EWC 341

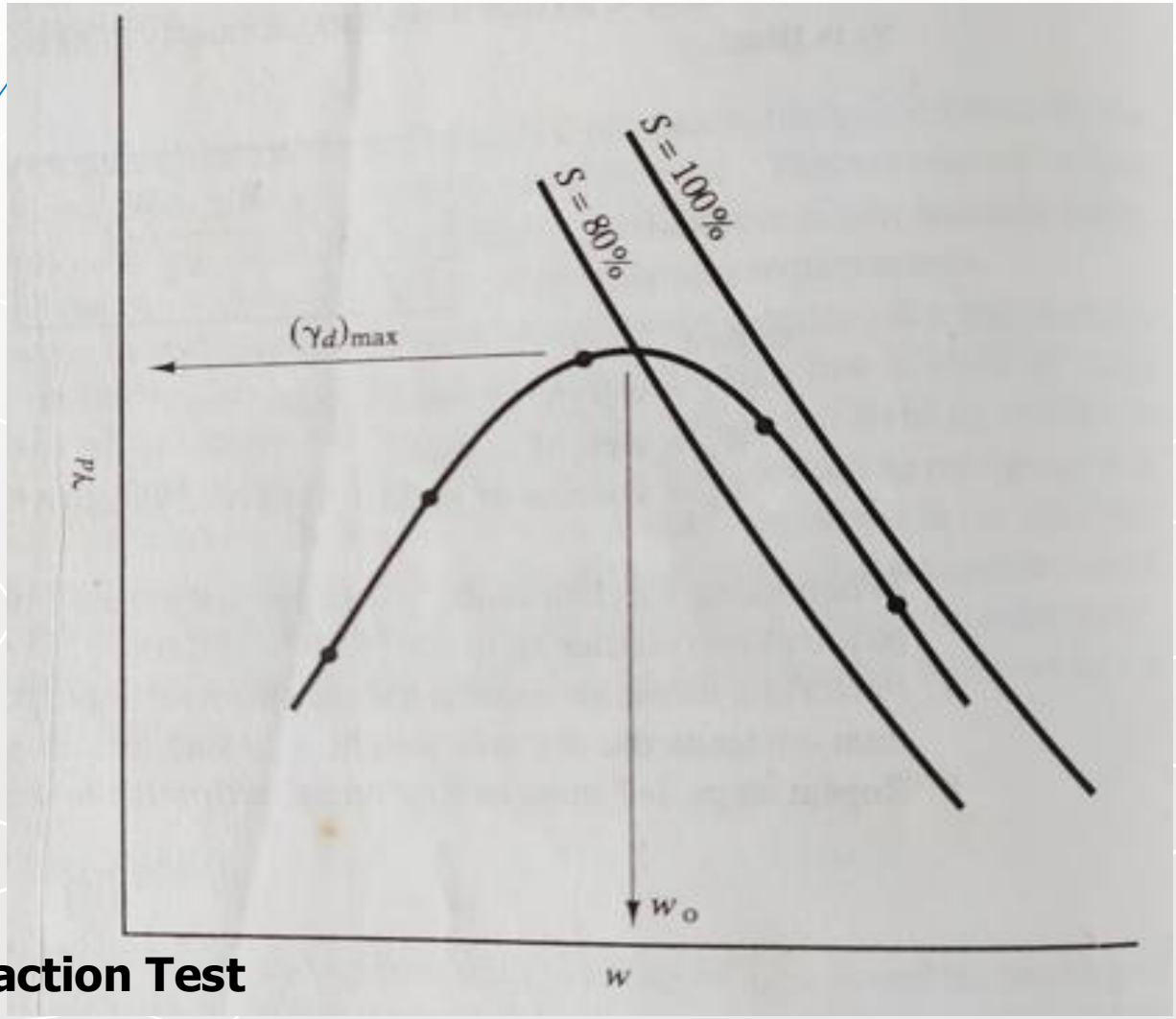
Principles of Soil Mechanics

Soil Compaction

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

$$w = S\left[\frac{\gamma_w}{\gamma_d} - \frac{1}{G_s}\right] x 100\%$$

- $w = \frac{W_w}{W_s} = \frac{W_2 - W_3}{W_3 - W_1}$ x 100%
-
- $\gamma_d = \frac{\gamma}{1+w}$
- Then plot the graph in **log paper γ_d vs w.**
- $C_R = \frac{\gamma_d}{\gamma_{d_{max}}}$ x 100%



Results from Proctor Compaction Test

A proctor compaction test has been performed on a soil sample. The **test result** were as follows:

Data Point nos.	1	2	3	4	5
• **Mass of compacted Soils and mold(kg)**	**3.762**	**3.921**	**4.034**	**4.091**	**4.040**
• Mass of can (g)	20.11	21.24	19.81	20.30	20.99
• Mass of can + wet soil(g)	240.85	227.03	263.45	267.01	240.29
• Mass of can + dry soil(g)	231.32	212.65	241.14	238.81	209.33

Mass of the compaction mold was 2.031kg. Moisture tests were performed on small portion of compacted soils sample.

- Compute γ_d **and w** for each data point and plot these result.
- **Develop and plot curves** for **S =80%** and **S= 100%** using a specific gravity of 2.69.
- Using data from a and b, **draw the proctor compaction curve** and **determine** $\gamma_{d_{max}}$ **and** w_0.

Solution:

Computation for data point no. 1:

For unit weight, $\gamma = \frac{W_{ms} - W_m}{V_m} = \frac{(M_{ms} - M_m)g}{V_m}$

$$= \frac{(3.762kg - 2.031kg)9.81m/s^2}{9.44x\ 10^{-4}\ m^3} \text{x (1N/1000kN)}$$

$$= 17.99\ \text{kN}/m^3$$

For water content, $w = \frac{M_1 - M_2}{M_2 - M_c}$ x100%

$$= \frac{240.85 - 231.32}{231.32 - 20.11} \text{x100\%}$$

$$= 4.5\%$$

$$\gamma_d = \frac{\gamma}{1+w} = \frac{17.99}{1+0.045} = 17.22\ \text{kN}/m^3$$

Thus, **this data point plots** at w =4.5% and $\gamma_d = 17.22\ \text{kN}/m^3$

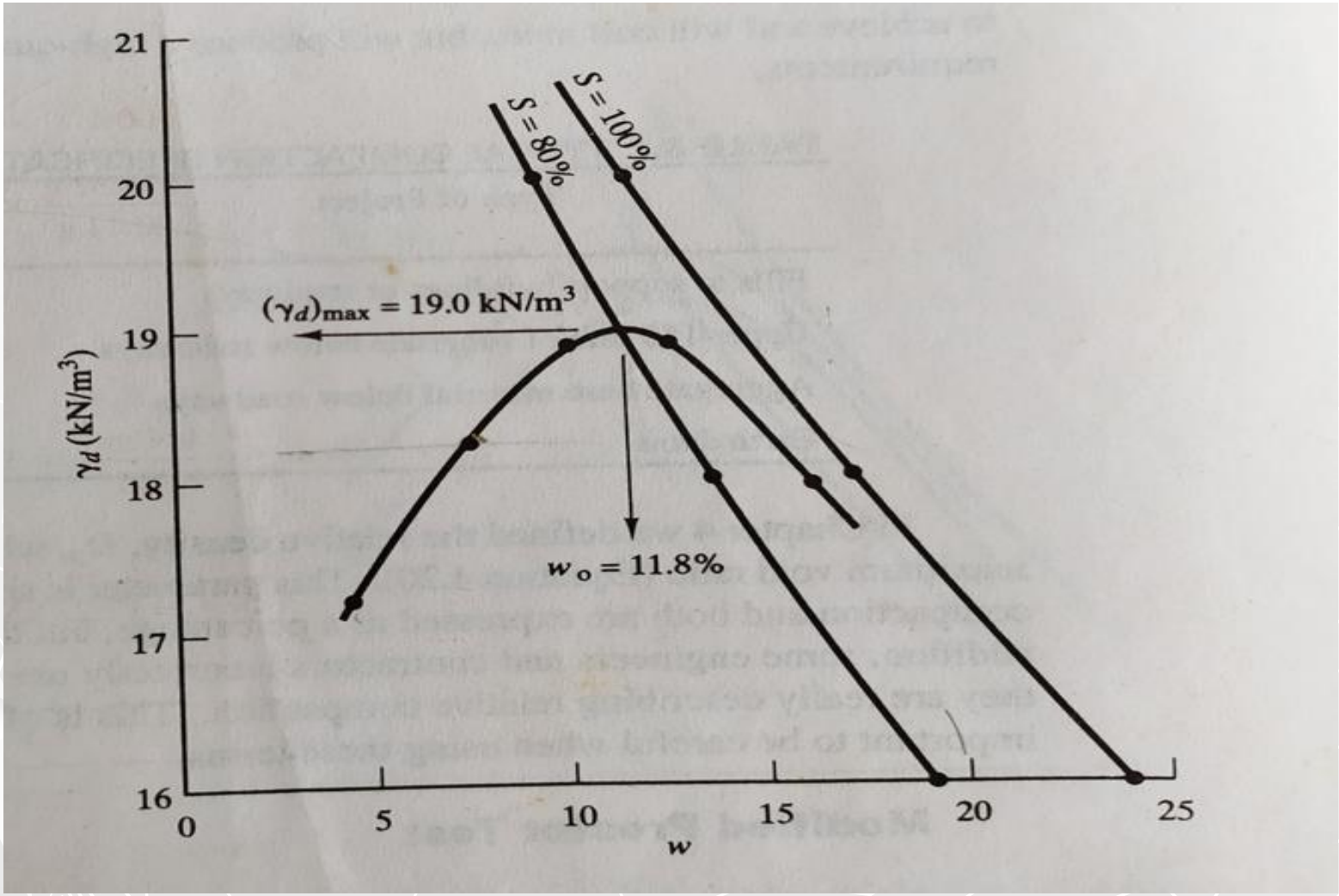
Following the same procedures for other data points gives:

Data point No.	1	2	3	4	5
γ kN/m^3	17.99	19.64	20.81	21.41	20.88
w	4.5%	7.5%	10.1%	12.9%	16.4%
γ_d kN/m^3	17.22	18.27	18.90	18.96	17.94

- From equation, $w = S\left[\frac{\gamma_w}{\gamma_d} - \frac{1}{G_s}\right]$ $\gamma_w = 9.807\ \text{kN}/m^3$
- Select value of γ_d in the range of test data and compute the corresponding values of w foe S=80% and S=100%:

γ_d **kN/**m^3	**w**	
	@ S=80%	@ S=100%
16.00	19.3%	24.1%
18.00	13.9%	17.3%
20.00	9.5%	11.9%

Plots data points and draw the compaction curves.



Final Results are: $\gamma_{d_{max}}$ = 19.0 kN/m^3 and w_0=11.8%

Field Density/Unit Weight Tests:

- Final link in assessing fill compaction by Proctor Compaction Test method is to measure γ_d in the fill after compaction and thus enabling to use equation $C_R = \frac{\gamma_d}{\gamma_{d_{max}}} \text{x} 100\%$

- Several methods have been developed to do so and known as ***Field Density Tests/Field Unit Weight Test***.

- All of these methods are **performed in the field**, thus making it possible to immediately present the test results to the contractor.

- Such **rapid feed back is important**, because contractor must rectify an inadequately compacted zones before they are buried by additional fill.

Sand Cone Test

- One of the most common field density test method.

Procedures:

- Prepare a level surface in the fill and dig a cylindrical hole about 125mm (5 inch) in dia and 125mm (5 inch) deep.
- **Save all the soi**ls that comes out of the hole and determine its weight W.
- **Fill the sand cone apparatus** with special free flowing SP (Southern Specific) sand (Density Test Sand). Sand Cone Test Sand, Model: HM-106)
- Determine **weight of cone apparatus and sand= W_1**

- **Place sand cone over the hole**, open the valve and allow the sand to fill the hole and the cone.
- **Close the valve**, remove the sand cone from the hole and **determine the new weight =W_2** .

Volm of hole, $V=\frac{W_1 - W_2}{\gamma_{sand}}$ - Vcone

$$\gamma=\frac{W}{V}$$

- **Need to measure w**
- $\gamma_d=\frac{\gamma}{1+w}$

$$CR=\frac{\gamma_d}{\gamma_{d_{max}}} \times 100\%$$

Where,

V= volume of test hole

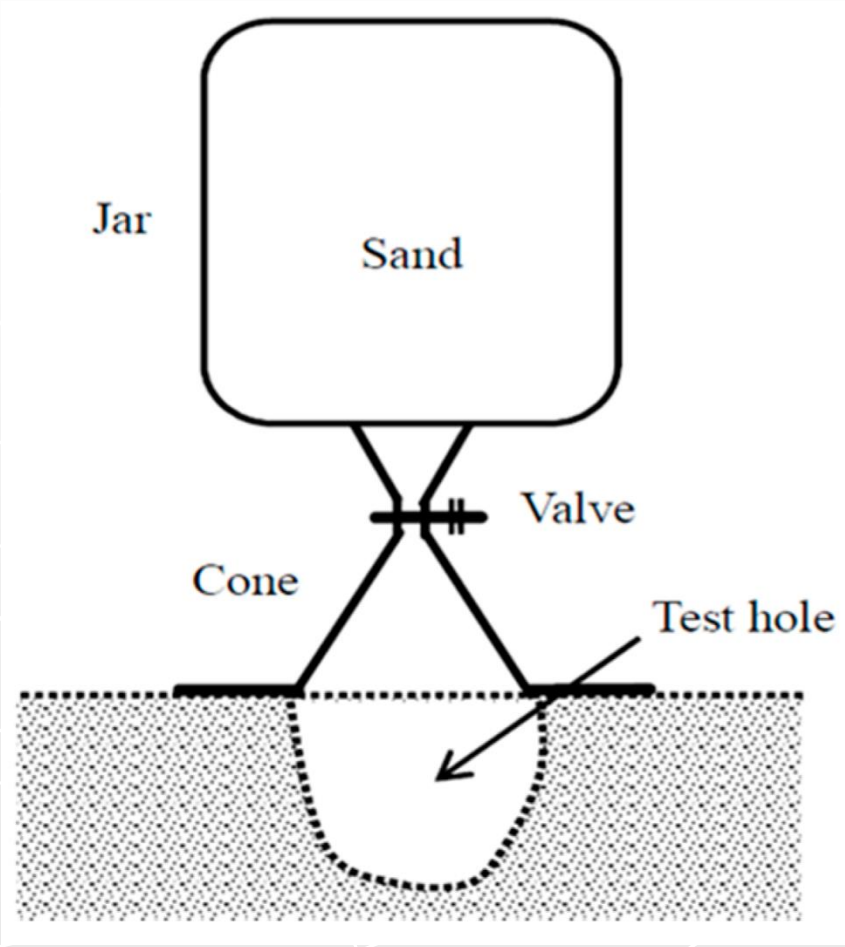
W_1= Initial weight of sand cone apparatus

W_2= Final weight of sand cone apparatus

γ_{sand}= unit weight of sand used in sand cone

V_{cone}= volume of sand cone below the valve

W= weight of soil removed from the test hole.


Jar
Sand
Valve
Cone
Test hole


gettyimages
JEFFREY_JK
690792954



- Naturally **rounded silica sands** of nearly **pure quartz** are mined from the Ottawa, Illinois area. Three different grading's are available, each designed for a specific type of test.

- **HM-106 Density Test Sand** (Sand Cone Test Sand) for sand cone density testing of soils is clean, uniform, un-cemented and free-flowing, and meets **ASTM D1556/1556M** and **AASHTO T 191**.



Determination of w% in the field:

- **Stir-frying the soil sample** in a **frying pan** over **a portable propane stove**
- **Speedy Moisture Tester**
- **Drive Cylinder Test**
- **Water Ring Test**

Measurement of Moisture Content:

- To measure moisture content, normally it requires placing the soils sample in the oven overnight, which is unacceptably slow.

Special rapid methods to measure the moisture content in the field:

- **Stir-frying the soil sample** in a **frying pan** over **a portable propane stove.**

  -Method is fast and gives **reasonably accurate results** in clean sand and gravel.

  -Much hotter than laboratory oven, thus producing **erroneous results in clay and organic soils**; w will be too high.

Speedy Moisture Tester:

- Mixing the soil with **calcium carbide** in a **special sealed container** known as a ***speedy moisture tester***.

-Water in the soil reacts with CaC_2 to produce **acetylene gas (C_2H_2)** and reaction continues until water is depleted.

-A **pressure gauge measures** the resulting pressures generated by the production of gas and calibrated to **compute w.**

-Results are **not as accurate** as a standard laboratory moisture test, but are usually sufficient for field density tests.

 # A sand cone test has been performed in the compacted fill of which $\gamma_d$max= 19.0 kN/m³ . The test results are as follows:

Initial mass of sand cone apparatus = **5.912** kg

Final mass of sand cone apparatus = **2.378** kg

Mass of soil recovered from the hole = **2.883** kg

Moisture contents of soil from hole **= 7.0%**

Density of sand = 1300 kg/m³.

Volume of cone below the valve = **1.114x 10^{-3} m³**

The project specification requires to a relative compaction of at least **90%.**

Compute γ_d and C_R, and determine whether project specification has been meet.

Solutions:

$M_{sand\ (cone+hole)}$ = 5.912 kg-2.378kg= 3.534 kg

$$V_{cone+hole} = \frac{(M_{sand)\ cone+hole})}{\rho_s} = \frac{3.534\ kg}{1300 kg/m^3} = 2.718\text{x } 10^{-3} m^3$$

$$V_{hole} = V_{cone+hole} - V_{cone} = 2.718\text{x } 10^{-3} m^3 - 1.114\text{x } 10^{-3} m^3$$

$$= 1.604 \text{ x } 10^{-3} m^3$$

$W_{soil} = M_{soil}\, g = 2.883\text{kgx } 9.81\text{m/s}^2 \text{ x } 0.001 = 2.828\text{x}10^{-2}\text{kN}$

$$\gamma = \frac{W_{soil}}{V_{hole}} = \frac{2.828\text{x}10^{-2}\text{kN}}{1.604 \text{ x } 10^{-3} m^3} = 17.63\ \text{kN}/m^3$$

$$\gamma_d = \frac{\gamma}{1+w} = \frac{17.63\ \text{kN}/m^3}{1+0.07} = 16.5\ \text{kN}/m^3$$

$$C_R = \frac{\gamma_d}{\gamma_{(d)\,max}} = \frac{16.5\ \text{kN}/m^3}{19.0\ \text{kN}/m^3} = 86.8\%$$

Nuclear Density Test (ASTM D2922)

- Consists of **Special Device** which **emits gamma rays** and **detects how they travel through soils**
- **Amount of gamma rays received back** into the device **correlates** with unit weight of soils.
- Measurements of w and γ **depends on empirical correlation** and which must be ultimately be programmed into the device.
- Results **display on digital electronic readouts.**
- In spite of its use of hi-tech equipment, this method is **slightly less accurate** than sand cone, because it is based on empirical correlations with transmission of radiation.



Performing nuclear density test



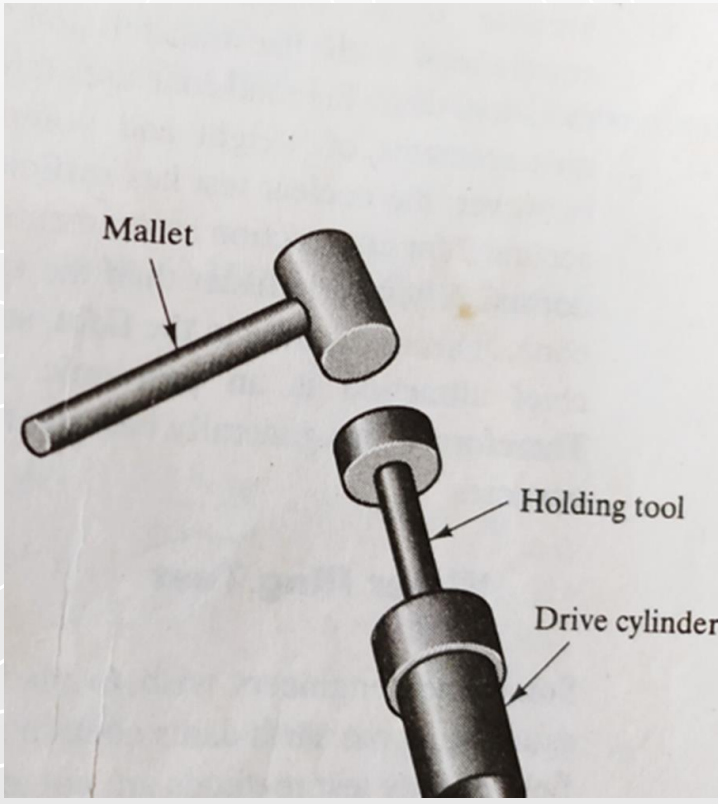




Performing nuclear density test

Drive Cylinder Test (ASTM D2937):

- Consists of **driving a thin-wall steel tube** in to the soil using **special drive head** and **a mallet**.
- **Cylinder is then dugout** of the fill using a shovel, soil is **trimmed smooth** and it is **weighed**.
- γ of the fill is the computed based on this **weight** and the **volume** of the cylinder.
- Then **w is determined**.
- **Much faster** than sand cone but slightly less precise.
- **Only suitable** for **fills with sufficient silt and clay** to provide enough dry strength to keep the sample inside the cylinder.

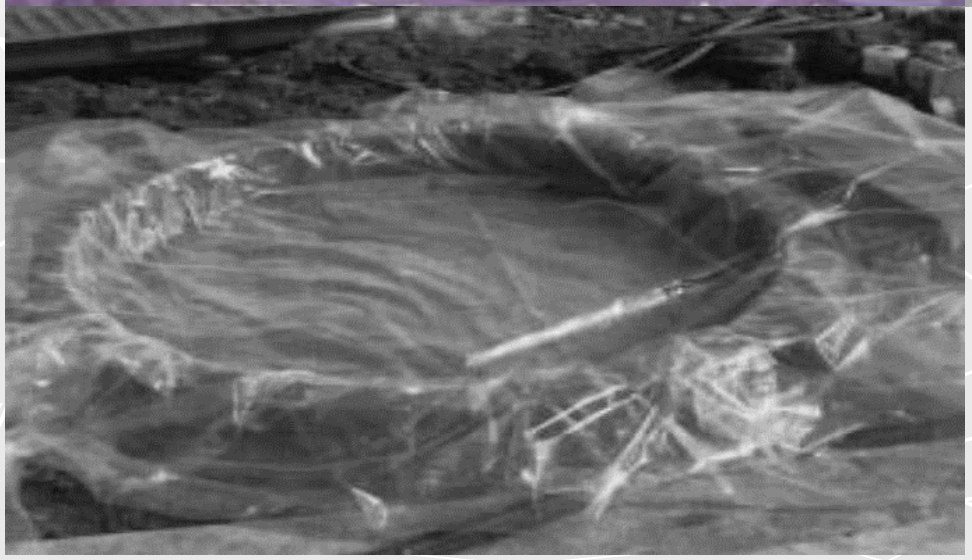


Water Ring Tests (ASTM D5030):

- Sometimes **engineers wish to place fills** that **contains cobbles** (2.5–10.1 inch) and **small boulders**.
- Some **earth dams contains** zones made of such soils.
- **Conventional field density test methods are not applicable** because of the large particle sizes.
- One way to evaluate such fills is the **water ring test**.
- Test uses a **much larger sample** and **uses water** instead of sand to measure the volume.

- Holes has been dug (a ring is **typically 1800mm in diameter)** and excavated soils has been **weighed**.
- Hole has been lined with plastic and **filled with water to measure its volume.**








Thank you