving Equipment

Backhoe

Reference: N. Sivakugan

Earthmoving Equipment

Crawler mounted **Hydraulic Excavator**

Reference: N. Sivakugan

Earthmoving Equipment

Rock Breaker

Reference: N. Sivakugan