FUNDAMENTALS OF GEOTECHNICAL ENGINEERING

Lesson 2. Basic characteristics of soils and rocks.

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2. BASIC CHARACTERISTICS OF SOILS AND ROCKS.

LESSON OVERVIEW

This lesson provides an introduction to the main characteristics of soils and rocks. First, terminology and definitions related to soil composition are introduced, and then, the basic properties of soils, such as unit weight, porosity or water content, among others, are defined and explained. The second part of the lesson is devoted to intact rocks. First, the difference between intact rock and rock mass is introduced and then, the physical properties of intact rocks are defined. Along the lesson, the international standards of application are referenced.

LEARNING OUTCOMES

On completion this lesson, the student will be able to:

- ✓ Identify the three phases of a soil, and know and apply the mass and volume relationships between them.
- ✓ Determine the basic properties of soils: unit weights, porosity, void ratio, density index, water content and degree of saturation.
- ✓ Obtain relationships between the basic properties of a soil.
- ✓ Identify the different components of rock masses.
- ✓ Determine the physical properties of an intact rock: unit weight, porosity, effective porosity, durability and permeability.
- ✓ Know the international standards necessary to determine these properties in lab.

2. BASIC CHARACTERISTICS OF SOILS AND ROCKS.

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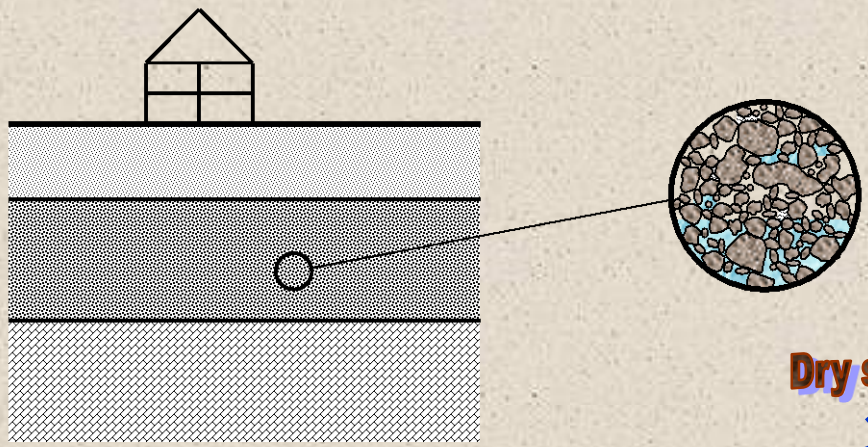
2. BASIC CHARACTERISTICS OF SOILS AND ROCKS.

BASIC PROPERTIES OF SOILS (I). The three phases of soils.



The three phases of soils:

- Solid (minerals, organic matter)
- Liquid (water)
- Gas (air)

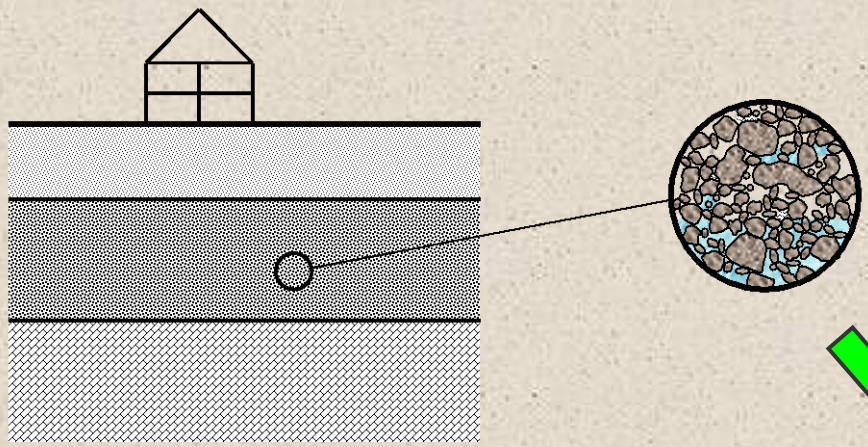
Dry soils, unsaturated soils and saturated soils

All the voids are filled with air

Voids are filled with water and air

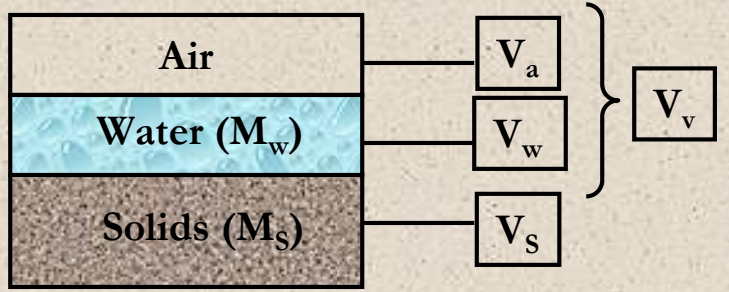
All the voids are filled by water

BASIC PROPERTIES OF SOILS (II). Mass and volume relationships.



Mass and volume relationships

- ✓ $M = M_S + M_w$
- ✓ $V = V_S + V_w + V_a = V_S + V_v$
- ✓ $V_v = V_w + V_a$



Idealised soil

BASIC PROPERTIES OF SOILS (III). Unit weights (I).

Unit weight (kN/m^3)

- Bulk unit weight: $\gamma = \frac{W}{V}$
  - Typical values: 15 ÷ 22 kN/m^3. UNE 103301:1994 Standard.
- Unit weight of soil solids: $\gamma_S = \frac{W_S}{V_S}$
  - It is obtained from G_S, specific gravity of soil solids, which ranges from 2.5 to 2.8. UNE 103302:1994 Standard.

$$G_S = \frac{\rho_S}{\rho_w} = \frac{\gamma_S}{\gamma_w} \Rightarrow \gamma_S = G \cdot \gamma_w$$

γ_w → 9.8 kN/m^3

- Dry unit weight: $\gamma_d = \frac{W_S}{V}$

BASIC PROPERTIES OF SOILS (IV). Unit weights (II).

Unit weight (kN/m^3)

- Saturated unit weight: $\gamma_{sat} = \frac{W_{sat}}{V}$

- Effective or buoyant unit weight:

$$\gamma' = \frac{W_{sat} - V \cdot \gamma_w}{V} = \gamma_{sat} - \gamma_w$$

Table D.26. Typical values of unit weight of soils.

Soil type	γ_{sat} (kN/m^3)	γ_d (kN/m^3)
Gravel	20 - 22	15 - 17
Sand	18 - 20	13 - 16
Silt	18 - 20	14 - 18
Clay	16 - 22	14 - 21

Table D.27. Basic properties of soils.

	Soil type	Bulk unit weight (kN/m^3)	Friction angle
Natural soils	Gravel	19 - 22	34º - 45º
	Sand	17 - 20	30º - 36º
	Silt	17 - 20	25º - 32º
	Clay	15 - 22	16º - 28º
Fill materials	Topsoil	17	25º
	Earthfill	17	30º
	Rockfill	18	40º

Technical Building Code. Foundations.

BASIC PROPERTIES OF SOILS (V). Porosity (n) and void ratio (e).

Both terms measure the importance of voids in soil.

$$n = \frac{V_v}{V}$$ (UNE 7045:1952)

n < 1

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

Typical values:
0'3 < e < 1'3

BASIC PROPERTIES OF SOILS (VI). Relative density (D_r) and density index (I_D).

Both terms measure the compact or loose condition of the soil.

$$D_r = \frac{e_{max} - e}{e_{max} - e_{min}} \qquad I_D = \frac{\rho_d - \rho_{dmin}}{\rho_{dmax} - \rho_{dmin}}$$

ρ_{dmax} (UNE 103105:1993) and ρ_{dmin} (UNE 103106:1993)

$\rho_d \approx \rho_{dmax} \Rightarrow I_D \approx 1 \Rightarrow$ Soil shows more resistance to compression and less deformability.

$\rho_d \approx \rho_{dmin} \Rightarrow I_D \approx 0 \Rightarrow$ Soil shows less resistance to compression and more deformability.

I_D	Descriptive condition	γ (kN/m^3)
0 – 15	Very loose	
15 – 35	Loose	< 14
35 – 65	Medium dense	14 – 17
65 – 85	Dense	17 – 20
85 – 100	Very dense	> 20

BASIC PROPERTIES OF SOILS (VII). Water content (w) and degree of saturation (S_r).

Both terms measure the relative importance of water in soil.

$$w = \frac{M_w}{M_S} = \frac{W_w}{W_S} \qquad S_r = \frac{V_w}{V_v}$$

(UNE 103300:1993 Standard)

BASIC PROPERTIES OF SOILS (VIII). Relationships between basic properties.

	Output	
Input data	**n**	**e**
e	$\frac{e}{1+e}$	
n		$\frac{n}{1-n}$
γ_S, γ_d	$\frac{\gamma_S - \gamma_d}{\gamma_S}$	$\frac{\gamma_S - \gamma_d}{\gamma_d}$
Input data	γ_d	
γ_S, **n**	$\gamma_S \cdot (1-n)$	
γ_S, **e**	$\frac{\gamma_S}{1+e}$	

	Output	
Input data	γ_{sat}	γ'
γ_d, **n**	$\gamma_d + n \cdot \gamma_w$	$\gamma_d - \gamma_w \cdot (1-n)$
γ_d, **e**	$\gamma_d + \frac{e}{1+e} \cdot \gamma_w$	$\gamma_d - \frac{1}{1+e} \cdot \gamma_w$
Input data	γ	
γ_d, **w**	$\gamma_d \cdot (1+w)$	
γ_d, S_r, **n**	$\gamma_d + S_r \cdot n \cdot \gamma_w$	
Input data	S_r	
γ_d, **w**, **n**	$\frac{w}{n} \cdot \frac{\gamma_d}{\gamma_w}$	
γ_S, **w**, **e**	$\frac{w}{e} \cdot \frac{\gamma_S}{\gamma_w}$	

BASIC PROPERTIES OF SOILS (IX). Geochemical properties.

Other characteristics

- Content of oxidisable organic matter. UNE 103204:1993.
- Content of soluble salts. NLT 114-99.
- Gypsum content. NLT 115-99.

PG-3

Other characteristics: chemical aggressiveness

- Degree of soil acidity (Baumann-Gully). UNE 83962:2008.
- Sulfate content. UNE 83963:2008.

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PHYSICAL PROPERTIES OF INTACT ROCKS (I). Definitions.

Intact rock

It is the part of the rock mass which does not have fractures, or the blocks of intact rock between them.

Rock mass

It is composed of blocks of intact rock and fractures (faults, shear zones, joints and bedding planes).

(Own picture)

Image by CSalem from Pixabay under Pixabay License

PHYSICAL PROPERTIES OF INTACT ROCKS (II). Unit weight and porosity.

Unit weight (γ) $\quad \gamma = \frac{W}{V}$

Porosity (n) $\quad n = \frac{V_v}{V}$

It is a very important property, because if voids exist, there will be weakness areas.

Effective porosity (n_e)

$$n_e = \frac{(W_{sat} - W_s)}{\gamma_w \cdot V}$$

The interconnected void spaces in a rock that contribute to fluid flow.

Rock	Mass density (g/cm^3)	Porosity (%)
Basalt	2.7 - 2.9	0.1 - 2
Chalk	1.7 - 2.3	30
Gneiss	2.7 - 3.0	0.5 - 1,5
Granite	2.6 - 2.7	0.5 - 1,5
Limestone	2.3 - 2.6	5 - 20
Quartzite	2.6 - 2.7	0.1 - 0.5
Schist	2.5 - 2.8	3
Sandstone	2.3 - 2.6	5 - 25
Slate	2.5 - 2.7	0.1 - 1
Tufa	1.9 - 2.3	14 - 40

These properties are determined by the test method defined in UNE-EN 1936:2007 standard.

PHYSICAL PROPERTIES OF INTACT ROCKS (III). Durability (I).

Durability (I_D)

It is a measure of the strength of rocks due to weathering process. Durability increases with density and reduces with water content.

"Slake durability test" – NLT 251:1996 and ASTM D4644-16.

- Mass of drum plus oven-dried sample before the first cycle: A.
- Mass of drum: D.
- Mass of drum plus oven-dried sample retained after the first cycle: B.
- Mass of drum plus oven-dried sample retained after the second cycle: C.

(Image from www.controls-group.com)

Slake durability test

Two cycles, 10 minutes each.
Rotation speed: 20 rpm.

PHYSICAL PROPERTIES OF INTACT ROCKS (IV). Durability (II).

Durability (I_D)

$$I_{d2} = \frac{C - D}{A - D}$$

If $I_{d2} < 10$, durability index will be calculated as:

$$I_{d1} = \frac{B - D}{A - D}$$

Durability	% retained after 1st cycle	% retained after 2nd cycle
Very high	99	98
High	98-99	95-98
Medium high	95-98	85-95
Medium	85-95	60-85
Low	60-85	30-60
Very low	60	30

PHYSICAL PROPERTIES OF INTACT ROCKS (V). Permeability.

Permeability

The permeability of a rock is a measure of how easily a fluid can flow through the pore channels in a rock.

It is measured through K, hydraulic conductivity (m/s). ASTM D5084-16a.

Rock	k (m/s)
Sandstone	$10^{-5} \div 10^{-10}$
Limestone and dolomite	$10^{-6} \div 10^{-12}$
Schist	$10^{-7} \div 10^{-8}$
Granite	$10^{-9} \div 10^{-12}$
Slate	$10^{-11} \div 10^{-13}$
Metamorphic rocks	$10^{-9} \div 10^{-12}$
Volcanic rocks	$10^{-7} \div 10^{-12}$
Salt	$10^{-11} \div 10^{-13}$