UNIVERSITAS TRISAKTI
PRODI TEKNIK PERTAMBANGAN

Tanah, Batuan dan Partikel Tanah

MTT6201 – MEKANIKA TANAH

1st session
1.5 hours

Lecturer :
Dr. Pantjanita Novi Hartami, S.T., M.T.
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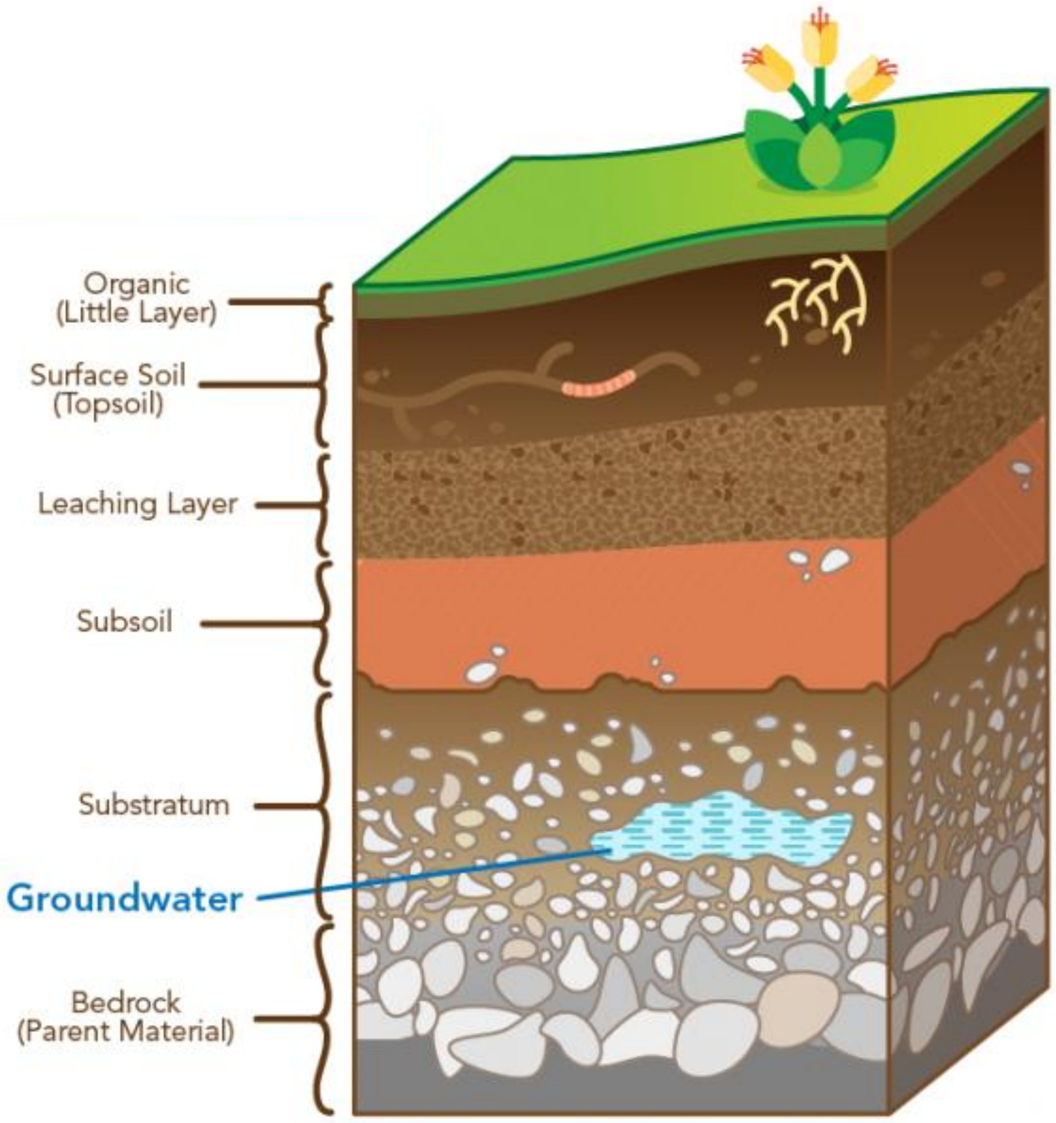
Danu Putra, S.T., M.T.



SEMESTER SYLLABUS

1. Introduction
2. **Pengertian Tentang Tanah dan Batuan, Partikel Tanah**
3. Analisis Ayakan dan Analysis Hydrometer
4. Hubungan Volume, Berat, Porositas, Kadar air, Kerapatan Relative Tanah
5. Konsistensi Tanah, Batas Plastis, Batas Cair
6. Klasifikasi tanah berdasarkan USDA, AASHTO, dan Unified
7. Tegangan Efektif dan penentuan tegangan bidang

Mid Term

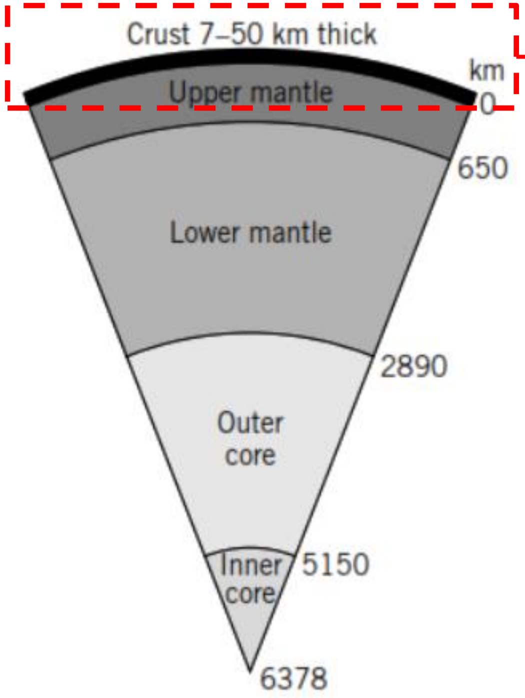
1. Konsep Tegangan, regangan, dan kekuatan tanah
2. Kekuatan geser tanah
3. Kompaksi
4. Permeabilitas dan rembesan
5. Aliran Air dalam tanah
6. Kestabilan lereng
7. Daya dukung tanah

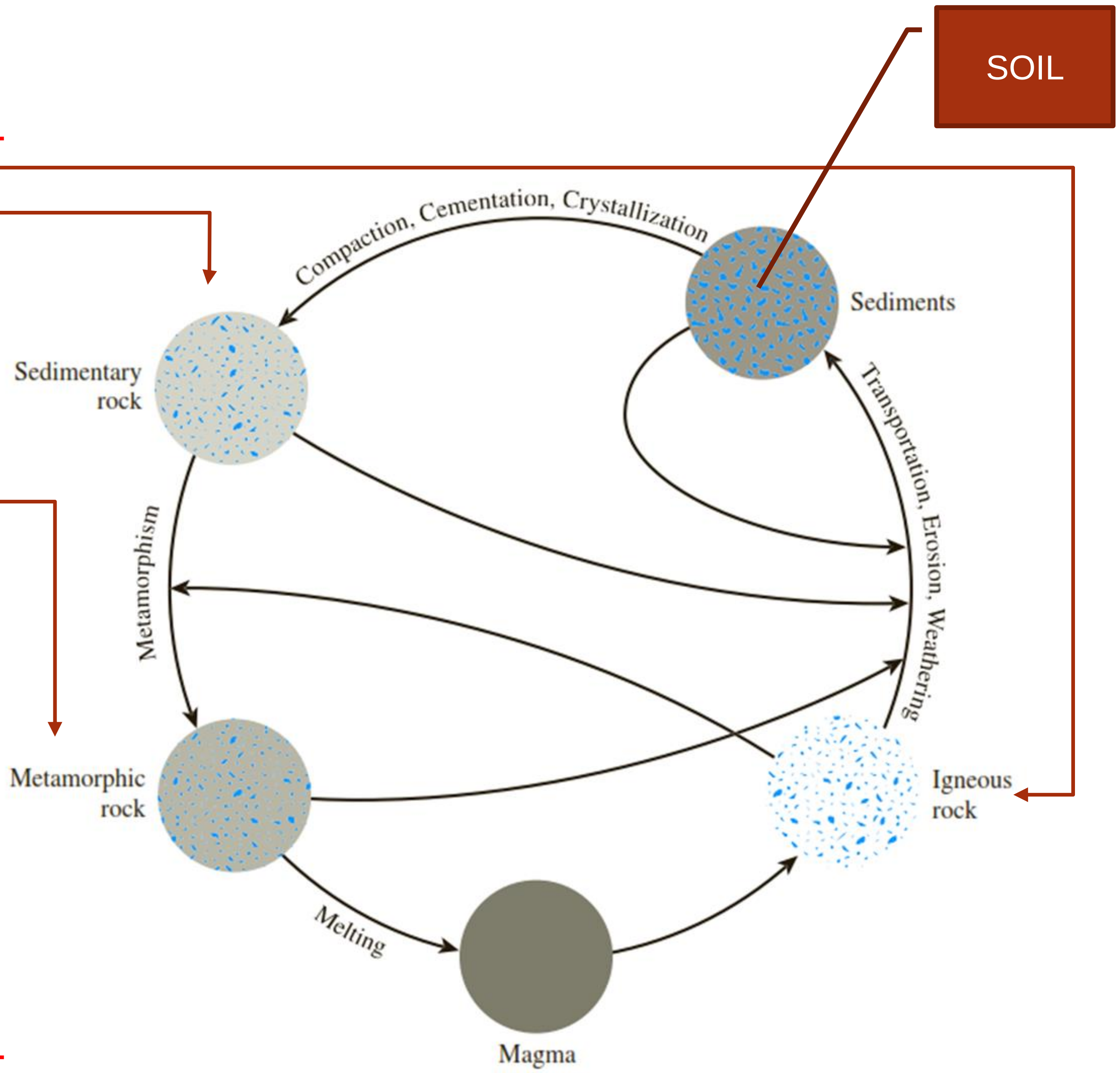
Final Term

Siklus Batuan

Berdasarkan asal-usulnya, batuan dibagi menjadi tiga tipe dasar yaitu :

1. Batuan beku (*igneous rocks*)
2. Batuan sedimen (*sedimentary rocks*)
3. Batuan metamorf (*metamorphic rocks*)

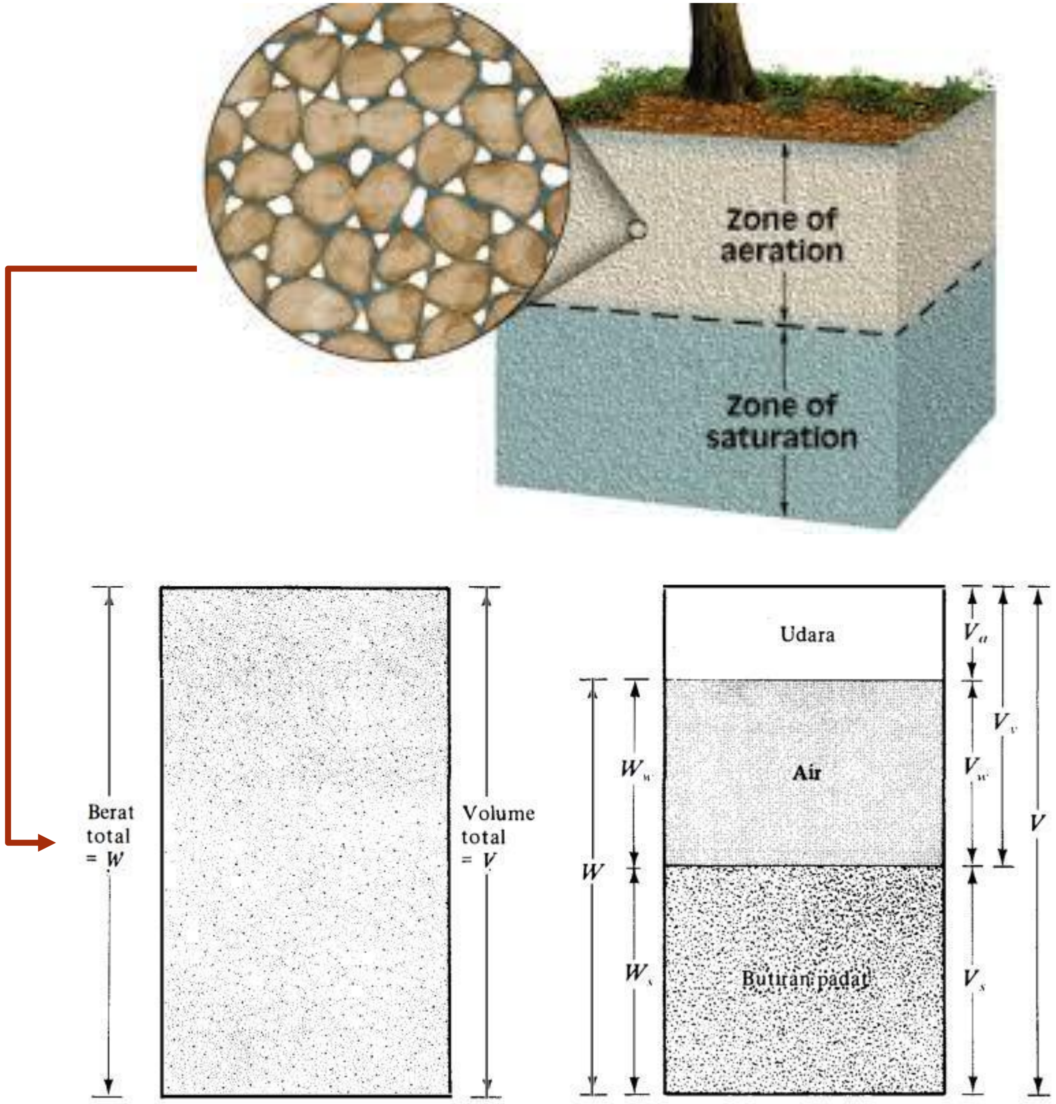




Tanah

Tanah adalah **bagian yang terdapat pada kerak bumi** yang **tersusun atas mineral dan bahan organik**.

Secara keteknikan, tanah didefinisikan sebagai material yang terdiri **dari agregat (butiran) mineral-mineral padat** yang tidak tersementasi (terikat secara kimia) satu sama lain dan dari **bahan-bahan organic yang telah melapuk** (yang berpartikel padat) disertai dengan zat cair dan gas yang mengisi ruang-ruang kosong di antara partikel-partikel padat tersebut (Braja M. Das, terjemahan:1995)



Tanah merupakan **objek pekerjaan** pada teknik pertambangan, disamping itu tanah juga berfungsi sebagai **pendukung/pondasi** untuk peralatan penambangan maupun infrastruktur penambangan.

Seorang ahli teknik tambang harus juga mempelajari **sifat-sifat dasar dari tanah**, seperti :

1. asal usulnya (*origin*),
2. penyebaran ukuran butiran (*particles size*),
3. kemampuan mengalirkan air (*permeability*),
4. sifat pemampatan bila dibebani (*compressibility*),
5. kekuatan geser (*shear strength*),
6. kapasitas daya dukung (*bearing capacity*)

Sifat Fisik

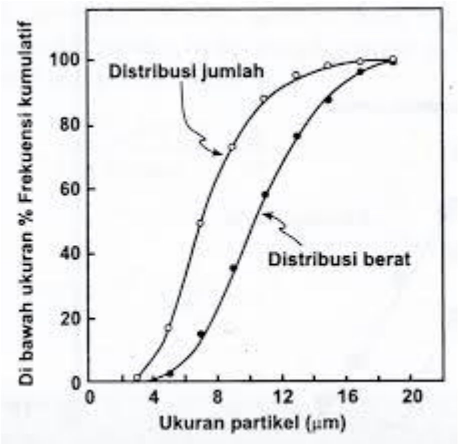
Sifat Mekanik

Ilmu yang mempelajari tentang hal tersebut adalah :

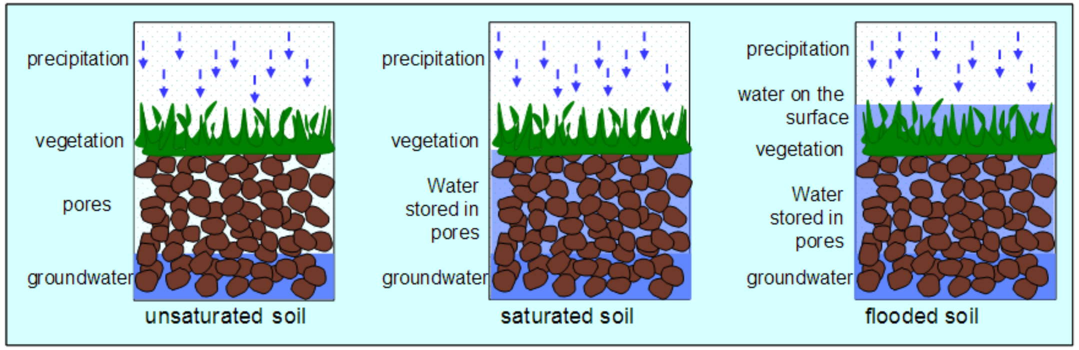
Mekanika Tanah (Soil Mechanics).

Sifat Fisik Tanah

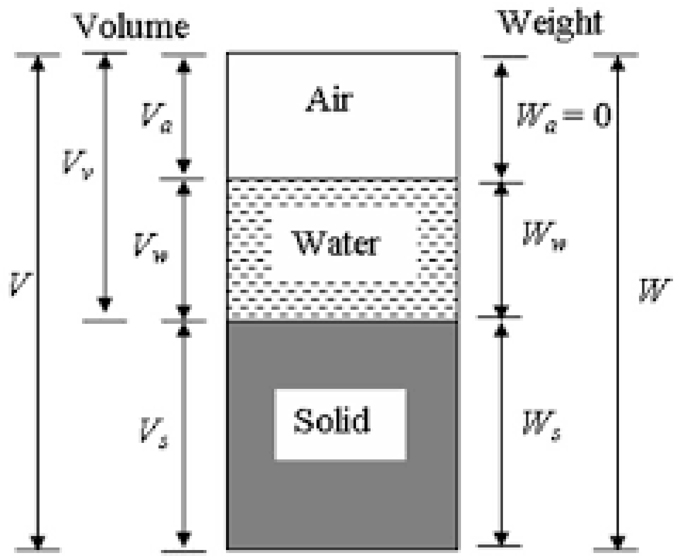
Origin
Distribusi ukuran partikel

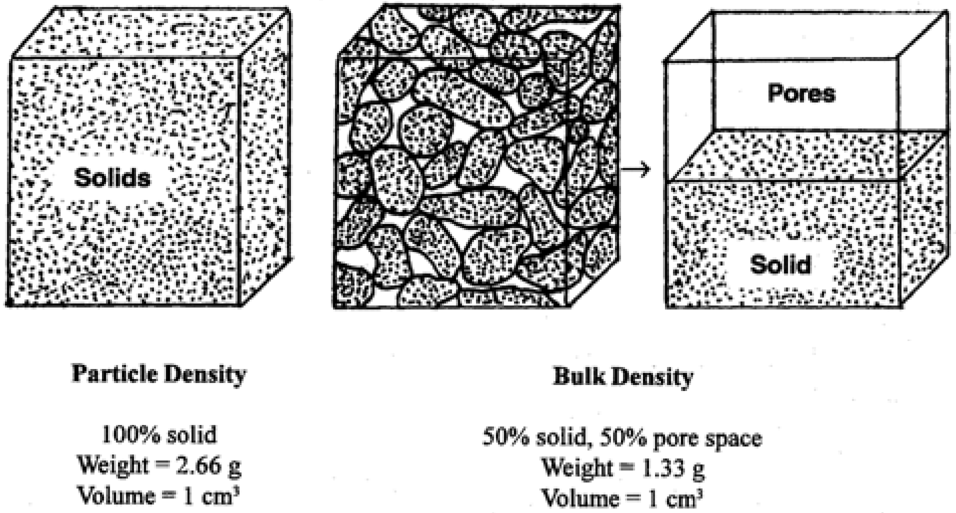


Kadar air

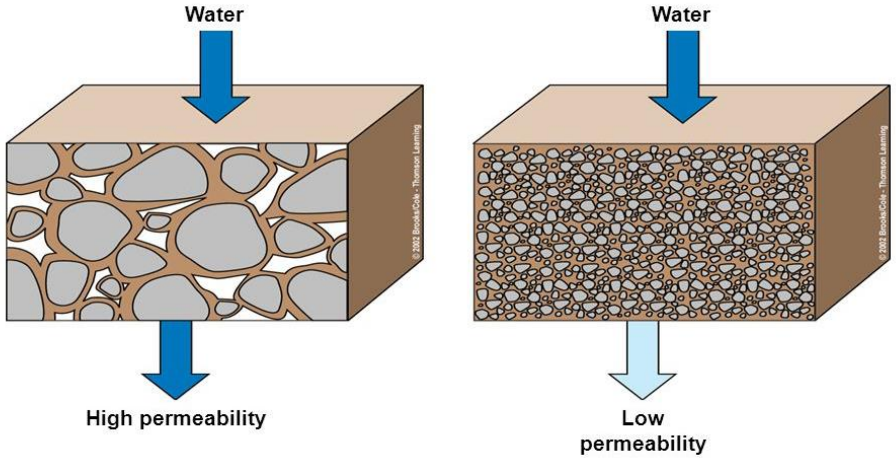


Berat jenis
Angka pori
Berat unit

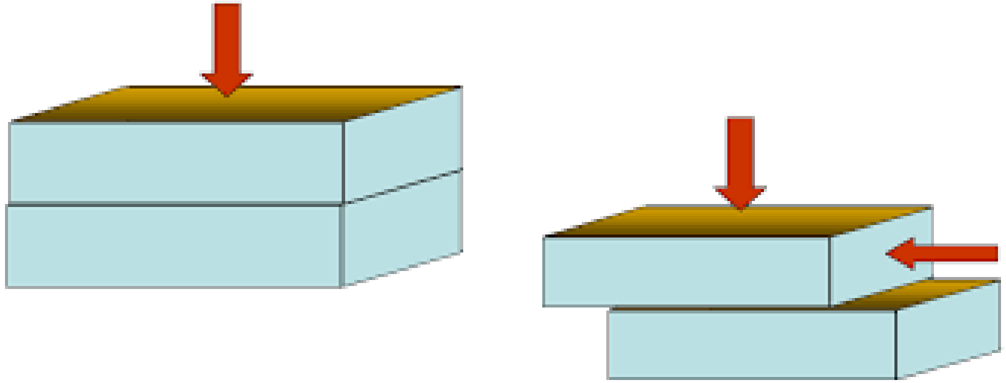


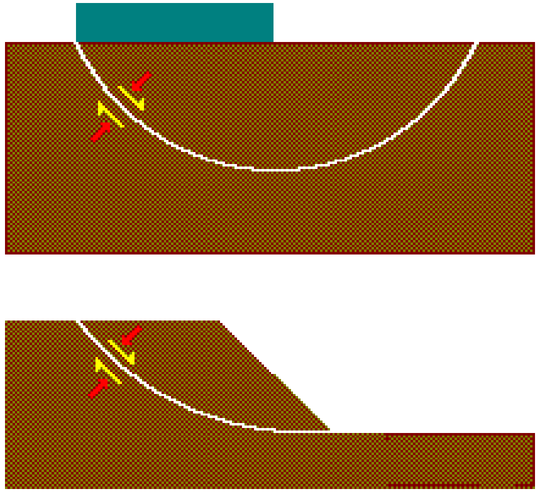


Permeabilitas

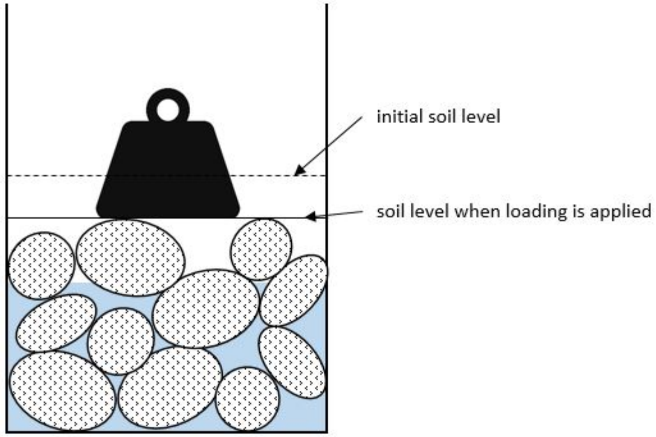


Kuat geser





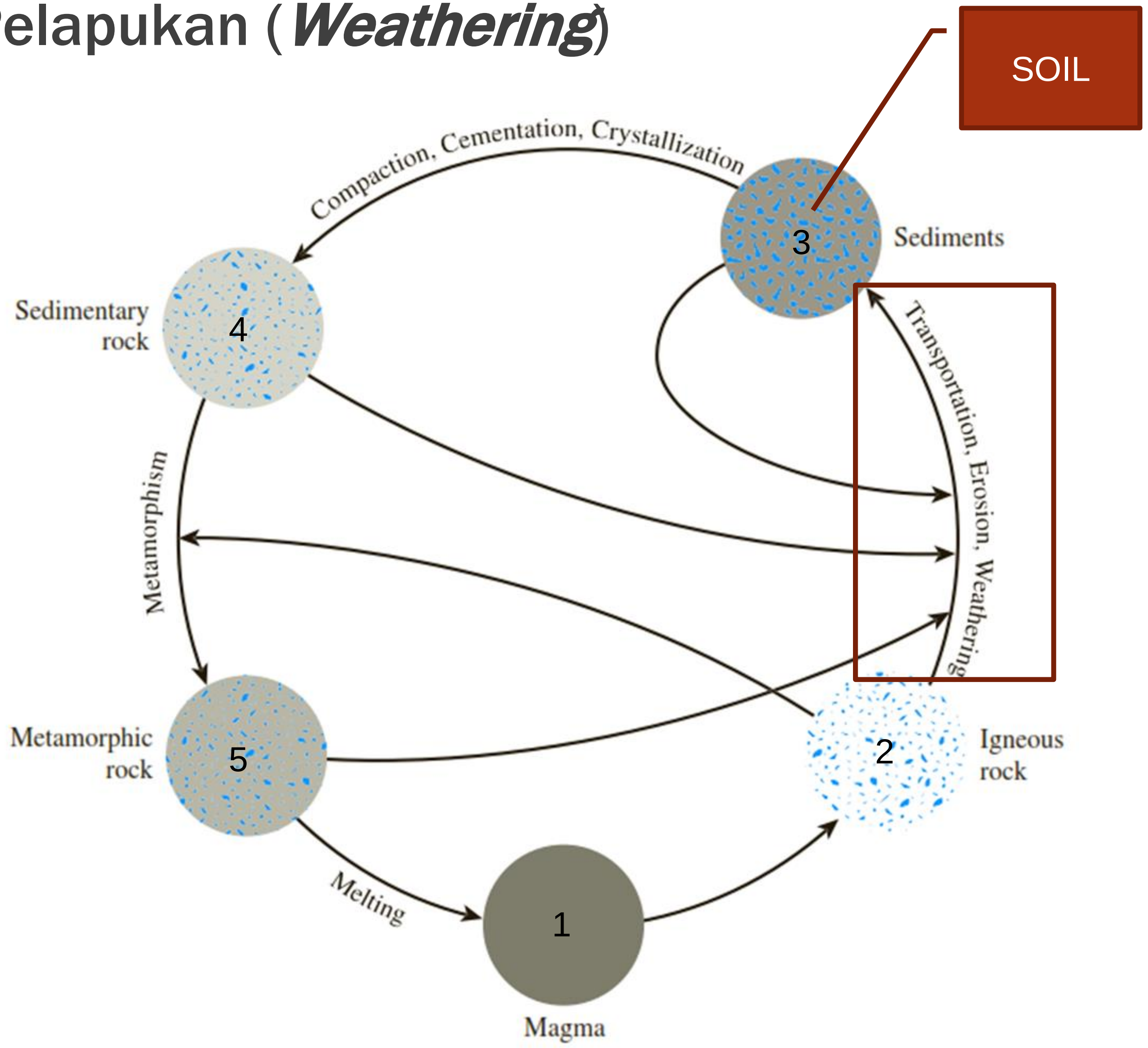
Kompresibilitas



Sifat Fisik Tanah

Origin
Partikel Tanah

Pelapukan (*Weathering*)

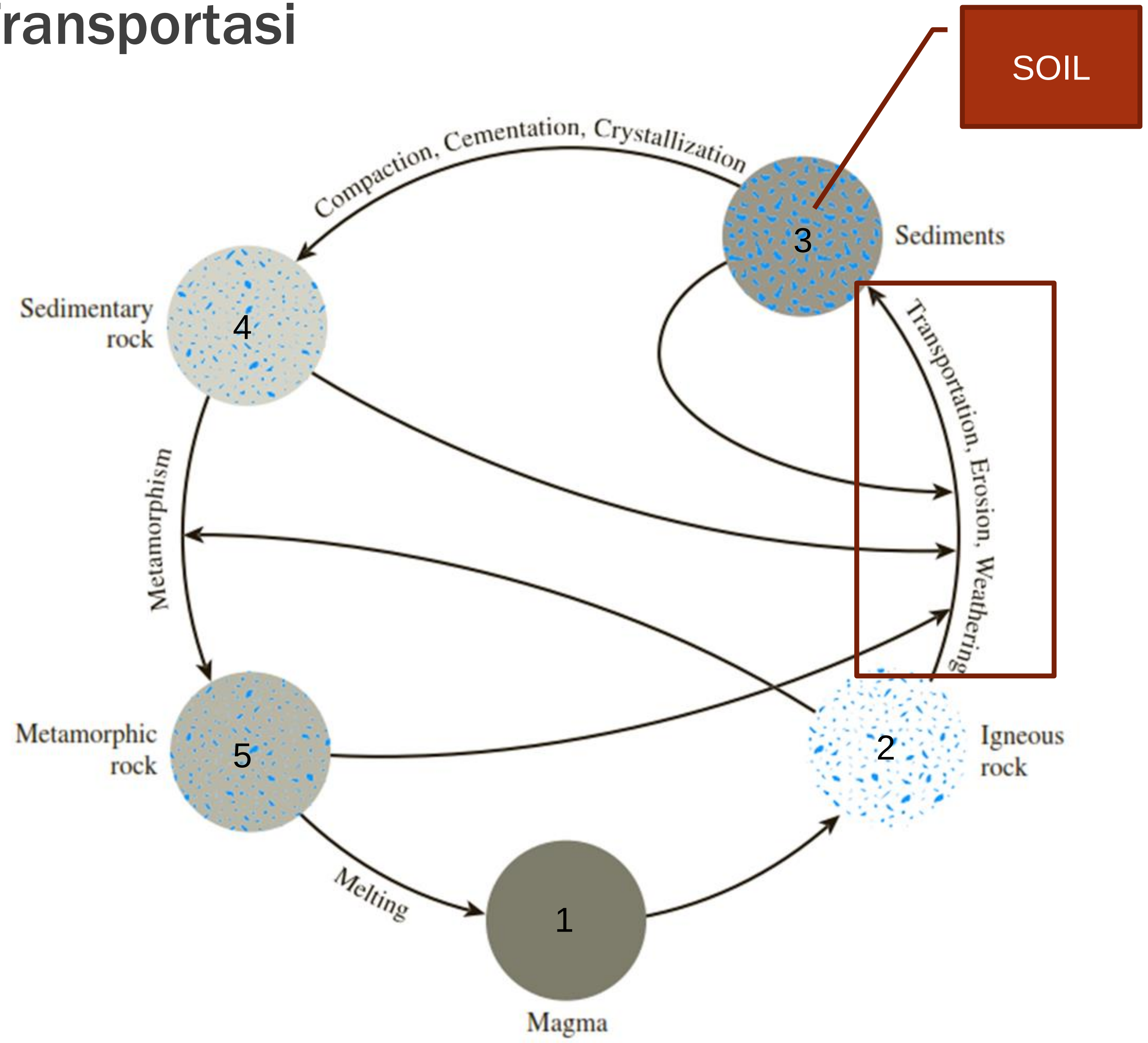


Pelapukan adalah suatu proses terurainya batuan menjadi partikel-partikel yang lebih kecil akibat proses mekanis dan kimia.

Pelapukan mekanis dapat disebabkan oleh memuai dan menyusutnya batuan akibat perubahan panas dan dingin yang terus-menerus (cuaca, matahari dan lainnya).

Sedangkan pelapukan kimia, mineral batuan induk diubah menjadi mineral-mineral baru melalui reaksi kimia. Air dan karbon dioksida dari udara membentuk asam-asam karbon yang kemudian bereaksi dengan mineral-mineral batuan dan membentuk mineral-mineral baru ditambah garam-garam terlarut.

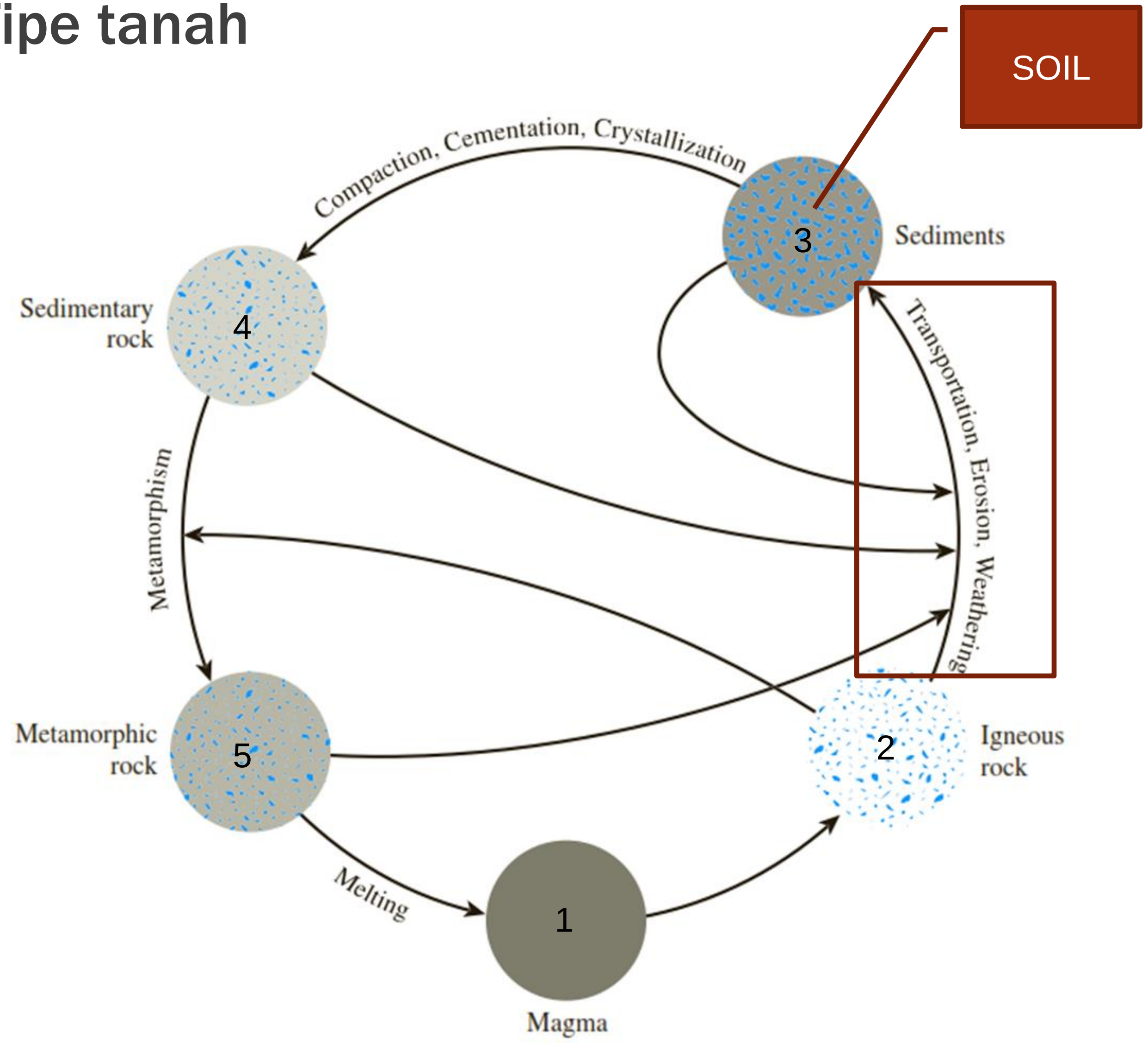
Transportasi



Produk-produk dari pelapukan dapat tetap tinggal di suatu tempat atau terbawa ke tempat lain oleh unsur-unsur pembawa seperti es, air, angin dan gravitasi **transportasi**.

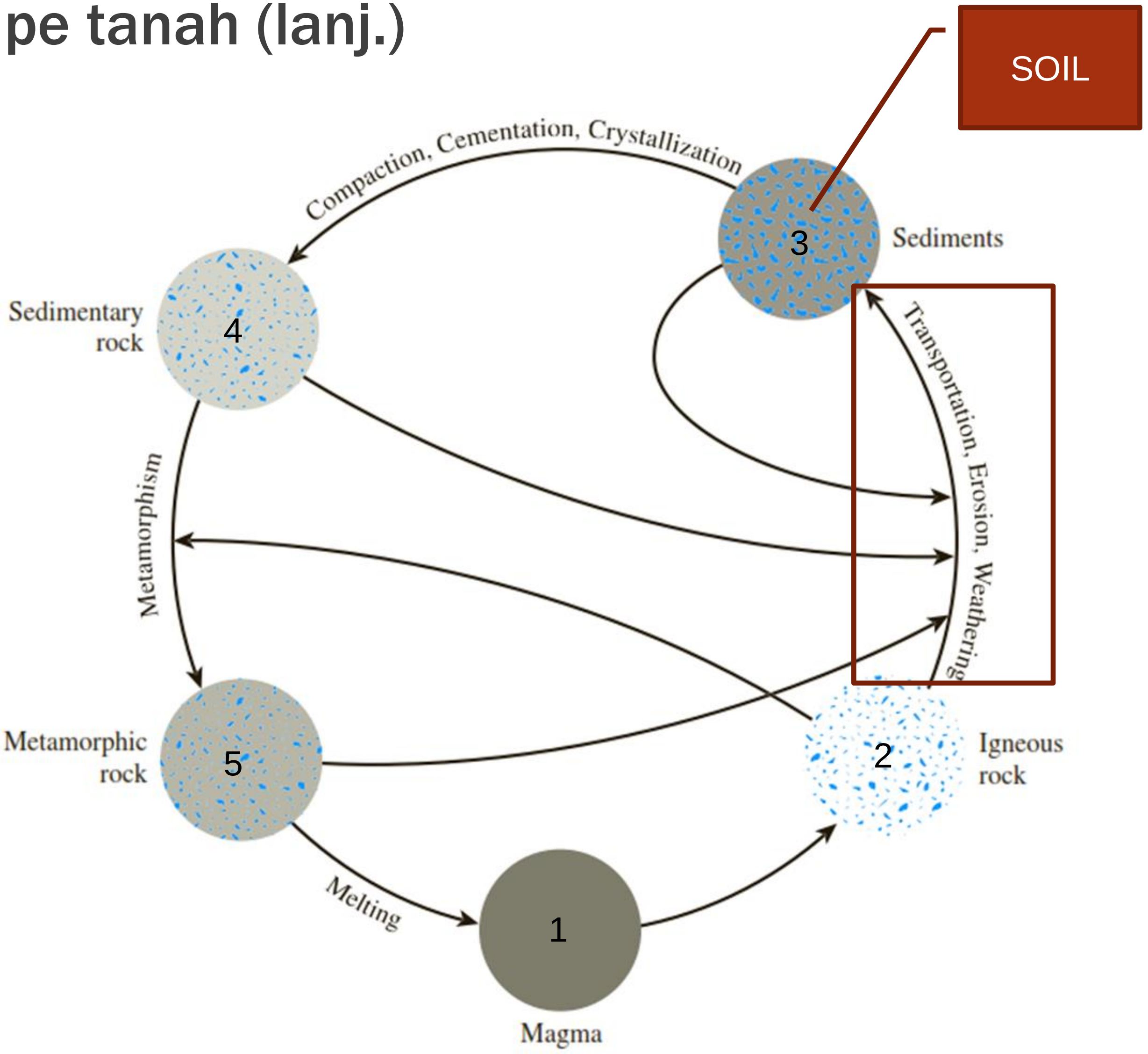
Tanah-tanah yang terjadi oleh penumpukan produk-produk pelapukan hanya di tempat asalnya saja disebut **tanah residual**.

Tipe tanah



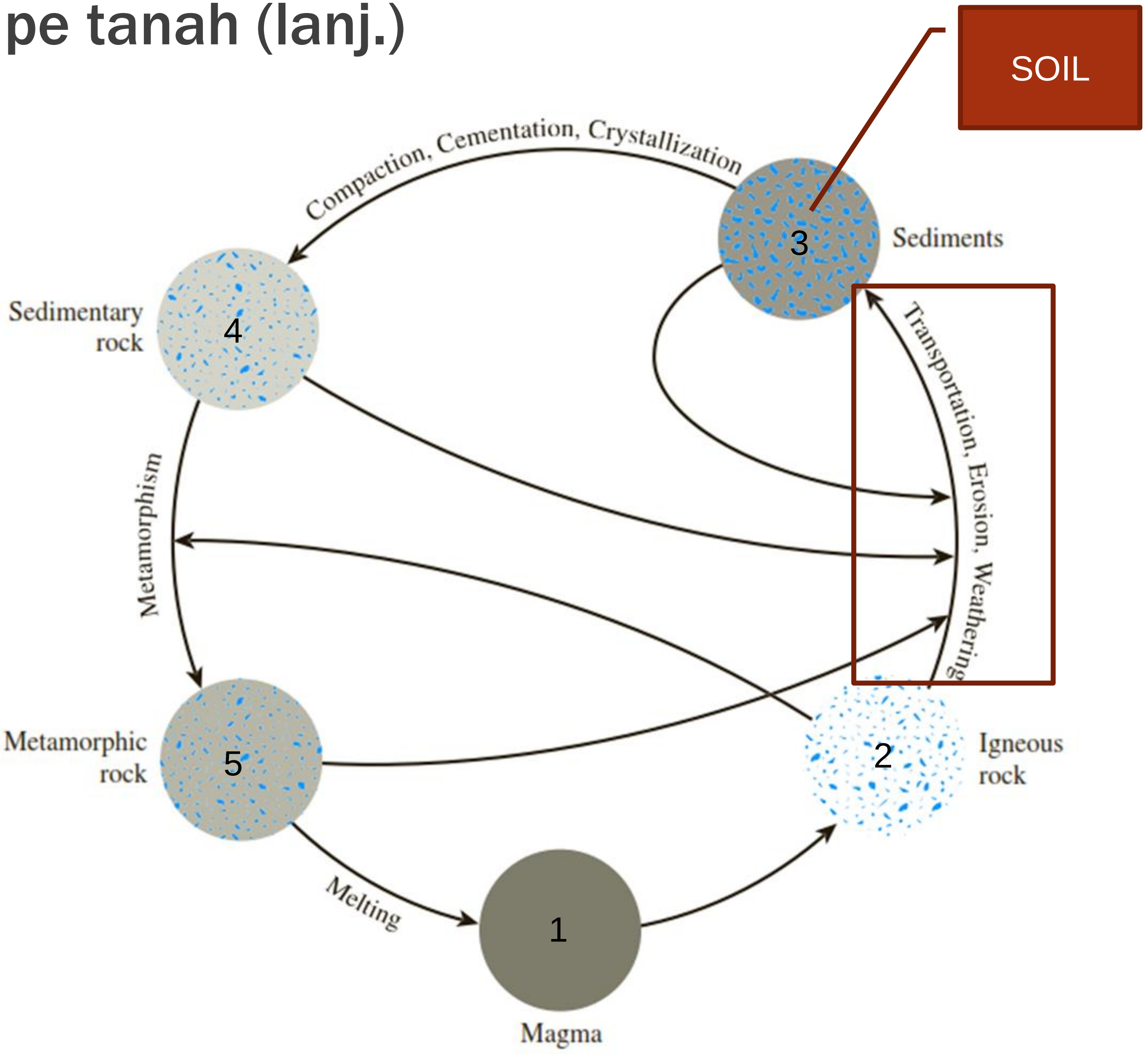
- Alluvial soils are fine sediments that have been eroded from rock and transported by water, and have settled on river and stream beds.
- Calcareous soil contains calcium carbonate and effervesces when treated with hydrochloric acid.
- Caliche consists of gravel, sand, and clay cemented together by calcium carbonate.
- Collovial soils (collovium) are soils found at the base of mountains that have been eroded by the combination of water and gravity.
- Eolian soils are sand-sized particles deposited by wind.
- Expansive soils are clays that undergo large volume changes from cycles of wetting and drying.
- Glacial soils are mixed soils consisting of rock debris, sand, silt, clays, and boulders.
- Glacial till is a soil that consists mainly of coarse particles.

Tipe tanah (lanj.)



- Glacial clays are soils that were deposited in ancient lakes and subsequently frozen. The thawing of these lakes revealed soil profi les of neatly stratifi ed silt and clay, sometimes called varved clay.
- The silt layer is light in color and was deposited during summer periods, while the thinner, dark clay layer was deposited during winter periods.
- Gypsum is calcium sulfate formed under heat and pressure from sediments in ocean brine.
- Lacustrine soils are mostly silts and clays deposited in glacial lake waters.
- Lateritic soils are residual soils that are cemented with iron oxides and are found in tropical regions.
- Loam is a mixture of sand, silt, and clay that may contain organic material.

Tipe tanah (lanj.)



- Loess is a wind-blown, uniform, fine-grained soil.
- Marine soils are sand, silts, and clays deposited in salt or brackish water.
- Marl (marlstone) is a mud (see definition of mud below) cemented by calcium carbonate or lime.
- Mud is clay and silt mixed with water into a viscous fluid.

Ukuran Partikel Tanah

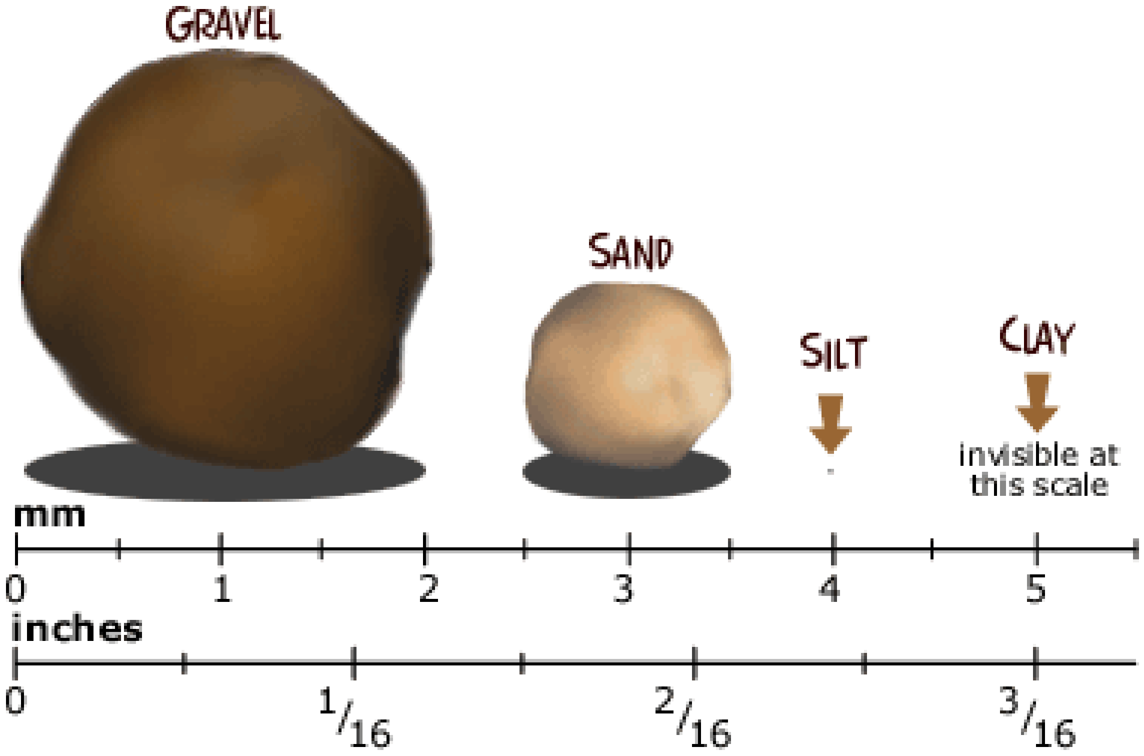
Berdasarkan ukuran partikel nya, tanah umumnya dapat disebut sebagai

- kerikil (*gravel*),
- pasir (*sand*),
- lanau (*silt*) atau
- lempung (*clay*),

Semakin halus

tergantung pada ukuran partikel yang paling dominan pada tanah tersebut.

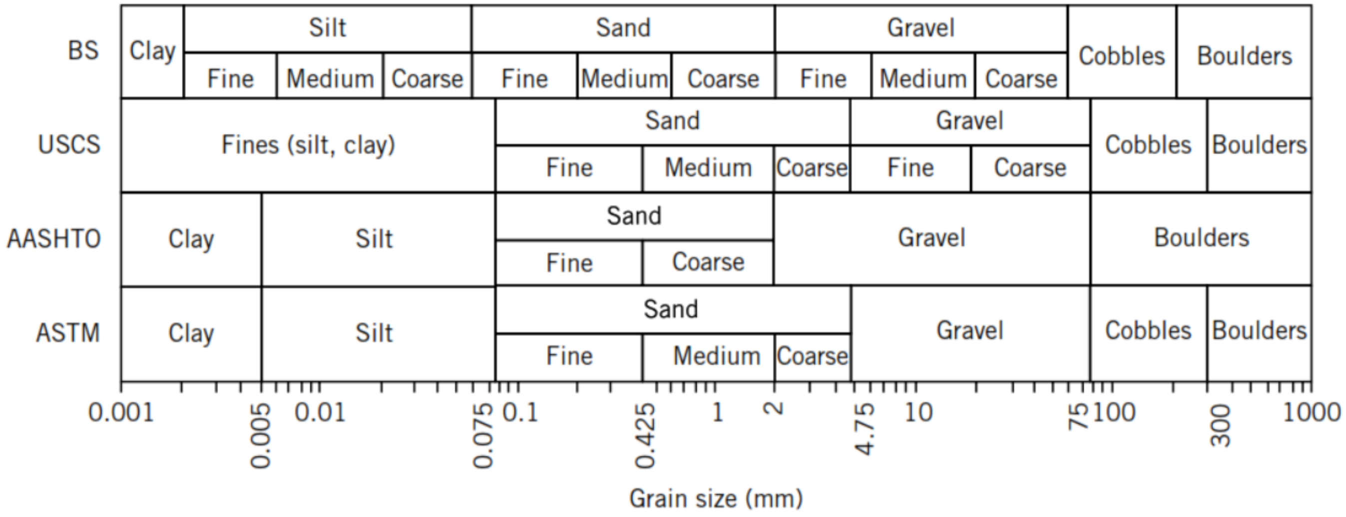
Untuk menerangkan tanah berdasarkan ukuran partikelnya, maka beberapa organisasi telah mengembangkan batasan-batasan ukuran golongan jenis tanah (soil-separate-size limits)



Semakin halus

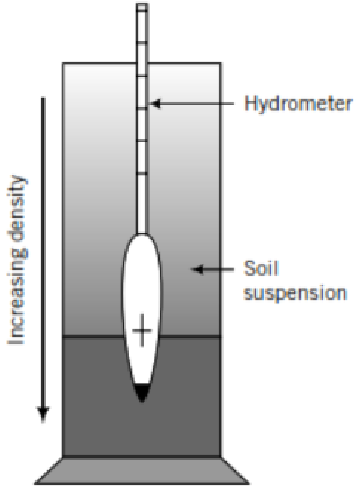
Organisasi Standarisasi Tanah

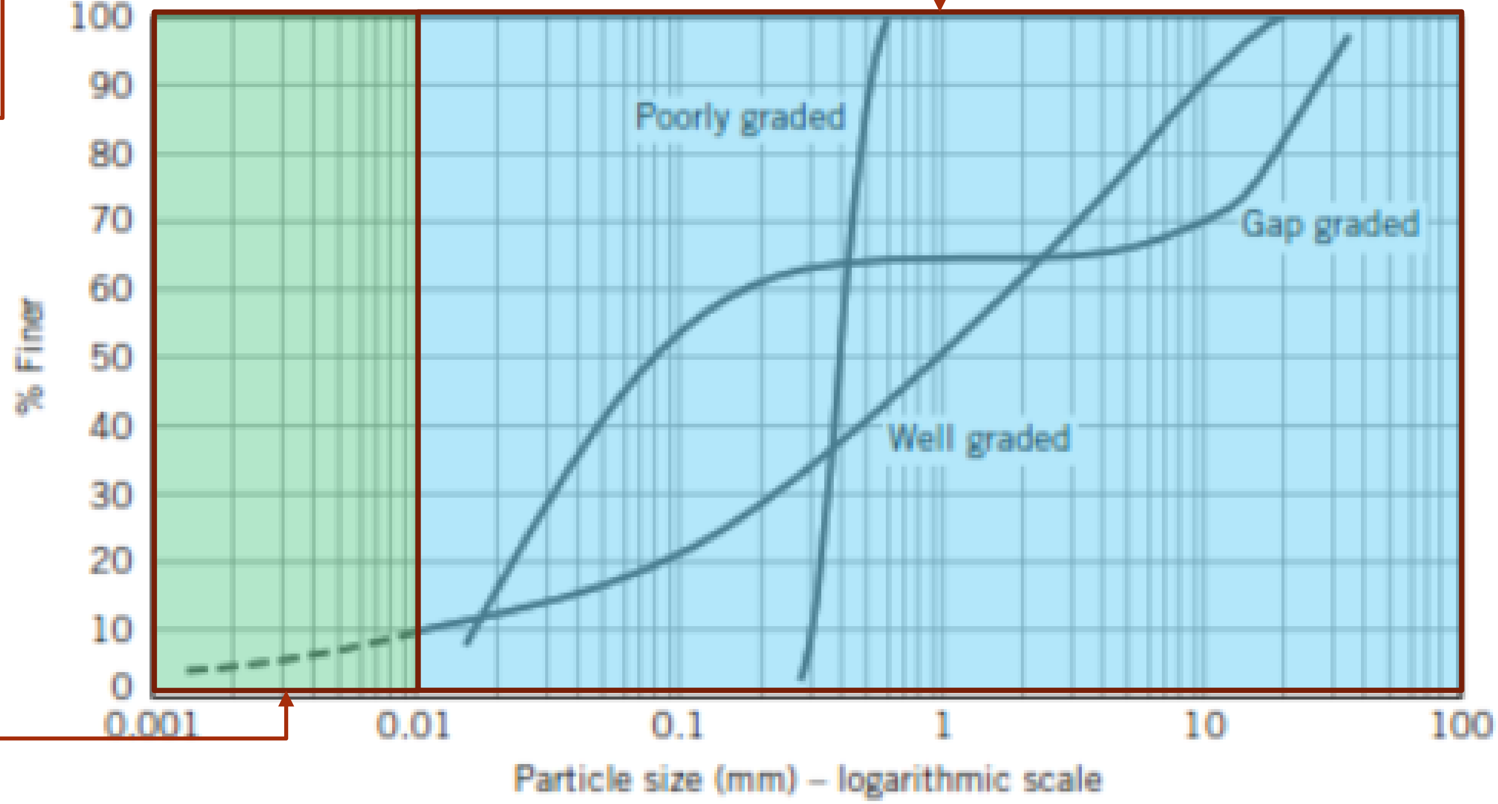
- **MIT** (Massachussetts Institute of Technology).
- **USDA** (United State Department of Agriculture).
- **AASSHTO** (American Association of State Highway and Transportation Officials).
- **USCS** (Unified Soil Classification System), yang dikembangkan oleh US. Army Corps of Engineer dan US. Bureau of Reclamation.



Soil type	Description	Average grain size
Gravel	Rounded and/or angular bulky hard rock, coarsely divided	Coarse: 75 mm to 19 mm Fine: 19 mm to 4.75 mm
Sand	Rounded and/or angular hard rock, finely divided	Coarse: 4.75 mm to 2.0 mm (No. 10) Medium: 2.0 mm to 0.425 mm (No. 40) Fine: 0.425 mm to 0.075 mm (No. 200)
Silt	Particle size between clay and sand. Exhibit little or no strength when dried.	0.075 mm to 0.002 mm
Clay	Particles are smooth and mostly clay minerals. Exhibit significant strength when dried; water reduces strength.	<0.002 mm

Analisis Ayakan dan analisis hidrometer





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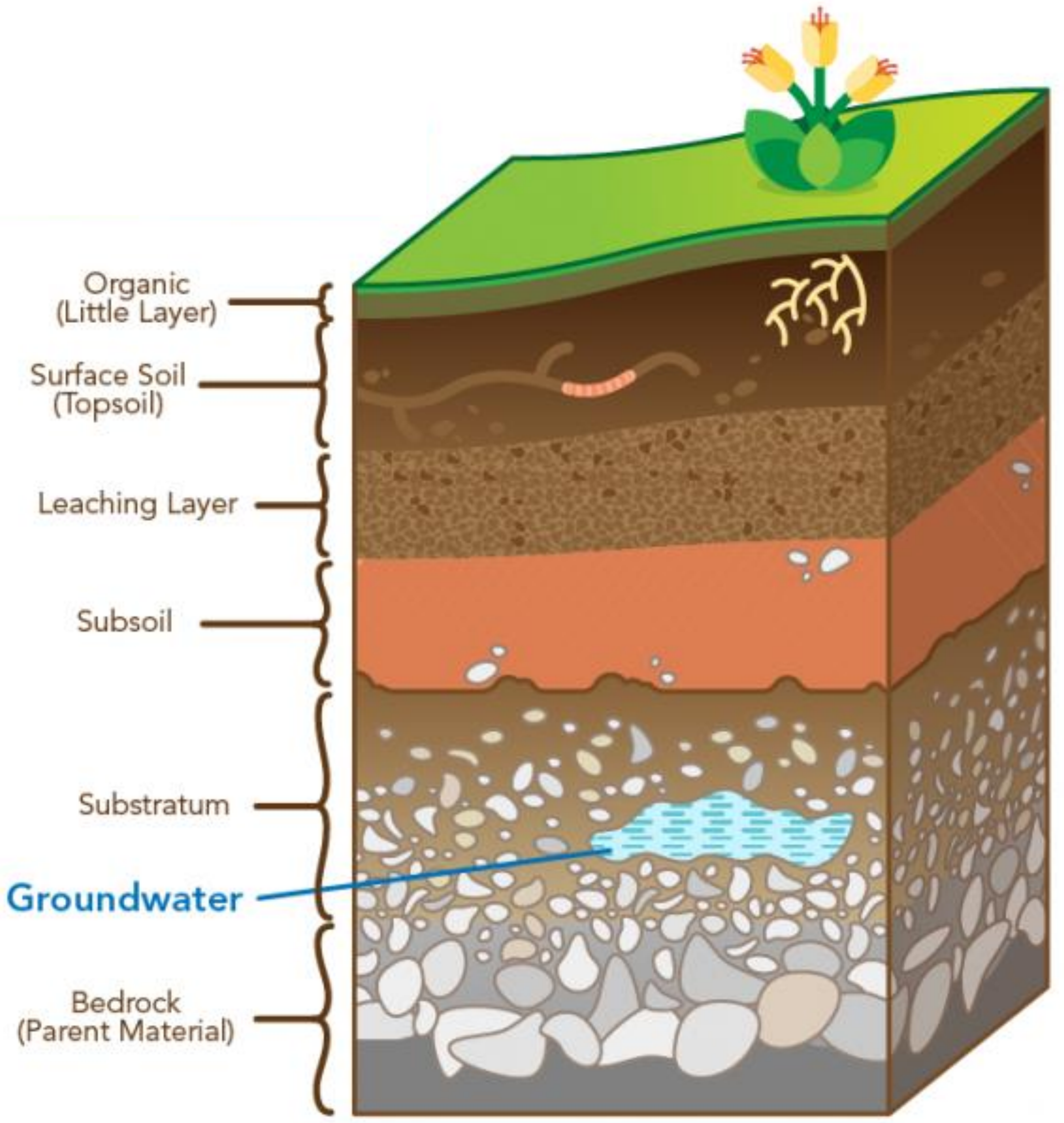

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Final Term

OBJECTIVE

- Dapat mengklasifikasikan tanah berdasarkan analisis ayakan
- Dapat mengklasifikasikan tanah berdasarkan analisis hidrometer

Ukuran Partikel Tanah

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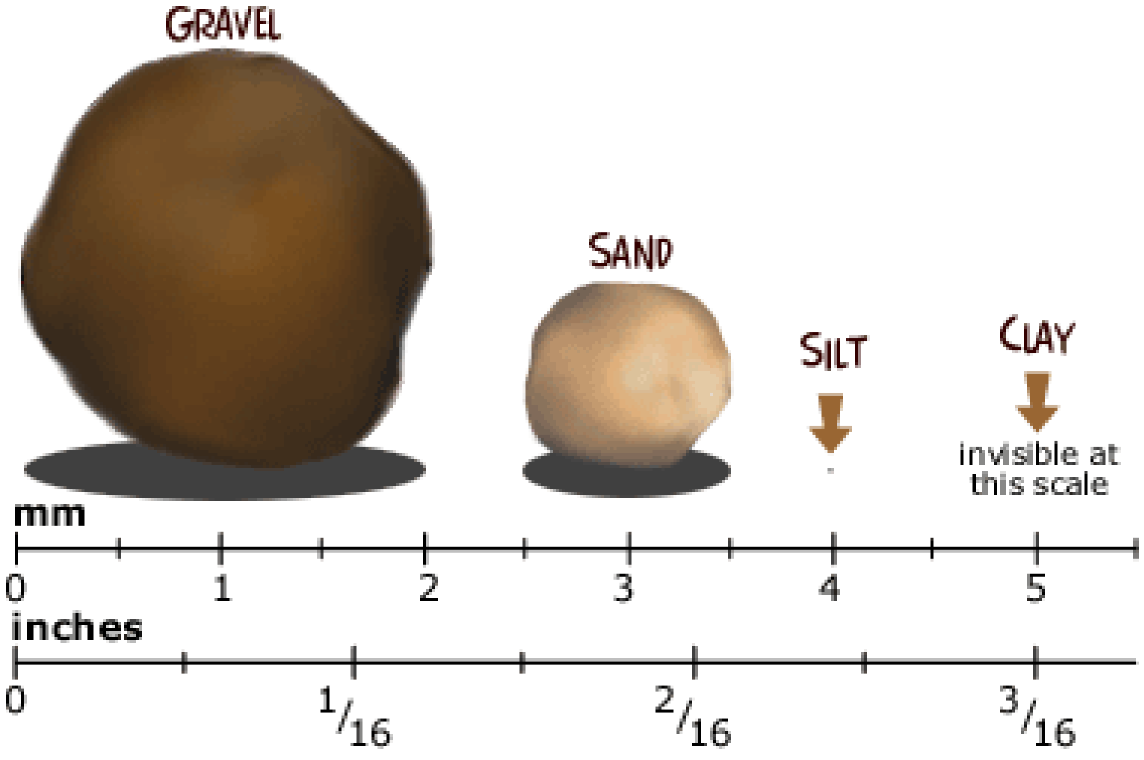

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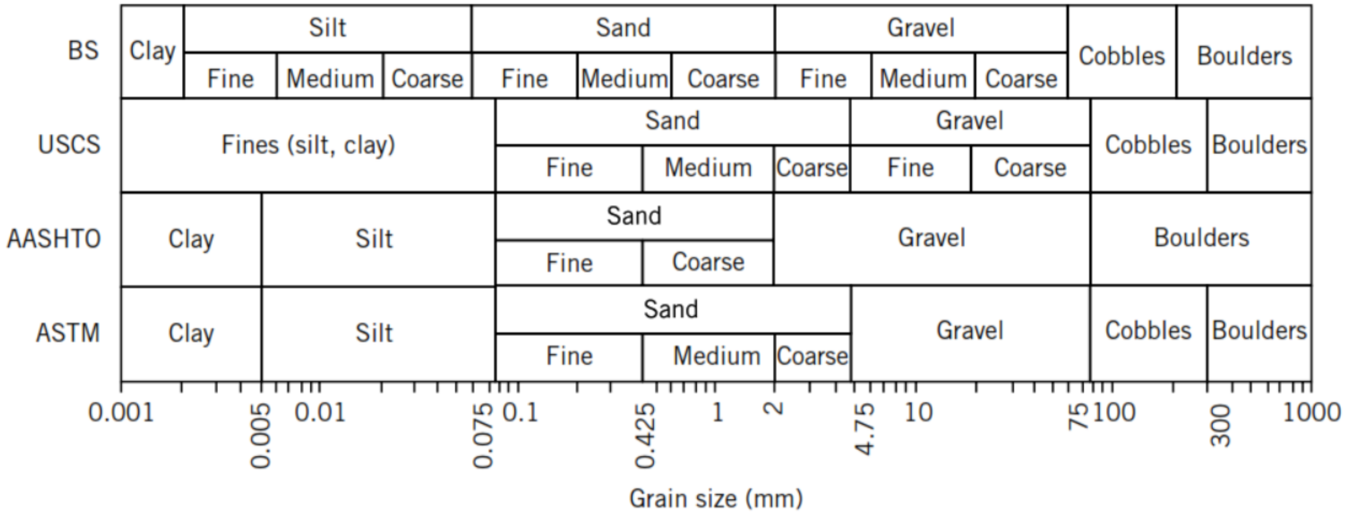

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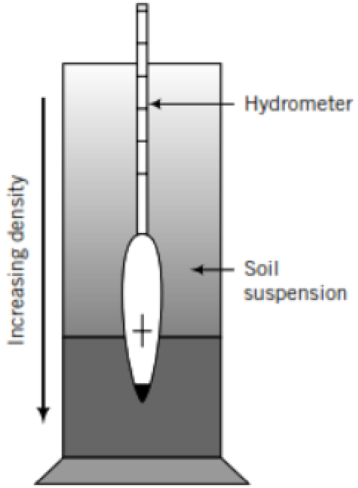
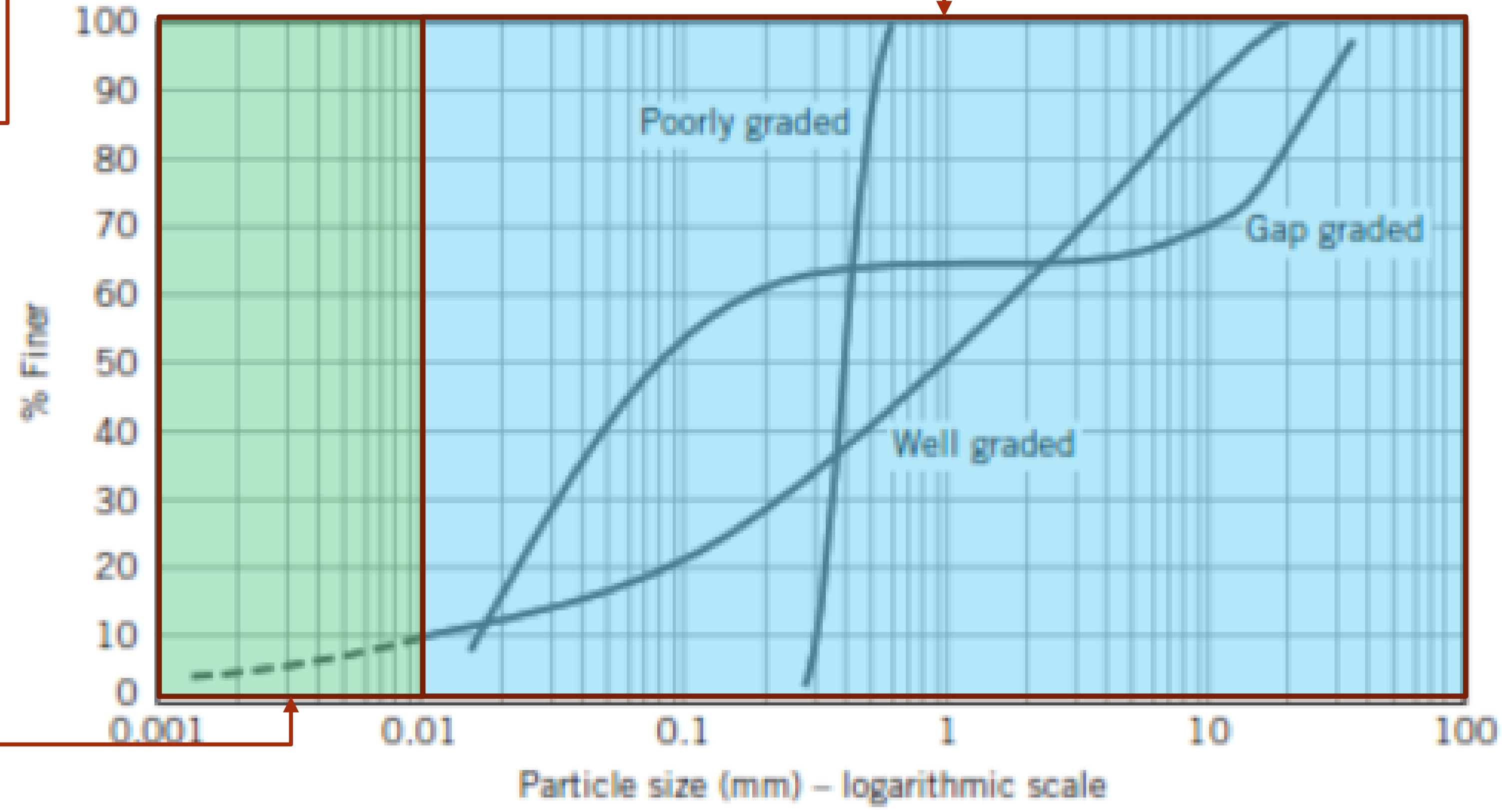
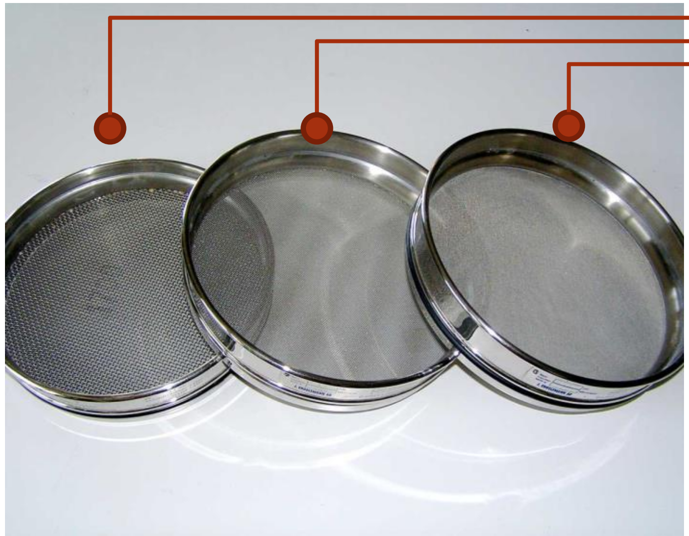
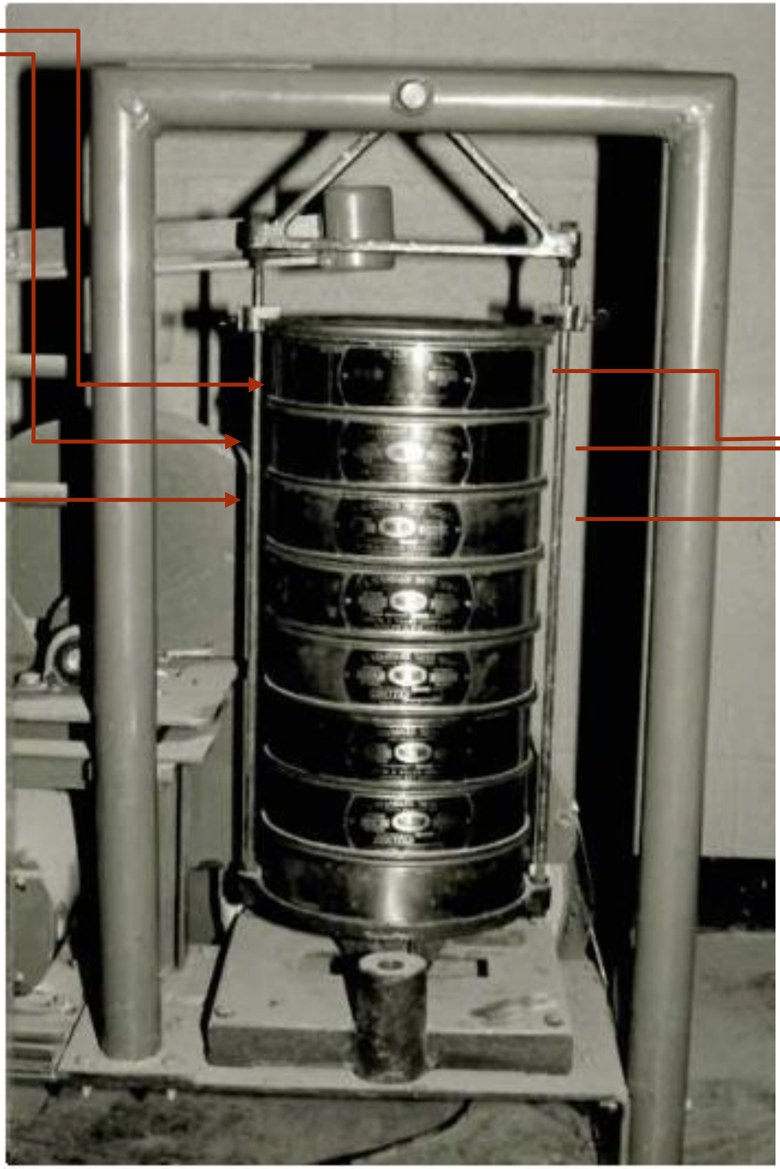
Analisis Ayakan dan analisis hidrometer





Analisis Ayakan (Sieve Analysis





Sieve no.	Opening (mm)	Sieve no.	Opening (mm)
4	4.75	45	0.355
5	4.00	50	0.300
6	3.35	60	0.250
7	2.80	70	0.212
8	2.36	80	0.180
10	2.00	100	0.150
12	1.70	120	0.125
14	1.40	140	0.106
16	1.18	170	0.090
18	1.00	200	0.075
20	0.85	230	0.063
25	0.71	270	0.053
30	0.60	325	0.045
35	0.500	400	0.038

Sieve analysis consists of shaking the soil sample through a set of sieves that have progressively smaller openings

Source : Braja M Das, 2015;

Standar Ukuran Ayakan

British Standard

75 mm	3.35 mm
63 mm	2 mm
50 mm	1.18 mm
37.5 mm	0.600 mm
28 mm	0.425 mm
20 mm	0.300 mm
14 mm	0.212 mm
10 mm	0.15 mm
6.3 mm	0.063 mm
5.0 mm	

Australian Standard

75.0 mm	2.36 mm
63.0 mm	2 mm
37.5 mm	1.18 mm
26.5 mm	0.600 mm
19.0 mm	0.425 mm
13.2 mm	0.300 mm
9.50 mm	0.212 mm
6.70 mm	0.15 mm
4.75 mm	0.063 mm

Source : Braja M Das, 2015;

Penentuan Ukuran Ayakan

$$\text{Opening for the } i\text{th sieve} = \frac{\text{Opening for the } (i-1)\text{th sieve}}{(2)^{0.25}}$$

$$\text{The opening for the No. 5 sieve} = \frac{\text{Opening for the No. 4 sieve}}{(2)^{0.25}}$$

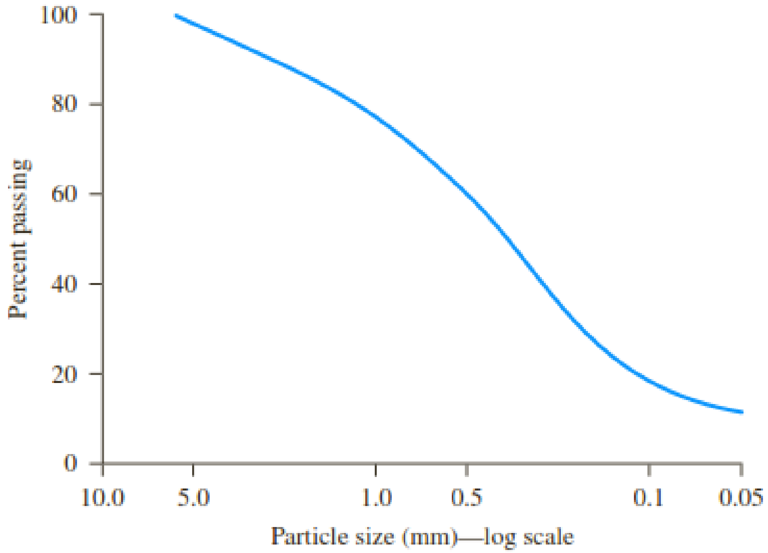
$$= \frac{4.75 \text{ mm}}{1.1892} = 3.994 \text{ mm} \approx 4.00 \text{ mm}$$

$$\text{The opening for the No. 50 sieve} = \frac{\text{Opening for the No. 45 sieve}}{(2)^{0.25}}$$

$$= \frac{0.335 \text{ mm}}{1.1892} = 0.2985 \text{ mm} \approx 0.300 \text{ mm}$$

Source : Braja M Das, 2015;

Perhitungan Persen Material Terlewat



- Timbang material tertahan pada masing-masing ayakan (M_1, M_2, ... , M_n dan pada nampan akhir (M_p)
- Hitung total material yang terayak ($M_1 + M_2 + ... + M_n + M_p = \sum M$)
- Hitung *kumulatif material yang tertahan* pada masing-masing ayakan. Ex, pada ayakan ke $_{i\text{-th}}$ maka jumlah material kumulatifnya $M_1 + M_2 + ... + M_i$
- Hitung *material yang terlewat* pada masing-masing ayakan. Ex, pada ayakan ke $_{i\text{-th}}$ maka jumlah material kumulatifnya $\sum M – (M_1 + M_2 + ... + M_i)$
- Hitung persen material yang terlewat pada ayakan ke $_{i\text{-th}}$

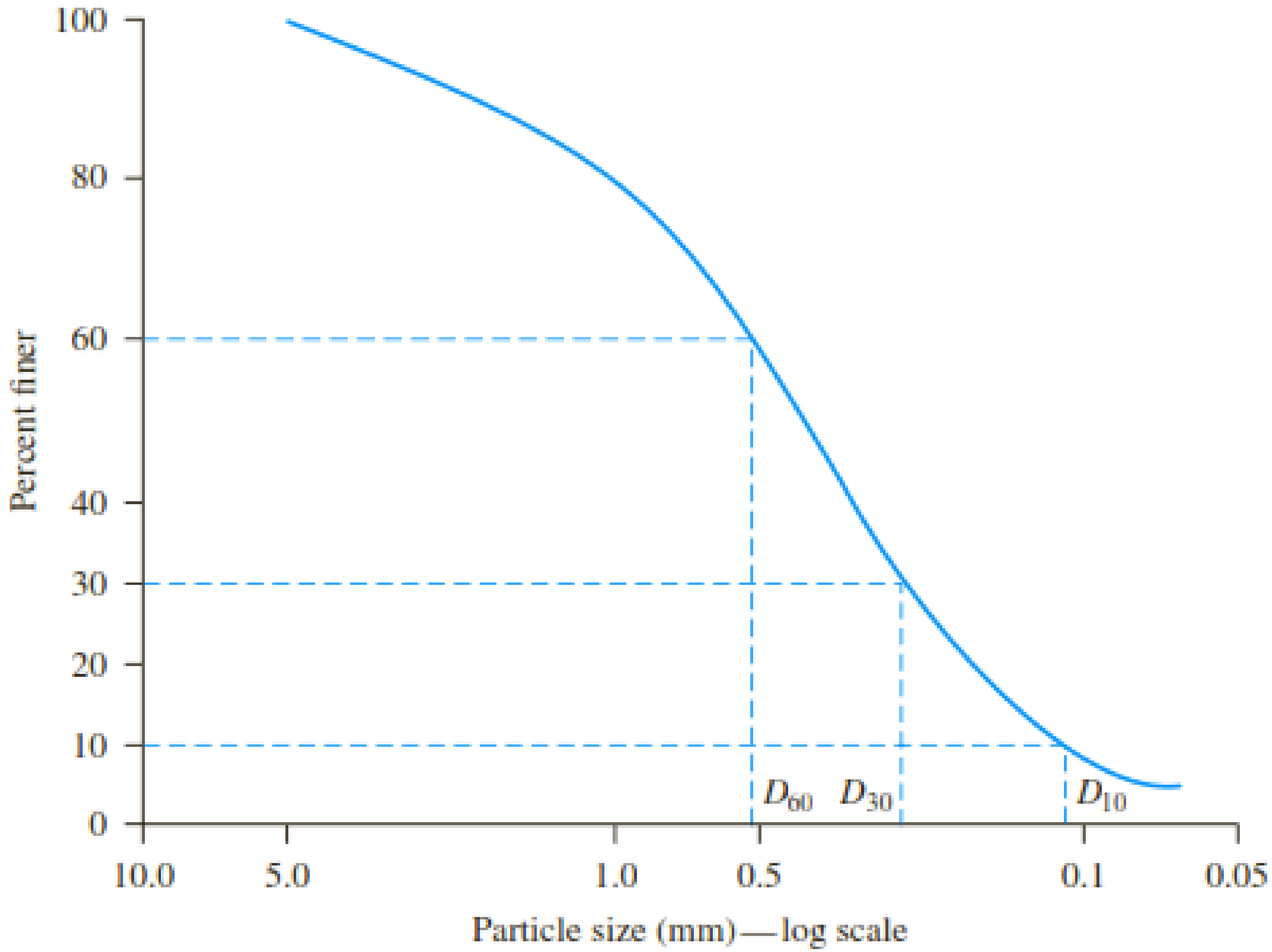
$$F = \frac{\Sigma M - (M_1 + M_2 + \cdots + M_i)}{\Sigma M} \times 100$$

- Plot pada grafik semilogaritmik

Source : Braja M Das, 2015;

Analisis Ayakan (Sieve Analysis

Perhitungan Persen Material Terlewat



D_{60}

D_{30}

D_{10}

Source : Braja M Das, 2015;

Uniformity Coefficient (C_u)

- A well-graded soil has a uniformity coefcient greater than about 4 for gravels and 6 for sands
- A soil might have a combination of two or more uniformly fractions

$$C_u = \frac{D_{60}}{D_{10}}$$

Coefficient for Gradation (C_c)

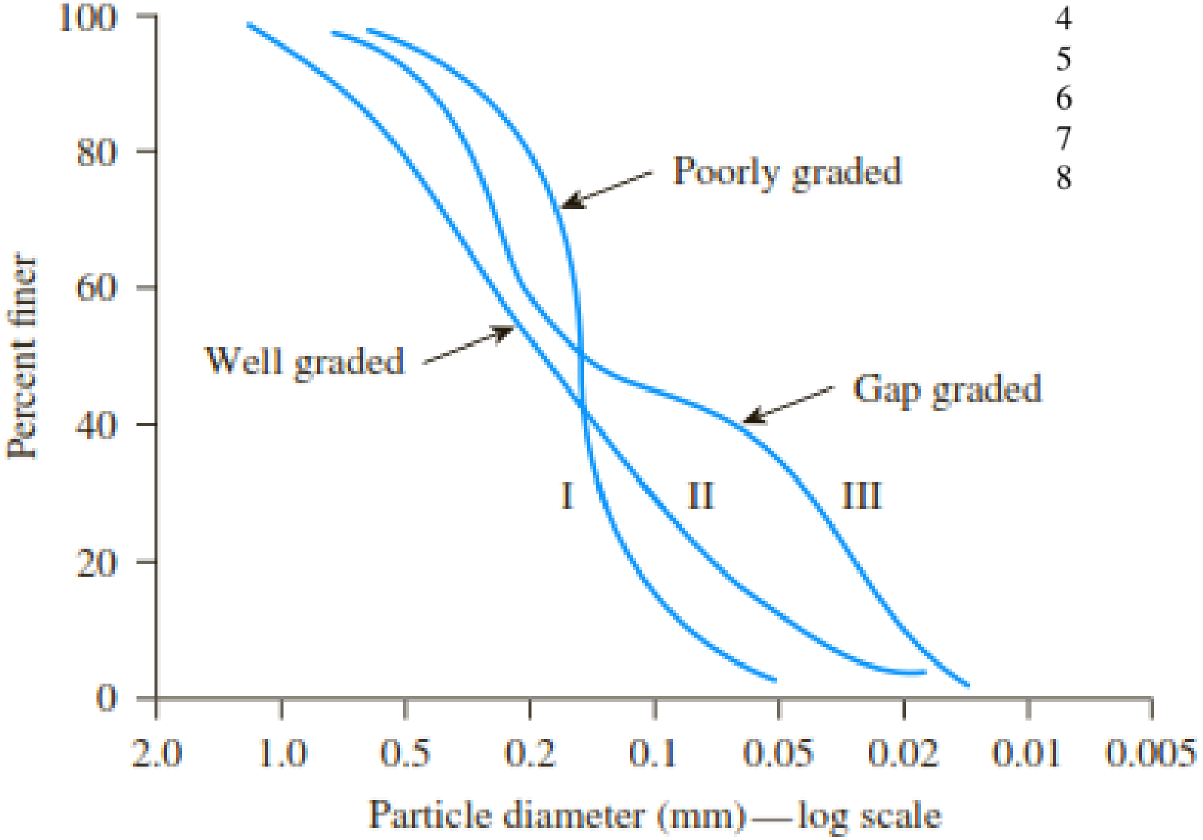
- A well-graded soil has a coefcient of gradation between 1 and 3 (for gravels and san
- A soil might have a combination of two or more graded fraction

$$C_c = \frac{D_{30}^2}{D_{60} \times D_{10}}$$

Source : Braja M Das, 2015;

Contoh

Curve III represents such a soil. This type of soil is termed *gap graded.*



Depth (m)	% Gravel	% Sand	% Silt	% Clay	C_u	C_c	Soil Type (USCS)
0	5.76	82.34	8.71	0	4.29	1.22	Poorly graded sand with silt (SP-SM)
1	9.64	80.46	2.81	0	8.7	1.22	Well graded sand (SW)
2	4.90	94.5	0.65	0	5.29	0.76	Poorly graded sand (SP)
3	14.37	85.34	0.15	0	4.75	0.84	Poorly graded sand (SP)
4	11.68	88.22	0.10	0	4.44	0.8	Poorly graded sand (SP)
5	11.35	88.51	0.15	0	3.67	0.82	Poorly graded sand (SP)
6	7.39	92.21	0.40	0	3.67	0.76	Poorly graded sand (SP)
7	8.72	91.03	0.25	0	4.29	0.8	Poorly graded sand (SP)
8	15.00	84.71	0.30	0	5.14	0.73	Poorly graded sand (SP)

Contoh 1

A sieve analysis test was conducted on 650 grams of soil. The results are as follows.

Sieve no.	9.53 mm (3/8")	4	10	20	40	100	200	Pan
Opening (mm)	9.53	4.75	2	0.85	0.425	0.15	0.075	
Mass retained (grams)	0	53	76	73	142	85	120.5	99.8

Determine

(a) the amount of coarse-grained and fine-grained soils, and

(b) the amount of each soil type based on the ASTM system.

Strategy

Calculate the % finer and plot the gradation curve. Extract the amount of coarse-grained soil (particle sizes .0.075 mm) and the amount of fine-grained soil (particle sizes ,0.075 mm). **Use table 2.1**

TABLE 2.1 Soil Types, Descriptions, and Average Grain Sizes According to ASTM D 2487

Soil type	Description	Average grain size
Gravel	Rounded and/or angular bulky hard rock, coarsely divided	Coarse: 75 mm to 19 mm Fine: 19 mm to 4.75 mm
Sand	Rounded and/or angular hard rock, finely divided	Coarse: 4.75 mm to 2.0 mm (No. 10) Medium: 2.0 mm to 0.425 mm (No. 40) Fine: 0.425 mm to 0.075 mm (No. 200)
Silt	Particle size between clay and sand. Exhibit little or no strength when dried.	0.075 mm to 0.002 mm
Clay	Particles are smooth and mostly clay minerals. Exhibit significant strength when dried; water reduces strength.	<0.002 mm

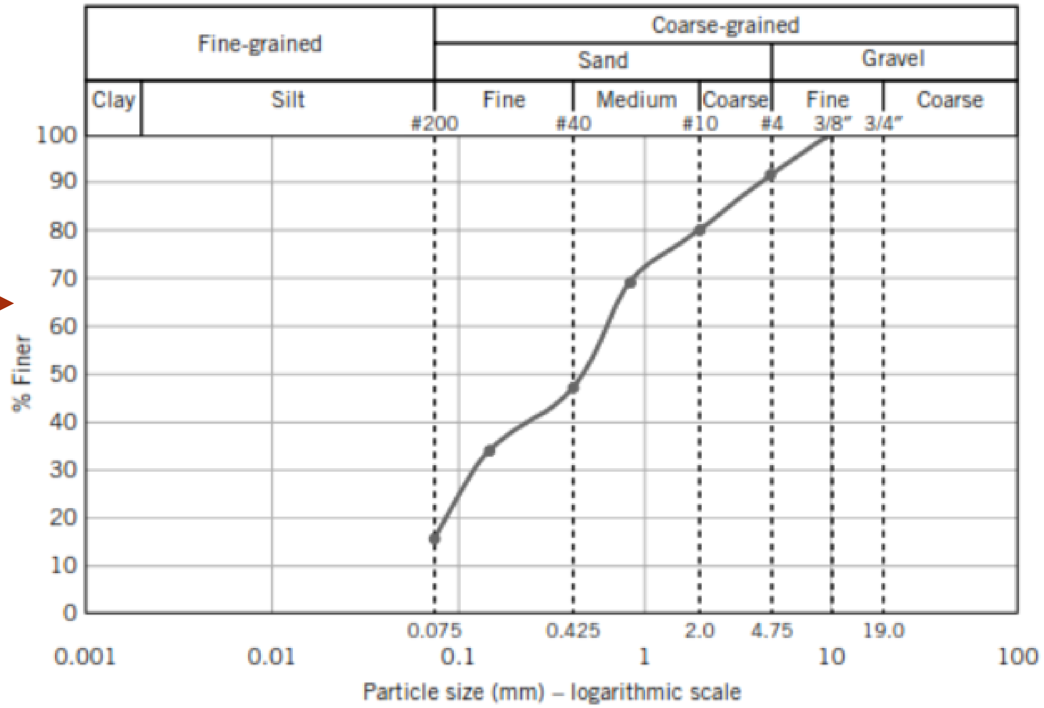
Sieve Analysis

Solution 1

A	B	C	D	E	F
Sieve no.	Opening (mm)	Mass retained (grams) M_r	% Retained ($100 \times M_r/M_t$)	Σ (% Retained) (Σ column D)	% Finer (100 − column E)
9.53 mm (3/8″)	9.53	0	0.0	0.0	100.0
4	4.75	53	8.2	8.2	91.8
10	2	76	11.7	19.9	80.1
20	0.85	73	11.2	31.1	68.9
40	0.425	142	21.9	52.9	47.1
100	0.15	85.4	13.1	66.1	33.9
200	0.075	120.5	18.5	84.6	15.4
Pan		99.8	15.4		
	SUM	649.7	100.0		
	M_t =	649.7			

add

Note: In the sieve analysis test, some mass is lost because particles are stuck in the sieves. Use the sum of the mass after the test.



(a) The amount of fine-grained soil is the % finer than the No. 200 sieve (opening 5 0.075 mm). The amount of coarse-grained soil is the % coarser than the No. 200 sieve, i.e., cumulative % retained on the No. 200 sieve.

% fine-grained soil = 15.4%

% coarse-grained soil = 100 – 15.4 = 84.6%

(b)

Fine gravel (%) = 8.2
Total gravel (%) = 8.2
Coarse sand (%) = 11.7
Medium sand (%) = 33.0
Fine sand (%) = 31.7
Total sand (%) = 76.4
Silt + clay (%) = 15.4

Contoh 2

A sample of a dry, coarse-grained material of mass 500 grams was shaken through a nest of sieves, and the following results were obtained:

Sieve no.	Opening (mm)	Mass retained (grams)
4	4.75	0
10	2.00	14.8
20	0.85	98
40	0.425	90.1
100	0.15	181.9
200	0.075	108.8
Pan		6.1

Determine

(a) Plot the particle size distribution (gradation) curve.
(b) Determine : (1) the effective size, (2) the average particle size, (3) the uniformity coefficient, and (4) the coefficient of curvature.
(c) Determine the textural composition of the soil (i.e., the amount of gravel, sand, etc.).

Strategy

The best way to solve this type of problem is to make a table to carry out the calculations and then plot a gradation curve. Total mass (M) of dry sample used is 500 grams, but on summing the masses of the retained soil in column 2 we obtain 499.7 grams. The reduction in mass is due to losses mainly from a small quantity of soil that gets stuck in the meshes of the sieves. You should use the “after sieving” total mass of 499.7 grams in the calculations.

Solution 2

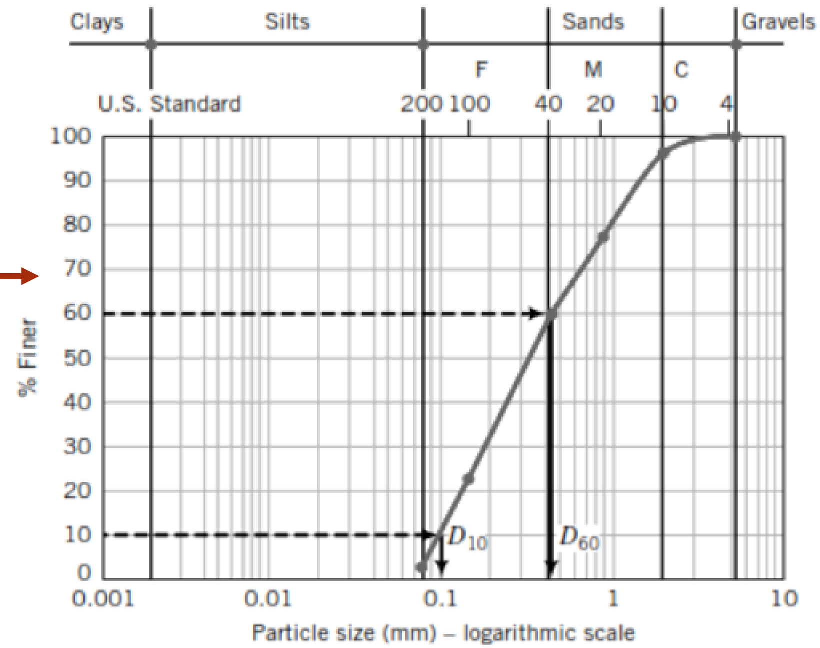
Sieve no.	Mass retained (grams), M_i	% Retained $(M_i/M) \times 100$	Σ (% Retained)	% Finer
4	0	0	0	100 − 0 = 100
10	14.8	3.0	3.0	100 − 3.0 = 97.0
20	98.0	19.6	22.6	100 − 22.6 = 77.4
40	90.1	18.0	40.6	100 − 40.6 = 59.4
100	181.9	36.4	77.0	100 − 77 = 23.0
200	108.8	21.8	98.8	100 − 98.8 = 1.2
Pan	6.1	1.2		
	Total mass M = 499.7	100.0		

add

check

Note: In the sieve analysis test, some mass is lost because particles are stuck in the sieves. Use the sum of the mass after the test.

(a)



(b)

Effective size D_{10} = 0.1 mm

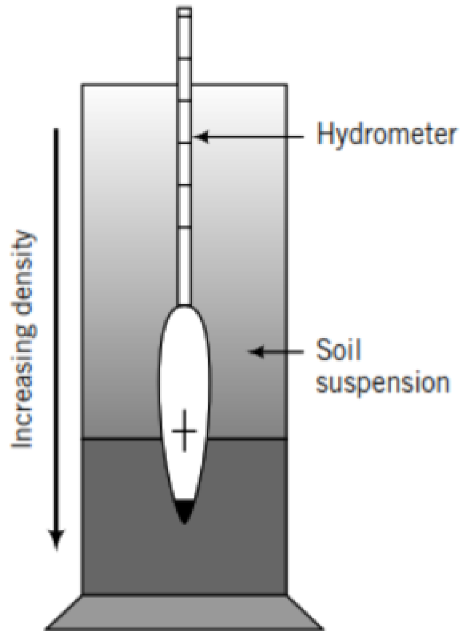
$$Cu = \frac{D_{60}}{D_{10}} = \frac{0.45}{0.1} = 4.5$$

$$Cc = \frac{(D_{30})^2}{D_{10}D_{60}} = \frac{0.18^2}{0.1 \times 0.45} = 0.72$$

(c)

Gravel	= 0%
Sand	= 98.8%
Silt and clay	=1.2%

Intro



The screening process **cannot be used for fine-grained soils—silts and clays—because of their extremely small size**. The common laboratory method used to determine the size distribution of fi ne-grained soils is a **hydrometer test**.

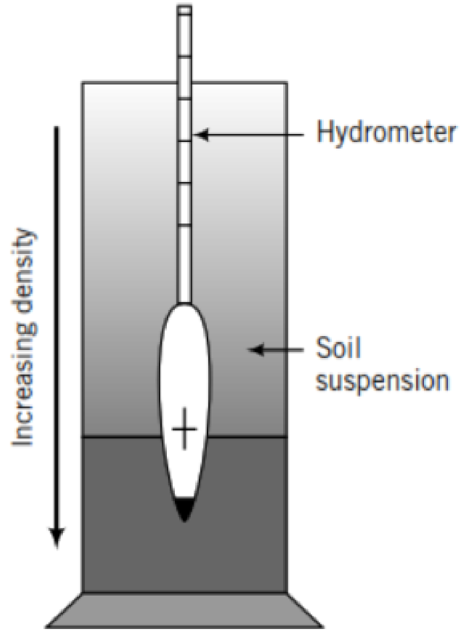
The hydrometer test involves **mixing a small amount of soil into a suspension and observing how the suspension settles in time**.

Larger particles will settle quickly, followed by smaller particles. When the hydrometer is lowered into the suspension, it will sink into the suspension until the buoyancy force is sufficient to balance the weight of the hydrometer.

The length of the hydrometer projecting above the suspension is **a function of the density**, so it is possible to calibrate the hydrometer to read the density of the suspension at different times.

The calibration of the hydrometer is **affected by temperature and the specific gravity of the suspended solids**. You **must then apply a correction factor** to your hydrometer reading based on the test temperatures.

Proses Pelaksanaan



$$D = \sqrt{\frac{18\mu z}{(G_s - 1)\rho_w g t_D}}$$

Typically, a hydrometer test is conducted by these steps:

1. Taking a small quantity of a dry, fine-grained soil (approximately 50 grams) and thoroughly mixing it with distilled water to form a paste.
2. The paste is placed in a 1-liter glass cylinder, and distilled water is added to bring the level to the 1-liter mark.
3. The glass cylinder is then repeatedly shaken and inverted before being placed in a constant-temperature bath.
4. A hydrometer is placed in the glass cylinder and a clock is simultaneously started.
5. At different times, the hydrometer is read.
6. The diameter D (cm) of the particle at time t_D (seconds) is calculated from Stokes's law

where :

- μ is the viscosity of water [0.01 gram/(cm.s) at 20^{o}C],
- z is the depth (cm), rw is the density of water (1 gram/cm^3),
- g is the acceleration due to gravity (981 cm/s^2),
- Gs is the specific gravity of the soil particles. For most soils, Gs < 2.7.

Problem 1

At a certain stage in a hydrometer test, the vertical distance moved by soil particles of a certain size over a period of 1 minute is 0.8 cm. The temperature measured is 20^0C. If the specific gravity of the soil particles is 2.7, calculate the diameter of the particles using Stokes's law.

Determine
Are these silt or clay particles?

Strategy
For this problem use Equation 2.3, making sure that the units are consistent.

Solution 1

$\mu = 0.01$ gram/(cm.s) at 20°C, $\rho_w = 1$ gram/cm^3 at 20°C, $g = 981$ cm/s^2, $t_D = 1 \times 60 = 60$ seconds

$$D = \sqrt{\frac{18\mu z}{(G_s - 1)\rho_w g t_D}} = \sqrt{\frac{18 \times 0.01 \times 0.8}{(2.7 - 1) \times 1 \times 981 \times 60}} = 0.0012 \text{ cm} = 0.012 \text{ mm}$$

Silt particles have sizes between 0.075 mm and 0.002 mm.
Therefore, the soil particles belong to the silt fraction of the soil.

Problem 2

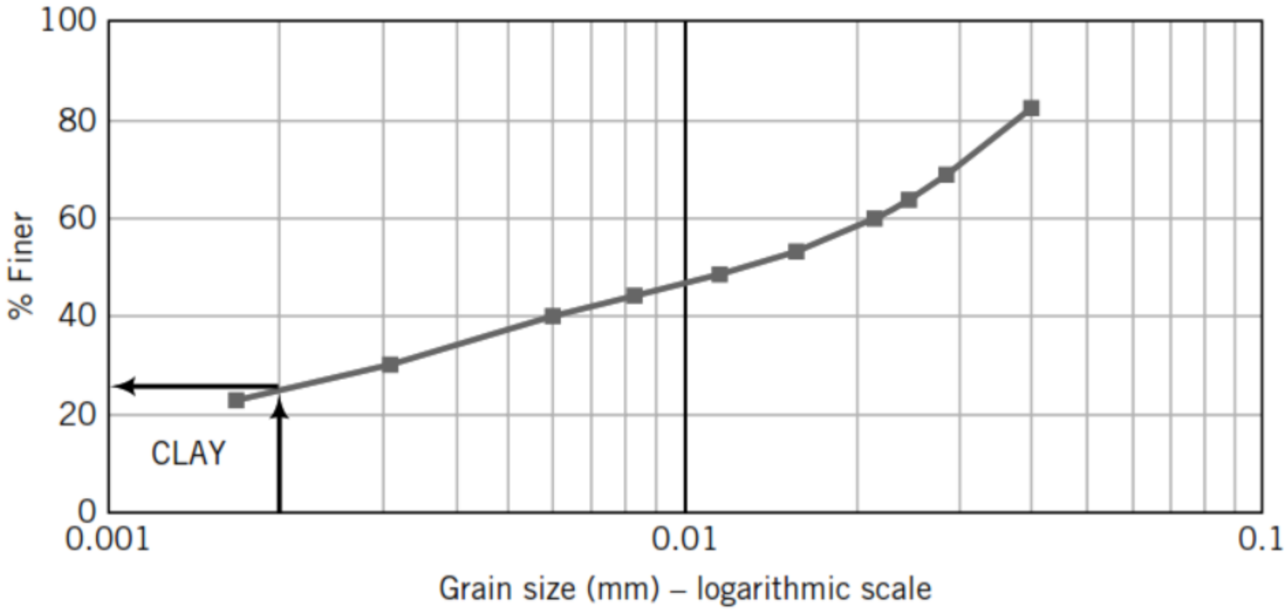
The soil passing the No. 200 sieve in Example 2.1 was used to conduct a hydrometer test. The results are shown in the table below.

Time (min)	Hydrometer reading (gram/liter)	Temperature (°C)	Corrected distance of fall (cm)	Grain size (mm)	% Finer by weight
1	40.0	22.5	8.90	0.0396	82.2
2	34.0	22.5	9.21	0.0285	68.8
3	32.0	22.0	9.96	0.0243	64.2
4	30.0	22.0	10.29	0.0214	59.7
8	27.0	22.0	10.96	0.0156	53.1
15	25.0	21.5	11.17	0.0116	48.4
30	23.0	21.5	11.45	0.0083	43.9
60	21.0	21.5	11.96	0.0060	39.5
240	17.0	20.0	12.45	0.0031	30.0
900	14.0	19.0	13.10	0.0017	22.9

Determine
What are the amounts of clays and silts in the soil?

Strategy
Plot % finer versus grain size (log scale) and extract % of grain size finer than 0.002.

Solution 2



% finer than 0.002 mm = 24.5%
% clay in the soil in Example 2.1 is (24.5/100) x 15.4 = 3.8%
% silt = 15.4 – 3.9 = 11.6%

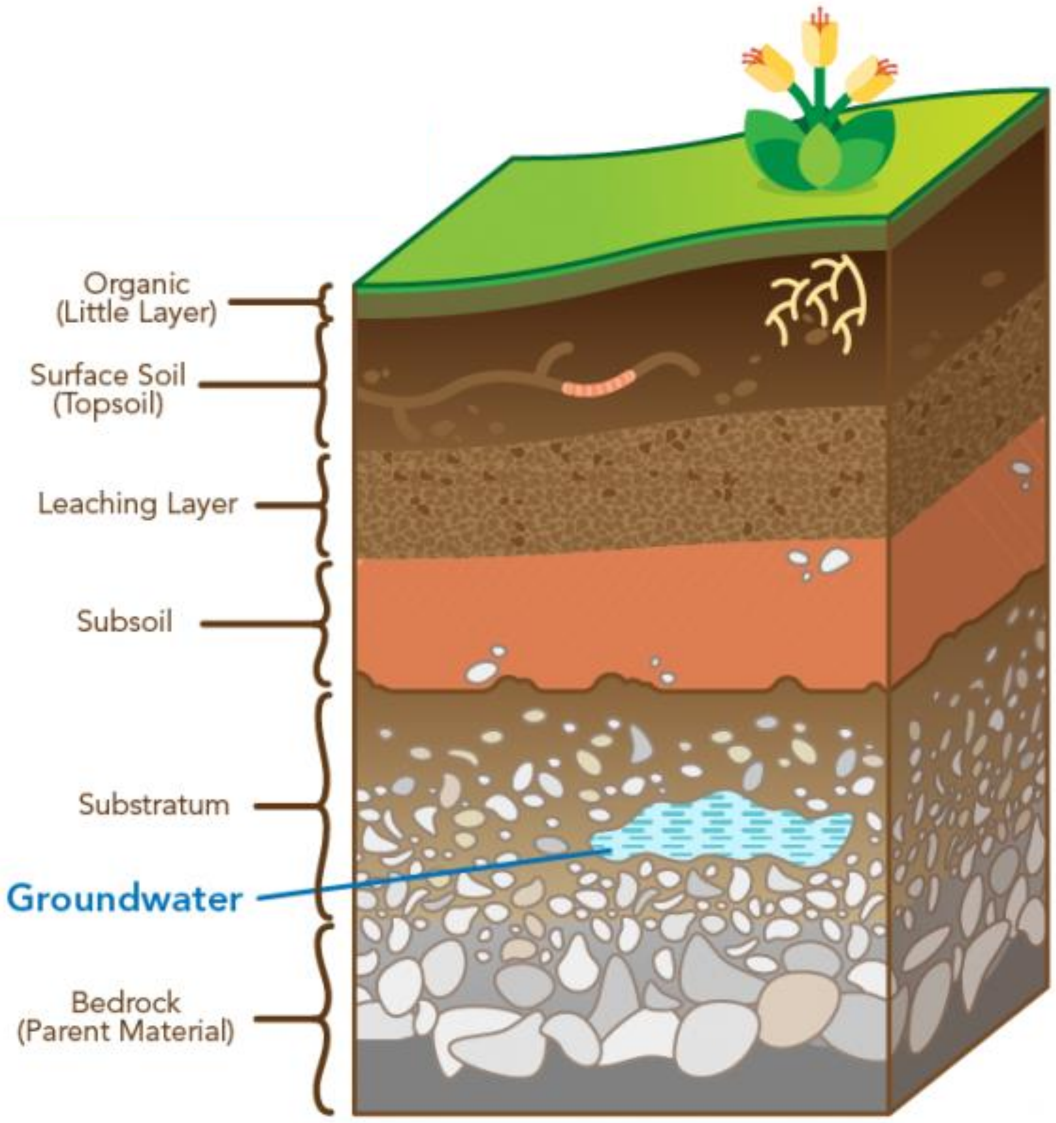
UNIVERSITAS TRISAKTI
PRODI TEKNIK PERTAMBANGAN

Hubungan Volume, Berat, Porositas, Kadar air, Kerapatan Relative Tanah

MTT6201 – MEKANIKA TANAH

1st session
1.5 hours

Lecturer :
Dr. Pantjanita Novi Hartami, S.T., M.T.
Reza Aryanto, S.T., M.T.
Danu Putra, S.T., M.T.



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2. Pengertian Tentang Tanah dan Batuan, Partikel Tanah
3. Analisis Ayakan dan Analysis Hydrometer
4. **Hubungan Volume, Berat, Porositas, Kadar air, Kerapatan Relative Tanah**
5. Konsistensi Tanah, Batas Plastis, Batas Cair
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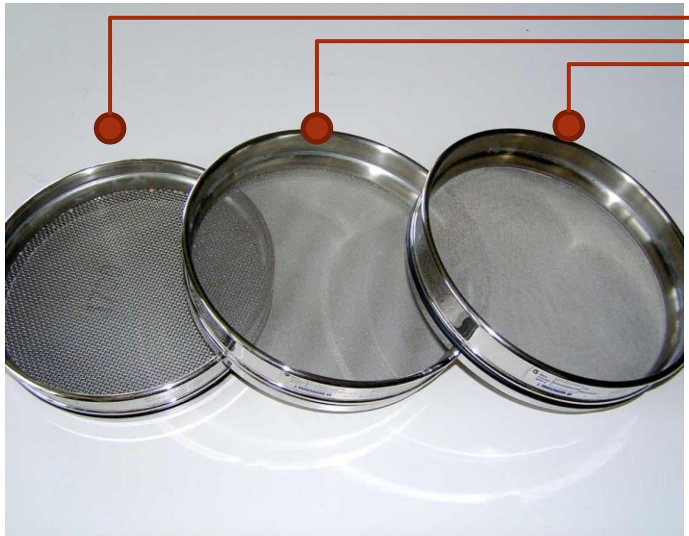
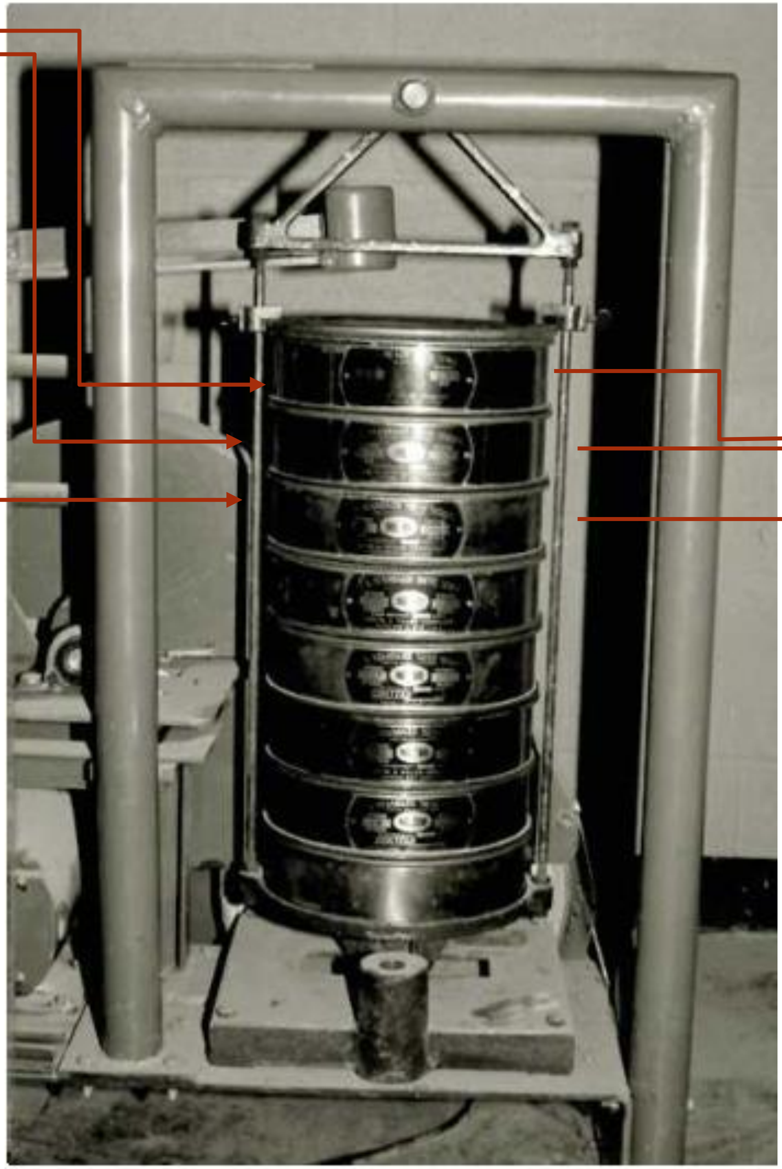
Final Term

OBJECTIVE

- Dapat mengklasifikasikan presentase air, solid dan rongga pada tanah
- Dapat melakukan perhitungan terkait presentase solid dan air pada tanah
- Dapat menjelaskan dampak presentase material pada tanah terhadap kegiatan perekayasaan

Rekap – Analisis Ayakan





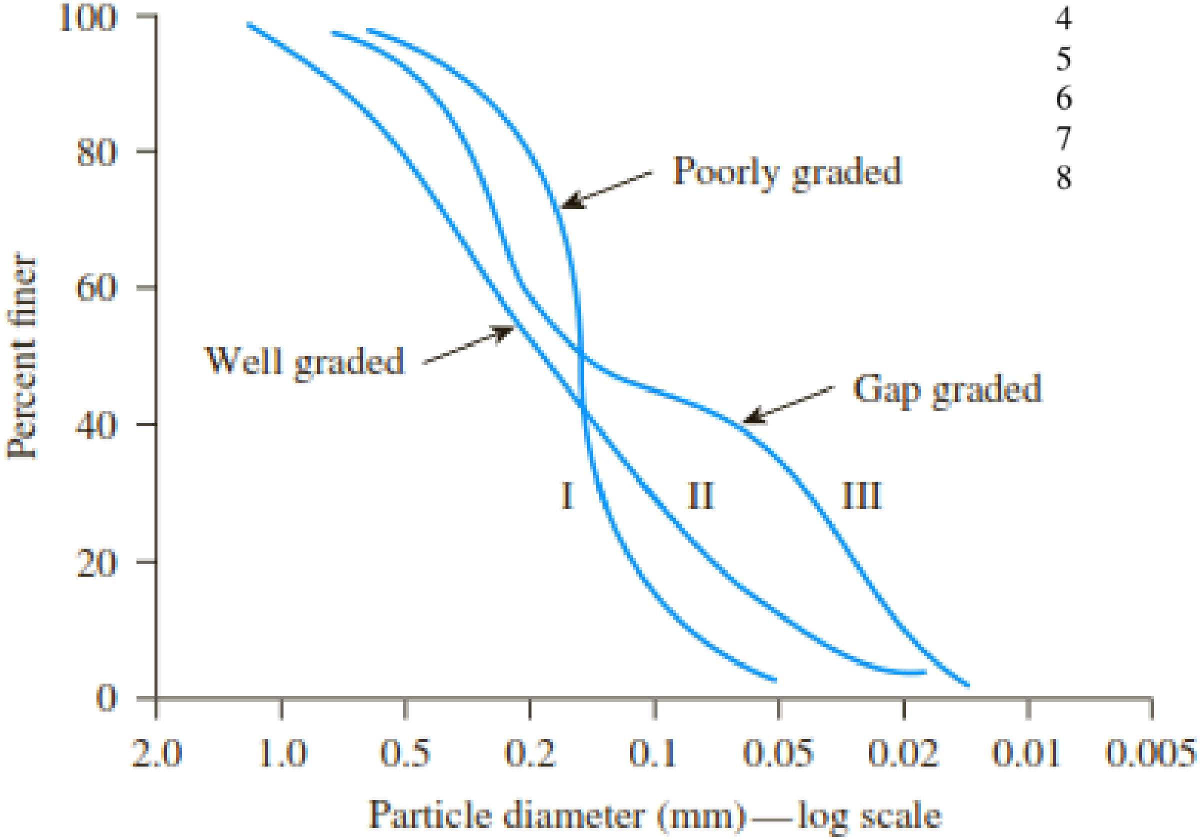
Sieve no.	Opening (mm)	Sieve no.	Opening (mm)
4	4.75	45	0.355
5	4.00	50	0.300
6	3.35	60	0.250
7	2.80	70	0.212
8	2.36	80	0.180
10	2.00	100	0.150
12	1.70	120	0.125
14	1.40	140	0.106
16	1.18	170	0.090
18	1.00	200	0.075
20	0.85	230	0.063
25	0.71	270	0.053
30	0.60	325	0.045
35	0.500	400	0.038

Sieve analysis consists of shaking the soil sample through a set of sieves that have progressively smaller openings

Source : Braja M Das, 2015;

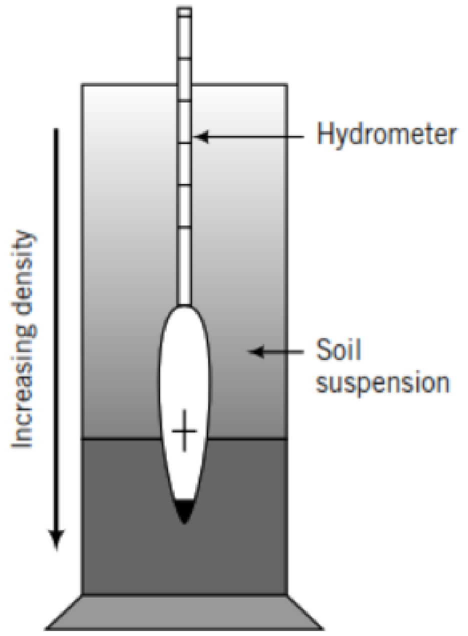
Rekap – Analisis Ayakan

Curve III represents such a soil. This type of soil is termed *gap graded.*



Depth (m)	% Gravel	% Sand	% Silt	% Clay	C_u	C_c	Soil Type (USCS)
0	5.76	82.34	8.71	0	4.29	1.22	Poorly graded sand with silt (SP-SM)
1	9.64	80.46	2.81	0	8.7	1.22	Well graded sand (SW)
2	4.90	94.5	0.65	0	5.29	0.76	Poorly graded sand (SP)
3	14.37	85.34	0.15	0	4.75	0.84	Poorly graded sand (SP)
4	11.68	88.22	0.10	0	4.44	0.8	Poorly graded sand (SP)
5	11.35	88.51	0.15	0	3.67	0.82	Poorly graded sand (SP)
6	7.39	92.21	0.40	0	3.67	0.76	Poorly graded sand (SP)
7	8.72	91.03	0.25	0	4.29	0.8	Poorly graded sand (SP)
8	15.00	84.71	0.30	0	5.14	0.73	Poorly graded sand (SP)

Rekap – Analisis Ayakan



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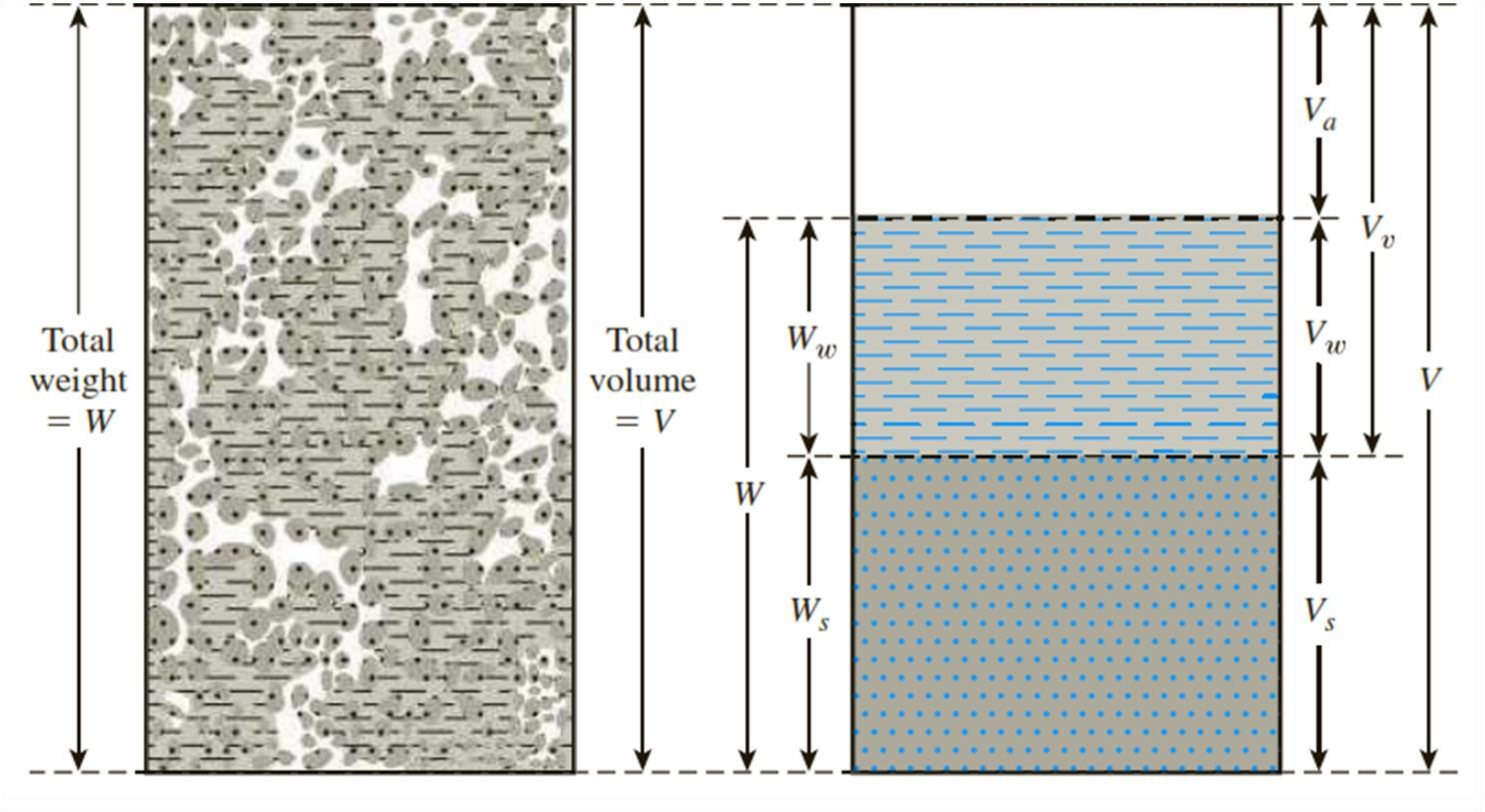
Hubungan Volume dan berat

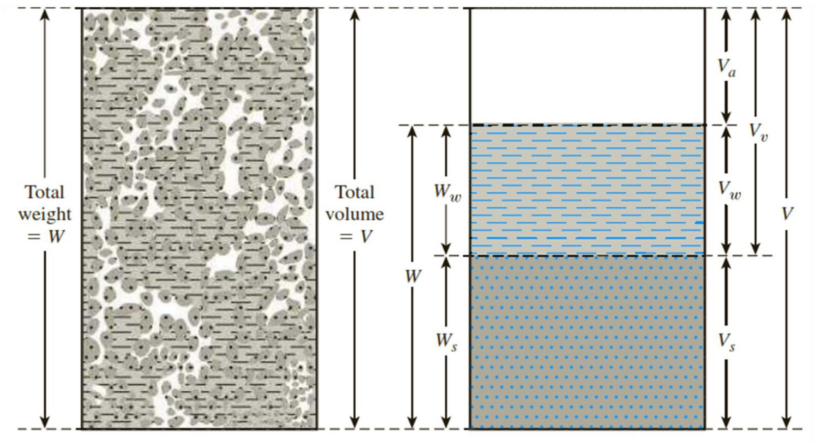
Diagram tanah



Source : Braja M Das, 2015;

Hubungan Volume dan berat

Definitions



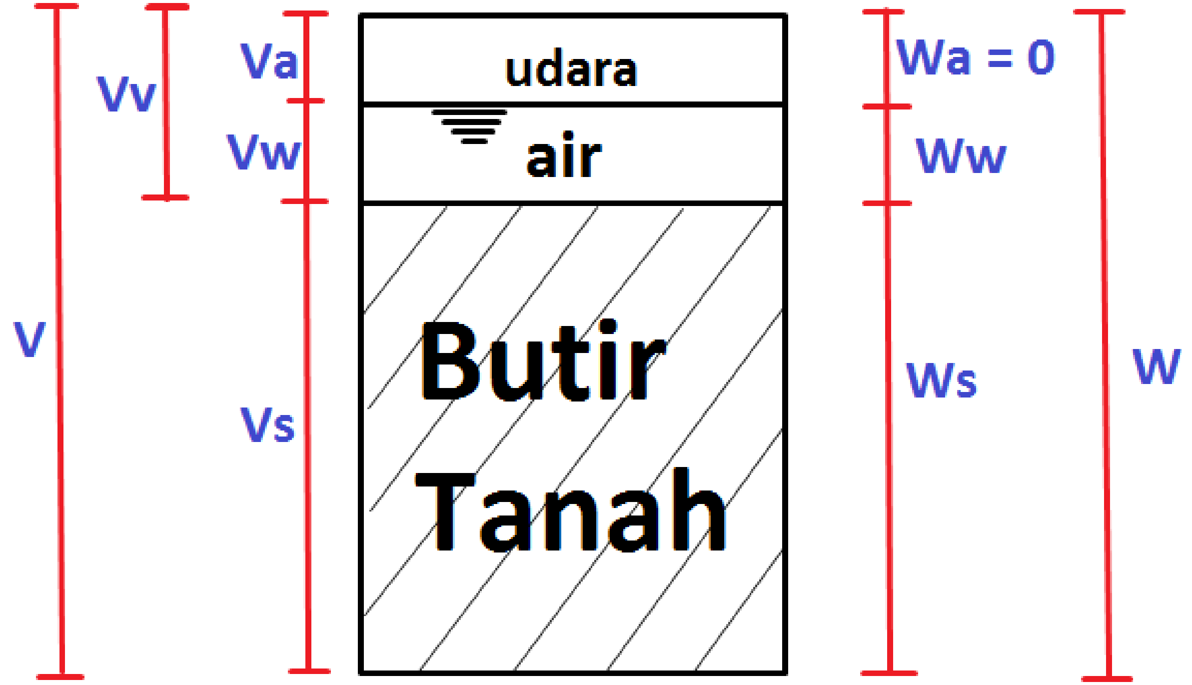
Water content (w)	the ratio of the weight of water to the weight of solids.
Void ratio (e)	the ratio of the volume of void space to the volume of solids.
Specific Volume (V’)	the volume of soil per unit volume of solids
Porosity (n)	the ratio of the volume of void to the total volume of soil.
Degree of saturation (S)	the ratio of the volume of water to the volume of void.
Bulk unit weight (γ)	the weight density, that is, the weight of a soil per unit volume.
Saturated unit weight (γ_{sat})	the weight of a saturated soil per unit volume.
Dry unit weight (γ_d)	the weight of a dry soil per unit volume.
Effective unit weight (γ')	the weight of soil solids in a submerged soil per unit volume.
Relative density (D_r)	an index that quantifies the degree of packing between the loosest and densest state of coarse-grained soils.
Swell factor (SF)	the ratio of the volume of excavated material to the volume of in situ material (sometimes called borrow pit material or bank material).

SOIL STATES

Liquid limit (LL)	the water content at which a soil changes from a plastic state to a liquid state.
Plastic limit (PL)	the water content at which a soil changes from a semisolid to a plastic state.
Shrinkage limit (SL)	the water content at which a soil changes from a solid to a semisolid state without further change in volume.

Source : Braja M Das, 2015;

Hubungan Volume dan berat



Total Volume (V)

$$V = V_s + V_v = V_s + V_w + V_a$$

TotalWeight (W)

$$W = W_s + W_w$$

Water Content (w)

$$w = \frac{W_w}{W_s} \times 100\%$$

Void Ratio (*e*)

$$e = \frac{V_v}{V_s}$$

Specific Volume (V')

$$V' = \frac{V}{V_s} = 1 + e$$

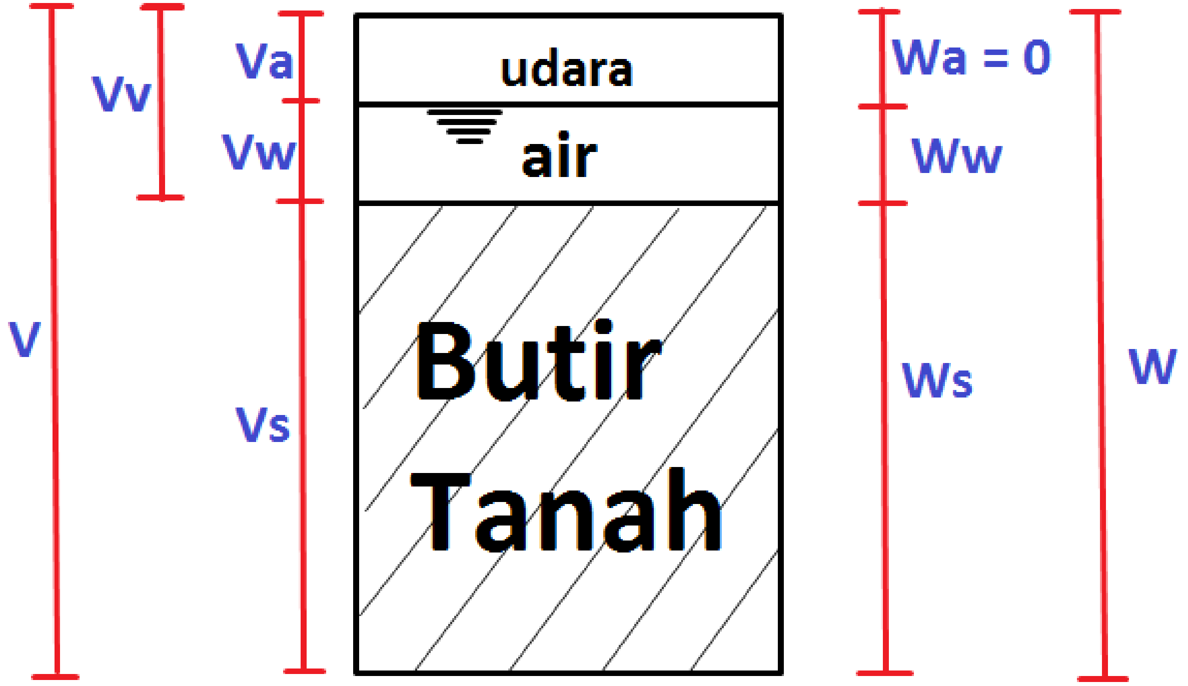
Porosity (*n*)

$$n = \frac{V_v}{V}$$

$$n = \frac{e}{1+e}$$

$$n = \frac{V_v}{V} = \frac{V_v}{V_s + V_v} = \frac{V_v/V_s}{V_s/V_s + V_v/V_s} = \frac{e}{1+e}$$

Moisture Content and Specific Gravity



Mositure content (w)

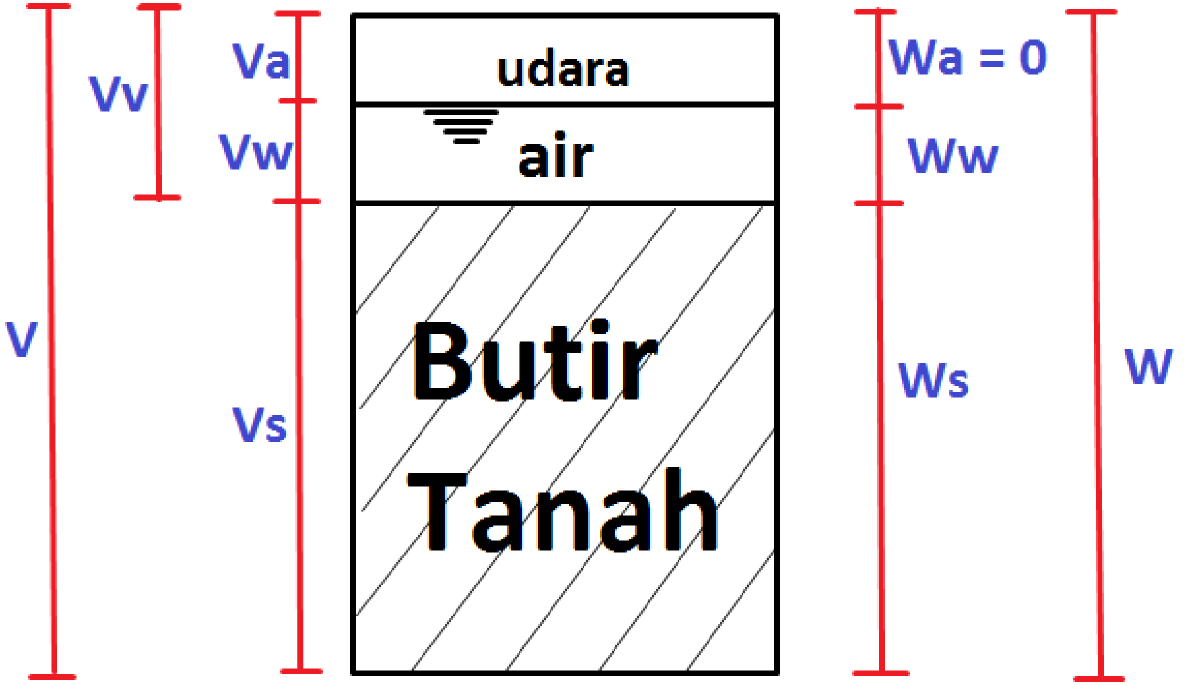
$$w = \frac{W_w}{W_s}$$

$$\gamma = \frac{W}{V} = \frac{W_s + W_w}{V} = \frac{W_s\left[1 + \left(\frac{W_w}{W_s}\right)\right]}{V} = \frac{W_s(1 + w)}{V}$$

Specific Gravity (w)

$$G_s = \frac{W_s}{V_s \gamma_w}$$

Unit Weight and Degree of Saturation



Degree of Saturation (S)

$$S = \frac{V_w}{V_v} = \frac{wG_s}{e} \quad \text{or} \quad Se = wG_s$$

Unit weight (y)

$$\gamma = \frac{W}{V} = \left(\frac{G_s + Se}{1 + e}\right)\gamma_w$$

$$\gamma = \frac{W}{V} = \frac{W_s + W_w}{V} = \frac{W_s\left[1 + \left(\frac{W_w}{W_s}\right)\right]}{V} = \frac{W_s(1 + w)}{V}$$

saturated

dry

Saturated Unit Weight (y_{sat})
S=1

$$\gamma_{sat} = \left(\frac{G_s + e}{1 + e}\right)\gamma_w$$

Dry Unit Weight (y_d)
S=0

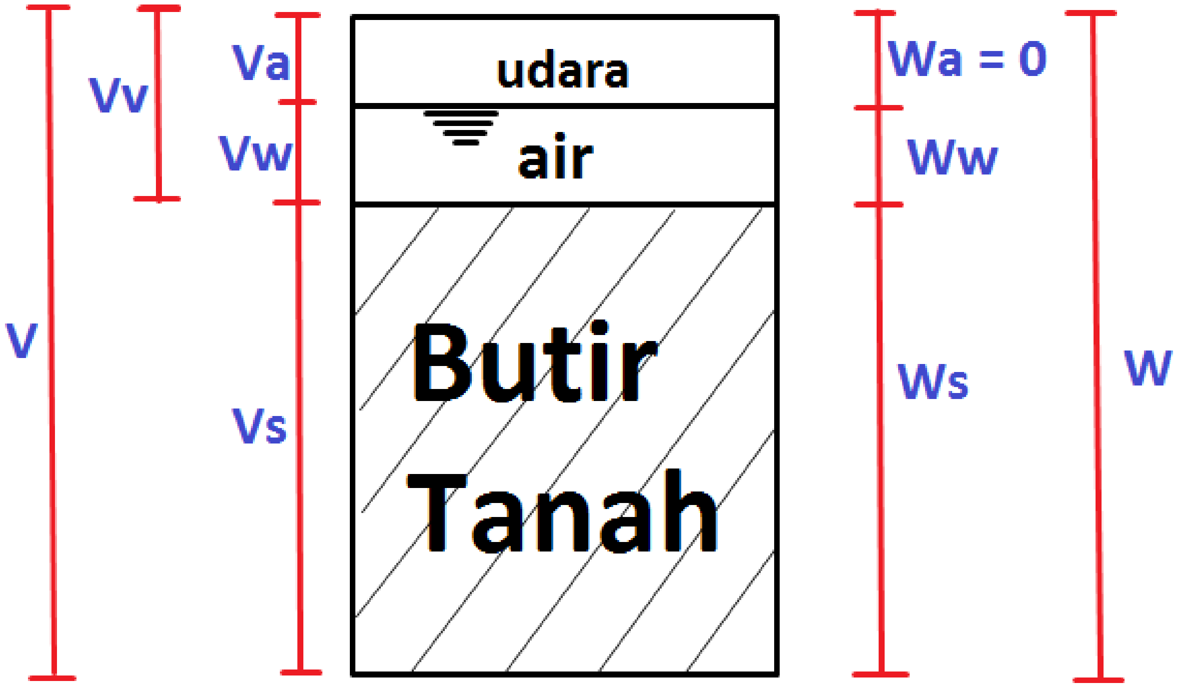
$$\gamma_d = \frac{W_s}{V} = \left(\frac{G_s}{1 + e}\right)\gamma_w = \frac{\gamma}{1 + w}$$

submerged

Effective or buoyant unit weight (y')

$$\gamma' = \gamma_{sat} - \gamma_w = \left(\frac{G_s - 1}{1 + e}\right)\gamma_w$$

Density and Conversion to Unit Weight



Density (p)

$$\rho = \frac{M}{V}$$

Dry Density (p_d)

$$\rho_d = \frac{M_s}{V}$$

Relative Density (D_r)

$$D_r = \frac{e_{max} - e}{e_{max} - e_{min}}$$

or

$$D_r = \frac{\gamma_d - (\gamma_d)_{min}}{(\gamma_d)_{max} - (\gamma_d)_{min}} \left\{ \frac{(\gamma_d)_{max}}{\gamma_d} \right\}$$

Unit dry weight in (kN/m³) (y_d)

$$\gamma_d\ (\text{kN/m}^3) = \frac{g\rho_d(\text{kg/m}^3)}{1000}$$

Unit weight in (kN/m³) (y)

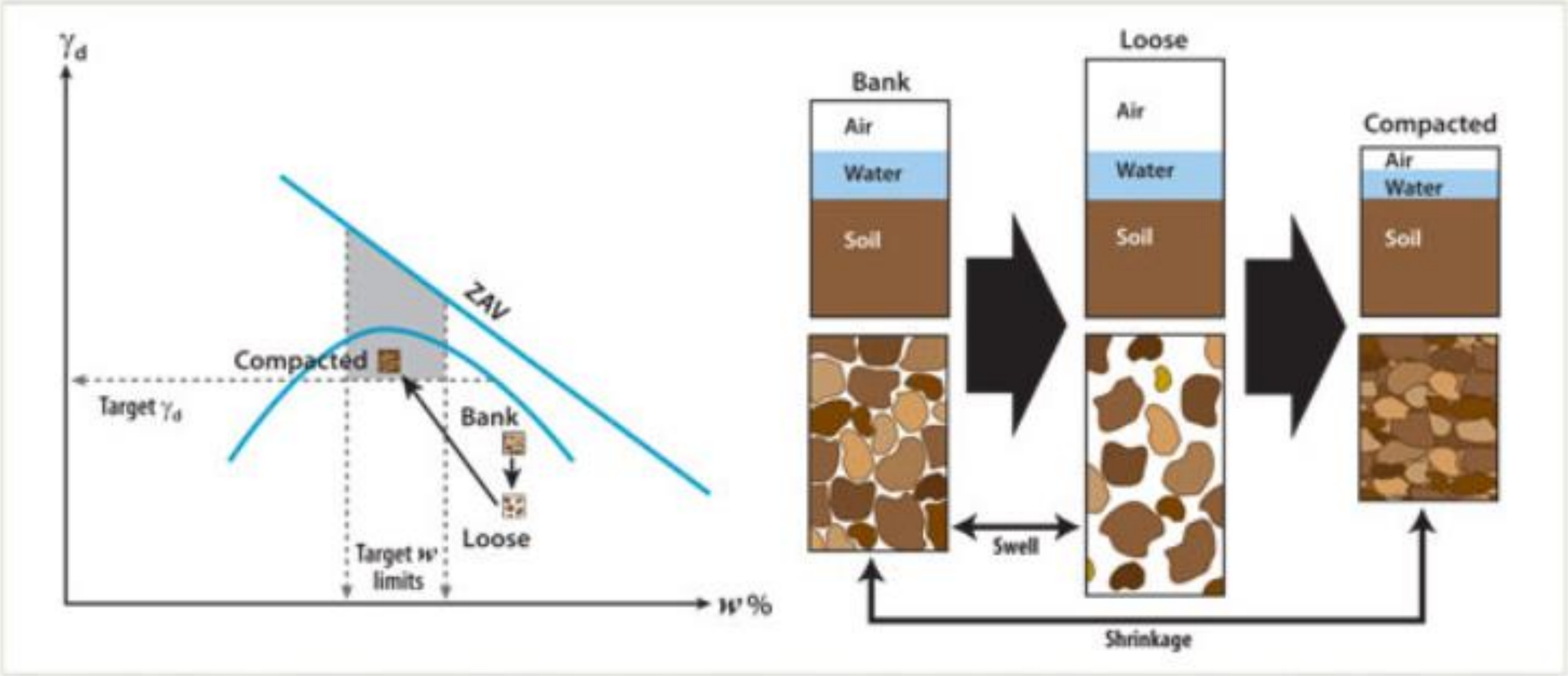
$$\gamma\ (\text{kN/m}^3) = \frac{g\rho\,(\text{kg/m}^3)}{1000}$$

gravity

Hubungan Volume dan berat

Swell Factor

$$SF = \frac{\text{Volume of excavated material}}{\text{Volume of in situ material}} \times 100\,(\%)$$



Exercise

Typically, a hydrometer test is conducted by these steps:

1. Taking a small quantity of a dry, fine-grained soil (approximately 50 grams) and thoroughly mixing it with distilled water to form a paste.
2. The paste is placed in a 1-liter glass cylinder, and distilled water is added to bring the level to the 1-liter mark.
3. The glass cylinder is then repeatedly shaken and inverted before being placed in a constant-temperature bath.
4. A hydrometer is placed in the glass cylinder and a clock is simultaneously started.
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6. The diameter D (cm) of the particle at time t_D (seconds) is calculated from Stokes's law

where :

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UNIVERSITAS TRISAKTI
PRODI TEKNIK PERTAMBANGAN

Konsistensi Tanah, Batas Plastis dan Batas Cair

MTT6201 – MEKANIKA TANAH

5th session
1.5 hours

Lecturer :
Dr. Pantjanita Novi Hartami, S.T., M.T.
Reza Aryanto, S.T., M.T.
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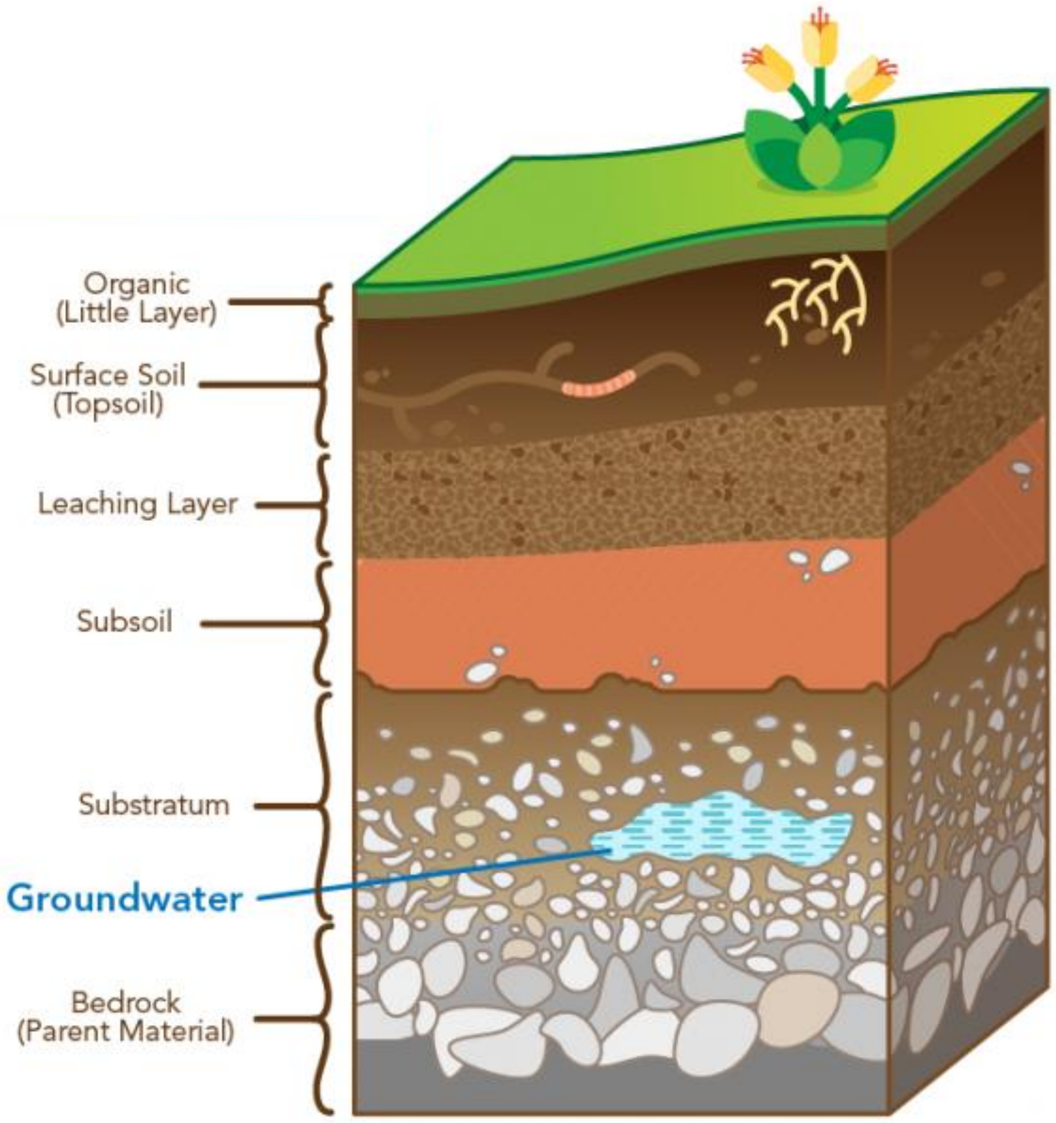

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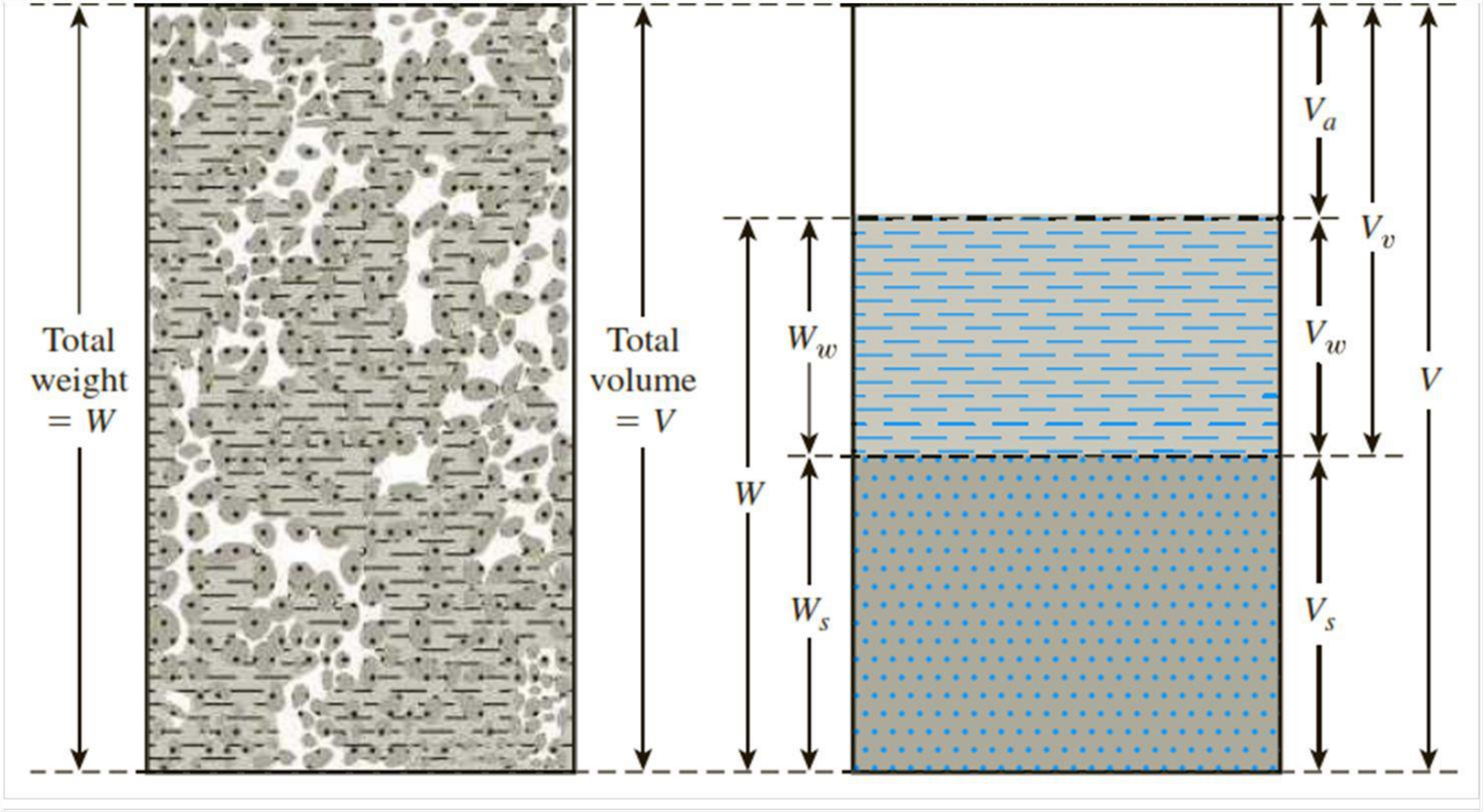
- Dapat menjelaskan dampak presentase material pada tanah terhadap kegiatan perekayasaan

Hubungan Volume dan berat

Diagram Tanah

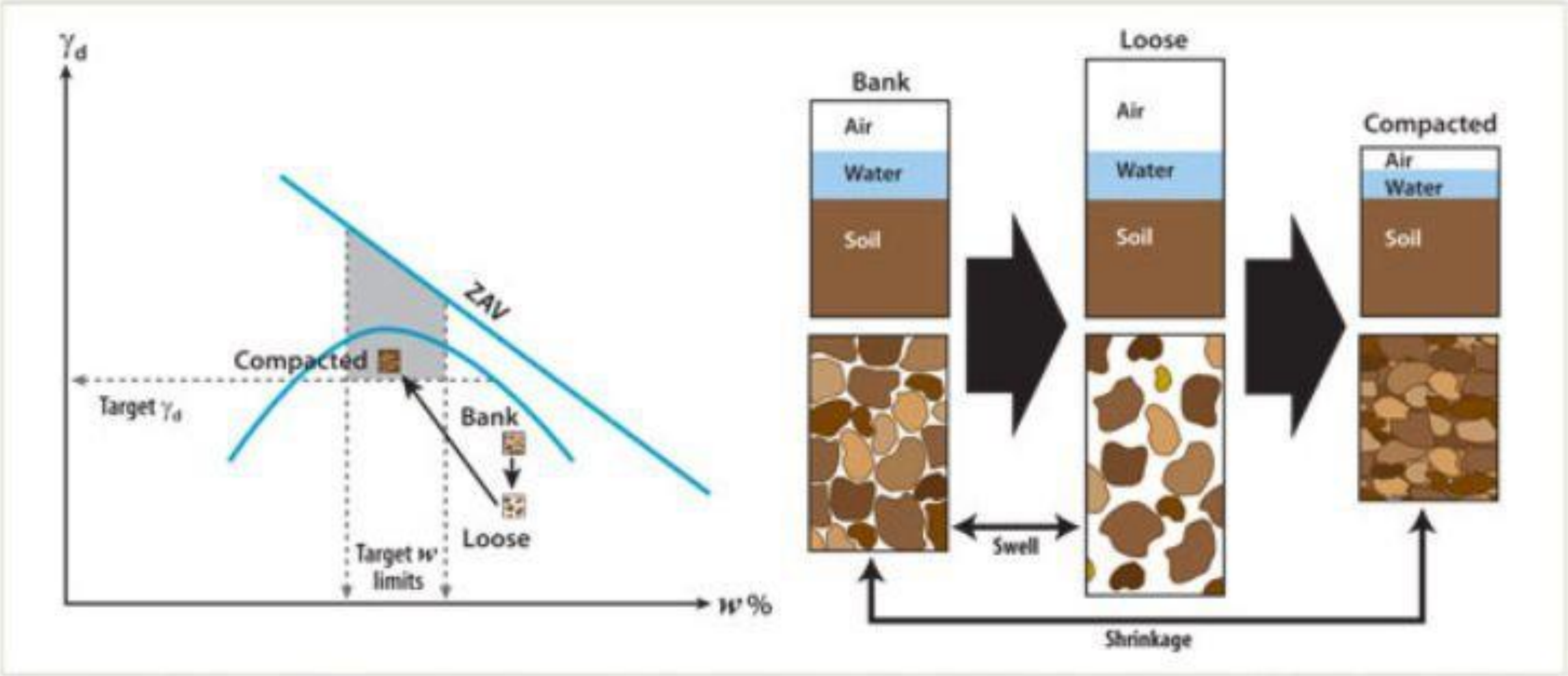


Source : Braja M Das, 2015;

Hubungan Volume dan berat

Swell Factor

$$SF = \frac{\text{Volume of excavated material}}{\text{Volume of in situ material}} \times 100\ (\%)$$



Source : Braja M Das, 2015;

Atterberg limits

- The behavior of soil can be divided into four basic states ***solid, semisolid, plastic,* and *liquid***
- **The moisture content, in percent,** at which the **transition from solid to semisolid** state takes place is dened as the ***shrinkage limit.***
- **The** moisture **content** at the point of **transition from semisolid to plastic** state is the ***plastic limit***

from **plastic to liquid state** is the ***liquid limit.***

- These parameters are also known as *Atterberg limits*

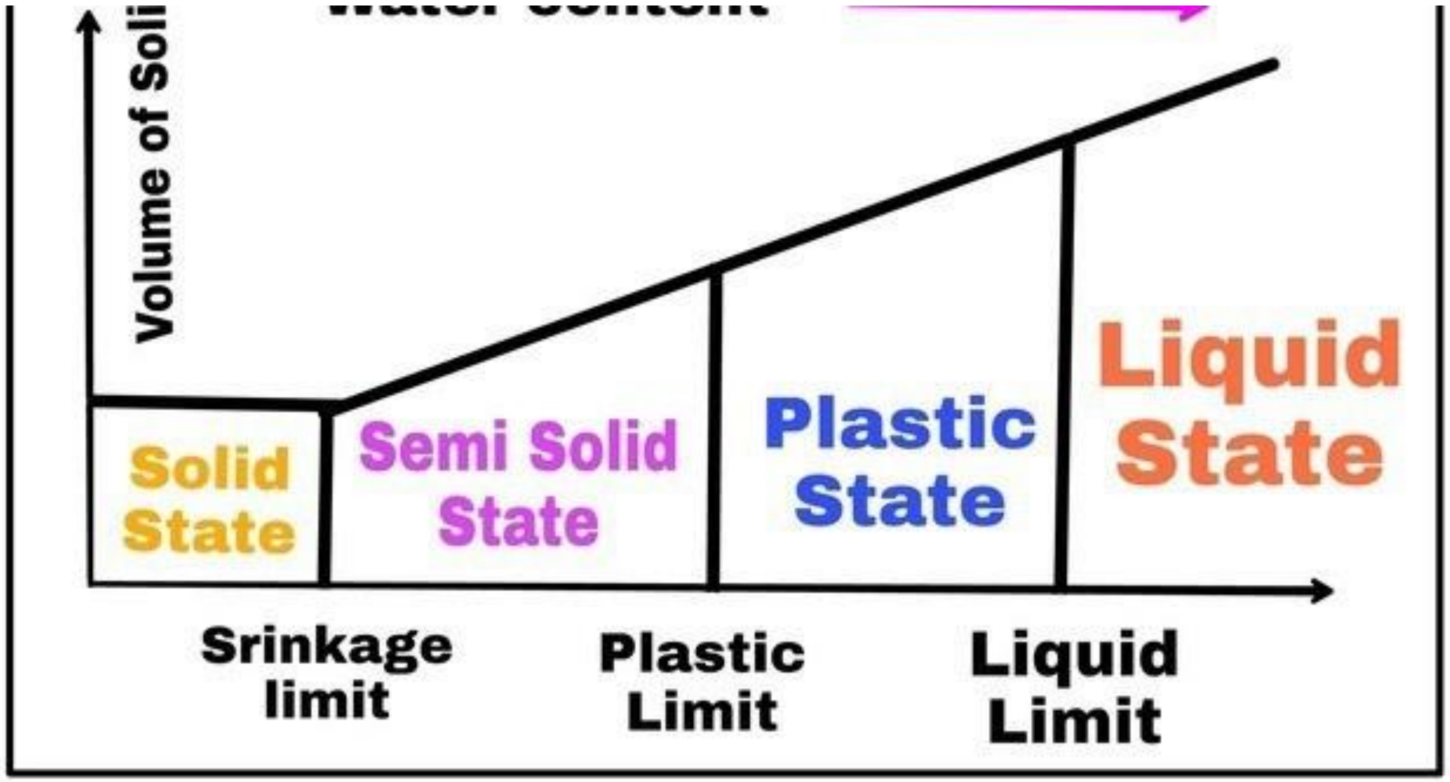


Fig:- States of Consistancy

Source : Braja M Das, 2015;

Hubungan Volume dan berat

Percussion Cup Method

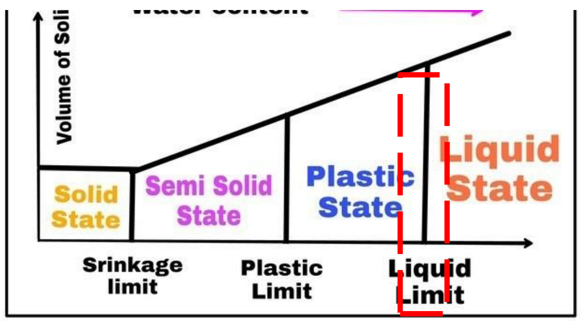


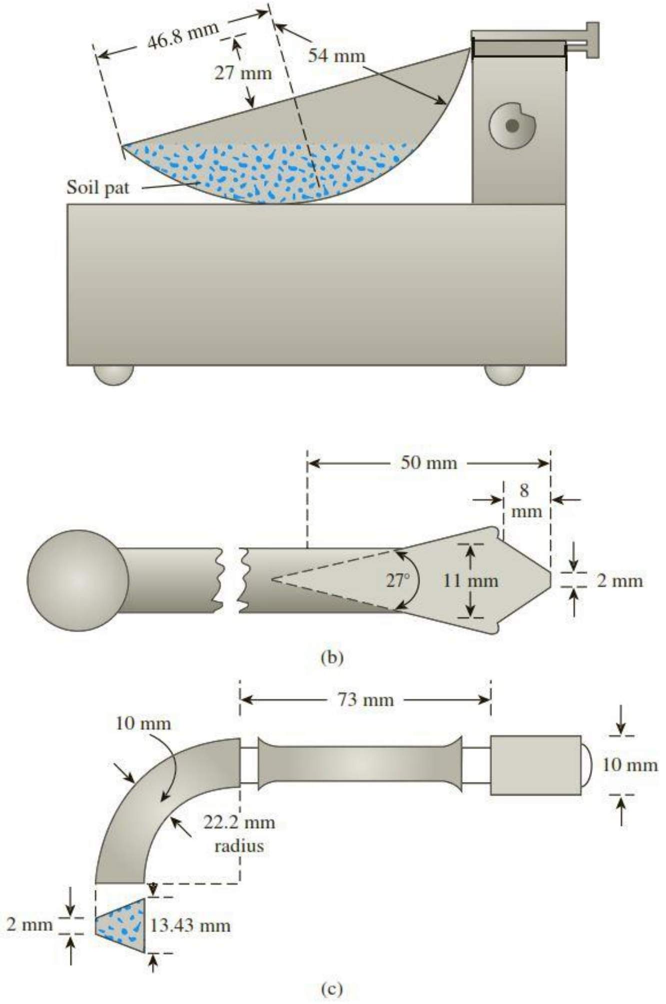
Fig:- States of Consistancy

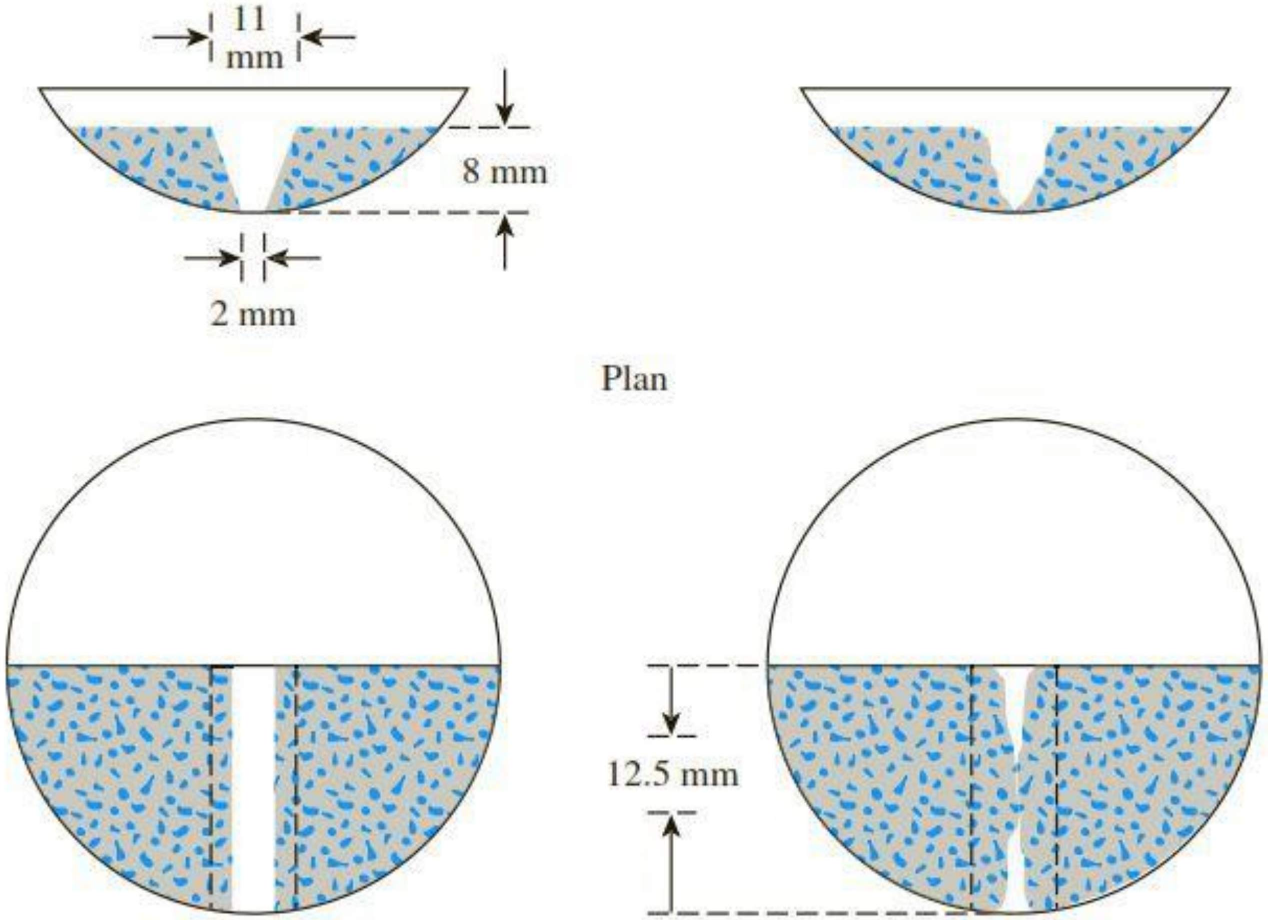
ASTM (Test Designation D-4318)

- To perform the liquid limit test, one must place a soil paste in the cup.
- A groove is then cut at the center of the soil pat with the standard grooving tool
- By the use of the crank-operated cam, the cup is lifted and dropped from a height of 10 mm (0.394 in.).
- The moisture content, in percent, required to close a distance of 12.5 mm (0.5 in.) along the bottom of the groove after 25 blows is dened as the *liquid limit.*

Source : Braja M Das, 2015;

Percussion Cup Method





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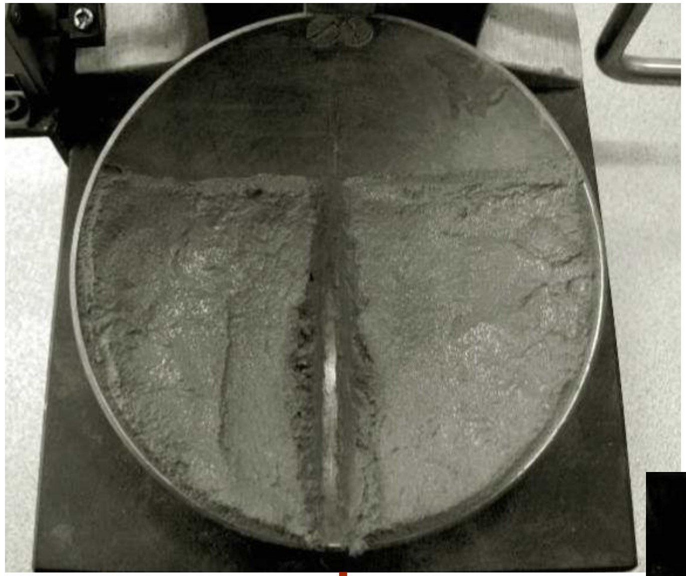
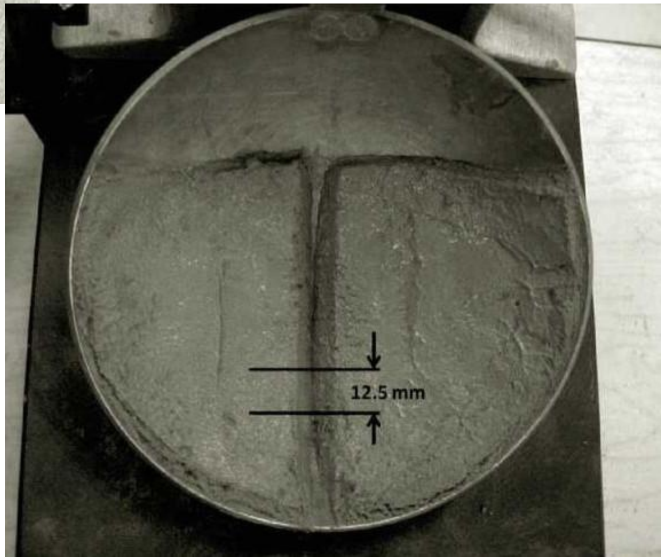
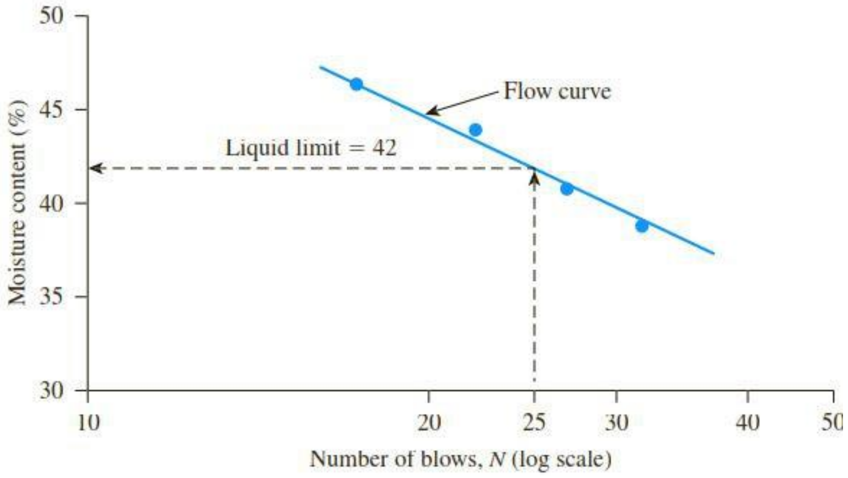
Liquid Limit

Percussion Cup Method







Flow Curve Equations

$$w = -I_F \log N + C$$

Empirical Equations

$$LL = w_N \left(\frac{N}{25}\right)^{\tan\beta}$$

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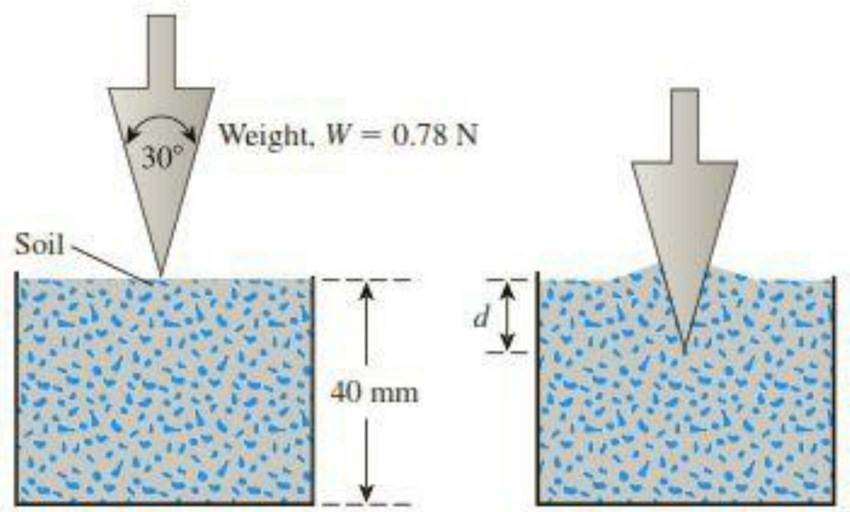
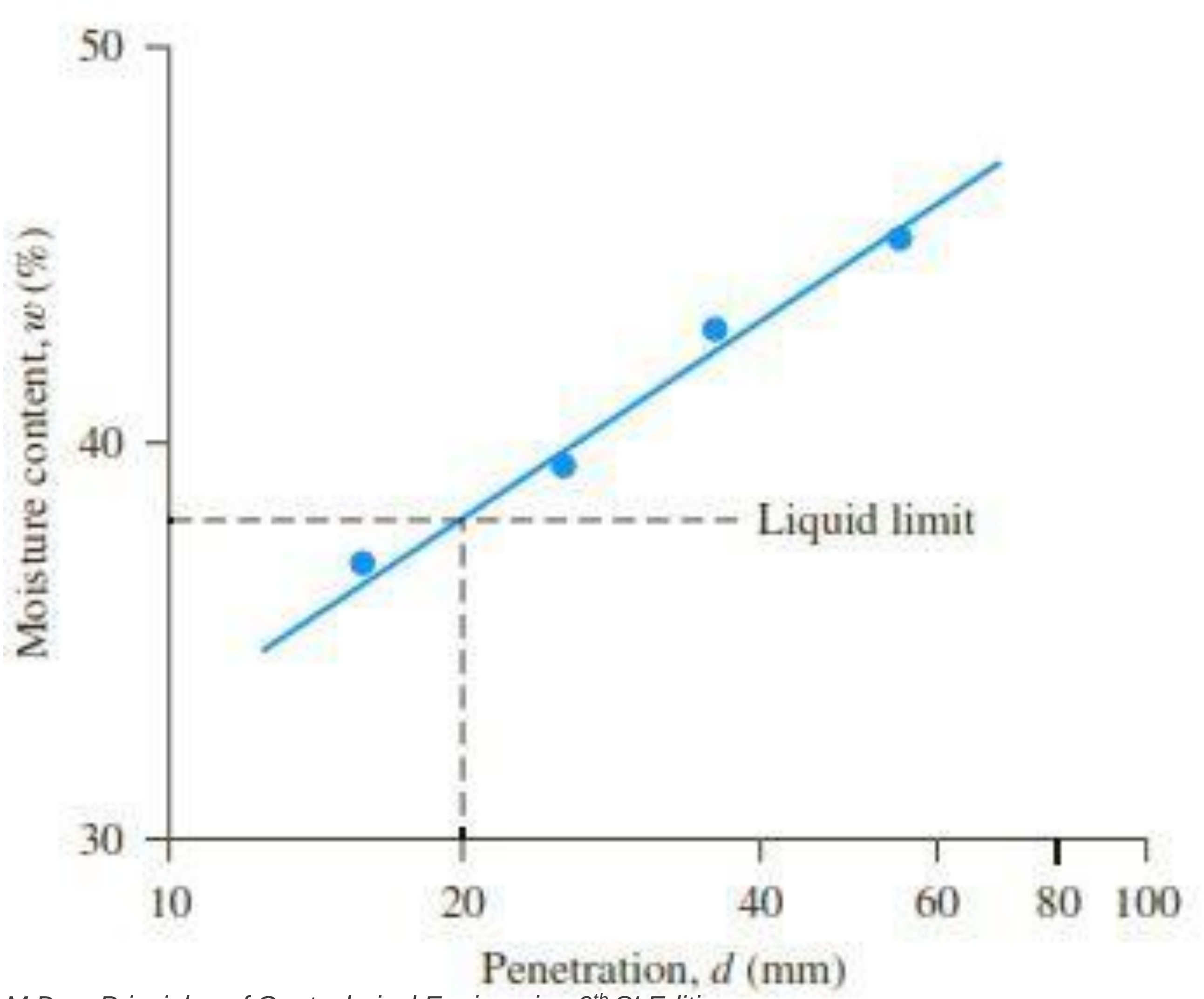
Fall Cone Method

- British Standard—BS1377
- the liquid limit is dened as the moisture content at which a standard cone of apex angle 30º and weight of 0.78 N (80 gf) will penetrate a distance (*d)* = 20 mm in 5 seconds when allowed to drop from a position of point contact with the soil surface



Fall Cone Method



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Flow Curve Equations

$$I_{FC} = \frac{w_2(\%) - w_1(\%)}{\log d_2 - \log d_1}$$

Empirical Equations

Feng (2001)

$$LL = w\left(\frac{20}{d}\right)^{0.33}$$

Nagaraj and Jayadeva (1981)

$$LL = \frac{w}{0.77 \log d}$$

$$LL = \frac{w}{0.65 + 0.0175d}$$

Fall Cone Method - Summary of Main Differences among Cones

Country	Cone details	Penetration for liquid limit (mm)
Russia	Cone angle = 30° Cone mass = 76 g	10
Britian, France	Cone angle = 30° Cone mass = 80 g	20
India	Cone angle = 31° Cone mass = 148 g	20.4
Sweden, Canada (Quebec)	Cone angle = 60° Cone mass = 60 g	10

Note: Duration of penetration is 5 s in all cases.

$$LL_{(BS)} = 2.6 + 0.94[LL_{(ASTM)}]$$

Budhu, 1985

Plastic Limit Limit (PL)

Rolled Test

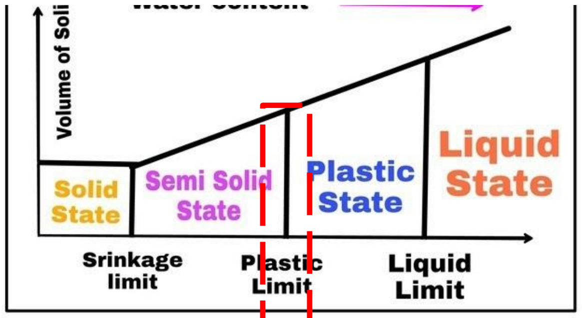


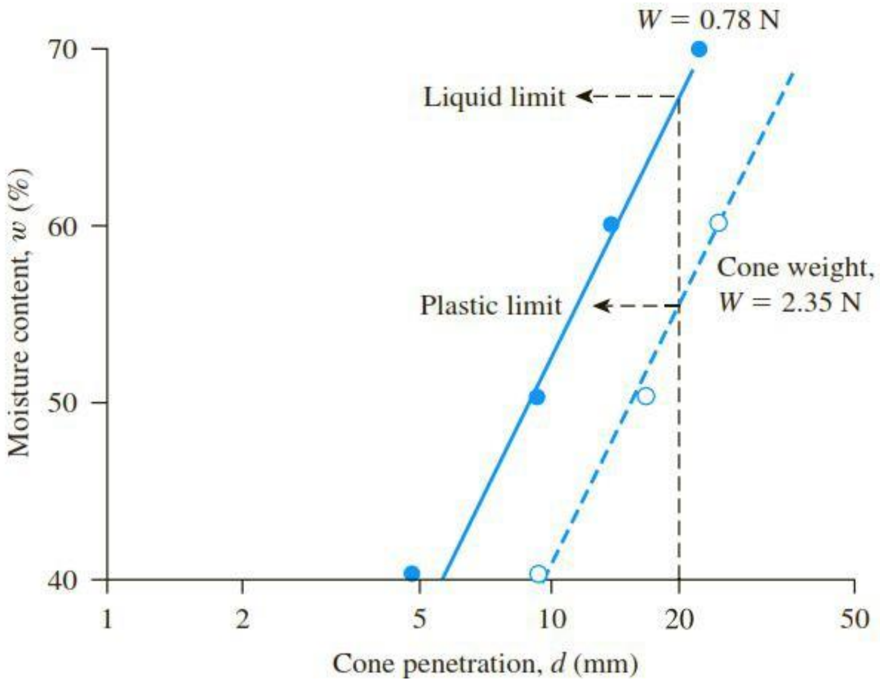
Fig:- States of Consistancy

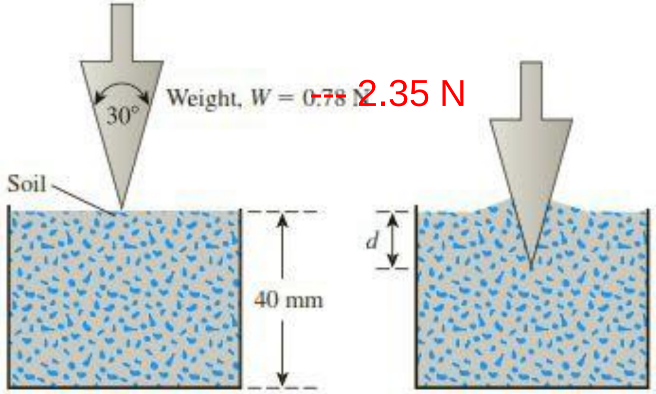
- The *plastic limit is dened as the* ***moisture content in percent,*** *at which the soil crumplastic limit is dened as the moisture content in percent, at which* ***the soil crumbles,*** **when rolled into threads of 3.2 mm (18 in.) in diameter.**
- The plastic limit test is simple and is performed by **repeated rollings of an ellipsoidal-sized soil mass by hand on a ground glass plate**
- **ASTM in Test Designation D-4318**

Plastic Limit (PL)

Fall Cone Method

- As in the case of liquid limit determination, **the fall cone method can be used** to obtain the plastic limit.
- This can be achieved by **using a cone of similar geometry but with a mass of 2.35 N (240 gf)**.
- Three to four tests at varying moisture contents of soil are conducted, and the corresponding cone penetrations (*d) are determined.*
- **The moisture content corresponding to a cone penetration of *d = 20 mm is the plastic* limit**





Cambridge Gault clay reported by Wroth and Wood (1978)

Typical Values of Liquid Limit, Plastic Limit, and Activity of Some Clay Minerals

Mineral	Liquid limit, *LL*	Plastic limit, *PL*	Activity, *A*
Kaolinite	35–100	20–40	0.3–0.5
Illite	60–120	35–60	0.5–1.2
Montmorillonite	100–900	50–100	1.5–7.0
Halloysite (hydrated)	50–70	40–60	0.1–0.2
Halloysite (dehydrated)	40–55	30–45	0.4–0.6
Attapulgite	150–250	100–125	0.4–1.3
Allophane	200–250	120–150	0.4–1.3

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Plasticity Index (PI)

PI	Description
0	Nonplastic
1–5	Slightly plastic
5–10	Low plasticity
10–20	Medium plasticity
20–40	High plasticity
>40	Very high plasticity

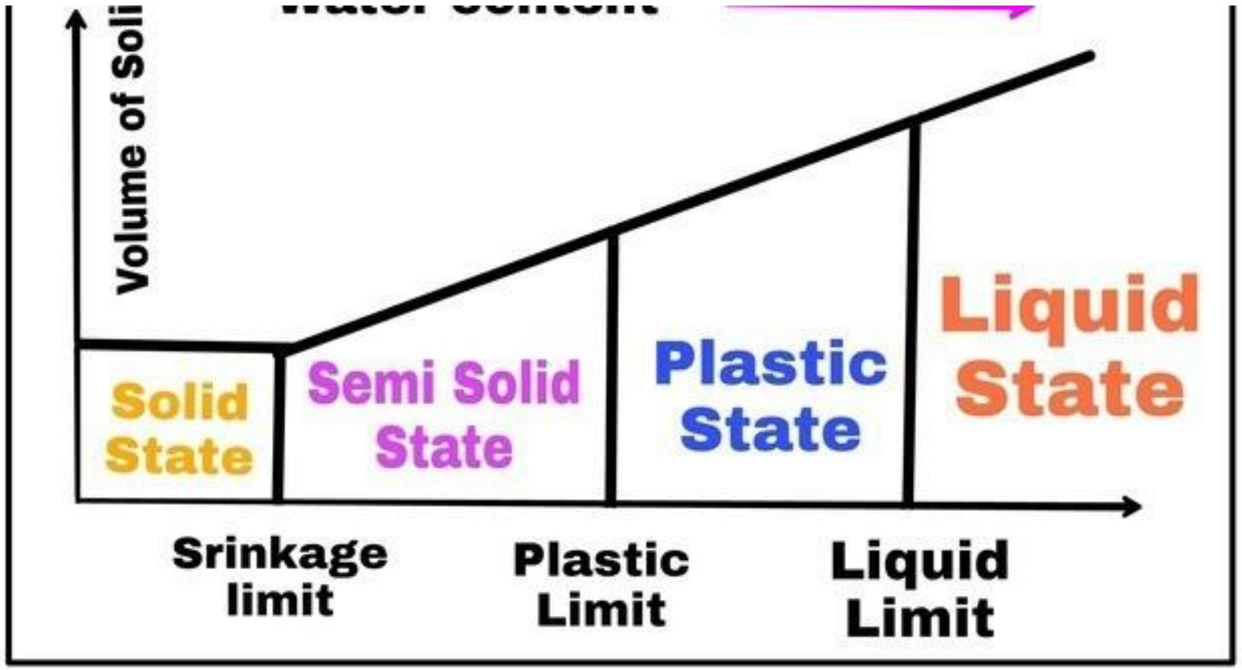


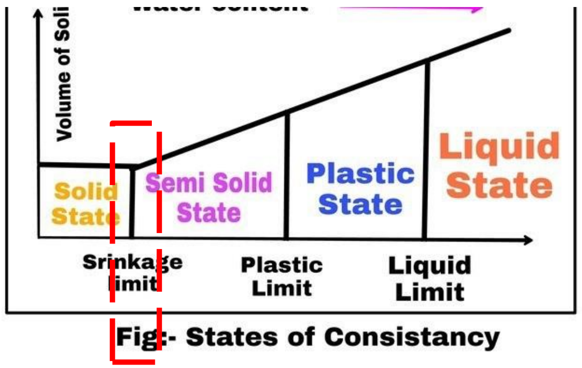
Fig:- States of Consistancy

The difference between the liquid limit and the plastic limit of a soil

$$PI = LL - PL$$

Burmister (1949)

Shrinkage Limits Test



Definitions

The moisture content, in percent, at which the volume of the soil mass ceases to change is dened as the *shrinkage limit*

The Test

- Shrinkage limit tests are performed in the laboratory with a **porcelain dish about 44 mm (1.75 in.) in diameter and about 12.7 mm (12 in.) high.**
- The inside of the dish is **coated with petroleum jelly and is then lled completely with wet soil**.
- **Excess soil** standing above the edge of the dish is **struck off with a straightedge.**
- The **mass of the wet soil** inside the dish is **recorded.**
- The **soil pat** in the dish is then **oven-dried.**
- The **volume of the oven-dried soil pat is then determined.**

Shrinkage Limits Test Calculations

$$SL = w_i\,(\%) - \Delta w\,(\%)$$

M_1 = mass of the wet soil pat in the dish at the beginning of the test (g)

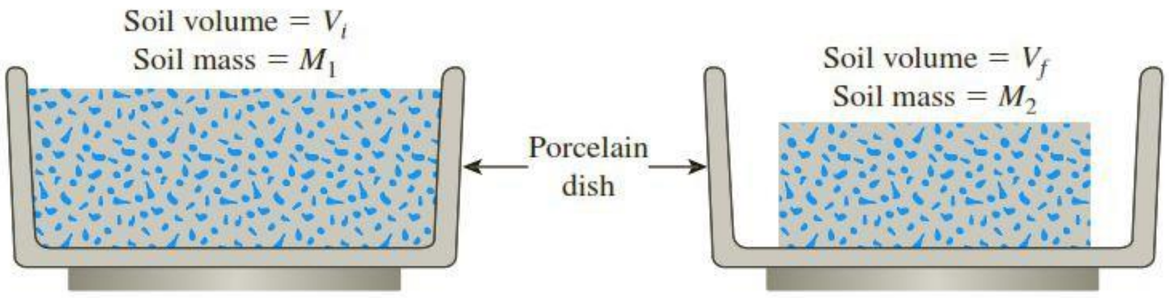
M_2 = mass of the dry soil pat (g)

V_i = initial volume of the wet soil pat (that is, inside volume of the dish, cm

V_f = volume of the oven-dried soil pat (cm)

P_w = density of water (g/cm)

$$SL = \left(\frac{M_1 - M_2}{M_2}\right)(100) - \left(\frac{V_i - V_f}{M_2}\right)(\rho_w)\,(100)$$



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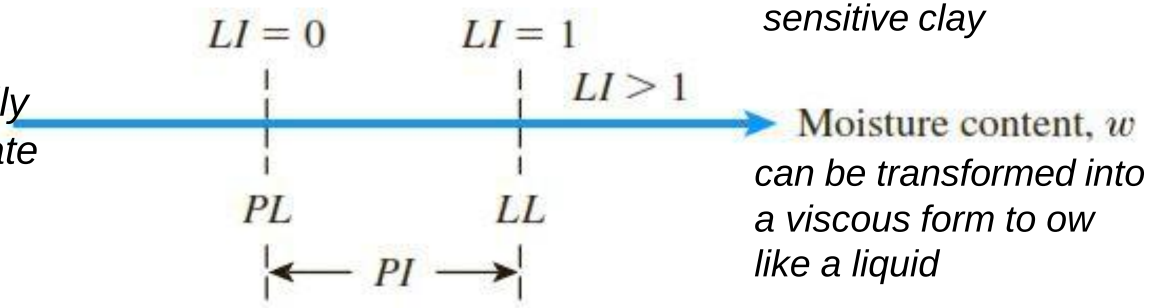
Liquidity Index (LI) and Consistency Index (CI)

- The relative consistency of a cohesive soil in the natural state can be dened by a ratio calle d the *liquidity index*

$$LI = \frac{w - PL}{LL - PL}$$

$$CI = \frac{LL - w}{LL - PL}$$

Soil deposits that are heavily overconsolidate d



sensitive clay

can be transformed into a viscous form to ow like a liquid

CI	Unconfined compression strength	
	kN/m²	lb/ft²
<0.5	<25	<500
0.5–0.75	25–80	500–1700
0.75–1.0	80–150	1700–3100
1.0–1.5	150–400	3100–8400
>1.5	>400	>8400

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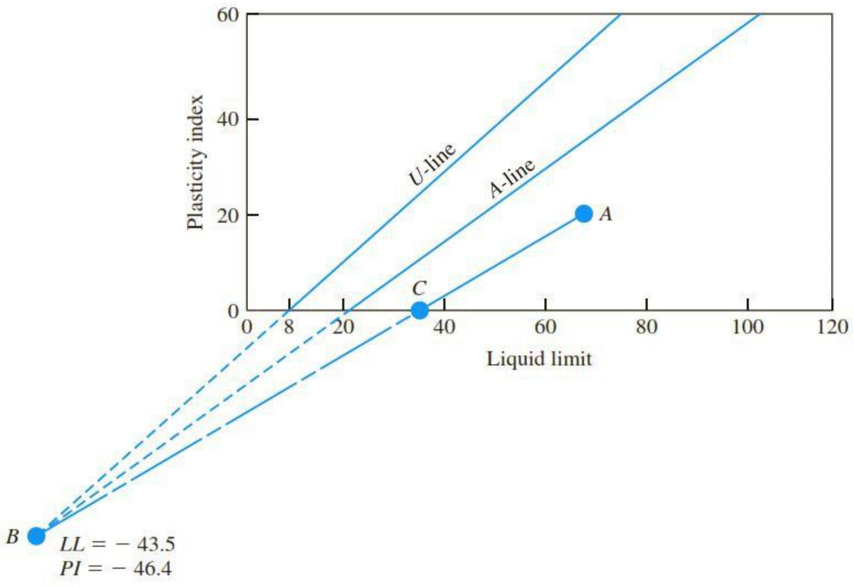
Casagrande (1932)

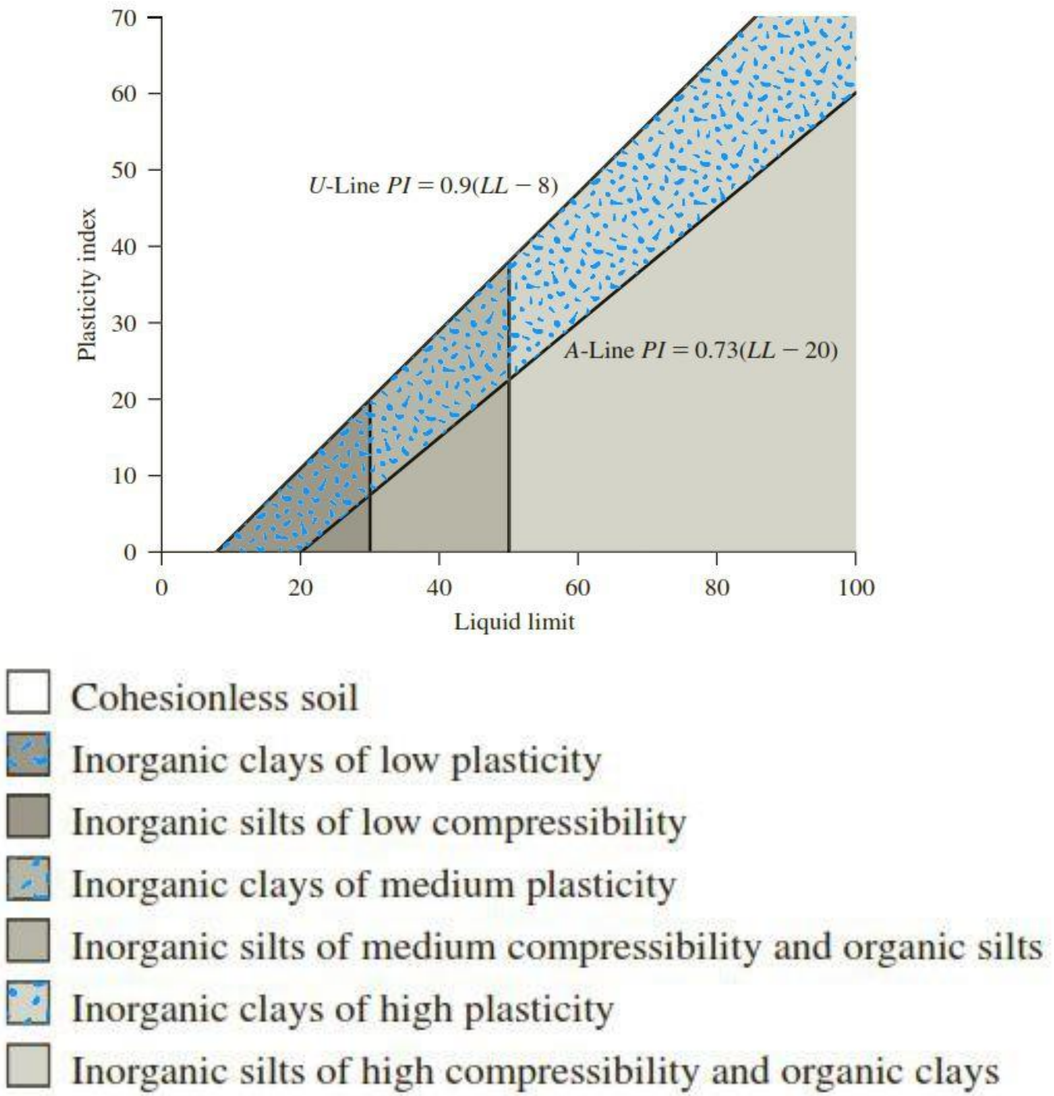
a **Plot the plasticity index against the liquid limit of a given soil** such as **point *A***

b **Project the A-line and the U-line downward to meet at point U-line downward to meet at point B**. Point B will have the coordinates of LL 5 243.5 and PI 5 246.4.

c **Join points B and A with a straight line.** This will intersect the liquid limit axis at point C.

d. The abscissa of point C is the estimated shrinkage limit.





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