ПОЛТАВСЬКИЙ НАЦІОНАЛЬНИЙ ТЕХНІЧНИЙ УНІВЕРСИТЕТ ІМЕНІ ЮРІЯ КОНДРАТЮКА

1930

M.L. Zotsenko, Yu.L. Vynnykov, I.V. Miroshnychenko

Engineering Geology and Soil Mechanics Starter

Training manual

Ministry of education and science of Ukraine
Poltava National Technical Yuri Kondratyuk University

M.L. Zotsenko, Yu.L. Vynnykov,
I.V. Miroshnychenko

Engineering Geology and Soil Mechanics Starter

Training manual

Poltava 2019

УДК 624.131
З 88

ISBN 978-966-616-181-2

Engineering Geology and Soil Mechanics Starter: Training manual / M.L. Zotsenko, Yu.L. Vynnykov, I.V. Miroshnychenko. – Poltava: PoltNTU, 2019. – 136 p.
Інженерна геологія та основи механіки ґрунтів: навчальний посібник / М.Л. Зоценко, Ю.Л. Винников, І.В. Мірошниченко. – Полтава: ПолтНТУ, 2019. – 136 с.

Engineering geology and Soil mechanics starter. The training manual includes lecture notes, journal for laboratory work and geological surveying log.
For students of specialty 192 construction and civil engineering, educational level „bachelor" (full-time study).

Compliers: **M.L. Zotsenko**, Doctor of Technical Sciences, Professor, Professor of Departments of organization and technology of construction and labor protection, **Yu.L. Vynnykov**, Doctor of Technical Sciences, Professor, Professor of Department of oil and gas engineering and technology; **I.V. Miroshnychenko**, candidate of technical sciences, associate professor of Departments of organization and technology of construction and labor protection.
Автори: докт. техн. наук, професор М.Л. Зоценко, докт. техн. наук, професор Ю.Л. Винников (сертифікат володіння англійською мовою С), канд. техн. наук І.В. Мірошниченко (сертифікат володіння англійською мовою С).

Liable for issue: Head of Departments of organization and technology of construction and labor protection **L.G. Shcherbinin**.
Відповідальний за випуск: завідувач кафедри організації і технології будівництва та охорони праці Л.Г. Щербінін

Reviewers: **O.V. Semko**, Doctor of Technical Sciences, Professor, Head of Departments of Architecture and urban construction, Poltava National Technical Yuri Kondratyuk University;
S.V. Bida, candidate of technical sciences, associate professor, professor of Department departments of organization and technology of construction and labor protection, Poltava National Technical Yuri Kondratyuk University.
Рецензенти: докт. техн. наук., професор О.В. Семко (Полтавський національний технічний університет імені Юрія Кондратюка);
канд. техн. наук, доцент С.В. Біда (Полтавський національний технічний університет імені Юрія Кондратюка).

Approved by the scientific and methodical Board of Poltava National Technical Yuri Kondratyuk University. Protocol №5 of 14.06.2019.
Затверджено науково-методичною радою Полтавського національного технічного університету імені Юрія Кондратюка. Протокол №5 від 14.06.2019 р.

ISBN 978-966-616-181-2

Engineering geology
and
Soil mechanics starter

Summary of lectures

1. Introduction. General data about earth. Minerals and rocks

Introduction

According to international statistics 80% of all problems during the exploitation of buildings and structures are caused by shortcomings and errors in the design, construction and exploitation (operation) of the soil bases and foundations. Money and time consumption, which are necessary to eliminate such negative effects may be compared with total cost of the new building. According to above facts, we can say that we have optimization task between enough strength and affordable foundation.

Engineering geology – is application of geology to engineering and construction business. It is using methods of geology, for studying soil layering, its properties and phenomena that occur within the construction area. This method is applied geological research, such as method of natural-historical analysis for area quality assessment.

It is usually considered that features of the area geological conditions are result of long-term joint action of internal and external geological processes. Instead, engineering geological processes are result of the human building and area exploitation. There are widely used experimental and theoretical-calculation methods for quantity estimation of the geological various factors.

Soil mechanics – is theoretical basis for foundation engineering. This is science of laws and patterns that occur during soil bases loading (dead live load etc.). Instead of Continuous Medium Mechanics, soil mechanics considers dispersed (ground) bodies. Soil consist of solid particles and pores, which are fully or partially filled with water. Soil Mechanics is using laws of theoretical mechanics for fully solid (rigid) material. Which further development leads to the structural mechanics for solid body with finite stiffness. But there are using progressive laws which are account soil dispersed state. Base of the Soil Mechanics were made by Sh. Coulomb, G. Boussinesq, K. Tertsahi etc. Soviet scientists are N. Gersevanov, M. Thitovich, V. Florin, V. Berezantzev, M. Maslov.

Foundations and artificial bases – is an applied discipline about calculation methods, design and construction of foundations, which is mostly depending on the properties of soil bases.

1. Earth in space, its origin and fabric

Earth form is – close to an ellipsoid of rotation, with average diameter – 12 742 km, difference between equatorial and polar diameters – is 43 km. Earth surface square is 510 million km^2, its volume 1 083 204 million km^3. Average density – 5,52 t/m^3 (tones per quibic meter).

Earth and other planets of the solar system move around The Sun, with almost circular concentric orbits. Distance from Earth to The Sun is 149,5 млн. км. The warmth and light of the sun makes life possible on Earth. At the same time, Sun creates a number of processes on Earth, which lead to change of its surface.

Moon is also made impact on Earth. Distance from Earth to The Moon is 384,4 thousand km. The moon causes the phenomenon of the tides in the Oceans and Seas. There are equal deformations to the tides on the continents, but they are relatively small. Moon impact also leads to the changes in inclination of Earth's axis to the plane of its orbit, which leads to changes in Earth's climate.

Solar system is in the central part of the giant Star Cluster, called Galaxy. In the galaxy there are over 100 billion. Stars, which form disk-shaped system. Dimensions of the galaxy is very large. Light passing it from one end to the other for 100 thousand Years. But there are also billions of galaxies. A light year – the distance, which is light beam throughout the year, it is 9.5 trillion. Km. By the way a matter is constantly changing its shape, is in eternal motion.

Knowledge about Earth origin is very important to study its structure, and for an explanation of the underlying processes which are affecting on its surface part. But till now there are absent reliably determination on how and what formed the Earth, other planets of the solar system. Therefore, our knowledge in this area have the character of scientifically based assumptions – hypotheses. For example in 1755 Kant in the work "General natural history and the sky theory" give general picture of the formation and development of the solar system by the laws of nature. He considered that the solar system formed from cosmic nebula, which is dispersed substance. By doing this was struck metaphysical worldview. In 1796 the French mathematician and astronomer P. Laplace in the appendix to the book "Statement of Peace" presented a similar picture of the formation of the solar system. These two hypotheses for their closeness was later known as the Kant-Laplace hypothesis. According to those hypothesis Earth was fiery-liquid body after formation. During the next continuous cooling on its surface formed hard shell – earth crust, which seems to be floating on the molten material. Kant-Laplace hypothesis was dominating the beginning of XX century. When clearly defined its shortcomings. The fact that this hypothesis could not explain the series laws observable in the solar system, including the distribution moment of momentum (some satellites planets rotate in the direction opposite to the general movement).

In 1944 Schmidt proposed a new hypothesis of the formation of planets: Cold gas and dust clouds of matter, which rotate around the sun. He suggested that the matter of the clouds at the time of capture of by the Sun has had some angular momentum. In the evolution of matter in it clouds formed body with sizes ranging from dust to asteroids. Coming together during movement around the sun, that bodies formed planets. Schmidt considered that the initially cold

Earth after reaching a certain size warmed by heat accumulation, which stood by the decay of radioactive elements. This process took billions of years and was accompanied by gravitational differentiation substance. As a result of this process in the Earth formed separate shells. Schmidts Hypothesis explains almost all the basic laws of the solar system.

Considerable interest is the hypothesis Sobotovich E. (1973). He paid attention to the fact that modern hypotheses about the Earth formation out from the assumption that in the initial period of formation Earth consisted of relatively homogeneous material. Radioactive elements were uniformly placed in such elements. However, as shown by a recent study, the content of radioactive elements decreases with depth. Sobotovich said that close to clouds of cold matter with a diameter of 1-2 light years super new star exploded. From the explosion plasma were released, which mass was equal about ten suns, some clouds spin, turning on the gas. Later, in the central part of the cloud formed sun, after cloud sealing (compaction). On the periphery of the cloud were solid formations – planetary embryos, including the Earth. Which are include mostly metals with low content of radioactive elements. During the further development of the Earth layer substance rich in radioactive elements that resulted from the explosion of the supernew star. Such way hypothesis explain the concentration of radioactive elements in the Earth's surface parts. Reheating Earth were caused by radioactive processes, resulting shift in the molten state of the surface of the Earth. As a result of subsequent hardening earth crust formed.

According to modern views the Earth consists of several concentric shells. There are external and internal membranes. The external shells include: the atmosphere, hydrosphere and biosphere.

Atmosphere – is air shell thickness can be Accept, and about 1,000 km. The composition of the atmosphere are, % nitrogen – 78.1, oxygen – 21.0 and other gases – 0.9. The lower part of the atmosphere (up to a height of 8-10 kilometers above the poles and 16-18 kilometers above the equator) is called the *troposphere*. The troposphere contains water vapor and dust, characterized by continuous movement of air masses, ie winds. Above the troposphere to an altitude of 80 km is the *stratosphere*, and even higher – the *ionosphere*.

Hydrosphere – no continuous water membrane that includes water oceans, seas, lakes, rivers and underground water. The movement of water in the hydrosphere has the character flows and waves.

Biosphere – a special membrane, which includes flora and fauna of the Earth. It is located in the atmosphere, hydrosphere and crust.

The internal layers of the Earth are: core, mantle and crust.

The core has a radius of 3470 km. It is divided into external and internal. The density of matter in it is very high and reaches the central part of 9-11 t/m^3 at pressures 0,30-0,35 million MPa and temperatures is not higher than 4000° C. Data on the composition of the substance is very inaccurate. It is considered that the substance in the outer core is in a molten state, and a solid inner core. This is confirmed by calculations possibility of melting substances under appropriate pressures and temperatures and the fact that elastic transverse waves can propagate only in solids, does not pass through the core.

Mantle – a membrane that surrounds the core; its thickness is about 2900 km. There are lower and upper mantle. Mantle density ranges from 3.3 t/m^3 on the edge of the crust to 5.6 t/m^3 on the edge of the core. Temperatures in these boundaries increased from 1000 to 2300° C. The substance of the mantle is in a solid state, but in the upper mantle at depths of 100-200 km under the continents and 50-100 km under the oceans, where there are pockets of melt. The molten substance rising to the surface, directly on the crust. The substance of the upper mantle rich in iron and magnesium.

Crust – surface shell of the Earth, which has an average density of 2.7 t/m^3. Its thickness beneath the oceans of 5-6 km, and within the continents it is equal to an average of 35 km. In mountain areas, the thickness of the crust is 70 km. 71% of the earth's crust is covered with water, 29% is land. Temperatures in the crust range from 100° C at a depth of 5.6 km to 1,000° C on the edge with the mantle.

The crust is separated from the mantle Mokhorovichich surface. On this surface density of matter during the transition from crust to the mantle increases by big jump. The earth's crust is divided into three layers: sedimentary, granite and basalt. The structure of the crust under the oceans is different from continents. Under the oceans granite layer is absent. The layers of the crust formed by rocks, which are consist from various minerals.

The formation of the crust associated with the formation of rocks occurred throughout geologic history. The crust was formed **igneous**, **sedimentary** and **metamorphic** rocks. Igneous rocks are formed by hardening in the thickness of crust or on crust surface, it was rising from the melt environment in the upper mantle. Sedimentary rocks formed by the accumulation of destruction of rocks that previously existed. Metamorphic rocks are products of igneous rocks and sedimentary rocks modifying, which occur under high temperatures and pressures.

On the continents distinguish such large areas of the earth's crust as **platforms**, **folded systems** (mountain systems) and **belts**. Platforms have folded foundation composite by metamorphic and igneous rocks which covering by relatively young sedimentary rocks. The main structural elements of the platform are **shields** and **plates**. Shields – is areas where the rocks that form the foundation laying on the surface or relatively small depth. In areas of plates buried basement rocks are buried significantly and sedimentary rocks have a larger thickness.

Folded system and belts, characterized by the fact that in these areas thickness of sedimentary rocks crumpled into folds (mountains), and cut by cracks include arrays of igneous rocks. This is typical for mountain areas. Folded systems and belts are formed at different times in place of deep sea hollows due to complex and lengthy process of accumulation of sediments, crushing them in the folds and general uplift.

Platforms – are the most persistent areas of the Earth's crust, and folded systems and belts – are the most movable. Scientists consider that under foundation of platforms, folded systems and belts at depths of 5-10 km lies a granite layer, and at depths of 15-20 km – Basalt. In such arrays are concentrated the main mass of igneous rocks. Within the **Russian** platform distinguish Baltic and Ukrainian shields; Moscow, Dnieper-Donetsk, Poland-Lithuania Caspian basin, and other; Voronezh, Belarus and other protrusions. Folding systems and belts – are mountain areas (Carpathians, Crimea, Caucasus, etc.).

Temperature condition of the crust is determined by the heat that it receives from the Sun (external) and the mantle (internal). Inbound heat uniform both within continents and oceans. External heat directly affects the Earth's crust only within continents. On the continents, depending on the temperature distribution is divided into three zones, namely: variable, constant, and temperature zone in which the temperature increases with depth. Variable temperature zone has thickness 6 m for tropics and 15-25 m for temperate zone. Until this depth observed annual temperature fluctuations in the rocks. At surface these fluctuations reach 100° C. In this zone, in the temperate zone is a layer that freezes in winter, on thickness of 2.5 m. Below is the constant temperature zone where the temperature is equal to an annual average temperature of respective geographic areas. For example, in Kyiv it is + 4,8° C. Increased temperatures with depth Zone, due to internal heat of the Earth. Such increase is certain regularity. The depth at which the temperature rises by 1° C is called geothermal degree. Average value of its 33 meters, but in different places it varies from 5 to 150 m. In the North Caucasus geothermal degree is 12 m, and in Belarus – 86.5 m. Features of the temperature distribution in the crust should be considered during solving of practical problems related to civil engineering. Choosing a depth of laying the foundation should consider freezing of the soil base in winter, and the presence of permafrost. During the construction of warehouses, storages, facilities, which are buried in the ground, their constant temperature conditions cannot be achieved without the temperature distribution in the crust.

2. Minerals, their classification and physical properties

All rocks are composed of minerals. Mineral – is native element or natural chemical compound that has a unique set of physical and chemical properties. More than 2,000 known minerals. The chemical composition they are divided into 10 classes. Characteristic for each class of minerals given in Table 1.

Table 1. **Classification of the chemical composition of minerals**

Class	Group	Mineral	Chemical composition
Silicates	Feldspars	plagioclase	$Na_2O \cdot Al_2O_3 \cdot 6SiO_2$
	Trokseny	orthoclase	$K_2O \cdot Al_2O_3 \cdot 6SiO_2$
	amphibole	augite	$Ca \cdot Al_2O_6$
	mica	horny blende	Complex
		muscovite	$K_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$
		biotit	$K_2O \cdot 6FeO \cdot AI_2O_3 \cdot 6SiO_2 \cdot 2H_2O$
	Chlorite	olivine	$2FeO \cdot Si0_2$
		talc	$4Si0_2 \cdot 3MgO\text{-}H_2O$
	Clay minerals	kaolin	$2H_20 \cdot Al_20_3 \cdot 2SiO_2$
		montmorrulonit	Complex
Oxides		quartz	SiO_2
		loadstone (magnetite)	Fe_3O_4
Hydroxide		opal	$SiO_2 \cdot nH_2O$
Carbonates		limonite	$Fe_2O_3 \cdot H_2O$
		calcite	$CaCO_3$
Sulfates		dolomite	$CaCO_3 \cdot MgCO_3$
		gypsum	$CaSO_4\text{-}2H_2O$
Sulfides		anhydrite	$CaSO_4$
Phosphates		pyrite	FeS_2
Haloid		apatite	$Ca_5(F, C1)[PO_4]_3$
		halite	NaCI
Native		sylvinite	KC1
elements		graphite	C
		diamond	C
		sulfur	S
		gold	Au

Number of most minerals is small, and only 50 of them make up the bulk of rocks and therefore called rock-generators. Under the terms of the formation of minerals can be divided into three groups: **primary-formed** during solidification of magma; **secondary** – formed as a result of chemical and nutrient destruction of primary minerals and the subsequent accumulation of destruction; **modified** – formed as a result of conversion of primary and secondary minerals at high temperatures and pressures.

Most of the minerals have a crystalline structure, and only a small portion – amorphous. In crystals of the smallest particles of substances – atoms, ions and molecules – are placed in a certain order to form a crystal lattice. The crystals usually are shaped polyhedrons, cubes, octahedral, prisms and others. Surfaces that restrict crystal faces are called; lines that form the intersection of edges – ribs; the point of intersection of ribs – tops.

An important property of crystals of the same mineral is uniformity of angles between corresponding faces. This allows us to distinguish minerals by measuring the edge corners. The form of faces and their size may vary. Minerals in the form of crystals of regular shape we can find very rare. Often they are in the form of crystal grains or crystalline solid masses. Usually minerals crystal grains form polymineral rocks. For example, granite is composed of crystal grains of quartz, orthoclase and mica.

Monomineral rocks consist of crystalline solid mass of minerals. Thus calcite is formed marble.

The main physical properties of minerals are color, luster, transparency, hacking, cleavage, hardness, density.

The color is different for different minerals. There are light and dark minerals. Color dashes that the mineral leaves in unglazed porcelain plate, describes the color of the mineral in powder form.

Glitter of mineral depends on the ability to refract and reflect light rays. It is a metal, glass, pearl, silky, fat and so on. Minerals lackluster called matt.

Transparency – is a property of a thin plate of mineral transmit light. Minerals can be clear, translucent, and opaque.

Hacking formed by splitting minerals and it could be sink, rough, uneven, grainy and so on.

Cleavage – the ability of mineral split upon impact of punch in one, two, three, four or six directions to form flaps surfaces. There are gradations of cleavage: almost perfect, perfect and imperfect. For example, mica has a rather perfect cleavage in one direction because it easily disconnected to separate parts. Magnetite, quartz etc. have imperfect cleavage.

The hardness of mineral is characterized by resistance to pressure or cutting. There is a standard scale of hardness, which consists of ten reference minerals located in order to increase their hardness: talc – 1, gypsum – 2, calcite – 3, fluorite – 4, apatite – 5, orthoclase – 6, quartz – 7, topaz – 8, corundum – 9, diamond – 10. Scratching investigated mineral by reference material (one of ten above), you can set its relative strength.

Mineral density is determined in the laboratory. Minerals with a density of 3.5 t/m^3 belong to the light, from 3.5 to 6 t/m^3 – for heavy and over 6 t/m^3 – to very heavy.

Special properties inherent in some minerals, birefringence, mahnitnist, smell, taste, solubility, flammability and so on.

Considered properties allow to identify minerals in the field case with special books. Using them on the set of properties specify the mineral.

3. Rocks, their origin and differences

Rocks – is a mineral aggregates. They may consist mainly of one mineral (monomineral) or a certain ratio of two or more parts of the minerals (polymineral). We know about 1000 rocks. By origin (genesis) are divided into three groups: igneous – formed by solidification of magma; sedimentary – formed in the upper crust due to destruction of life and other species of plants and animals; metamorphic – formed as a result of these changes igneous and sedimentary rocks under high temperature and pressure.

Distinguishing features of rock mineralogical composition are structure and texture. In the rock minerals dominate the class of silicates. They accounted for 85% of the rocks of the crust. Mineralogical composition determines only substance of rock. Terms of rock formation established by studying their structures and textures.

Structure indicates features of the rock internal architecture due to size, shape, quantitative ratio of minerals that make it, and the nature of relationships between minerals of the rock. The structures of magmatic rocks could be fully-crystalline (granular), semi-crystalline (amorphous and crystal substance), amorphous (Glass Wool). For sedimentary rocks, breccias, organogenic, mixed and other structures are typical (Fig. 1).

Texture describes how fill the space rock. It reflects the external structure features: solidity, lamination, porosity, etc., so the texture is massive, layered, macroporous (Fig. 2).

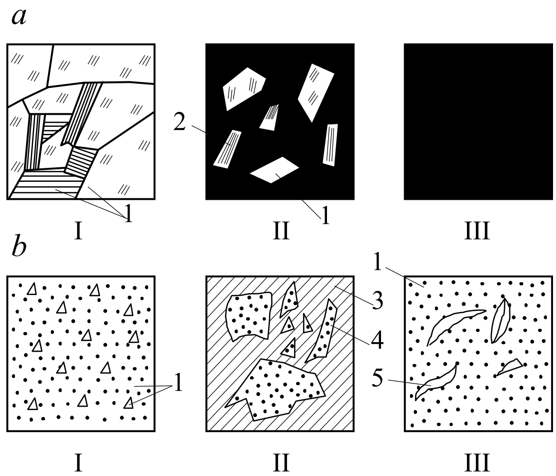


Fig. 1. The structures of rock:
a – igneous rocks, I – fully-crystalline, II – semi-crystalline; III – amorphous:
b – sedimentary rocks, I – sediments (psamitova); II – breccia type; III – organic (phyto pelitic), 1 – grains, 2 – amorph substance; 3 – clay, 4 – sediments; 5 – plant remains

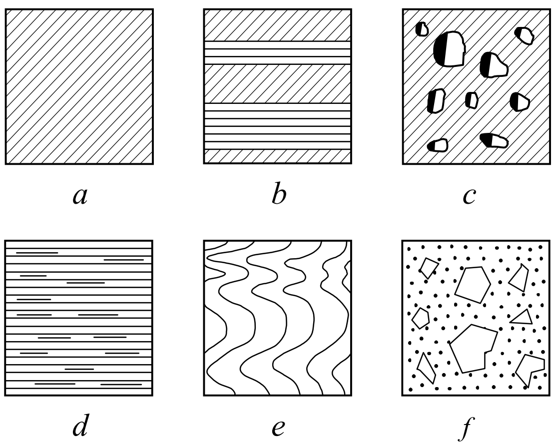


Fig. 2. The texture of rock:
a – massive; b – layered; c – macroporous; d – dispersed; e – fluid; f – chaotic

In the formation igneous of rock magma – molten silicate substance – arrives in the earth's crust and its surface from magma chambers in the upper mantle. When the magma does not achieve the surface and hardens at depth in the earth's crust formed depth (intrusive) igneous rocks. If magma poured onto the surface and hardens - form outpouring (effusive) igneous rocks.

Solidification of magma at depth is slow, in large pressures. This process takes thousands and sometimes millions of years. During this time, all minerals have time to crystallize. Firstly, refractory minerals, and minerals with a lower melting point are crystallized. Magma solidification on small depth or on the surface of the crust occurs rapidly, at low pressure. These conditions allow to crystallize only for the most refractory minerals, and the rest mineral hardens, forming a microcrystalline or amorphous mass. Spilled on the surface magma is called **lava**. Gases that contain in lava rapidly leave it and form porous, foaming lava. As a result of hardened lava is more or less porous. Features of the lava formation conditions deep or surface rocks cause particular structure and texture of the rocks. For the underlying rocks fully crystalline structure and massive texture are typical, and for surface rocks – porphyritic or amorphous or porous structure and fluid texture.

Depending on the content of igneous rocks SiO2 in the form of quartz, and as part of various silicates, they are divided into acidic (SiO2> 65%), medium (SiO2 = 52 ... 65%), basic (SiO2 = 40 ... 52%) and ultrabasic (SiO2 <40%). Each deep rock has analogue among the poured because they have the same source product (magma). General information about the most important igneous rocks are shown in Table 2.

Table 2. **The most important magmatic rocks**

Division on content SiO_2	**Deep rock**	**Poured rock**			**Mineral composition**
		The structure of porphyritic		**Amorphous structure**	
		Old	**Young**		
Sour	Granite	Quartz porphyry	liparites	Obsidian, pumice	Quartz, feldspar, biotite, hornblende
Averages	Syenite	Without quartz	trachyte		Feldspar, horn snag, sometimes biotite
	diorite	porphyry porphyries	Andesite		Feldspar, horn snag, sometimes augite
Basic	Gabbro	Diabase	Basalt		Augite, hornblende, feldspar, sometimes chrysolite
Ultra-basic	Peridotite		Pikryt		Olivine, augite

Most of the igneous rocks are concentrated in granite and basalt layers of the crust that were formed in the early geological history through a long process of melting relatively light substance in upper mantle and its elevation to the surface. But formation of igneous rocks was occurred further. Igneous rocks were forming during magma penetration of in the thickness of existing crust, or when magma were pouring on the surface. Above formed typical occurrence of igneous rocks, deep – batholiths, stocks, laccoliths veins; poured – and covers flows (Fig. 3).

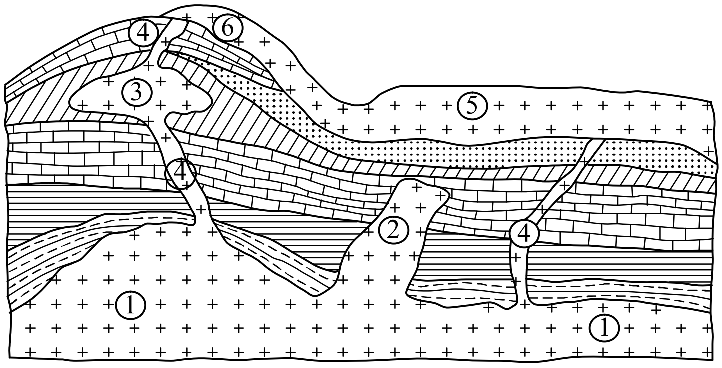


Fig. 3. Igneous rocks layering: 1 – Batholith; 2 – Stocks; 3 – Laccoliths; 4 – Veins; 5 – Covers; 6 – Flows

Batholith - a huge magmatic body formed at considerable depth, which can be traced in the horizontal direction for many kilometers. Geology considers that the lower parts of Batholiths reaches magmatic centers.

Stocks – a magmatic body, elongated vertically, with the plan (cross section) size up to several kilometers.

Laccoliths – igneous body with round shape, size is from half of a kilometer to several kilometers. Sometimes laccoliths pour on surface, due to destruction of rocks around them. Such way, they are forming a separate mountain, such as Mashuk and Beshtau at the Caucasus. *Veins* are forming in the cracks of rocks, where magma enters under high pressure. The thickness of veins usually not exceed few meters. *Covers* are placed on the surface of the crust. Thickness of coverings varies from a few meters to several kilometers. Covers occupy sometimes hundreds and thousands of square kilometers. Magma that solidifies on the slopes are formed *Flows*.

Usually arrays of igneous rocks are divided by system of cracks into separate blocks. Cracks appear during magma solidification due to reducing of its volume. Each igneous rock is characterized by some form of separation: the granite have – layer separation, basalt – column separation. Besides separation cracks there are also present deformation cracks that occur under the influence of external forces, such as cracks that occur during earthquakes.

Formation of the *sedimentary rocks* associated with the processes of weathering and denudation. Weathering – is the process of rocks destruction under influence of air temperature, sunlight, water freezes, atmosphere, organisms and water soluble effect. Weathering products not always left at the places of formation. They moved with flowing waters, glaciers ice, wind power, gravity forth in places such as: slope foots, valleys, hollows, bottoms of lakes, seas and oceans. In the lowered places weathering products accumulate and compact to form sedimentary rocks. Weathering could be physical, chemical, organic.

With the *physical* weathering, which is caused by fluctuations in temperature, mechanical action of freezing water, tide waves, wind and other factors, rocks break down into separate chunks, pieces and mineral grains.

Under *chemical* weathering rocks obtain a deep change. In this case, new minerals are forming. Chemical weathering occurs either as direct dissolution of rocks with water, which contains oxygen, carbon dioxide and other substances, or in a variety of chemical reactions (oxidation, carbonization, etc.).

For example Chemical weathering of orthoclase is as follows:

$$K_2O \cdot Al_2O_3 \cdot 6SiO_2 + CO_2 + 3H_2O \rightarrow K_2CO_3 + \mathrm{Al_2O_3} \cdot 2SiO_2 \cdot 2H_2O + 4SiO_2 + n \cdot H_2O$$

Organic weathering is the result of plant organisms life, they by roots mechanically destroy rocks, also they produce various acids that that cause chemical transformation of minerals.

In the deserts and highlands physical weathering is dominated. In temperate and tropical climate physical weathering is supplemented by chemical and organic. The scale of these processes is very high. 5.5 billion. Tons of material in solution and 30 bln. tons in ruins for each year are flew out from the continents in the seas and oceans. As a result of the accumulation of weathering products occur compaction and cementation.

Sedimentary rocks are divided clastic, chemical and organogenic. *Clastic* rocks formed from weathering products transferred and deferred in the form of fragments of various sizes. They can be loose and cemented various natural cement – clay, ferruginous, calcareous, siliceous and more. *Chemical* rocks are formed by precipitation of substances from saturated solutions by changing their parameters. These rocks are formed mainly in the area of shallow sea. *Organic* rock are formed by activity of organisms, most of which live in the water and father existence by its shells or skeletons they are forming the rock thickness. Some species of this type of plant matter formed both on land and in water. The principal sedimentary rocks are shown in Table 3. Mineralogical composition of sedimentary rocks determined by the conditions of their formation. For example, in clastic rocks it meets the mineralogical composition of the rocks from which they emerged. Many species of chemical origin composed of a mineral, gypsum, anhydrite, calcite and so on.

The structure of sedimentary rocks is very various: in sand is granular in clay – clay in limestone – crystal.

As for texture, the most of sedimentary rocks have layered composition. Forms occurrence of sedimentary rocks is shown in Fig. 4. Layers of sedimentary rocks in terms immutable bedding horizontal. Power thickness of sedimentary rocks in the crust reaches 15-20 km in geosynclines.

Table 3. **The frequently (main) sedimentary rocks**

Chemical		Organic	Clastic
Loose	**Cemented**		
Pebble Gravel	Conglomerate	Gypsum	Limestone
scree Zhorstva	Breccia	Anhydrite	Dolomite
Sand sandy loam	Sandstone	rock salt	Chalk
Loam	Amvralit	Limestone	Peat
Clay	Mudstone	-	Coal

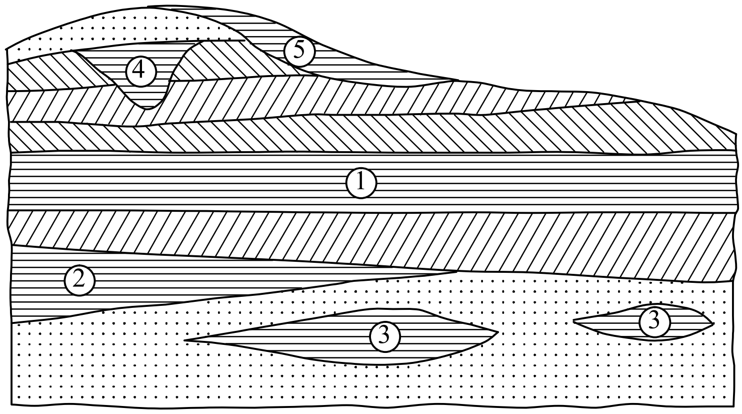


Fig. 4. Forms occurrence of sedimentary rocks:
1 – parallel layers; 2 – wedging seam; 3 – Lenticulars deposits; 4 – bag or pocket; 5 – trail

Metamorphic rocks formed from sedimentary and igneous because of their change under high temperatures and pressures. This process is called metamorphism. Distinguished *regional, dislocation and the contact metamorphism*. Regional metamorphism occurs at great depths and cover large expanses. This process associated with dipping of some sections of the earth's crust at great depths under the weight of sediments that accumulated in depressions (hollows) or due to crustal movements. At a depth of source rocks under the influence of high pressure and relatively high temperature recrystallization occur in the solid state.

Dislocation metamorphism or dynamometer morphism occurs at orogeny when rock mass undergo large unilateral compression, which leads to recrystallization. The contact metamorphism explains by the influence of hot magma on the rock which penetrates the earth's crust. Along contact with magma contact rocks undergo melting and burning with subsequent recrystallization. In addition, contact rocks affect reactive substances released from magma. In addition, on contact rocks reactive chemical active substances released from magma make impact.

Mineralogical composition of metamorphic rocks basically the same as the primary igneous and sedimentary. But there are minerals that are found only in metamorphic rocks, cordierite, kyanite, staurolite, andalusite and more. Metamorphic rocks usually have a crystalline structure. Textures most schistose metamorphic rocks. This distinctive texture is caused by the development of crystal grains during recrystallization – along axis perpendicular to the direction of preferential pressure. There are also occur rocks with massive texture.

The main metamorphic rocks formedas next: gneiss – from magma (ortho gneiss) and sedimentary (steam gneiss) clay rocks have schistose texture; Philetus – from clay rocks texture – slaty; mica schist – clay with rocks due to deep modifications, texture – slate; marbles – from limestone and dolomite, texture – solid; quartzite – with sand and sandstone textures – massive. Metamorphic rocks have some form of occurrence, they are determined by the shape of occurrence of the species from which they were formed.

4. Age of rocks and geological time scale

Different rocks had been arising at different times throughout geological history. First, arising igneous rocks, metamorphic and sedimentary later. Each rock has a certain age. Data on the age of the rocks needed to systematize their deposits and compilation of geological maps and sections. The rocks formed at the same time in similar circumstances, have roughly the same properties. There are relative and absolute age.

The relative age is determinate by the stratigraphic and paleontological methods. Stratigraphic method allows to determine the relative age of sedimentary rocks in this place, in terms of undisturbed bedding. The lowest layer older than the one located above it. Paleontological method allows to determine the relative age of sedimentary rocks on the fossil record of ancient organisms that are found in these rocks.

To do this, suitable only fossil organisms that are rapidly changing in the course of evolution. These organisms are called governing resources. Examples are the external shells like molluscs ammonites. So you can determine the relative age of both cases of disturbed bedding of sedimentary rocks, and in cases where these rocks are located in different places.

For example, the presence of certain species of ammonites in the thickness of sedimentary rocks in Europe and North America indicates that these rocks were formed at the same time. In some cases, you can determine the relative age of igneous rocks. If magma host rocks has a footprints of melting, the igneous rocks formed later than the host. If no such traces, the previously formed igneous rocks.

The absolute age of rocks is determined by radiological methods. The most common method of argon. Orthoclase and mica contain the chemical element potassium, which is contain about 0,011% weakly radioactive nuclide 40*K*. This nuclide is unstable. Products of his disintegration (half-lifeperiod of 40*K* is 1,92 billion. years) is nuclide 40*Ar*. Age of rock is determined by the ratio 40*Ar*/40*K*. Contains of the 40*Ar* in the minerals and rocks are dermined by spectrometric method, content of the 40*K* – by chemically method. Established that age of rocks is similar to the age of respective minerals. Exception is sedimentary clastic rocks where minerals older than rock. For example, The absolute age of the earliest igneous rocks of the Kola Peninsula and Dnieper determined by argon, is 3.5 billion. Years.

Age of the Earth as a planet – at least 4.5 billion. Years.

Depending on the relative and absolute age of rocks geological history, the duration of which is considered to be 3.5 billion years, the time was divided into five eras. Rock strata that formed while divided into 5 groups. Era is divided into periods, groups divided on – the system. Period divided to the era (with the division for ever century), and the systems are divided into tiers.

There are scales: geochronological and stratigraphic that is on time and on deposits. In its present form are shown in Table 4. There's also listed the main stages of geological history.

Placing of different ages rocks in the earth's crust described into, regional and detailed geological maps. Geological maps up according to the geological survey, which is applied to the topographic base. The scale of geological maps are 1: 5,000,000 in review to 1: 100,000 and more in detail. Distribution rocks or strata formed at a certain time, denoted using hatching and indices. Geological maps and sections complement used to produce geological maps and sections.

Table 4. **Geochronological and stratigraphic scales of the geological history of the Earth**

Precambrian Time

The Precambrian's lower limit is not defined, but ended about 542 million years ago. The Precambrian encompasses about 90% of Earth's history.

Eonothem eon	Duration[1]	Eras	Events
Archaean (Greek *archaios* = ancient)	2,500?	Eoarchean (Greek *eos* = dawn + *archaios* = ancient) Paleoarchean (Greek *palaios* = old) Mesoarchean (Greek *mesos* = middle) Neoarchean (Greek *neo* = new)	Formation of oceans, atmosphere, and continents; bacteria
Proterozoic (Greek *proteros* = earlier + *zoön* = animal)	c. 2,000	Paleoproterozoic (Greek *palaios* = old) Mesoproterozoic (Greek *mesos* = middle) Neoproterozoic (Greek *neo* = new)	Oxygen build-up; multicelled organisms

1. In millions of years.

Paleozoic Era

This era began 542 million years ago and lasted about 291 million years. The name was compounded from Greek *palaios* (old) and *zoön* (animal).

Period	Duration[1]	Epochs	Events
Cambrian (*Cambria,* Latin name for Wales)	54	Lower Cambrian Middle Cambrian Upper Cambrian	Invertebrate sea life proliferating during this and the following period
Ordovician (Latin *Ordovices,* people of early Britain)	45	Lower Ordovician Upper Ordovician	Diverse marine life, including vertebrates; vascular plants
Silurian (Latin *Silures,* people of early Wales)	28	Lower Silurian Upper Silurian	Coral reefs; giant scorpions; first jawed fish
Devonian (Devonshire in England)	57	Lower Devonian Upper Devonian	Numerous fishes, other sea life; many plants, first trees; wingless insects
Carboniferous (Latin *carbo* = coal + *fero* = to bear)	60	Upper, Middle, and Lower Mississippian[2] Upper, Middle, and Lower Pennsylvanian[2]	Maximum coal formation in swampy forests; insects, amphibians, reptiles; fishes, clams, crustaceans
Permian (district of Perm in Russia)	48	Lower Permian Upper Permian	Large reptiles, amphibians; most species become extinct

1. In millions of years.

2. Mississippian and Pennsylvanian names are used only in the U.S.

Mesozoic Era

This era began 251 million years ago and lasted about 186 million years. The name was compounded from Greek *mesos* (middle) and *zoön* (animal). Popular name: Age of Reptiles.

Period	Duration[1]	Epochs	Events
Triassic (*trias* = triad)	51	Lower Triassic Middle Triassic Upper Triassic	Early dinosaurs, crocodiles, turtles; first mammals
Jurassic (Jura Mountains)	54	Lower Jurassic Middle Jurassic Upper Jurassic	Many seagoing reptiles; early large dinosaurs; later, flying reptiles (pterosaurs), earliest known birds
Cretaceous (Latin *creta* = chalk)	80	Lower Cretaceous Upper Cretaceous	Dinosaurs and other reptiles dominate; seed-bearing plants appear

1. In millions of years.

Cenozoic Era[1]

This era began 66 million years ago and includes the geological present. The name was compounded from Greek *kainos* (new) and *zoön* (animal). Popular name: Age of Mammals.

Period	Duration[2]	Epochs	Events
Paleogene (Greek *palaios* = old + *genes* = born)	42	Paleocene (Greek *palaios* = old + *kainos* = new). Eocene (Greek *eos* = dawn). Oligocene (Greek *oligos* = few).	Rich insect fauna, early bats, increasingly diverse varieties of mammals and birds
Neogene (Greek *neo* = new + *genes* = born)	23	Miocene (Greek *meios* = less + *kainos* = new). Pliocene (Greek *pleios* = more). Pleistocene (Greek *pleistos* = most) (popular name: Ice Age). Holocene (Greek *holos* = entire), the last 10,000 years to the present.	Further development of mammals and birds. Various forms of humans, including *Homo sapiens*

1. This table reflects the divisions used by the International Commission on Stratigraphy. The U.S. Geological Survey divides the Cenezoic Era into the Tertiary Period (with the Paleocene, Eocene, Oligocene, Miocene, and Pliocene Epochs) and the Quaternary Period (with the Pleistocene and Holocene Epochs).

2. In millions of years.

2. Geological and engineering-geological processes. Part 1

1. General knowledge about geological and engineering-geological processes

At the Earth's surface and in its depths constantly occur processes that are continuously changing its structure and composition. These processes are called geological. Most of them are very slow compared to human life and even of mankind. But they over billions of years of Earth's history led to amazing and major changes in its external appearance and internal structure.

Among the geological processes there are those which taking place very violently and lead to catastrophic consequences. These include volcanic eruptions, earthquakes, sudden landslides, floods and more. But these processes are relatively rare and cover little area crust, their role in the Earth's history is secondary.

For the convenience of all study geological processes are divided into internal and external. Internal processes occur under the influence of internal forces of the Earth to the crust. External procession is the result of interaction between the crust and the atmosphere, hydrosphere and biosphere.

The processes of the internal dynamics of the Earth – endogenous – appear in the form of tectonic movements of the crust, volcanic eruptions, earthquakes.

The processes of external dynamics of the Earth – exogenous – divided into three groups: weathering, denudation and accumulation. Due to weathering is the destruction of rocks and minerals. It comes down to mechanical crushing, loosening and changing of the chemical properties caused by water, oxygen, carbon dioxide and activity of organisms. Under denudation scientist understand the totality of transfer processes of weathering products from high to low areas of relief with the help of gravity, flowing water, moving ice, wind and so on.

Accumulation or sedimentation – a process the amount of savings products of rock. It is the first stage of the formation of new sedimentary rocks.

Internal and external processes occur simultaneously throughout the geological history of the Earth. In this case, their activity is such a common reguralty: internal processes form the Earth's surface irregularities – mountains and hollows, and external – reduce these inequalities, lower mountain and filled the basin.

Engineering geology studying modern geological processes arising from human activities engineering. It considered the impact of geological processes on engineering structures, and also effect of feedback – how engineered structures can cause change existing natural geological processes. Such processes are called **geotechnical** (geological engineering).

In their study detected the nature of interaction between structures and rocks, as well as possible changes in natural conditions. Often geological and geotechnical processes are the same, but their reasons are different.

Examples of communication between geological and engineering-geological processes:

Geological processes	Geotechnical processes
Sealing of sedimentary rocks under its own weight or weight of rocks situated above	Compaction of soil under construction foundation
Landslides formed as a result of changes in the stress state of argillaceous rocks at the foot of the slope	Landslides formed as a result of load on a slope by structures placed in its upper part
Settlements (Subsidence) due to the Earth's surface suffusion phenomena that occur when groundwater movement on steep slopes	Settlements (Subsidence) due to the ground suffusion phenomena arising from the open sewage Excavation deep
Pseudo karst in loess soils due to the penetration of atmospheric water	The formation of cavities in the thick loess rocks due to leakage of water from water pipes
The outputs of groundwater to the surface in the form of streams and springs	Covering wells and boreholes for groundwater use

2. Movements of earth's crust and dislocation

The earth's crust is constantly held various movements. If the cause of the movements are internal forces of the Earth, they are called tectonic. There are three main types of tectonic movements, vibration, folded and discontinuous. These movements occurred in the past and now.

Vibrational motions covering large areas of platforms, systems and folded zones. They are manifested as slow periodic raising and lowering of the crust. Now some parts of the Baltic Shield (Kola Peninsula) and Ukrainian shield (right bank of the Dnieper River) rising at a speed of 6-8 mm and Voronezh plateau – up to 15-20 mm per year. At the same time, the lower reaches. Terek falls to 5-7 mm per year. Raising in folded belt Pamir and Tien Shan places reach 50 mm per year.

Land uplift can be judged by the presence of the wave surf terraces raised above sea level. For example, in district of. Sukhumi up to a height 900 meters above sea level raised six terraces. Flooding of the sea river beds indicate land down-lift.

Vibrational motion detected directly by means of periodic leveling. For example, Precision leveling of the Baikal railway track in 1906 and 1928 pp. showed that in some places, raising and lowering ranged from 18 to 38 cm. Oscillating movements that were occurred in the past, confirmed by typical composition of the thickness of sedimentary rocks. Constant rotation of layers, which were formed on land and at sea, indicating the raising and lowering land, accompanied by attack and retreat of the sea.

Vibrational crustal movements determine the nature of the geological surface flowing water and the sea. Raising the process increases the erosion of land by flowing waters and weakens lowering (reducing) them. Land subsidence leading to activation of the process of destruction of coast by surf waves. Changes in altitude land surface position due to oscillatory movements should be considered in the design of bridges, dams, canals, roads on the coast.

Folded movements lead to the formation of folds in the strata of sedimentary rocks. The phenomenon of creep, which develops in the rocks at long impact squeezing forces, contributes to crumple into folds layers.

Folds form folded belt systems and in large spaces. Folds are of two kinds: anticlinal (convex) and synclinal (concave) (Fig. 1).

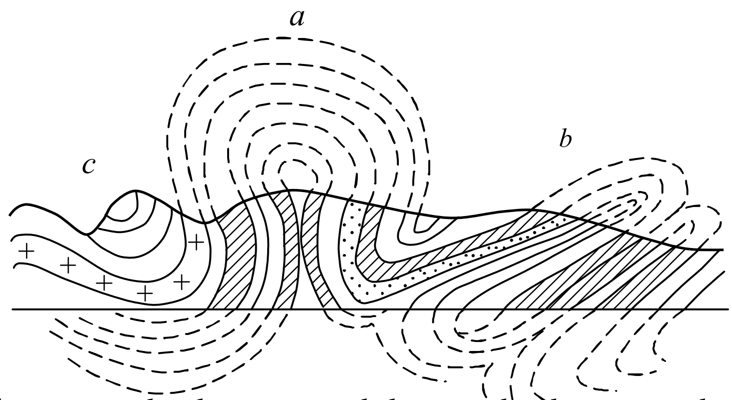


Fig. 1. Folds: a – anticlinal symmetrical; b – anticlinal overturned; c – synclinal

Discontinuous movements form a crust deep faults, for which its individual parts fall down, creating a gap, while others rise up to form protrusions. The gap known as grabens, lifting – Horst (Fig. 2). Lake Baikal is a large graben filled with water.

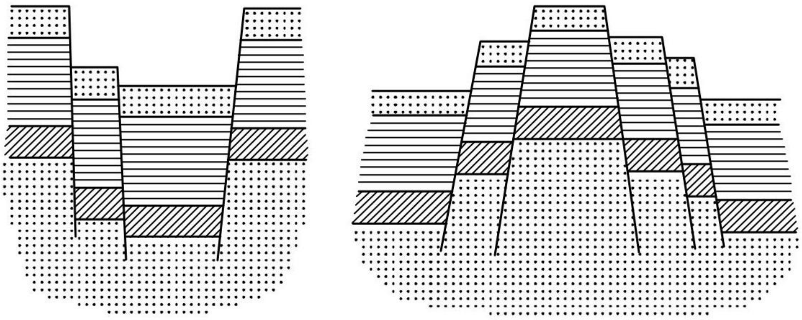
The movement of the rock mass is often accompanied by vertical displacement, horizontal – landslides. Folded and Discontinuous movements are generating mountains processes. Many scientists consider that these movements arise from horizontal displacement of large areas of the earth's crust – plates. This process is global.

Because of various orogeny processes occurs violation of rocks placement, called dislocations. Dislocations are without breaking continuity of rocks (eg, fold) and break the continuity (eg. horst and graben).

Presence of dislocations at the construction site creates peculiar conditions of the construction work. So, on top of the anticlinal we have rocks broken by cracks during the orogeny. Therefore, they are rapidly disintegrating (lost their strength). Often in places of ancient anticline are depressions (deepening) formed as a result of the destruction and removal of the weakened rocks.

In contrast, at the bottom of synclinal (trough) rocks are compressed by squeezing stress. When developing these rocks sudden collapses occur often. It happens even for the visually stable slopes sometimes the release of rock debris occurs. Presence of dislocations much more complicates geotechnical conditions of construction sites. In some cases we have to do a foundation buildings on different soils, which could cause uneven deformation. Rock layers' inclination may cause a danger of landslides.

Spatial position of the layer defines by element deepening: azimuths lines of stretch and fall, angle of incidence (Fig. 3). Stretch layer line is characterized by a line which is formed by the intersection of the plane of a layer with a horizontal plane. Layer Falling line is defined by line, drawn in the plane of the layer perpendicular to the Stretch layer line. The angle of layer incidence – is the angle between the layer plane and horizon.



a *b*

Fig. 2. Dislocations that occur during discontinuous movements of the crust: a – graben; b – horst

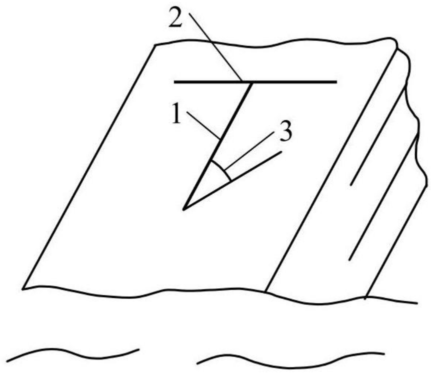


Fig. 3. Dip sloping beds: 1 – fall line; 2 – the stretch line; 3 – angle

To determine a layer deepening during a geological survey, there used mountain compass. It differs from conventional in that it has degree separation limb is directed counterclockwise. To determine the azimuth of Falling line it sets in a horizontal position, with south side parallel to the stretch line. Countdown to the north end of the needle gives azimuth line fall. The line has two stretch azimuths. The angle of incidence is determined using a plumb line, which is a mountain compass. Final measurements dip layer can be as follows: SW 234°, 21°. With the record shows that the reservoir is the angle to the southwest, but its plane located relative to the horizon at an angle of 21°. To determine azimuth strike, just add or subtract 90° of azimuth fall.

3. Magmatism and volcanoes

Processes of penetration of magma in the earth's crust from a centers of melts in the upper part of the mantle called magmatism. Magmatism is deep and surface (see. The formation of igneous rocks). Surface magmatism found in volcanic activity. Volcanoes is a place where magma break the surface crust. Most magma comes to the surface through channels like pipes. In the case of products forming eruption cone-shaped mountain with a crater at the top. This is centrally-crater volcano. With the eruption of volcanoes observed emission of gases, ash, sediments and volcanic lava. Volcanoes are periodically at intervals of several months to several hundred years. Often eruption accompanied by earthquake.

Volcanoes conventionally are divided into active and extinct. On Earth, we know existing 624 (including 78 submarines) and 4,000 extinct volcanoes. Many volcanoes – 67 operating (including 2 underwater) – located on the Kamchatka Peninsula and the Kuril islands. The most effective of these is Kluchevskoy height of 4810 m. Consider that the cone of the volcano formed by 700 explosions. When the eruption in 1945, was thrown 0.6 km^3 of ash that covered 2/3 on territory of Kamchatka by 4 cm ash layer. The eruption ended by lava pouring. There are occurs more grandiose eruption. With the eruption of the volcano Katmai (Alaska) in 1912, the atmosphere was thrown 20 km^3 of ash and sediments. With the eruption of the volcano Krakatau (Indonesia) amount of ash and sediments reached 80 km^3.

Another volcano eruptions type is fracture. An eruption of such volcanoes is rare now. In 1783 in Iceland with a crack length of 24 km 12 spilled km^3 of lava. Streams of lava floods on the area of 550 km^2. This is one of the streams had a length of 40 km. In the geological past such volcanoes were many.

In the early stages of geological history were volcanoes planar type. During the eruption of magma close to the surface absorbed rocks of the crust, forming melts over large areas. Consider that covered the Deccan Plateau in India of 500 thousand km^2 and covers of Yakutia formed that way. Most modern volcanoes geographically assigned to two main zones of tectonic activity that span the globe, Pacific and Mediterranean-Indonesian.

4. Earthquakes

Vibrations of individual sections of crust is called earthquakes. They are also known as seismic events. When a strong earthquake damaged homes and buildings, and sometimes completely destroyed, which often causes death. During the earthquake in the cities of Tokyo and Yokohama (Japan) in 1923, were totally or partially destroyed and very damaged about 500 thousand. buildings, killing nearly 140 thousand people and over 100 thousand man injured. Shifting earth's surface reach 4 m horizontally and 1.5 m vertically.

There were significant vertical displacement of the bottom bay sagas, so that there was a sea wave height of 12 m, which rushed ashore. Such waves called tsunamis.

Like volcanoes, earthquakes related mainly to the Pacific and Mediterranean-Indonesian belts. Huge seismic areas – the Carpathians, Crimea, Caucasus, Central Asia, Baikal, East Siberia, Far East, Kamchatka. There are earthquakes in Almaty (1887), Shemasi (1902), Ashgabat (1948), Tashkent (1966), Gazley (1976), and also Armenia (1988), Tajikistan (1989).

By origin divided into denudation earthquakes, volcanic and tectonic. Denudation and volcanic earthquakes have local significance. Denudation earthquakes occur in the vaults collapse of voids in the upper crust and collapses at the mountains and volcanic – magma during the eruption.

The overwhelming majority of earthquakes is tectonic. They are often disastrous. The emergence of these earthquakes associated with shear strain and tension in the rock mass and matter crust on top of the mantle during tectonic movements. When stress and strain reach critical values, is the destruction of the array, which is accompanied by strikes (punches) rocks or mantle mass. The center of the earthquake is located at a certain depth and is called the hypocenter, and the surface area is above it – the epicenter. Depending on the depth of the hypocenter scientists distinguish surface (50 km), intermediate (50-300 km), deep-focal (over 300 km) earthquakes.

As result of impact (punch) in the hypocenter elastic seismic waves are emerging, they have two types: longitudinal and transverse. These waves spread from the hypocenter in all directions and transmit impact energy into the environment. Distribution of seismic wave attenuation occurs with the amplitude of oscillation. During strong earthquakes seismic waves could passing through the globe.

Longitudinal waves characterized by the fact that fluctuations of massive particles through which they pass, going in the direction of wave spreading. They are waves of compression and rarefaction (Fig. 4, a).

They going through both solid and liquid array. Transverse wave – a wave of displacement. This oscillation of particles occur in the direction perpendicular to the direction of propagation (Fig. 4, b).

Transverse waves are spreading only in a solid medium, ie a medium that resists shear. Through melts and water such waves do not pass. Longitudinal and transverse waves in the transition from one medium to another refracted and reflected. This property of seismic waves used to study the structure of the depths of the Earth. Due to the interaction of longitudinal and transverse waves at the surface of the Earth emerging surface waves that propagate along the surface, forming a depressions shaft and a certain height. Surface waves have the smallest speed.

Seismographs use to register Earthquakes, they could be of two types: for registration of vertical and horizontal vibrations (Fig. 5). At the seismic station there is set of three seismographs, two of them register horizontal and one vertical fluctuations. Seismographs that recorders horizontal vibrations set so that the pendulum one of them shaking in the meridional direction, and the second – in latitude.

Pendulum oscillations recorded on photosensitive paper are called an earthquake seismogram. They allow by the time difference between arrival of longitudinal and transverse waves to determine the distance to the epicenter. When the distance to the epicenter known at several seismic stations, his position was determined by serif.

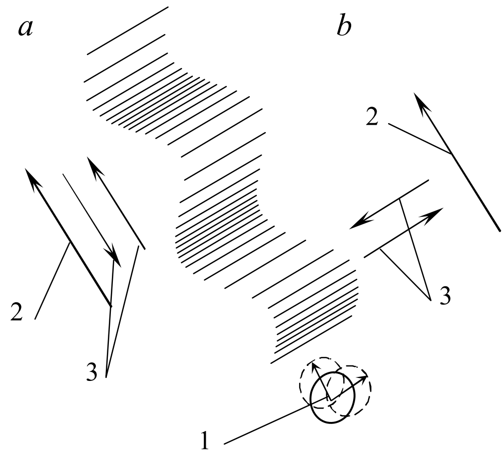


Fig. 4. The scheme of formation of seismic waves:a – longitudinal; b – transversal; 1 – the center of the earthquake; 2 – the direction of wave spreading; 3 – the direction of oscillation of particles

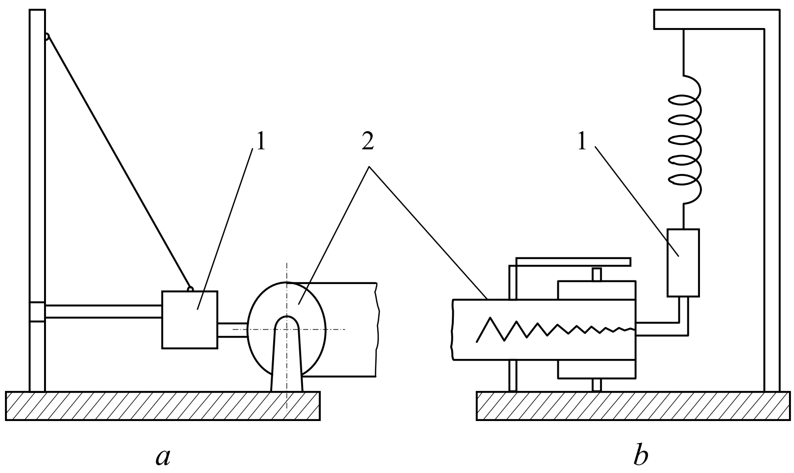


Fig. 5. The principal scheme seismographs to record vibrations: a – horizontal; b – vertical; 1 – pendulum; 2 – recording device

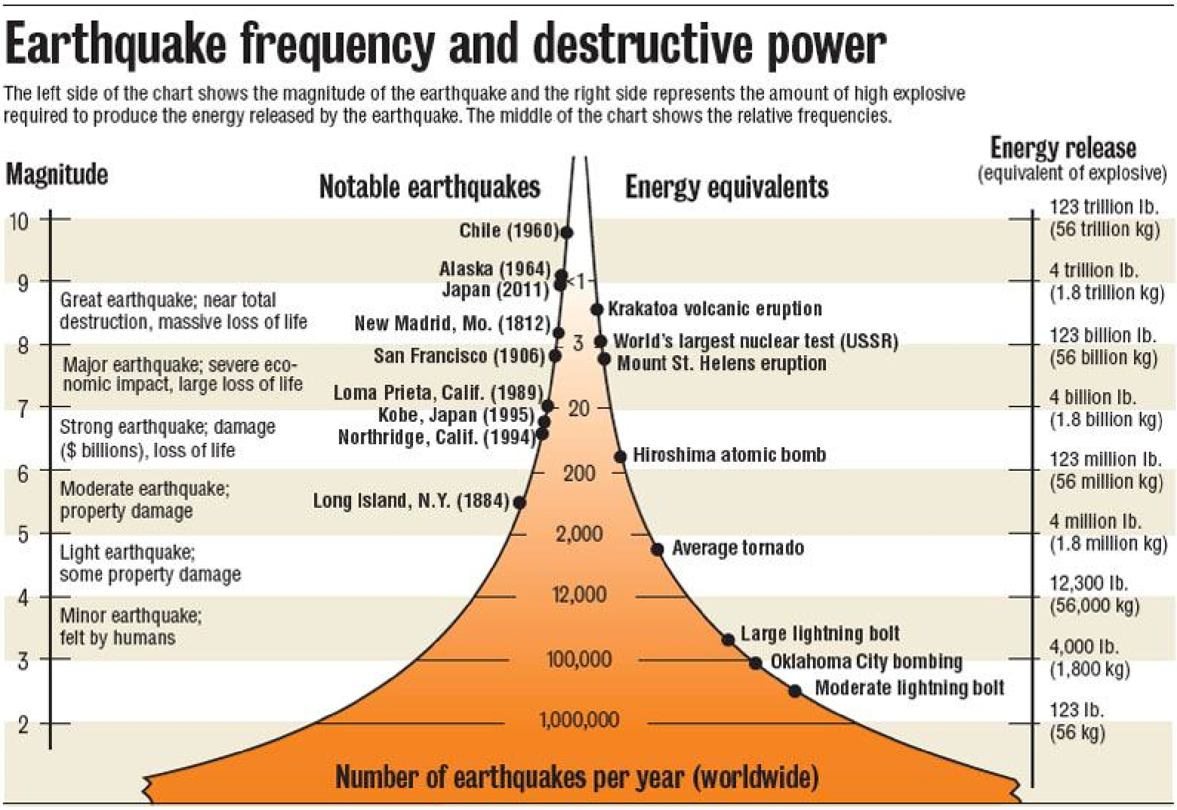


Table 1. **Magnitude earthquake based on energy earthquake hypocenter**

Energy earthquake in hypocenter E, J	Logarithm Energy	magnitude	Energy earthquake in hypocenter E, J	Logarithm Energy	magnitude
10^3	3	1	10^{13}	13	6
10^5	5	2	10^{15}	15	7
10^7	7	3	10^{17}	17	8
10^9	9	4	10^{19}	19	9
10^{11}	11	5			

The earthquake power in the hypocenter is characterized by magnitude and the intensity. On the earth surface (seismic) is measured in points. The intensity, I, magnitude, M, of earthquake in balls and depth of the hypocenter location, h, km connected with such empirical formula

$$I = 1{,}5M - 3{,}5 \cdot lg\, h + 3\,. \quad (1)$$

Energy earthquake hypocenter, J, which determines its strength can be determined by the formula B. Golitsyn

$$E = \pi^2 \rho v (A/T)^2, \quad (2)$$

where ρ – density crust; v – velocity of seismic waves; A – amplitude, T – oscillation period.

Energy weakest earthquakes that can be registered seismographs, equal to 103 J, and the strongest – 1019 J. This interval was compiled and scale of earthquake strength, as measured magnitude (Table 1). The intensity of earthquakes is determined by a 12-point scale based on the size of the displacement of the elastic spherical pendulum seismometers in the system S. Medvedev or seismic acceleration that occurs in rocks that form the foundations of buildings and structures

$$\alpha = A4\pi^2 / T^2. \tag{3}$$

Table 2 presents the characteristic damage of buildings during earthquakes. Based on the study material earthquakes up seismic maps. With the help of seismic maps can be obtained seismic data point that we are interested in points. The resulting seismic value specified on the basis of the geological structure and hydrological conditions of a particular area. Clarification do with the seismic zoning maps.

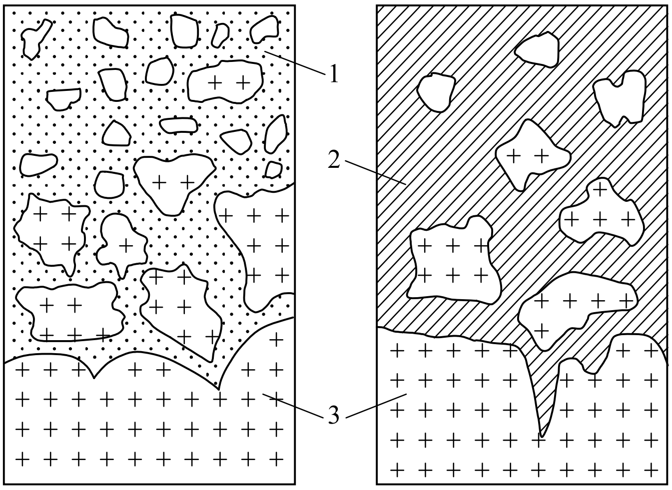
Table 2. **The characteristic damage of buildings depending on magnitude earthquake**

Intensity balls	Displacement of a spherical pendulum mm	Acceleration, cm / s2	Description of damage buildings (By S. Medvedev)	Notes
6	1,1-2	25-50	Many homes light damage. In some homes groups A, B and C major damage. In some cases, fine cracks on roads	Group A - one-storey houses with walls of jagged stone, brick raw, adobe Group B - brick and stone houses Group B - block, Frame houses Group G - wooden houses
7	2,1-4	50-100	Most buildings Group A considerable damage and in some - destruction. Most buildings in group B and light damage and in some - significant. Many homes Group G light damage and some - significant damage. In some cases, landslides on steep embankments of roads, cracked roads and destruction of joints of pipelines. Damage stone fences	
8	4,1-8	100-200	Many homes and destruction of Group A in particular - collapses. Most buildings in group B and major damage, and in some - destruction. Most of the buildings in Group G has light damage in many - significant damage. Small landslides on steep slopes and mounds roads seizures. Some cases of rupture of pipeline joints. Monuments and statues shifted. Stone fences destroyed	
9	8,1-16	200-400	Many homes group A falls. Many homes in groups B and destruction, and in some - collapses. In many homes Group G major damage and in some - destruction. In some cases, the curvature of rails and roads damaged embankments. Many cracks on roads. Gaps and damage to pipelines. Monuments and statues thrown. Most pipes and towers destroyed	

3. Geological and engineering-geological processes. Part 2

1. Weathering and eluvial deposit

Weathering products that stopped at the site of their formation, are called eluvium or eluvial deposits. An important feature of these deposits is that they lie on the rock from which they were formed. Eluvium is more common igneous, metamorphic or sedimentary rock types. Eluvial thickness (weathering crust) has a capacity from the half of meters to several tens of meters. Composition of eluvium is very diverse, which caused by a type of bedrock and the nature of weathering. If igneous bedrock and physical weathering predominates, then eluvium will consist of sand, gravel and large debris. When predominant chemical weathering, the eluvium remaining on the same bedrock, clay species will be presented with the inclusion of clastic material (Fig. 1).



a *b*

Fig. 1. Eluvium by weathering: a – physical; b – chemistry;
1 – sand;
2 – clay; 3 – bedrock

Eluvium thickness divided into 4 zones: fine parts, small debris, blocky and monolithic. In the first three zones particle size gradually increases with increasing depth. In the monolithic area external signs of bedrock change are absent. But it is not strong rule that in all cases there are four zones. Thus, the fine debris zone material can move with denudation processes. If weathering processes in this strata started recently, the entire sequence will have only eluvium blocky and monolithic form.

2. Geological work of surface flowing water and appearance of deluvial, alluvial and proluvial deposits

Temporary streams that arise during rain and snow melt, water streams and rivers belongs to surface flowing water. These waters execute huge geological work. In denudation processes they play a major role. Flowing water destroys rocks, move the destroyed material in chemical solution (in muddy condition) and by moving the bottom and lay it in humble places. Processes of rocks destruction by water that moves are called erosion.

There are planar erosion – flushing – deep and lateral erosion – blurring erosion. When flushing occurs the smallest streams of rain and melt water moving over the surface of the slope and shift to the lower part of the foot small and smallest parts of bedrock. By accumulating, this material forms a diluvium or talus deposits (Fig. 2). Deposits thickness could reach from the half of meters to several tens of meters. They are represented by loam and sandy loam. Deluvial deposits could be found everywhere, even on slopes with a small bow. While moving water erosion on the slope formed on its cavities – channels. In this case, the flow of water deepens and expands the channel. There is cutting slope that starts from a point located at the foot of the slope. This point is called the base level of erosion. Cutting of the slope going in the direction opposite to the movement of water. Below the basis of rocks erosion don't occurs. As the stream cuts through the slope, its longitudinal profile of the channel becomes more flat (Fig. 3).

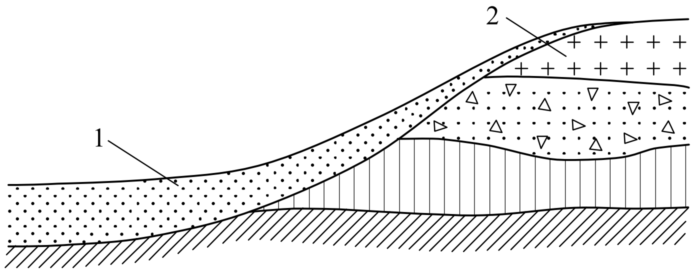


Fig. 2. Deluvial deposits: 1 – diluvium; 2 – bedrock

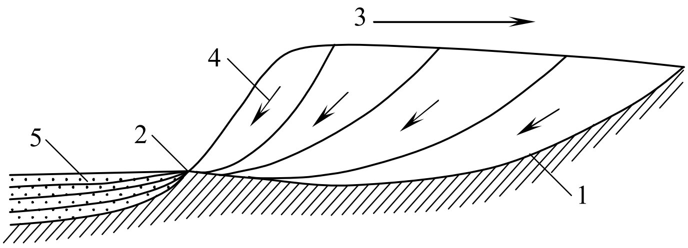


Fig. 3. Scheme erosion: 1 – channel; 2 – base level; 3 – cutting direction; 4 – direction water; 5 – cone of movement.

Eroding rocks on top of the bed, the flow moves ruined material and lay it at the base erosion. So there is a rock cone of movement. Every stream is trying to develop longitudinal profile of the channel slope threshold, called the profile of balance.

In this channel slope velocity of water are insufficient for the erosion of rocks and erosion stops. The nature of the flow depends on repositioning base erosion. If in stream that produced the profile balance reduce base level, it will produce new profile balance, again deepening and widening the channel. Specified rules are correct for temporary streams and for permanent streams and rivers.

Temporary streams form ravines on the slopes, and streams and rivers – depression, called valleys. Ravine most intensively developed on the slopes, which consist of clay rocks easily eroded. The speed of development – from a fraction of a meter to several meters per year. Ravines are divided into active and inactive. Active ravines naturally turn into inactive. As a result, there are ravines in place beams. Dominated ravines depth of 15 m with a length of about 1.5 km. But some ravines have a depth that reaches tens of meters and a length of 20 km. Ravine causing great damage to the national economy. With their increasing structure and threatened structures and destroyed valuable agricultural land.

River valleys flowing by waters washed out gradually. The width of the valleys of major rivers can reach tens of kilometers. Material delayed within the river valley or deltais called alluvium or alluvial deposits. Power of alluvial deposits from the half of meters to several tens of meters In the deltas of major rivers their power is much greater: Delta Terek – 200 m, and in the Volga delta – 300 m.

Alluvial deposits – a thickness in which alternating layers of silt, clay, loam, sandy loam, sand, gravel and pebbles. These layers of different thickness and stretch. There are channel, floodplain alluvium and deltoid.

As part of the channel alluvium mountain rivers dominated coarse material, gravel and pebbles, and lowland rivers – sand. Floodplain alluvium formed on lowland rivers. He is most often represented by sandy loam and loam, and oxbow rivers – as mules and clays. Deltaic alluvium located at the confluence of the rivers and lakes in the Sea. This moving the cone. Delta may occupy large areas. Volga delta area is 18 thousand km^2. In the delta deposited bulk material that is carried by the river. The composition of this material in mountain and lowland rivers varies. In the deltas of mountain rivers it is often coarse. In the same lowland rivers deltas – a clay that are interbedded by sands. Alluvial deposits are usually saturated with water.

The formation of river valleys associated with the change of river erosion basis, which may be the water level in the river or in the sea, where current river fall. Changing in the base erosion can occur as a result of lifting or lowering of the land and through changing the position of the water level.

River valleys often have very complex cross-section due to the formation of river terraces. River Valley are of accumulative (alluvial) and erosion terraces. The stages of the formation of terraces shown in cross-section (Fig. 4). Figure 4, a given section of the valley, which was formed as a result of a strong base erosion reduction, which led to the development of deep and lateral erosion. In this case, erosion formed the valley with terraces. Fig. 4, b shows a section of the same valley after a significant increase in base erosion. Erosion valley filled with alluvial deposits. Fig. 4, c given section of the valley after the new reduction in base erosion. Erosion processes are developed in alluvial deposits, forming accumulative terraces. Valley lowland rivers have up to 6 terraces (in the valley of the Dnieper River, near the city. Dnieper are 6 terraces). In the valleys of mountain rivers could be even more.

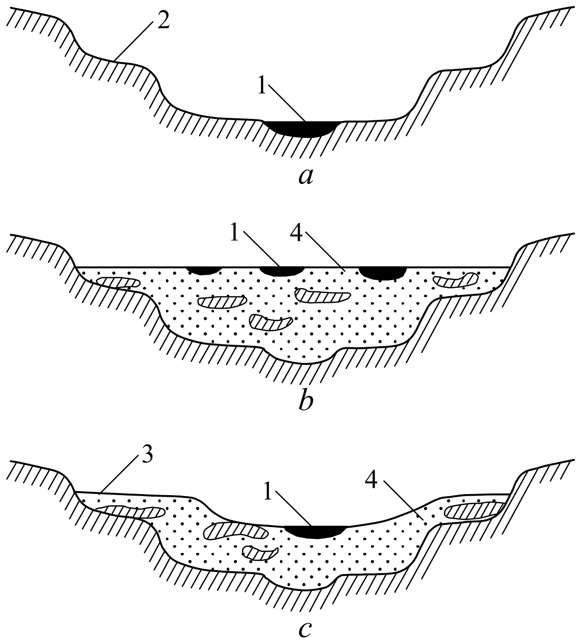


Fig. 4. Scheme of formation of river valleys: a – erosion; b – accumulative; c – accumulative while reducing erosion basis; 1 – the river; 2 – erosion terrace; 3 – accumulative terrace; 4 – alluvium

To surface flowing water are also included intermittent streams in the mountains that occur periodically, after extensive rains during rapid thawing of snow or ice. Such flows have large amounts of clastic material have great destructive power. They are called mudflow. For example, in 1921 mudflow, which moved to the valley Small Almaatynka forth in the city Almaty and its surroundings 3.6 million m^3 of sediments.

Consumption in this stream reaches 800-900 m^3 / s. It destroyed more than 250 buildings. More powerful mudflow formed in the same area in 1973. But he was stopped artificially built dam in the valley. Small Almaatynka. The formation of such flows in the initial stages associated with flushing processes of weathering products into the valley.

Mudslides divided into coherent (structural) and incoherent (turbulent). In the connected water flow and its repositionable detrital material form a mud-rock mass with density up to 1.8-2 t / m^3.

In such mudflow debris material is not separated from the water. In disconnected streams clastic material deposited in the usual way traffic in line or movement cone.

Mudslides are forming at the foot of mountains – proluvium or proluvium deposits. Their thickness reaches tens of meters. These sediments deposited layers formed as they make different forces that are repeated. Prolyuviem sequences in sandy loam and interspersed with sand and gravel.

The fight against the destructive activity of surface water is flowing through preventive measures and engineering. The most important preventive measures include a ban on agricultural industry slopes, deforestation and shrubs cutting. Engineering measures used to combat the ravines, lies in the equipment at the top of their fast streams and at the bottom – rock dams (Fig. 5). The land adjacent to the top of the ravine, planted by shrubs.

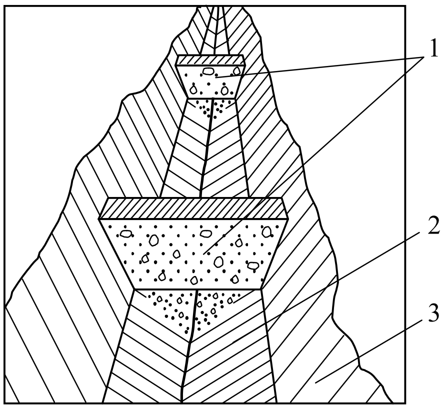


Fig. 5. Strengthening the bottom of ravines using dams (dams):
1 – stone dam; 2 – the bottom of the ravine; 3 – ravine slope

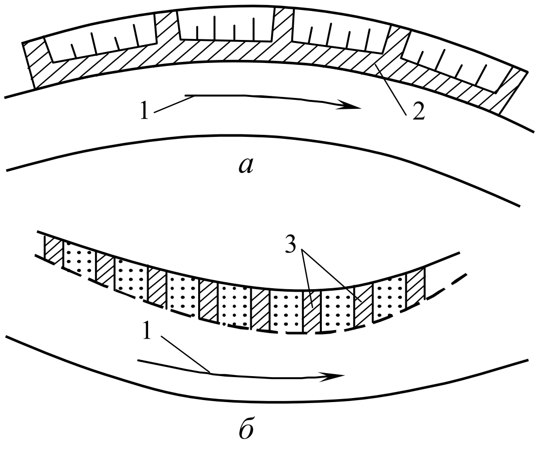


Fig. 6. River banks fortification: a – stream directing dam; b – semi dam;
1 – the direction of flow; 2 – dam; 3 – groynes

To save the riverbank from erosion by river waters they are strengthen by Paving stone on rubble, stones in steel cages and the construction of dams and semi dams for flow directing (Fig. 6). Dams built on the banks of concave and - convex from a variety material: stone wood and concrete.

The fight against mudflows drive by building dams, mud traps, dams for directing the flow, to protect roads – mud slopes. Mud slopes are arranged in the form of large tray from reinforced concrete on supports over the roads to direct and flow away mudflows.

3. Geological work of glaciers and glacial deposits

Glaciers are called formed on land (onshore) masses of ice, which are moving. The movement of glaciers mainly caused by plastic flow of ice in the presence of significant pressure differences. Ice Flow occur due surface slope on which it moves. But the glaciers also can move on a horizontal surface. When it is moving, glaciers perform great geological work. It is present mechanically destroying of rocks, destroyed material moving and laying it in certain places, which is forming various glacial deposits.

Modern glaciers are divided on the mainland and mountain. They cover an area of 16.3 million km^2, representing 11% of the land surface. Continental glaciers located in polar regions. This includes Greenland and Antarctic glaciers. The first area is 13.2 million km^2, the second – 1.65 million km^2. The ice in the Antarctic ice averaging 1,720 meters in Greenland – 2300 m. Thereforein these glaciers are concentrated the main mass of ice on land. The water contained in these ice would be enough to raise sea levels by 50 m. The velocity of the ice in the continental glaciers small: 1.5 m / day, but in some places it can reach 30 m / day. Mountain glaciers formed in the mountains. They occupy a relatively small area, the Caucasus – 2 thousand km^2 in Central Asia – 11 thousand km^2. Examples are valley glaciers: Inylchek in the Tien Shan length of 70 km, Fedchenko in the Pamirs – 77 km Dyhsu Caucasus – 15 km and others. The thickness of ice in glaciers reaches tens of meters or more, and velocity ranges from 0.1 to 7 m / day.

Geological formation and activity of glaciers can be considered on an example of mountain glaciers. In the mountains above the snow line in the valleys between the mountains snow piled up, which does not have time to melt in the summer. Under its weight it is compacted and turns at the first porous (firn), then – a tight, solid ice. With large capacity ice begins to flow down the valley. The end of the glacier, falling below the snow line, thaws.

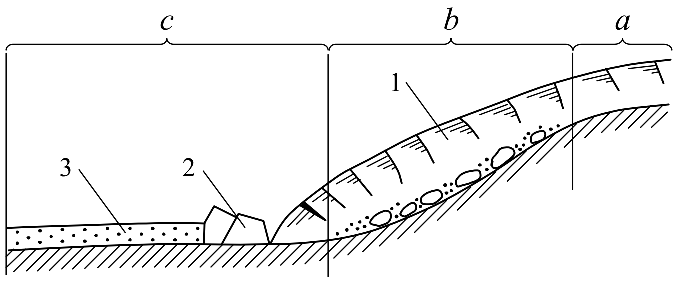


Fig. 7. Schematic cut rock glacier: 1 – Glacier; 2 – final moraine; 3 – outwash field; a – nutrition zone; b – glacier move zone;c – thawing zone

Typically, in a mountain glacier we can distinguish areas: nutrition, movement and thawing (Fig. 7). If there coming ice more than thaws, the moving zone going forward – glaciers attack. When the moving zone is moved higher – glacier retreats. But thawing zone may be located some time in one place. In the ice thickness and on its surface are contained large amounts of sediments of various sizes – from clay parts to gravel and huge boulders. This material glacier move during plow of the valley bottom in which it moves, as well as shifting the debris material from the slopes of the valley on its surface. On the glacier surface also deposited particles carried by the wind. Deposits, which is formed by glacier movement, is called moraine. Morena deposited during glacier thawing. There are final and main moraine. Final moraine formed by a stationary position on the end of the glacier in the form of a ridges hills. These moraines consist of unsorted, but washed water material – gravel, pebbles, boulders. The main moraine formed during the retreat of the glacier. This material is transported glacier deposited along the way of its retreat. Major moraines consisting of loam and clay with inclusions of coarse material.

In the area of glacier thawing are originated numerous water streams that endure and lay on moraines end sands, sandy loams and forming sand and clay (outwash) fields.

All that has been said about mountain glaciers concerns to the continental glaciers. But the activity of continental glacier there is a much larger scale. Of particular interest are the continental glaciers of the Quaternary period. Distinguish following icing in this period: lyhvynske, Dnieper and Valdai (Fig. 8). The largest was the icing Dnieper. The main center was the icing on the Scandinavian Peninsula, where ice thickness reached 3 thousand m.

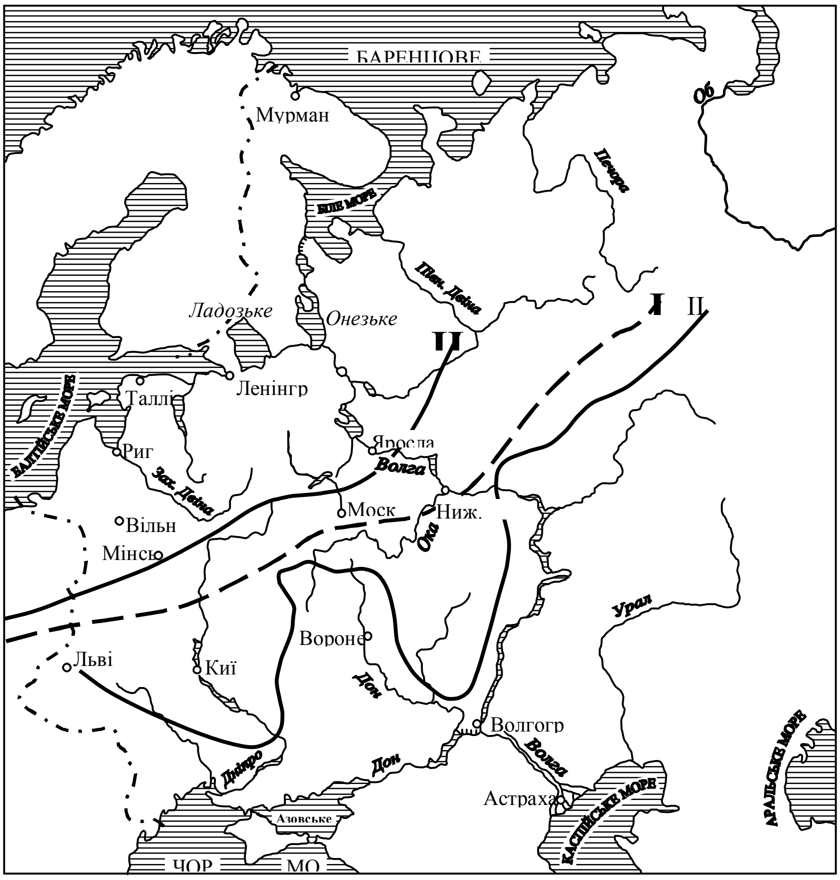


Fig. 8. Map of Quaternary iceland

Quaternary glaciation began about 500 thousand. Years ago. Since the last glaciation have passed 12 thousand. Years. All this time the icing varied interglacial epochs. Well preserved traces of the latter, Valdai, icing.

On the territory of Karelia on the Kola Peninsula in depressions which are formed by glacier after lakes. Igneous rocks came to the surface was treated with ice that move. There are strands final moraines up to 100 m, which sometimes stretch for hundreds of kilometers, and other entities of this kind: oz, kami, drumlin and others. All this creates a typical glacial landscape (Fig. 9 – 12).

Here there are lacustrine-glacial deposits, often with clay belt, which is very thin alternating layers (share centimeter or a few centimeters) of clay and fine sand. South-east of the main moraines are thicker and more on large expanses of water-ice (fluvioglacial) deposits of sand, gravel, gravel and loam. Loam overlying glacial deposits formed before and so called blanket. Their thickness does not exceed 12 m. Water-ice deposits resemble alluvial composition.

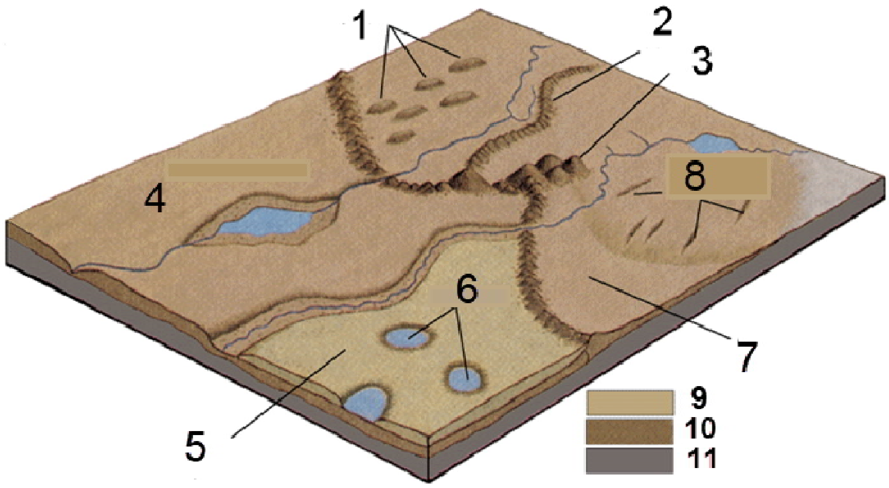


Fig. 9. A characteristic landscape after the decomposition of the ice sheet: 1 – drumlin; 2 – oz; 3 – kami; 4 – main moraine; 5 – zander morena; 6 – depressions; 7 – lake plain; 8 – filling cracks; 9 – shady deposits; 10 – main moraine; 11 – indigenous rocks

Fig. 10. A characteristic landscape after the decomposition of the ice sheet

Fig. 11. A characteristic landscape after the decomposition of the ice sheet

Fig. 12. Brown-red cover glacial loams on sediments of the Cretaceous period (Aptian white sands)

The causes of a previous ice times have not yet clarified. Most likely to be changes in the contours of the land and the direction of the ocean currents that cause certain environmental conditions. For example, Greenland now covered with ice, and some areas of Yakutia with lower temperature balance free of it. This is because there is very little snow falls and it cannot accumulate.

4. Geological and engineering-geological processes. Part 3

1. Geological work of wind and eolian deposits

The horizontal movement of air in the troposphere from places of high pressure in place of low pressure called **wind**. Wind takes on the surface of the continents significant geological work. First, he driveth away particles weathering products (clay, silty and sandy), moving them into a state of suspended and rolling on the surface. This is called **deflation**.

But the wind, while carrying in a hanging up state particles, by them mechanically destroys rocks. This process is called **corrasion**. Distances that are transferred by rolling particles in hangings up state, depend on the particle size and the strength of the wind. Wind speed at 10 m/s can move a particle size of 1 mm and at a speed of 20 m/s – size of 5 mm. Sand particles are transported over tens or hundreds of kilometers. Small particles of silty clay and can be transported by wind for hundreds or even thousands of kilometers. The volume of material that is carried by the wind, is very significant. For example, hurricane winds, which blow from Afghanistan, known as "Afghans" in the Karakum desert bring a lot of dust.

The geological work of wind is especially noticeable in those areas where, because of the dry climate and lack of vegetation, dominated by physical weathering, and the winds blow constantly, often achieve great power.

Material that is carried by the wind, falling and eventually accumulates. So there are **aeolian** processes. These include aeolian sands and the thick woods. Aeolian sands mainly occur in deserts. Desert Karakum and Kyzyl-Kum take 1 mln. km^2. In addition, many aeolian sands have significant spread along the shores of seas and lakes and in the valleys of major rivers. Large areas occupied by these sands on the coast of the Baltic and in the valleys of the Volga, Dnieper and Don.

In such places as a result of the wind moving sand hills there are original strands, which are called desert **barchans** and on the coast – **dunes**. In plan (cross-section) dunes have spherical shape (Fig. 1 and Fig. 2) and a height of 20-30 meters. Windward side of the dune flat (5-14°), and lee – cool (30-33°).

Instead of Barkhans dunes have extended hills with rounded peaks of up to 30 m. In dunes, as in the Barkhans, windward slope is sloping and leeward steep. Barkhan and dunes under the influence of major wind moves by sand flow from windward to leeward side.

These shifting sands cause major damage to the national economy as capture valuable fertile land, hamper operation of roads, canals, poured structure and facilities. The speed of the Barkhan and dune varies from a few to 20 meters per year. There are also cases moving them at a speed of several meters per day. Moving sands are usually loose structure that should be considered when designing buildings, especially hydroengineering.

The fight against shifting sands are mainly by planting forests, shrubs and grass. In desert areas this purpose Haloxylon seat. In areas with a humid imposed pine.

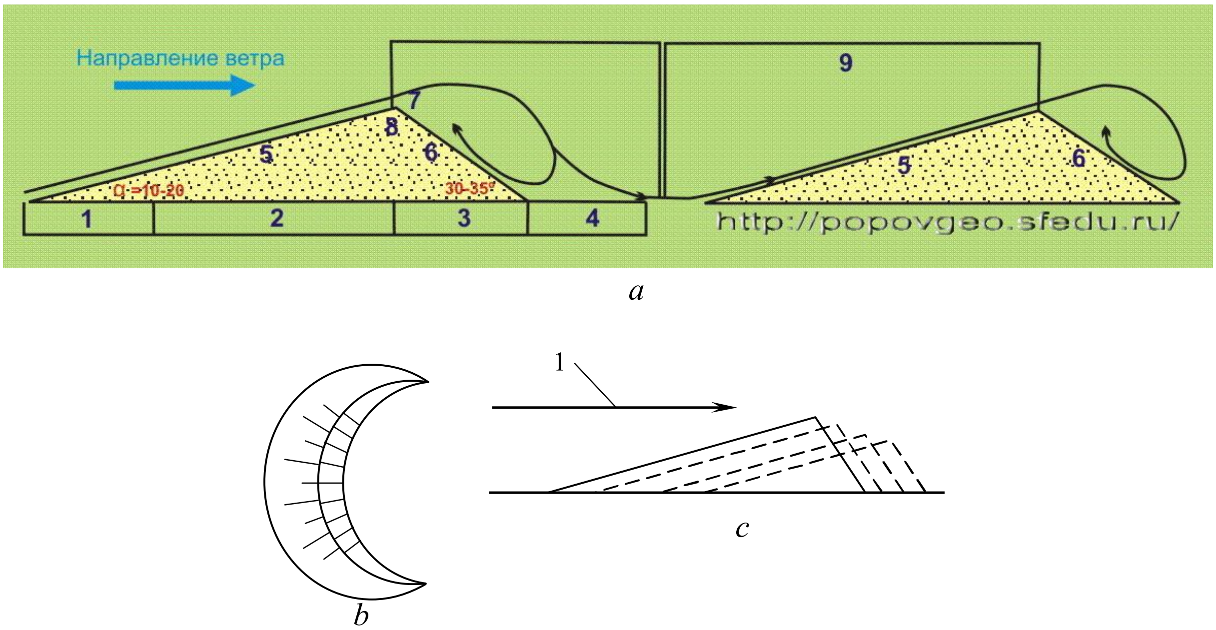


Fig. 1. Barkhan: a – barkhans formation; b – plan; c – section; 1 – wind direction

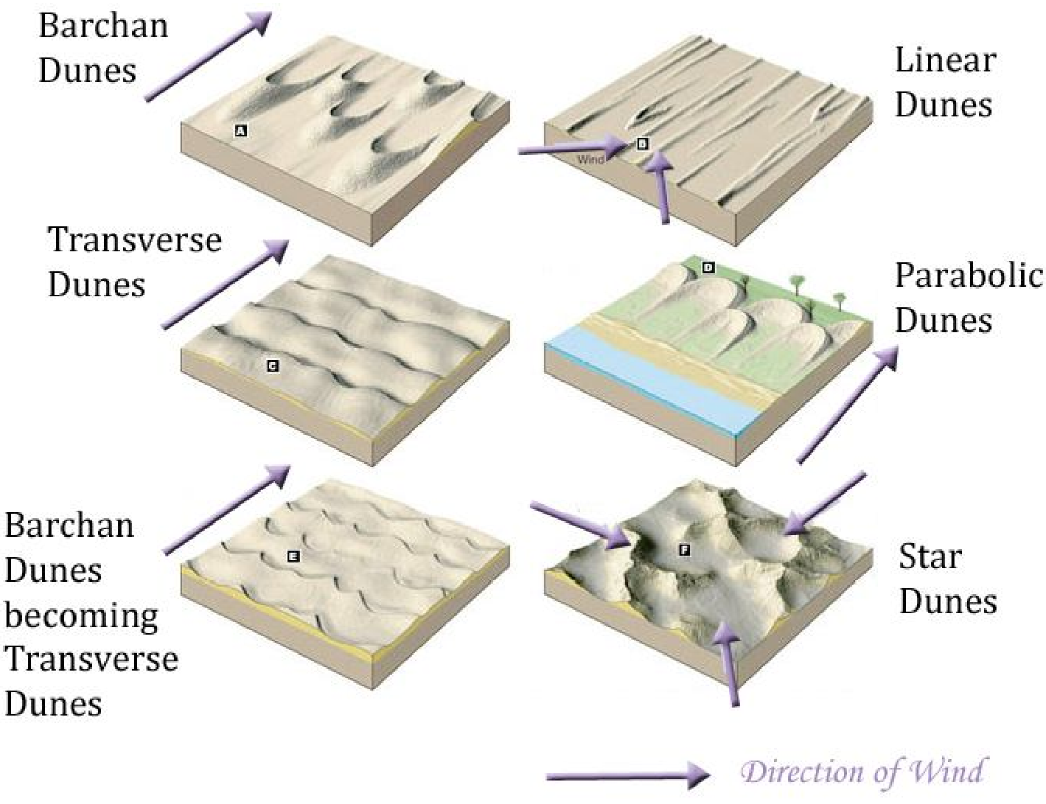


Fig. 2. Forms of barkhans and dunes

A thicker **loess** formed in conditions of dry climate due to the deposition and accumulation of silty and clay material, which brings winds from deserts and other areas, dispelling weathering products. Silty parts of the loess dominate. During the accumulation of loess material, in the soil thickness particles weak cementation occur by calcium carbonate. At the same time, dying plants causing particles presence of large pores – **macropores**. As a result, loess is a porous rock. Color loess – fawn. Les extended to Ukraine and Central Asia. Large areas occupied by them in China. Les has a peculiar property: when soaking under load it decreases in volume, major settling. This complicates the construction in loess strata buildings and structures.

2. Geological work of sea and marine deposits

The **sea** also serves great geological work – both destructive and creating. Nowadays the square, occupying the seas and oceans can be divided into three parts: the **continental shelf** (shelf) – to a depth of about 200 m (8.4% of the area); **continental slope** – at depths of 200 to 2400 m (9.3%), **ocean floor** with deep cavities – at depths exceeding 2,400 m (82.3%) (Fig. 3).

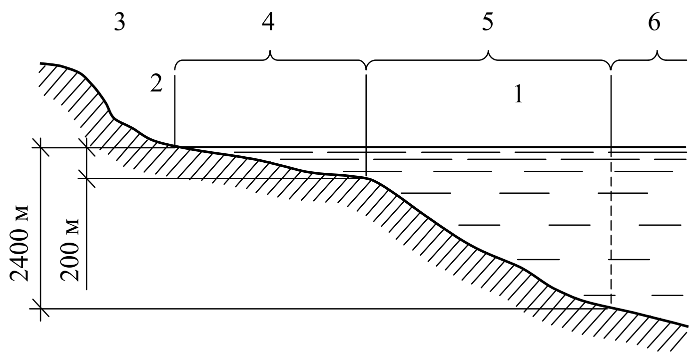


Fig. 3. Scheme bottom of the oceans: 1 – sea level; 2 – the beach; 3 – coastal wall; 4 – continental shelf; 5 – continental slope; 6 – bed oceans

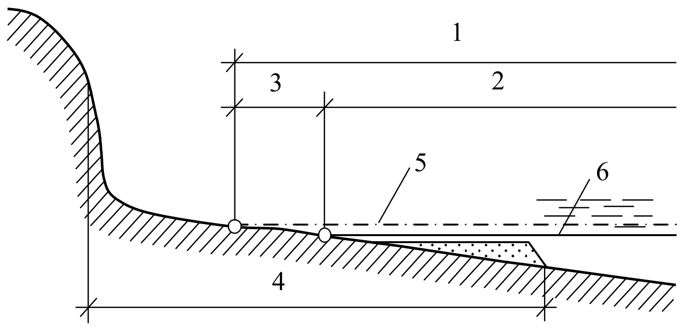


Fig. 4. Surf wave erosion terrace: 1 – continental shelf; 2 – neritic zone; 3 – intertidal zone; 4 – surf wave erosion terrace; 5 – inflows; 6 – outflows

Within the shallow **littoral** and sea produce **neritic zone**, the first occupies the coastal part, which is filled with water during high tide and is released from it during low tide. The destructive work going on in the sea littoral zones and partially neritic and turns in breaking waves coast surf. This process is called **abrasion**.

Destructive work contribute surf waves wave tide and low tide and coastal currents. Under the influence of the wind in the sea there are waves whose height can reach 15 meters. When the waves close to shore, they are due to closeness of the bottom, destroyed and facing the flow of water reflected coast, moving towards them. During that forms a splash height which exceeds the height of the wave. The weight of the water goes to the coast and hit him. Acts of the mass of water in the coastal wall is very large. For example, the pressure waves of the Black Sea near the city. Tuapse reaches 57 kPa, and the waves of the Atlantic coast of northern England range – 380 kPa. As a result, the coast is destroyed and there is forming wave surf terrace erosion to a depth up to 20 m (Fig. 4). Destructive waves work reinforced by sand, gravel, pebbles and larger detrital material, which water takes and hit in coastal wall. At the same time the destruction of the sediments occur. Part wave surf terraces from the water to the coastal wall called the **beach**.

If land in this place is at rest state, then after some time destroying waves surf coast stop, because even the largest waves will not reach the coastal wall. If the land falls, the sea will continuously attack on land, destroying banks. The rate of destruction of the coast depending on their geological structure, rocks composition, height and direction of waves. For example, the rate of destruction of the Black Sea coast near Odessa. Folded limestone is 1.5-2 m, and in some areas of the coast of the Azov Sea clay rocks – 12 meters per year. At the same time the speed of destruction of the coast of the Kola Peninsula near the city. Murmansk with rocks is only a fraction of a centimeter per year.

Fig. 5. Destructive work of the sea

Fig. 6. Destructive work of the sea

Sediments and wave surf beach terrace (sand and gravel) can move along the coast under the influence of waves that run on shore at an angle. This should be taken into account in the construction of protective structures – wave demolition of walls, **underwater breakwaters and dams** (Fig. 7 and Fig. 8).

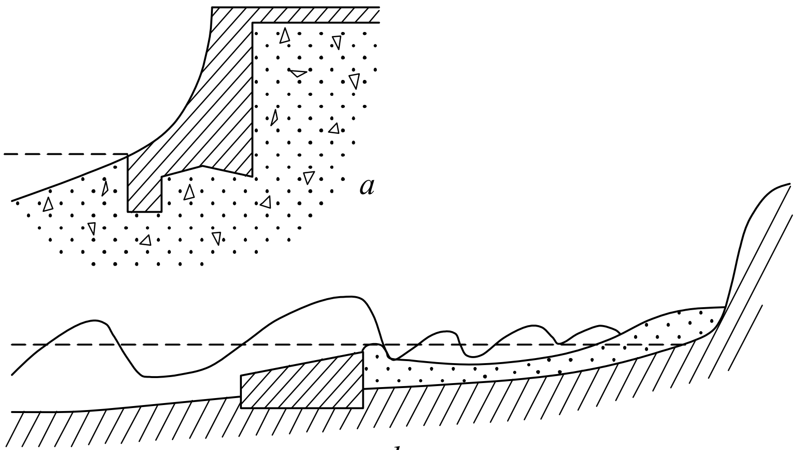


Fig. 7. Structures to protect the coast of the sea:
a – blasting wave wall; b – underwater cutwater

Fig. 8. Concrete structures for the protection of the sea

However, in the sea construction is prevailing. It is known that the majority of sedimentary rocks formed in the sea. Deposits of weathering products that fall into the sea from the surface of the continents and the material produced during the destruction of the coast are all areas of the seabed and ocean floor.

On the continental shelf, in the intertidal zone and upper zone neritic deposited detrital material: first **boulders, pebbles, gravel, and sand, large and smaller.** It also can be formed **limestone** (Fig. 9 and Fig. 10) and form **coral reefs**. At the bottom of neritic zone and the top of the continental slope deposited fine-grained material, which dominate the particle size of 0,1-0,01 mm. These deposits also contain **foraminifera shells**, and other organisms.

Fig. 9. Examples of limestone deposits

Fig. 10. Examples of limestone deposits

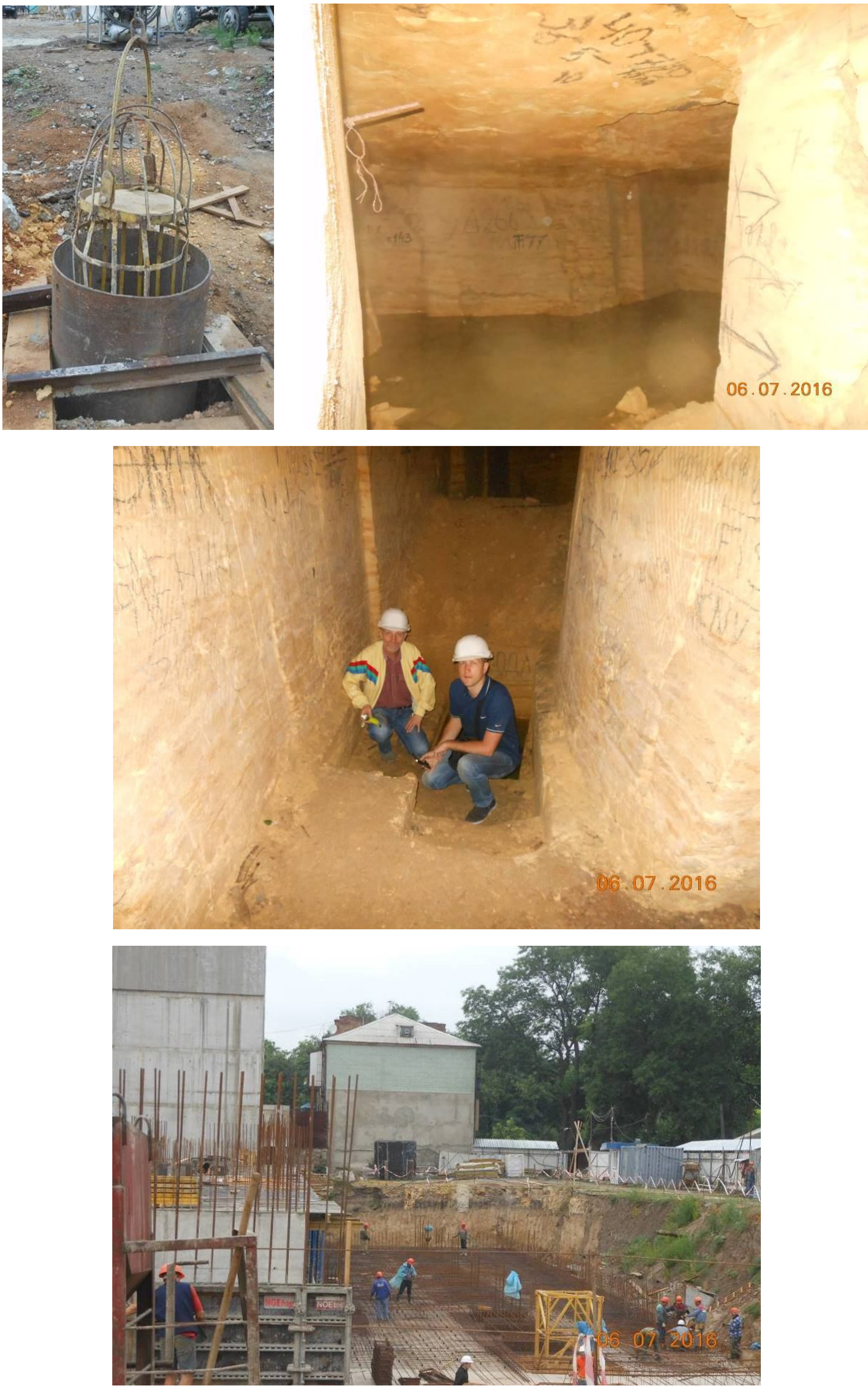


Fig. 11. Examples of underground workings in limestone deposits and construction under such conditions (Odesa)

At the bottom of the continental slope in the bed of the ocean deposited the most fine-grained mineral and organic (Turtles foraminifera) material with particles less than 0.01 mm. These deposits – various **silts, clay, lime, clay, siliceous-clay, volcanic**.

Interestingly, in the marine sediments of past eras, which now is on land, deposits are characteristic of the continental slope. This indicates that sea that were in the past on the present continents, had a little depth.

3. Deposits of lakes and swamps

The **Lake** is called depression on the surface of the land, filled with water. These recesses are of different origin. For example, Lake Baikal and Issyk-Kul formed at the site of major depressions, grabens. Burying Ladoga, Onega and numerous other lakes have arisen as a result of glaciers. Burying Lake Sarez in Pamir was formed as a result of the gorge, the barrage. Bartang River collapse in 1911 p. Many lakes (Elton, Baskunchak, Chelkar etc.) formed at the site of failures and water soluble cavities in rocks. Lakes also occur in lowland rivers oxbows. They are formed in the deltas of major rivers. Built people large and small reservoirs, in fact, are artificial lakes.

Fig. 12. Types of lakes

Geological work **great lakes** (Caspian and Aral seas, lakes Baikal, Ladoga, Onega etc.) Generally resembles the work of the sea. Geological peculiarity of large reservoirs is an intense destruction of the coast surf waves under conditions of variable water level. In small lakes is mainly the accumulation of sediment.

The deposits of **freshwater lakes** dominate detrital material (pebbles, gravel, sand and clay rocks) and organic silt (sapropel), established under the withering away of small animals and plant organisms. The banks of these lakes with lush vegetation, the remains of which gradually fill them. This happens eutrophication of lakes. In the freshwater lakes of chemical and biological deposited by as iron hydroxide – limonite (iron ore lake). The deposits of salt lakes (North Crimea Caspian lowland) dominated halide, sulfate and carbonate of lime, which precipitate summer at higher concentrations.

Fig. 13. Deposits of fresh lakes

Swamps – is excessively wet land areas. They are divided into lowland and upland. Fens often develop at the site of the lakes in the valleys. The remains of sedge, cattail, reeds and plaster mosses that grow here, form **peat**.

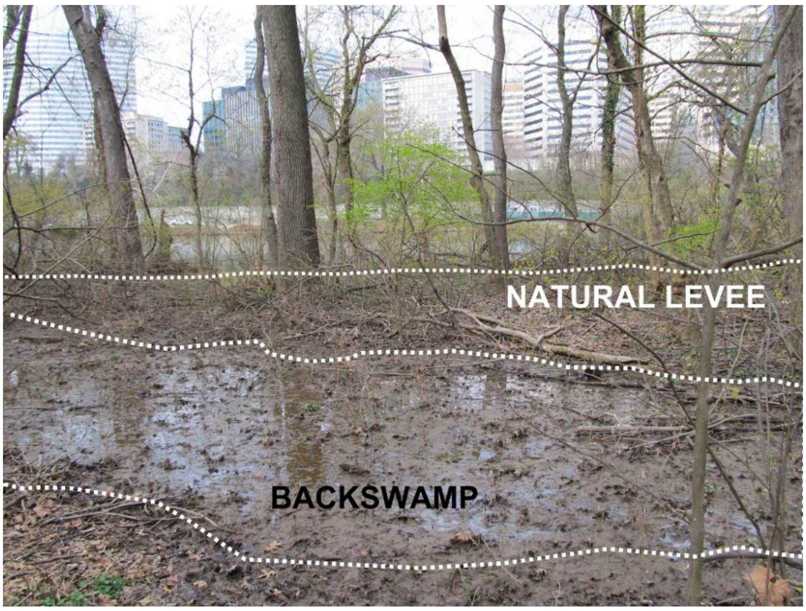


Fig. 14. Varieties of swamps

Fig. 15. Peat

Bogs are formed in spaces between the river where developing excessive atmospheric moisture sphagnum moss, and so on. Remains also create their turf. **Peat bogs** are different from peat fens low ash content and high calorific value. Many peat bogs in Karelia, Polesie and Western Siberia (Vasyugan Swamp), they contributed to the formation of flat terrain of these areas, humid climate and availability to shallow watertight rocks.

4. Quaternary deposits and bedrock

Eluvial, talus, alluvial proluvium, glacial, aeolian, sea and lake-marsh sediments were formed throughout geological history. Sedimentary that form these deposits gradually evolved and turned into sedimentary rocks – clastic, organogenic and chemical.

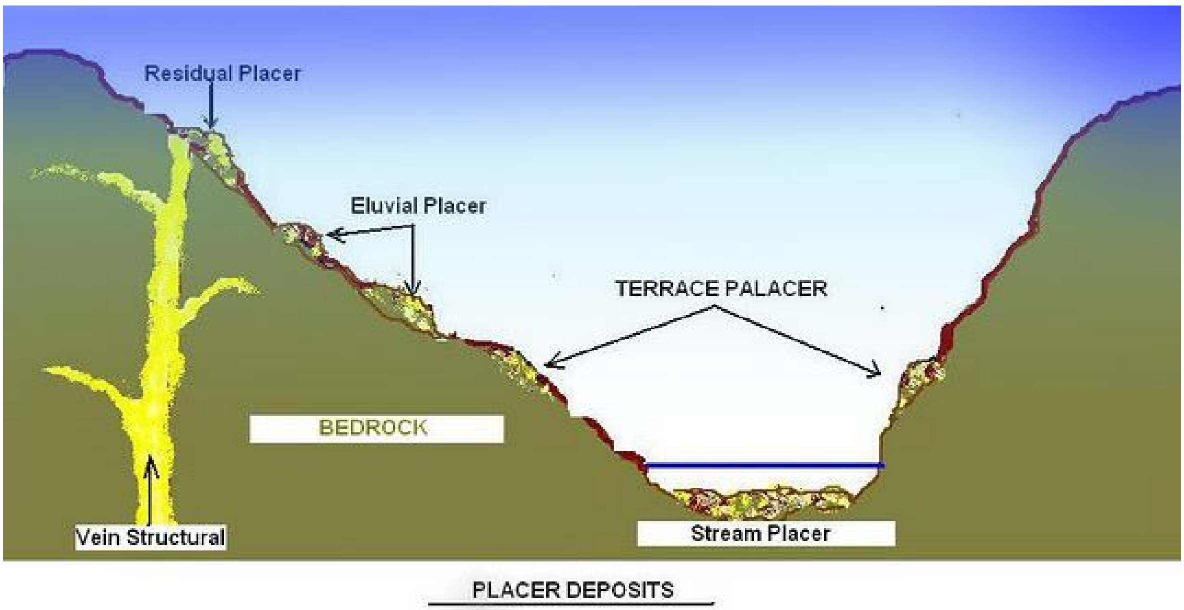


Fig. 16. Scheme of quaternary deposits and bedrock

Converting of sediments on the rocks is mainly influenced by the sealing pressure of the upper layers resulting in the cementation of various substances. And cementation can occur due to the substances that make up the sludge and by substances brought about there. The final stage of the modifications of sediments, during which they become rock type called **diagenesis**. Of course, not all sediments pass this stage. The deposits of coarse, sandy and clay rocks not affected by diagenesis.

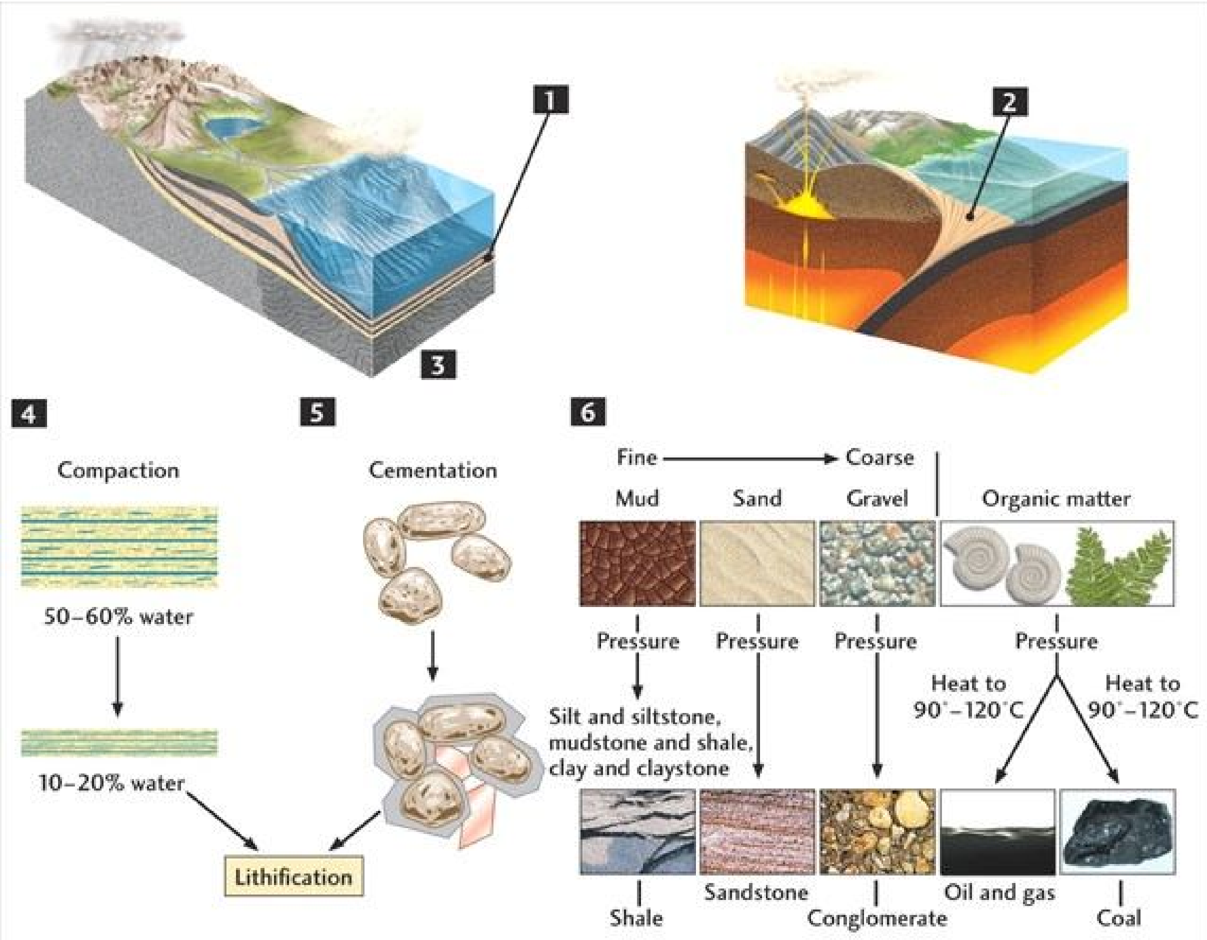


Fig. 17. Schemes of formation of quaternary deposits and bedrock

Sediments that are formed in the last Quaternary period, are called **quaternary**. They occur almost everywhere near the surface of the crust layer thickness of several tens of meters. Only in some places thick Quaternary sediments reaches hundreds of meters. Most rocks quaternary did not have time to go diagenesis stage, so they are not rocks. It is for these rocks often deal builders. Unlike Quaternary rocks previously formed rocks and **sediments called roots**. For several reasons bedrock can come to the surface or placed in shallow water, such as granite sills Dnieper in Zaporizhia (Fig. 18 and Fig. 19).

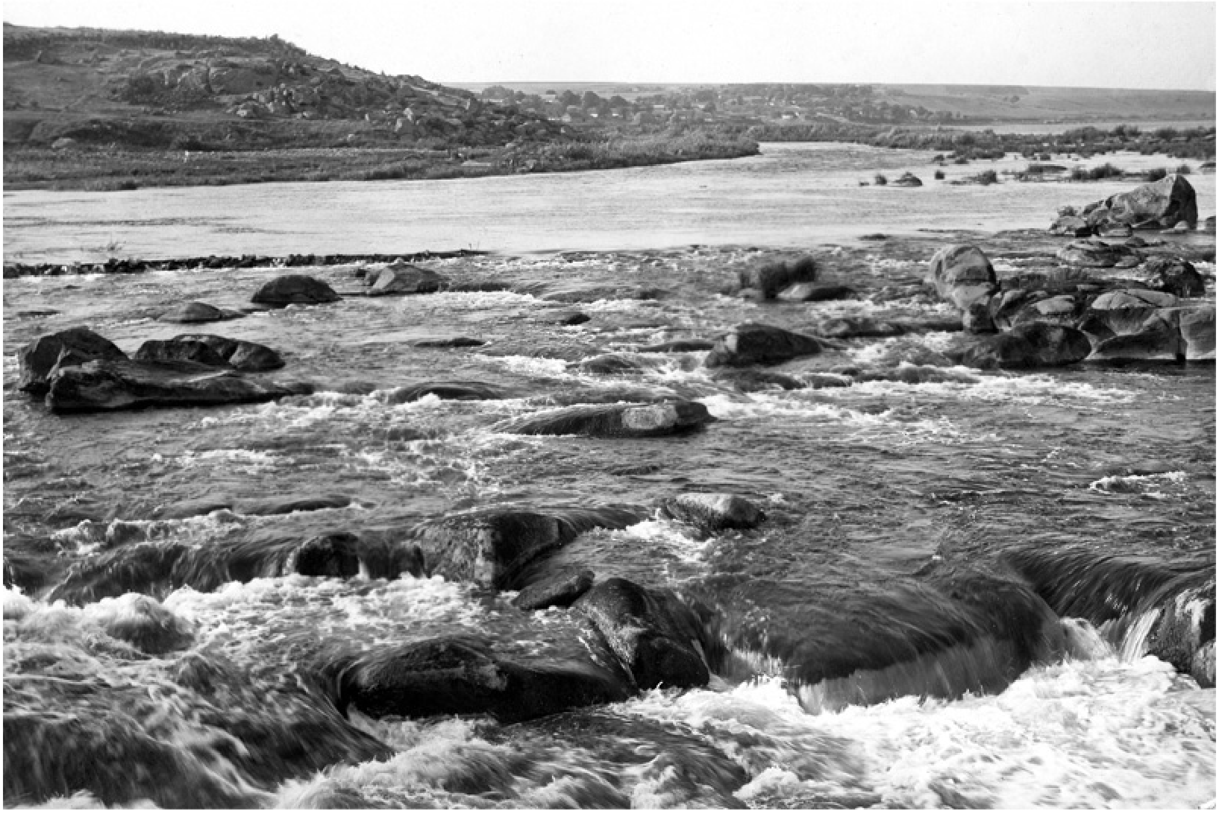


Fig. 18. Outputs of indigenous deposits (granites) on the earth's surface

Fig. 19. Outputs of indigenous deposits (granites) on the earth's surface
(in the Zaporozhye area)

5. Geological and engineering-geological processes. Part 4

1. Quicksands and peculiarities of erection of buildings and structures on them

Quicksands are so rich in water soils, which, under certain conditions, become fluid and acquire the properties of the liquid. This means that their bias resistance becomes zero. Sands, sandy loaves, and sometimes some loams and mules can flow into a fluid state.

O.F. Lebedev divided the swimmers into false and real ones. *False quicksands* include sand that passes into a floating state under the influence of the ascending movement of water. Such movement of water is possible in the places of access to the surface of artesian waters or water, which is filtered in the bases of dams and dams in the grass side, with open drainage from the pits. The upward temporal movement of excessive water may also occur in the layers of loose sand after being compressed by a dynamic effect, for example, in an earthquake. When spraying sands during an earthquake, the foundations of buildings and structures deepen in them. Possible dilution of flooded slopes, made of sand of earth dams, dams, transport embankments in floodplains of rivers, etc.

The peculiarity of false quicksand is that they, having a significant permeability, give a good water. Therefore, when reducing the hydraulic gradient, they quickly move from a floating state to a stable.

Unlike false, *real quicksand's* pass into the floating state mainly due to the violation of structural thixotropic-coagulation bonds in them under the influence of shock and vibration loads, and also if they are ruined. Such quality of these squirrels is explained by the content of colloidal particles in them. These particles in dusty sands, sandy loams and partially in loams and mules form gel-like systems that undergo shock and vibrational actions in a suspension. This leads to dilution. But after a while, after a kind of "rest", the suspensions are once again converted into gel-like state and the broken structural bonds are renewed. Such transformations are called *thixotropy*. The filtration pressure in this process is not significant. Since most of the water in the actual spillways is in a connected state and it is difficult to remove it, the transfer of such a floating to a stable state is a complicated and difficult task.

The signs of the quicksand's are as follows: high density (1,8-2,2 t / m^3), low permeability (k_f=0,01 ... 0,5 m / day), mineralization of cementation during drying, formation of a stable suspension during defecation in water.

In conditions of undisturbed occurrence, typical real quicksand's, often dusty sands, are low-rusted soils. They can be the foundation of buildings and structures. But the presence of quicksand's creates serious difficulties during construction. When in production buildings and structures equipment is installed that creates shock and vibration loads, then there is a danger of thawing of quicksand's in the bases and the emergence of large deposits of foundations. To prevent this, the foundations are made with spring shock absorbers or vibration plugs.

Significant difficulties arise during excavation of construction pits. The work of the excavator buckle removes the soil from the soil and drains the quicksand and causes it to enter the pits from the outside. In this case, the volume of excavation is sometimes increased 2-3 times. There is a danger of destruction of houses that are located next to it. In connection with this, the distribution of pits with the use of water depletion.

For water drainage in soils with a filtration coefficient of 1-2 m / day, lightweight filtration systems such as LHU-3 or LHU-5 (Fig. 1) can be used. The main part of the installation is a needle filter with a length of 8.5 m. In the lower part, they have a receiving link 60 mm in diameter with a valve and a brass net. The acoustic filters are immersed in the soil by means of a damp. The distance between the needle filters is assigned according to the calculation, based on the required amount of water level and permeability of the soil. Valve filters are connected to the collector pipe. On this pipe there are couplings with a distance of 0,75 m between them, where you can connect hoses from the needle filters. Air and water are taken from the collector pipe with the help of a pump unit. During the operation of the valve filter, the water level in the middle of the contour is reduced by 4.5-5 m.

In soils with lower water permeability (k_f = 0.01 ... 3 m / day), use of vacuum dewatering units such as UVB-M, which can pump water and air at high vacuum in suction collectors.

In soils with a filtration coefficient k_f <1 m / day, but practically no water is used, electrocoating (electro-osmotic dewatering) is used. The equipment necessary for conducting electric drying consists of a lightweight head filter unit, a DC source with a voltage of 60 V (may be an electric welding unit), a set of pipes or rods. The schematic diagram of the installation is shown in Fig. 2.

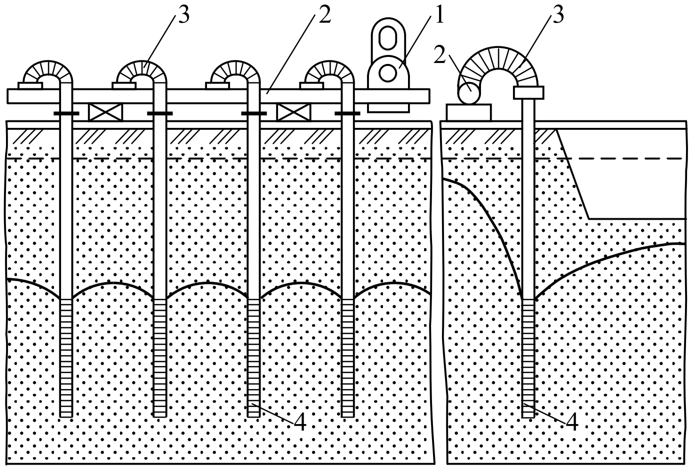


Fig. 1. Scheme of a mud-filter unit: 1 – pump unit; 2 – collector pipe; 3 – hose; 4 – head filter

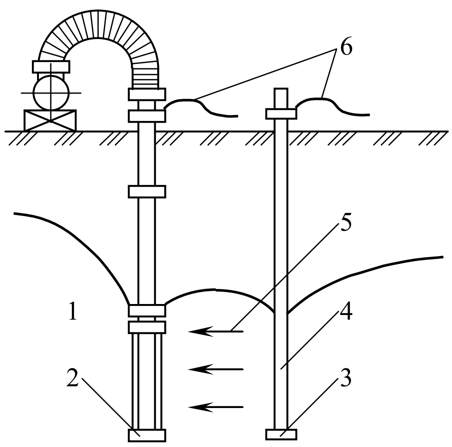


Fig. 2. Installation for electric drying: 1 – needle filter; 2 – cathode; 3 – anode; 4 – pipe (rod); 5 – the direction of movement of water; 6 – DC source

Electro-drying is based on the fact that the water, including connected, moves from the anode to the cathode. Due to the movement of previously bound water, the porosity of the soil increases and as a result increases permeability. At the same time, the phenomenon of electrophoresis occurs in the ground, resulting in the accumulation of hard-soluble salts that cement the soil in the cathode zone. The strength of the soil thus increases. It is established that the properties obtained by soil are stored. After drainage of soils, their development in the pit is the usual way.

Digging pits can also be carried out under the protection of tiled walls, ice curtains from frozen ground, etc. Siliconization is solvable (at $k_f > 2$ m / day) and is soluble (for $k_f = 0{,}1$-5 m / day) for fixing the pivots in the bases of the foundations and in the case of equipment for anti-filtration curtains.

2. Piping

Piping is called the process of removing the smallest and small mineral particles from the soil with filtered underground water. Piping occurs in sandy soils, and sometimes in soups It takes place on the slopes where underground waters emerge, in the slopes of earth dams and dams, in sand dams of concrete dams, in construction pits with open drainage, in the pumping of water from wells and in others such cases In this process, the main value is the mechanical removal, rather than passing the substance in the form of a solution. There is also a chemical piping.

The removal of mineral particles is due to the effect on them of filtration pressure, which is numerically equal to the hydraulic gradient. The intensity of the sulphosity process depends on the degree of heterogeneity of the soil composition of the soils. The higher the degree of heterogeneity, the lower the hydraulic gradients there is a piping. To install a critical gradient for a given soil, in which there is a piping, use the device system. During the test, water through a sample of soil is passed from the bottom up to different values of the hydraulic gradient. The appearance in the filtered water of mineral particles in the frozen state indicates the process of piping, which began. At this time, the value of the hydraulic gradient is noted. This will be a critical gradient.

To combat piping on the slopes, underground and lean drainages of various designs are used. The arrangement of underground drainage will be discussed further. *Sloping drainage* is used in the case when a small volume of groundwater exits practically throughout the slope surface. Scheme of benthole drainage is shown in Fig. 3. On the slope excavates shallow grooves and fill them with filtering material (gravel). The distance between these grooves should ensure their interaction and reduce the water level outside the grooves. Consequently, the discharge of water occurs only along the grooves and the integrity of the slope is not disturbed.

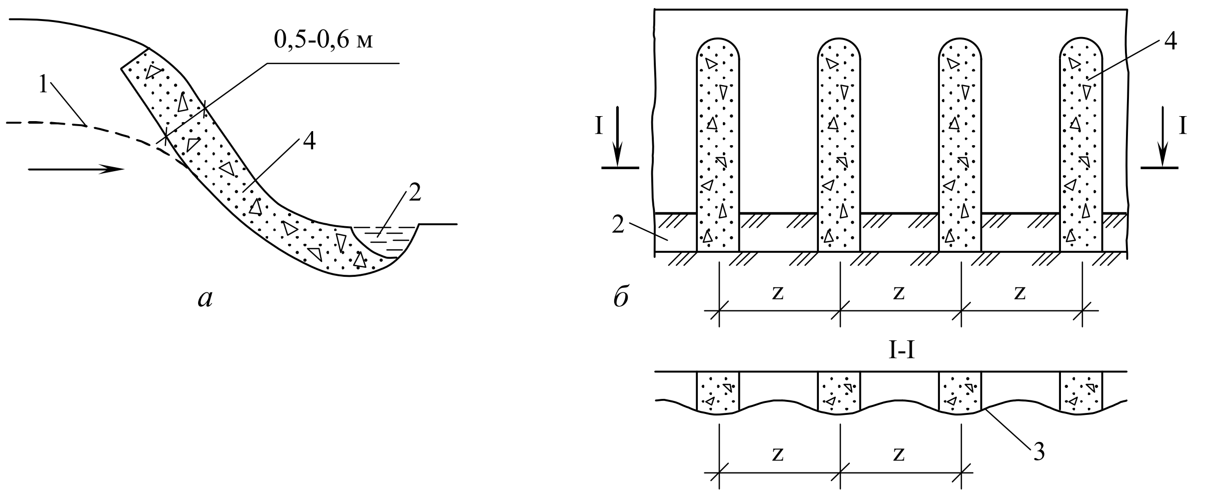


Fig. 3. Scheme of sloping drainage: a – cut; b – plan; 1 – level of ground water; 2 – spillage; 3 – reduced water level; 4 – gravel

In the earth's rocks are arranged so-called *return filters*. The danger of piping in the sand bases of concrete dams arises as a result of the presence of a difference in water pressure in the upper and lower parts of the dam, forming a significant hydraulic gradient. In order to prevent piping, the hydraulic gradient is reduced, extending the filtration path by arranging the plugs and barbed walls (Fig. 4).

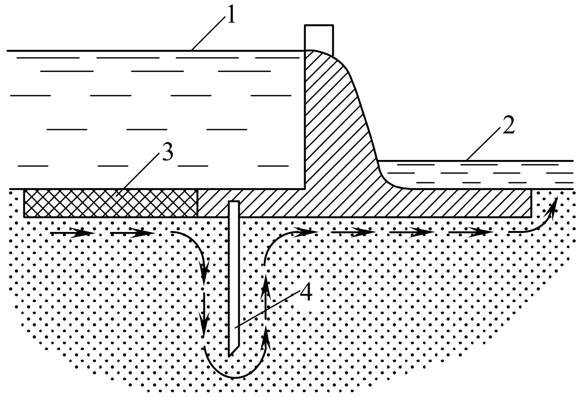


Fig. 4. Injectable concrete rocks on a sandy basis: 1 – the upper level of water; 2 – lower water level; 3 – pound; 4 – plywood wall

Piping in building pits occurs when open drainage. As a result of the removal of mineral particles from the soil, the foundation is weakened. This can cause the development of significant deposition of foundations. In addition, there is a collapse of the walls of the pits (Fig. 5). Therefore, open sewage is allowed only with a small flow of water into the pit. In other cases, excavation of trenches and laying of foundations is carried out by organizing water depletion, for example, by means of needle filtering plants. Filters are used in wells to protect water intakes from silting as a result of piping.

It should also be considered a special form of piping – *underground*. Under underground piping, the transfer of smallest and small particles of soils from one layer to another or from one part of the layer to another occurs. This causes changes in the grain composition of soils and their permeability.

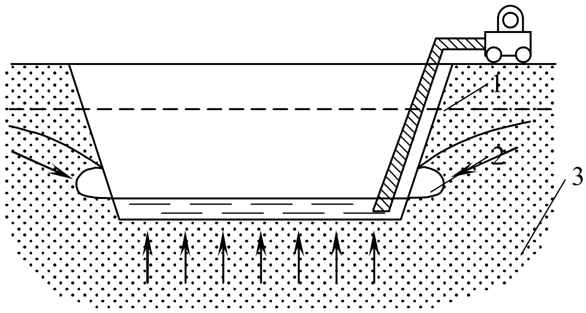


Fig. 5. Piping with open drainage: 1 – level of ground water; 2 – a niche; 3 – zone of weakening of the base

3. Karst

F. Savarensky under karst understood the consequences of processes associated with the activity of moving underground waters, which manifests itself in the dissolution of rocky soils and the formation of voids in them. The name "karst" is taken from the name of the limestone plateau on the coast of the Adriatic Sea. Karst is formed in the layers of limestone, dolomite, gypsum, anhydrite, rock and potassium salts. In karst processes there is a chemical suffusion, that is, the removal of matter in solutions. Chemical suffusion is sometimes supplemented by mechanical. It should be noted that the solubility of the abovementioned minerals is not the same. The highest solubility is found in rock and potassium salts, and the least are limestones and dolomite. For example, solubility of limestone (calcite $CaCO_3$) at t = 17° C is 11 mg / liter. With increasing content in water of free carbon dioxide (CO_2), their solubility increases. At a content of CO_2 equal to 6 mg / l, the solubility increases to 148 mg / g, and at 199.5 mg / l – to 455 mg / liter.

A similar picture is observed in other carbonates (dolomites, etc.). However, the solubility of carbonates increases significantly in the presence of ions in water HCO_3^-, Cl^- and SO_4^{2-}. Despite the low solubility of carbonates, carbonate karst prevails. At the same time, karst in gypsum and salt occurs relatively rarely, which is due to their characteristic occurrence (among clay) and the absence of fracture. Table 1 shows the classification of karts by A. Golovy.

Table 1. **Classification of karts by A. Golovy**

Karst group	Type of karst	Carte subtype
I (in difficult soluble rocks)	1. Carbonaceous	a) limestone
		b) dolomite
		c) chalky
		d) in fragments with carbonate cement
	2. Sulfate (gypsum)	—
	3. Sulfate-carbonate	—
II (in easily soluble rocks)	4. Salt	—

The typical carbonate karst is. The formation of karst occurs in this way. Rain, thaw and surface fluid flows into a layer of soluble soil through a grid of cracks. When moving in cracks there are voids – wells, galleries, tunnels and caves (Fig. 6). When encountering water taps, moving water accumulates, forming karst waters. Below the level of karst water, already saturated with the dissolved substance, dissolution does not occur. Thus, the level of karst waters is the basis of karst formation.

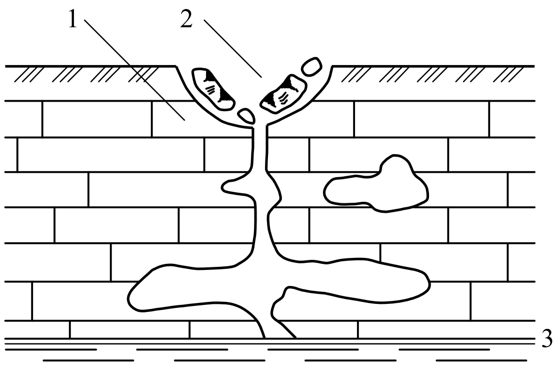


Fig. 6. Karst void in limestone: 1 – limestone; 2 – funnel; 3 – level of karst water

Depending on the position of the thickness with the void distinguish an open karst (the stratum is near the surface) and hidden karst (the layer is covered with insoluble soils).

All karst cavities begin at the surface, in places where the water reaches the water. Here on the surface of the surface are formed abrasions and furrow (curry). There is a peculiar karst relief.

Based on the experimental data Z. Makeev proposed to divide the strata by their resistance to karst formation, depending on the rate of formation of the pit, on 5 species. Thus, to very unstable strata were assigned thicker, where during the year there are 5-10 verves per 1 km^2, and to the strata are very stable – thicker, where new twists did not occur during 50 years.

Karst often causes circumstances that are unfavorable to construction. Especially great difficulties arise in hydraulic engineering. There have been cases where reservoirs could not fill up with water due to leakage of water into karst cavities. When a karst is placed between layers of clay or loam, the water can fill its void. In this case, there are no difficulties in the construction of buildings and structures. There are no difficulties even when thicker with voids, composed of hard-soluble soils (I group of karst), powerful, but there are no hidden (unpopulated) pits and cavities at a small depth. In other cases, construction is difficult.

The fight with karst consists, on the one hand, in the termination of access of surface and groundwater to a thicket on which buildings and structures are erected, and on the other – in increasing the strength (stability) of soils and reducing their water permeability. The latter is very important because the decrease in permeability reduces the intake of fresh water and the dissolution rate decreases. To stop access to surface water, the flow control is regulated by channeling it in the desired direction. To improve the strength and decrease in permeability, various properties of cracked water-soluble rocky soils are improved by various methods. At the same time they make cementation, clay, bitumen, and for temporary improvement – freezing.

4. Landslides

Landslides are called the displacement of the masses of soils on the slopes under the influence of force of weight. The general view of the displacement is shown in Fig. 7. The surface on which the soil was removed and displaced is called the *surface of the slip*, and the place of the exit of the surface of the slip on the surface of the slope or on the surface at its foot is the *sole of the landslide*. The sole offset does not always coincide with the foot of the slope. In some cases, the surface of the slide does not have a clearly defined position. This is possible in the case when the displacement of the mass of soils is associated with deformations of creep in clayey soils. The displacement of the soil forms the body of the landslide. In the upper part of the slope there is a landslide circus.

Landslides occur on the banks of the seas and lakes, on the slopes of river valleys, girders, ravines, on slopes of embankments and grooves. Thus, landslides can occur everywhere. But some districts are known as landslides, for example, the Black Sea coast near Odessa, the Crimea, the Caucasus, the Dnieper near Kiev and others.

Landslides cause significant damage to the national economy: hamper the construction, eliminate valuable land. Built on the slopes of the structure and structures due to landslides are damaged, and sometimes completely destroyed.

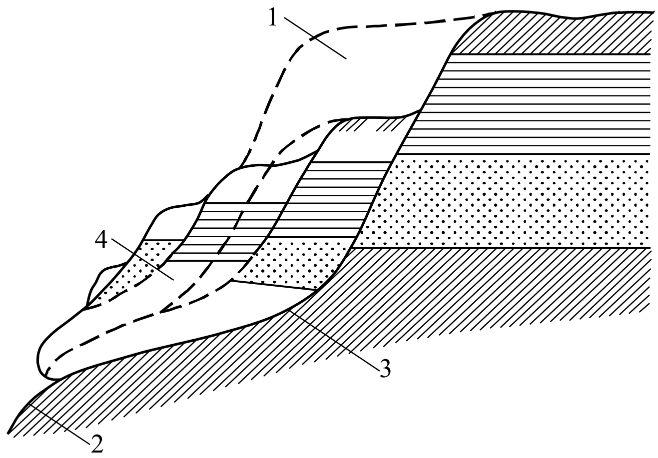


Fig. 7. General view of the andslide: 1 – landslide circus; 2 – the sole of the shear; 3 – the surface of the slide; 4 – body shift

The direct causes of landslides are many, but the main two:

1) a change in the stress state in the thickness of the soil forming the slope;

2) change of soil properties on the slope.

A change in the stress state can occur as a result of increased loads on the slope during construction, the arrangement of various types of masonry, the increase in the weight of the soil from moisture, as well as due to the violation of the integrity of the slope when it is washed by surface water, waves of the surf, when cutting the recesses for structures and structures, in particular for roads. In addition, the integrity of the slope may be disturbed by piping.

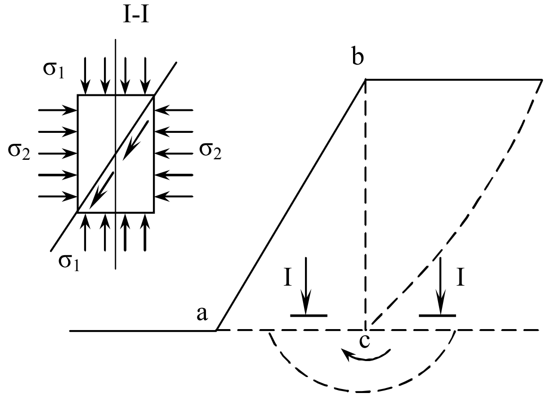


Fig. 8. Scheme of a stressed state on a slope

Why in these cases there is a change in the tense state? In order to clarify this issue, in the imagination we cut into the slope of the elemental prism of the soil (Fig. 8). The compression of this prism takes place in conditions of the impossibility of lateral expansion. Along the edges of the prism are the main stresses σ_1 and σ_2. A larger main voltage σ_1 acting on a horizontal platform is equal to the pressure from its own soil weight. The lower main voltage σ_2 acting on the vertical platform is equal to the side pressure soil. The destruction of such a prism can occur only at a certain ratio between the main stresses. This correlation occurs either with the increase of the main voltage σ_1 (increase of load on the slope), or with the reduction of the main voltage σ_2 (reduction of lateral pressure due to slipping or slipping). At a large steep slope near its sole (in the plane 1-1) there is a pressure drop that can cause the squeezing of the soil from under the foot of the slope.

The change in soil properties occurring on a slope occurs during weathering, wetting by surface and underground waters, under the influence of shock and vibration loads (for example, when piling the piles). Most often the violation of the stability of slopes is caused by soaking of clay soils with water, which reduces their resistance to landslides. It should also be noted that the reason for the landslides is the earthquake. During an earthquake, the stability of the slope may be affected by the direct effect on the thickness of the inertial forces.

The variety of causes that cause landslides complicates their classification. Many slider classifications are proposed based on various features.

F. Savarensky (1934) proposed the classification of landslides along the slope structure and the position of the sliding surface. He divided them into ascetic, consekvent and insectivent (Fig. 9). *Asecventic landslides* are formed on slopes with a homogeneous structure. They have a curved surface of the slip, which is approaching the cylindrical. The position of the surface of sliding in such displacements is determined by the peculiarities of the stressed state of the slopes and the value of the resistance of the lands of the landslide. *Consekvent landslides* are characterized by a surface of slip, the position, the outline of which is determined by the features of the structure of the slope. *Inspection landslides* occur on slopes where layers of different soils lie. The surface of slipping such shifts breaks these layers.

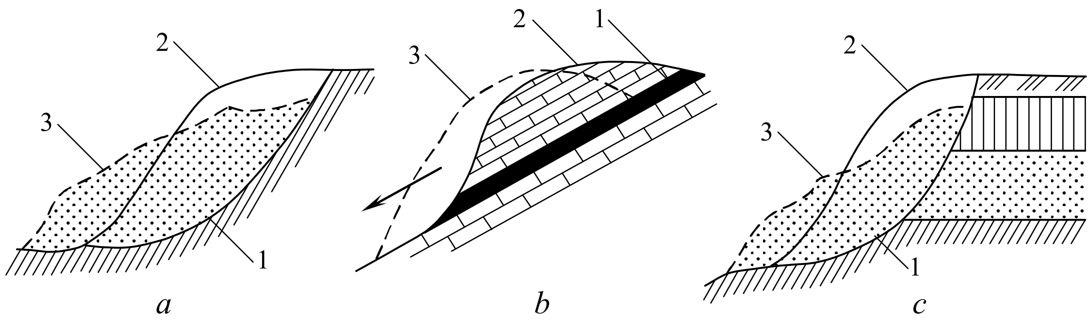


Fig. 9. Classification of landslides for F. Savarensky: a – asecctant; b – consekvent; c – insecent; 1 – clay; 2 – slope to shift; 3 – slope after shift

Fighting shifts requires a lot of effort and the use of different tools. Therefore, it should be done after careful and versatile study of landslides and determination of their species. Fighting offsets can be passive and active. The *passive struggle* consists of carrying out such preventive measures as the prohibition of trimming slopes and their development, limiting the speed of traffic on slopes, etc. *Active struggle* involves the construction of various engineering structures. Measures to combat landslides must be consistent with the causes that cause these landslides.

Fundamentals of hydrogeology

1. Types of water in pores of rocks

In pores and cracks in rocks, water is always found in a gaseous, liquid or solid state. There are various classifications of water types in rocks.

In engineering geology a classification was adopted, which was proposed by O. Lebedev (1930), and then refined in accordance with the latest ideas about the nature of water, the structure of its molecule and the nature of the physical-chemical interaction of water with mineral particles of rocks (Fig. 1):

1. Water in a state of steam (water vapor).
2. Free water:
   a) gravity;
   b) capillary.
3. Physically bound water:
   a) firmly connected – adsorbed (hygroscopic) water;
   b) weakly connected (film) water.
4. Water in solid state (ice).
5. Water in a crystal lattice of minerals (chemically bound):
   a) constitutional;
   b) crystallization;
   c) zeolite.

The water pair fills the pores of sand-clay and shingles, as well as the cracks and voids of rocky rocks. Here the air is usually saturated with a water vapor, that is, it has a relative humidity of 100% or close to it. Under the influence of changes in temperature and pressure, the vapor can condense and, conversely, liquid water turns into a pair. A water pair moves from places with higher temperature in places with lower temperature, where the elasticity of water vapor is less. Therefore, in the winter, the motion of the water vapor is directed to the upper layers of rocks, and in summer – on the contrary, deep into the ground. Thus, a couple of water in the pores of rocks is in a constant dynamic equilibrium with other types of water and with a pair of water in the atmosphere.

Free gravitational water – underground water, which moves in the pores and cracks of rocks under the influence of gravity. Gravity water has all the properties that are inherent in ordinary water: the ability to dissolve, transmit hydrostatic pressure, while driving, cause hydrodynamic forces that affect the mineral particles of rocks. The hydrostatic pressure of water in the pores of the breed reduces the weight of the skeleton of the breed in accordance with the law of Archimedes, and also creates a weighing pressure on the bottom of the foundations of structures constructed below the level of groundwater.

Free capillary water fills capillary voids and the finest cracks in the rocks. It rises from the level of groundwater upwards in capillary cavities under the influence of surface tension on the boundary between water and air, forming a zone of capillary saturation above the groundwater level and separating from the aeration zone with a capillary border. The height of the capillary rise in water reaches: in the sands of 0,15-1,0 m, in loams 2-4 m, in clay 5-20 m. Under certain conditions, water can fill capillaries, without direct connection with the level of groundwater. Such water, unlike capillary raised, is called capillary hanging.

The physically bound water is divided into tightly connected (hygroscopic) and weakly connected (film). Hydroscopic water is called water formed in the process of condensation of water vapor by adsorption by its mineral particles. Hygroscopic water is not exposed to gravity, does not transmit hydrostatic pressure, does not have the ability to dissolve the substance. It has a density of 1.7 t / m3 and does not freeze to a temperature of minus 78° C. When heating the rock to a temperature of 105°C, the hygroscopic water is completely removed.

There is incomplete and maximum hygroscopicity. With maximum hygroscopicity, water covers the whole surface of particles with a thin film in thickness up to 0.008 microns. Recent studies have made it possible to isolate two layers of tightly coupled water. A layer directly adjacent to a rock particle is usually observed at a humidity close to incomplete hygroscopicity. This layer of water (stationary over B. Deryagin) has a thickness of 1-3 molecules, consists of oriented molecules, while moisturizing gives heat. By its properties, this water is close to the solid. This layer of water has a clearly defined boundary that separates it from the next "upper" layer of the tightly bound water. The thickness of the upper layer consists of several molecules, the orientation of the molecules is less sustained, the heat at moisture is not allocated. This layer of water is still solvation, or osmotic, and corresponds to the humidity of the rock, equal to the maximum hygroscopicity. The maximum hygroscopicity depends on the size of the mineral particles from which the rock forms, and it is in sands – up to 1%, in loams – up to 7%, in clay – up to 21% by weight of particles. Hygroscopic water is not available to plants.

Film water, like hygroscopic, covers the surfaces of mineral particles of clay rocks with a film thickness of 0.25-0.5 µm. This water can also be separated from particles only by drying out. The formation of film water is not accompanied by the release of heat of moisture. Film water can move from particles with a larger film thickness to particles with a smaller film thickness, regardless of the effect of gravity. Its velocity depends on temperature, the ability to dissolve significantly lowered, freezes at a temperature below zero, does not transmit hydrostatic pressure.

According to O. Lebedev, hygroscopic water, together with the film, is called molecular water. The largest amount of such water contained in rocks is called *maximum molecular moisture content*. It is in the sands of 1-7%, in soups 9-13%, in loams 15-23%, in clay 25-44% of the mass of particles.

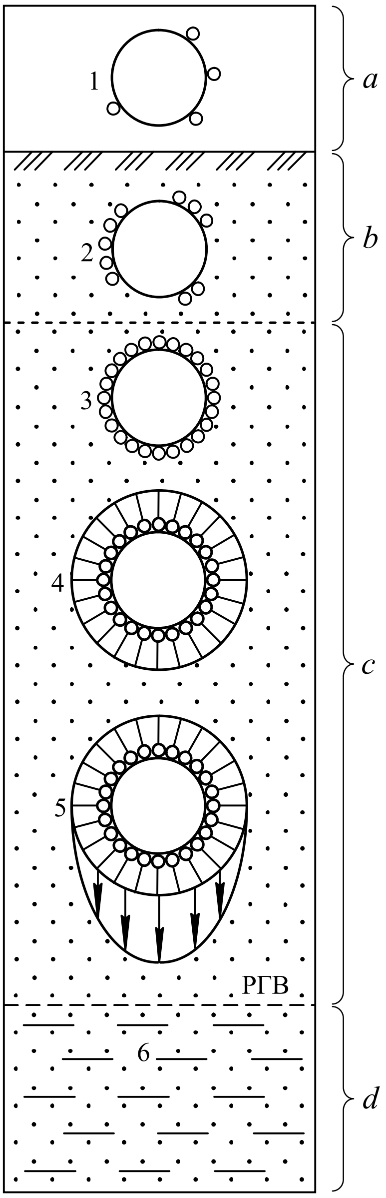
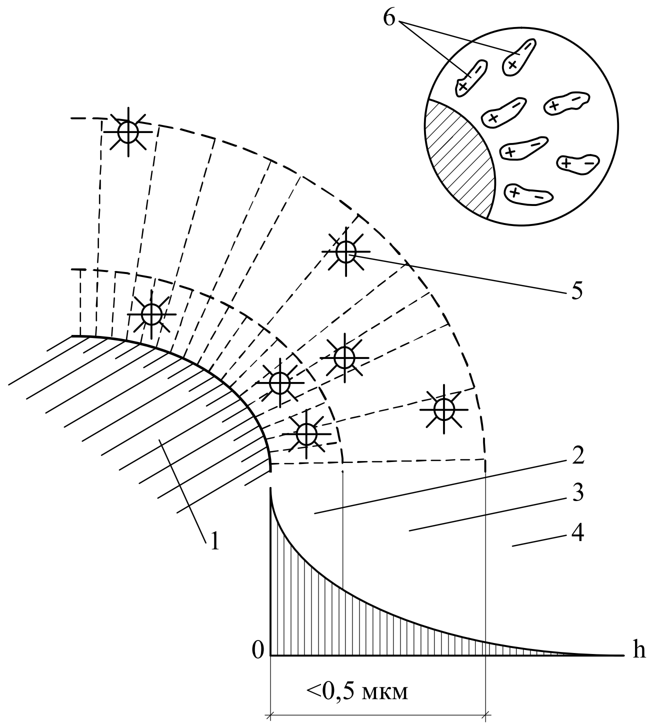


Fig. 1. Types of water in rocks: a – atmosphere; b – airborne and dry breed; c – wet rock; d – the rock is full of water; 1, 2 – particles with incomplete hygroscopicity; 3 – particles with full hygroscopicity; 4, 5 – particles with film water; 6 – gravitational

Fig. 2. Electromolecular forces in the system "mineral particle – water": 1 – mineral particle; 2 – hygroscopic water; 3 – film water; 4 – free water; 5 – cations; 6 – water dipoles



Molecular water is contained on the surface of the mineral particles by the electromolecular forces. The mechanism of action of these forces is as follows. The dielectric constant water is much larger than the dielectric constant of the mineral particles. Therefore, in the collision of a mineral particle with water, the particle receives a negative electric charge, and around it there is an electric field. At the same time, water molecules are dipoles with positive ions of hydrogen and negative oxygen ions. Getting into the electric field of mineral particles, dipoles of water are attracted to their surface and are oriented in the electric field in a certain way (Fig. 2).

So there are layers of bound water. The phenomena associated with the formation of hygroscopic and film water, appear more strongly than the smaller mineral particles. This is due to the fact that the total surface area of particles in 1 cm^3, or specific surface area, increases with a decrease in their size. If the side of the cube is equal to 1 cm, then the area of its surface is 6 cm^2, and if the size of the cube side is 0.0001 cm, the number of cubes in 1 cm^3 will be 10^{12} with a total surface area of 60000 cm^2 (6 m^2). This can be explained by the fact that the breeds, which contain even a small amount of clay particles, acquire the properties inherent in clay rocks.

What is the relation between bound and free water in rocks? In the sand, where the specific surface is small, most of the water is free. In clayey rocks – sandy loam, loams – almost all, and in clay all water is bound. Therefore, when designing water depletion, drainage and water intake, this should be taken into account. Thus, the arrangement of drainage in clay is ineffective because water, being connected, does not separate from mineral particles.

In the electric field of mineral particles there are not only water dipoles, but also cations of various substances, which orientate the water dipoles. Thus, one can speak of the shells of the water-colloid type around the mineral particles. Such shells play an important role in ensuring the interconnection of clay rocks.

Water in the solid state is formed at a rock temperature of less than zero when the gravitational and part of the bound water freezes and is found in rocks in the form of crystals, lenses, layers, veins, or large amounts of ice. Crystals of ice cement individual mineral particles, converting loose rocks in solid. Properties of rocks cemented with ice, sharply differ from the properties of marsh rocks. Studying their properties is engaged in a separate science – permafrost.

Constitutional water is part of the crystalline lattice of minerals in the form of ions H^+, OH^-, H_3O^+ and others, taking part in their structure, for example $Ca(OH)_2$. From minerals, hydroxyl groups can be removed only when heated to a temperature of 300º to 1000º C. With the destruction of the crystal lattice of minerals, the ions react with each other, forming water molecules.

Crystallization water is involved in the structure of the crystal lattice of some minerals in the form of molecules H_2O, such as gypsum $CaSO_4 \cdot 2H_2O$, mirabilite $Na_2SO_4 \cdot 10H_2O$ and others. This water can be removed, like constitutional, by heating (to a temperature below 300º C), which leads to the destruction of the crystal lattice and its rearrangement (for example, gypsum is converted into anhydrite).

Zeolite water is part of the crystallization water that can be released and re-absorbed without breaking the crystal lattice. It is part of the crystalline lattice of some zeolite minerals, which are representatives of water aluminosilicates.

2. Characteristics of underground water

At the very top of the earth's crust, which is most readily available for research and most interesting in terms of human economic activity, there are three zones that differ in the nature of underground water (Fig. 3). The upper zone between the earth's surface and the surface of groundwater is called the aeration zone. In it, in the pores of rocks, cracks and other voids are physically bound, capillary hanging water and water vapor. Part of the pore is filled with air. Sometimes the soil conditions contribute to the accumulation of groundwater on small lenses of waterproof or less permeable rocks due to the infiltration of rain and thawed waters. Such water is called a rattan. Characteristic features of it, in most cases, are relatively small area of distribution, seasonal existence, a small thickness of the aquifer and small reserves. However, sometimes the regiment's mode is characterized by relative constancy, and then its water is used for local water supply.

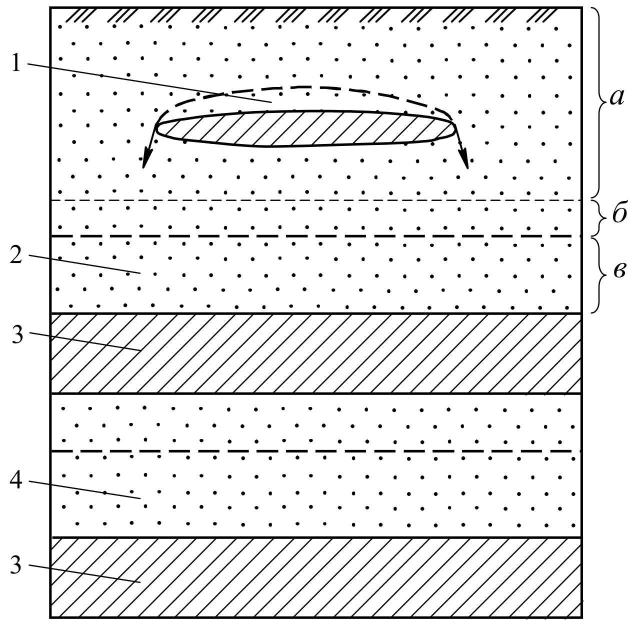


Fig. 3. Scheme of occurrence of non-pressure groundwater:
a – aeration zone; b – zone of capillary water; c – saturation zone; 1 – horseback riding;
2 – groundwater; 3 – a waterproof layer; 4 – interplastic water

The tipping point is not always detected during engineering and geological research, and as a result can damage the underground communications and premises.

Above the surface of groundwater is a capillary zone. In this area thin pores are filled with water, and more are free. The height of this zone is determined by the height of the capillary rise in the water in the breed.

The saturation zone is essentially a layer of groundwater, in which all pores are filled with water. Such a layer of soil is called an aquifer, the distance from the surface of groundwater to the waterproof layer determines the thickness of the aquifer layer.

Soil waters are called constant groundwater, which lie on the first from the surface of the waterproof layer. Such a waterproof layer – a vodka – can be a layer of clay or rock. In general, the concept of "waterproof" is relative. In nature, there are no soils that would not let water pass, just in the waterproof layers, this ability is less than a thousand or tens of thousands of times. Groundwater is usually located in layers of sandy, clayey, and shingles and has a significant horizontal distribution. Non-leaky waters in small, uniformly distributed cracks in the crust of weathering crust of rock formations belong to the soil. In this case, the water drain is a breed, not violated by the processes of weathering. The depth of groundwater fluctuates widely. In some places, it is more than 100 m, and in other groundwater they reach the surface, forming wetlands.

The groundwater is fed by the entire distribution area, mainly due to the infiltration of atmospheric precipitation and the condensation of water vapor. It is also possible to receive water from the year, lakes and other surface pools or the influx of water from deeper aquifers.

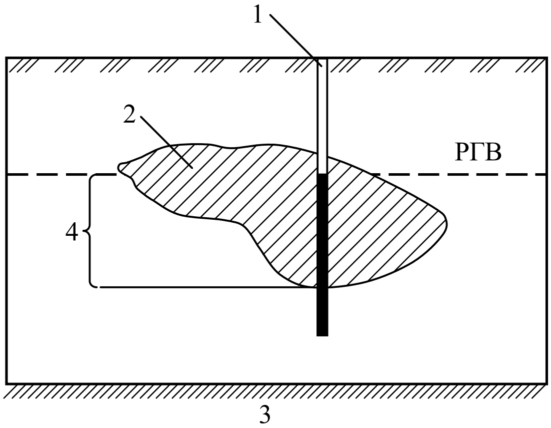


Fig. 4. Formation of local pressure in ground waters: 1 – well; 2 – local waterproof layer; 3 – a waterproof layer of an array; 4 – local pressure

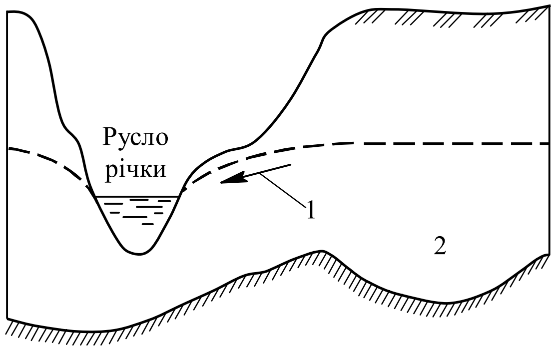


Fig. 5. Forms of occurrence of groundwater: 1 – flow; 2 – swimming pool

Ground water has a free surface, so they are not pressure, but in some places they can have local pressure, the emergence of which is visible from the Fig. 4. Typically, the groundwater surface has a weak wave character, often with a bias towards the nearest lowering of the relief. Depending on the inclination of the watercourse, the nature of the relief, water permeability of the layers and other reasons, groundwater is in motion, forming a *ground stream*. Areas with a horizontal surface of groundwater are called *groundwater basins* (Fig. 5).

Since the supply of groundwater flows is uneven, and the structure and composition of the aquifer rocks are heterogeneous, the flow of water in the stream is marked by variability.

The conditions of subsidence, feeding and movement of groundwater vary with time, therefore, their regime also changes. Under the *regime* understand the change in the position of the surface of groundwater, their physical properties and chemical composition under the influence of geological, climatic factors and human engineering activities. The main factor is the climate, namely rainfall and temperature.

In recent years, increasingly important human engineering activities. The construction of reservoirs, canals, massive buildings, etc. has a particularly great influence on the groundwater regime. Since the groundwater surface conditions change for a year or more, this determines the engineering and geological conditions for the construction of buildings and structures. Hence the need for a thorough study of the groundwater regime during engineering geological research.

On the features of the regime it is possible to isolate the groundwater of alluvial and glacial deposits, steppes and desert regions, intermontane basins, seafloor. The *groundwater of the alluvial deposits* is in the valleys of the rivers. These groundwater are connected with rivers. Ground water either feeds rivers or feed on them. For the rivers most of Ukraine is characterized by the fact that in the boundaries of the groundwater comes from them, and in the flood, on the contrary, the waters of the rivers replenish the reserves of groundwater. In the conditions of the arid climate of Central Asia, groundwater is fed by rivers. These features cause significant fluctuations in groundwater levels, which can reach 6 m or more. The capacity of the aquifers in alluvial deposits can reach tens or more meters, which allows them to make extensive use of these water for the needs of water supply.

Within the vast expanses occupied by *glacial deposits*, the main groundwater basins are found in water-glacial sands, gravel and pebbles. The water-bearing layers here are marked by considerable power and lie close to the surface. The water level ranges from 0.6-1.5 m. These waters are also used for water supply. The groundwater of the steppe and desert areas lie at a considerable depth, often forming closed pools. Usually the thickness of the aquifers is small and the water in them is very mineralized. In intermontane basins, groundwater is located in the sand, gravel, pebbles and clayey alluvial origin and is used for water supply and irrigation.

The groundwater of the seacoast is characterized by a mixed composition. Studies have found that fresh water, which feeds mainly due to infiltration of precipitation, at some depth, changes saltines. As a rule, the freshwater level is higher than the water horizon in the sea. The farther from the sea, the higher the level and the greater capacity of the reservoir of fresh water, deposited in salty waters.

Interplanetary is called underground water, which lies between two waterproof layers. Water resistant rocks, which underlie and overlap the aquifer, are called respectively a waterproof bed and a waterproof roof. Intermittent water can be non-slip and pressure. Non-leaky interplanetary water is found relatively rarely. As an example, it is possible to draw water from the extracorporeal aquifers of the Dnipro-Donets Basin.

When underground waters that lie between two waterfalls fill all the pores and voids of the aquifer and are under hydrostatic pressure, then they are called *artesian* (Fig. 6). Famous artesian pools that occupy vast expanses. For example, Dnipro-Donetsk – 350 thousand km^2. Large artesian basins contain several aquifers, separated by water-tight layers. As a result of such a characteristic occurrence, these waters, when exposed to the upper water-proof layer of wells, rise in them to the line of pressure, and in some places fountain. Waters of some aquifers of artesian basins are widely used for water supply. Prolonged use of artesian waters leads to a significant reduction in hydrostatic levels. Thus, the pool basins of Moscow, Paris, London decreased by 75-80 m.

Fragile names are groundwater, filling cracks and fractures of massive magmatic, metamorphic and rocky sedimentary rocks. These water can also be pressured and pressure-free. Water in the cracked part of the weathering crust belongs to groundwater, and water in cracks of soluble rocks – to karst.

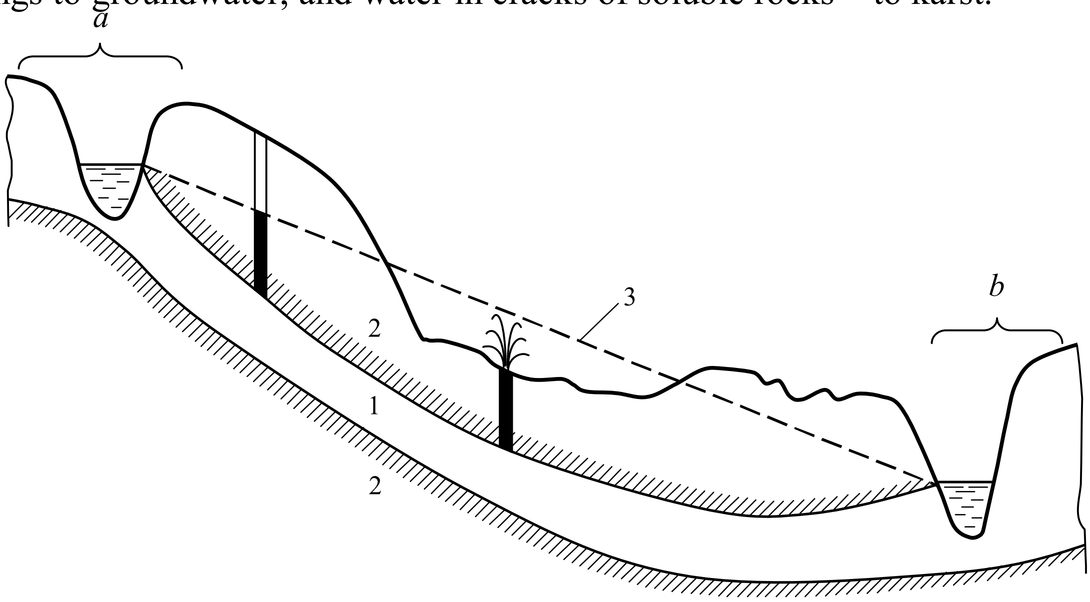


Fig. 6. Scheme of artesian waters: a – zone of feeding; b – unloading zone; 1 – aquifer; 2 – a waterproof layer; 3 – hydrostatic level

All underground waters in the permafrost zone are divided into over-burning, intermerged and submerged. The hydrophobic for such waters are frozen breeds. The main feature of over-frozen water and that they freeze in winter. Intermountain waters are called underground waters that lie between layers of frozen rocks. Often, they are pressurized due to ice pressure that freezes from the surface of the earth. Pressurized intermix water, which is fed by lower submerged artesian waters, often reach the surface in the form of sources with a flow rate of tens and hundreds of cubic meters per second.

3. Motion of water in rocks

Groundwater, as a rule, is in motion. *Non-gravitational motion*, characteristic of physically bound water, occurs in the zone of aeration in fine (clay) rocks. The movement of water in the pores of large-lobe, sand and clay rocks, as well as in cracks and fractures of rocky rocks is subject to the laws of gravity and is called filtration. In the case when separate streams of water move in parallel and at low speed, forming a continuous stream, the motion is called laminar. Such a movement is characteristic of water in the pores of rocks. In cracks and faults, the flow of water is characterized by high velocities and vortices and is called turbulent. In studying filtration, the French scientist A. Darsi in the middle of the XIX century constructed a device for studying the permeability of sand (Fig. 7).

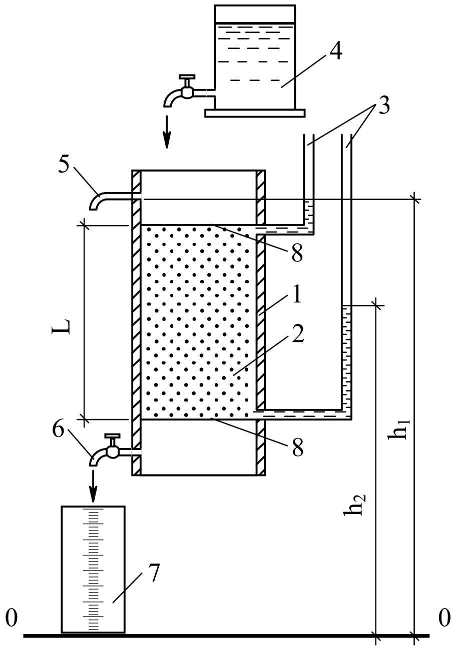


Fig. 7. The scheme of the Darcy device: 1 – working cylinder; 2 – sand; 3 – piezometric tubes; 4 – a tank with water; 5 – drain pipe; 6 – drain valve; 7 – measuring dishes; 8 – net

With this instrument Darcy in 1856 got such an addiction

$$Q = k_f \cdot I \cdot A \cdot t, \quad (1)$$

where Q – volume of filtered water; k_f – coefficient of proportionality, which depends on the type of breed; I – pressure gradient (hydraulic slope)

$$I = (h_1 - h_2)/L, \quad (2)$$

where h_1, h_2 – water pressure according to and after passing through a sample of soil, cm; L – length of filtration path, cm; A – filtering area, cm^2; t – filtration time, sec.

If we divide the left and right sides of the expression (1) on At, we obtain the formula for determining the filtration rate

$$q = k_f \cdot I. \quad (3)$$

This expression corresponds to the law of filtration under laminar motion – *the rate of filtration is directly proportional to the hydraulic displacement*. However, we must take into account that, using expression (3), we determine the fictitious velocity of water movement. The fact is that for the area of the cross-section of the flow A in this expression the area of the cross-section of the soil is taken, although in reality water only moves in pores. Therefore, the actual speed of water movement

$$V = q / n, \tag{4}$$

where n – part of the area that falls on the pores, in parts of the unit (equal to porosity).

If in expression (3) $I = 1$, then q will be equal to k_f, that is, the proportionality factor, which is also called the *coefficient of filtration*, and is a characteristic of the permeability of rocks. The coefficient of filtration is included in the calculation formulas for determining the flow of water to various water intake structures, as well as in the formula for calculating the deformations of the bases of buildings and structures in time.

The transition from laminar to turbulent motion occurs at the so-called *critical rate of filtration*. Experiments show that in coarse-grained sands this speed is greater than 400 m / s, respectively, the actual speed will be 1000 m / s (with porosity equal to 0.4). In natural conditions, the filtration rate does not exceed several dozens of meters per day, therefore, the theory of groundwater movement is basically based on the linear filtration law.

Water filtration at a rate exceeding the critical one occurs only in large cracks, karstic cavities and near artificial manifestations (mines, wells, shurfs) with a significant decrease in the level. Such a flow is characterized by dependence

$$Q = k_k \cdot \sqrt{I} \cdot A \cdot t, \tag{5}$$

where k_k – coefficient of permeability of the breed.

Accordingly, the rate of filtration

$$q = k_k \cdot \sqrt{I}. \tag{6}$$

Expression (6) is called the law of Chezia-Krasnopolskii – *with turbulent motion, the rate of filtration is proportional to the hydraulic displacement in power ½.*

7. Fundamentals of soil science. Part 1

1. Physical properties of soils

In building tradition **Soil –** is loose and rocky rocks and anthropogenic formations. Which use as the basis for buildings and structures, environment for underground structures and material for structures.

Further, we will consider only loose soils that differ primarily fragmentation, dispersion and porosity. **Fragmentation** – is a property, that soils consist of individual particles (grains), communication between them or nonexistent, or their strength is much lower than the strength of the particles themselves. **Dispersion** – is a property, that particles of the soil has different sizes. **Porosity** – is a property that particles are not completely fill soil volume, but there left space between particles, which occupied by gas and liquid.

The above characteristics largely lead the building properties of soils. Such as, porosity reduce under the load, which determines by the soils compressibility; permeability causes the filtration properties of soils; friction between particles during deformation occurs only at the points of contact of the particles, and it determine the strength of the soil massive.

Soils consider in close connection with the conditions of their formation. On land soil formation associated with eluvial, talus, proluvial, alluvial, eolian, glacial processes. Marine sediments accumulate at the bottom and in the result of the sea regression they appear on land.

In general, the soil has **three components (phases)**: solid mineral particles; liquid (water) and gas (usually air). The relationship between these components also leads to soil properties. If water fill-in all the pores in the soil, then it is a two-component (two-phase) system. Such soil call "soil mass".

Solid particles of soil characterized by size, shape and mineralogical composition. The size of particles lead to soil dividing into:

Large fragments	
blocks and boulders	200 mm
rubble and pebble	200…10 mm
gravel	10…2 mm
sandy	
large	2…0,5 mm
medium	0,5…0,25 mm
small	0,25…0,10 mm
thin	0,10…0,05 mm
dusty	0,05…0,005 mm
clay	0,005 mm

Liquid in the soil pores consists mainly of water and aqueous solutions. Content of the third component – **gas** in the soil depends on the pores amount and pores water filling. The more water in the pores, then there are less gases.

For quantitative estimation of the soil properties using several characteristic groups: classification; basic; derivatives. In accordance to ДСТУ Б В.2.1-2-96 (“Ukrainian normative document”) for the large fragment soils and sands **classification characteristics** are grain-size analysis and level of heterogeneity (for sandy varieties – also water saturation coefficient and density degree), for the clay soil plasticity index, liquidity index and sand content. By the volume of this characteristics establish name of the soil. Selection, packaging, transport and storage of soil samples performed in way to fully preserve state (structure, moisture content, etc.) of soil in natural conditions occurrence.

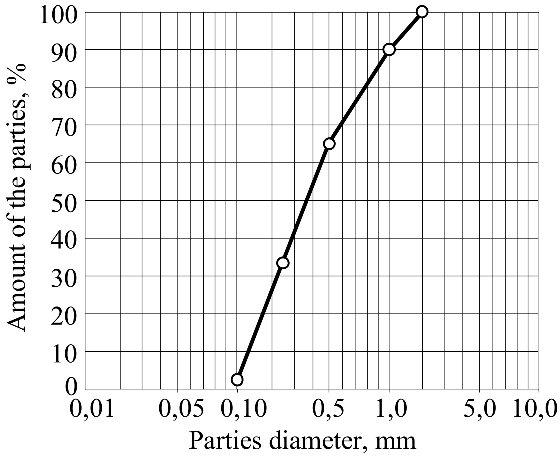


Fig. 1. Experimental curve of the sandy soil grain-size analysis

Grain-size analysis – is the proportion of different sizes solid particles in dispersed soils. For this estimation commonly used “Sieve analysis”. Which is sifting of the air-dry soil 100 gr through a set of sieves with holes of 10; 5; 2; 1; 0.5; 0.25; 0.1 mm with the following weighting of each fraction. Example of the sand grain-size analysis in Table. 1.

Table 1. **Example of sand grain-size analysis results**

Indicator	Sieve hole diameter, mm				
	2	0,5	0,25	0,1	bottom
	Fraction size, mm				
	> 2	2-0,5	0,5-0,25	0,25-0,1	< 0,1
Weight of the fraction, gr	10,5	22,6	32,8	30,9	3,2
Parties amount, %	10,5	22,6	32,8	30,9	3,2

Above data use for erection of the “**Experimental curve of the sandy soil grain-size analysis**” (Fig. 1). On this graph clearly shows the heterogeneity of soil structure. Bigger heterogeneity of the soil lead to the gentle curve on the graph. To quantify the heterogeneity of the large fragment soils and sand using the degree of heterogeneity of grain size (1)

$$C_u = d_{60} / d_{10}, \tag{1}$$

where d_{60}, d_{10} – parties diameter, mm, which less than soil contained respectively 60 and 10% (by weight) of the particles.

As C_u closer to the one, then degree of the soil uniformity higher by size distribution. When $C_u \geq 3$ soil classified as heterogeneous.

Plasticity index – is difference of the humidities, corresponding to the two states of the soil: the yield limit W_L and plasticity limit W_P

$$I_P = W_L - W_P. \tag{2}$$

Yield limit (**humidity at the yield limit**) – is soil humidity, when soil is at the border between elastic and liquid state. It corresponding to humidity of the dough, from soil and water when standard (polished steel) cone with a vertical angle of 30 ° in 5 seconds immersed in it to a depth of 10 mm.

Plasticity limit (**humidity at the plasticity limit**) – is soil humidity, when it is on the border between solid and plastic state. It meets the following humidity of the soil in the test, when soil rolled out in a cord with diameter of about 3 mm, and then cord begins to disintegrate into separate pieces length of 3-10 mm. Of course such test are quite inaccurate, but for engineering practice the accuracy of the values W_L and W_P is quite satisfactory.

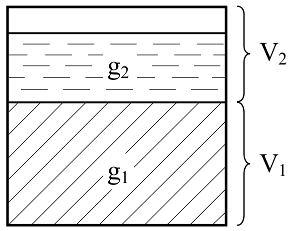


Fig. 2. Components (phases) of the soil sample

Liquidity index – is the ratio of the humidity difference, in two states of the soil, in the natural state W and at the plasticity limit W_P, to the plasticity index I_P

$$I_L = \frac{W - W_P}{I_P}. \tag{3}$$

The main physical characteristics: soil density ρ, soil skeleton density ρ_s, humidity in the natural state W – those characteristics determining directly from the experiments. Components of the soil sample show at the Fig. 2.

Soil sample conventionally divided into two parts: the first filling solid particles volume V_1, and the second filling pores volume V_2. Cavity (volume of pores) also is possible to divide into two parts, one of which is filling by water, the second part – is the air. The mass of the solid particles is m_1, and the mass of water – m_2 (air mass is not considered). Then the basic physical characteristics determined as follows.

Soil density – is the mass per unit soil volume. It determinate experimentally as the ratio of the mass of the soil sample to its volume

$$\rho = \frac{m_1 + m_2}{V_1 + V_2}. \tag{4}$$

Measurement units: g/cm^3 or kg/m^3. Determination of the soil density performs by the **method of cutting rings**. Mass and internal volume of these rings are known.

Firstly determinate mass of the ring with soil, then mass of the ring deducted, and the result divided by the internal volume of the ring. Soil density of the rocky sample is determined by **hydrostatic weighing** with previous covering of the sample by the paraffin.

Soil skeleton density – is the mass per unit solid particles volume. It determinate experimentally as the ratio of the mass of the solid particles to its volume, with help of the tool "density bottle"

$$\rho_s = m_1 / V_1. \qquad (5)$$

It depends only from the mineral composition of the soil. It's usually vary from 2,4 to 3,3 g/cm^3. As usual density of soil particles are: sand – 2,65-2,67; sandy loam – 2,68-2,72; loam – 2,69-2,73; clay – 2,71-2,76 g/cm^3.

Humidity in the natural state (Humidity) – is a ratio of the water mass to the solid particles mass

$$W = m_2 / m_1. \qquad (6)$$

In laboratory conditions the mass of water and solid particles determined by drying at 105° C.

Derivatives physical characteristics determinate by the calculation with use of the main characteristics, as usual. **Dry soil density** ρ_d – is ratio of the soil mass (without mass of water or ice) to its volume. Its determinate as the ratio of the solid particles mass to the volume of the soil sample unbroken structure between drying

$$\rho_d = \frac{m_1}{V_1 + V_2}, \qquad (7)$$

or by the next equation

$$\rho_d = \frac{\rho}{1 + W}. \qquad (8)$$

Measurement units: g/cm^3 or kg/m^3. It is used to evaluate soil consolidation. For example it use for quality control of the artificial foundation, sandy or soil embankments. As usual, clay soil compacted enough ρ_d=1,55-1,6 g/cm^3, sandy – ρ_d=1,65 g/cm^3.

Soil porosity n – is the ratio of the pores volume to the volume of the full soil sample

$$n = V_2 / (V_1 + V_2). \qquad (9)$$

The relative content of the solid particles per unit volume of soil indicate m and find ratio of the solid particles volume to the volume of the wholesoil sample

$$m = V_1 / (V_1 + V_2). \qquad (10)$$

Then

$$n + m = 1; \quad n = 1 - m. \qquad (11)$$

Measurement units n and m usually expressed in fractions of unity, sometimes as a percentage. Porosity of the not rock soils ranged from 0.3 to 0.5, but for loess and weak soils and it can be much higher values.

With use of the equations (5) and (8), is easy to get $m = \rho_d / \rho_s$, and take in to account (11), we get

$$n = 1 - \frac{\rho_d}{\rho_s}. \quad (12)$$

Porosity coefficient e – is ratio volume of the pores to the volume of the solid particles

$$e = \frac{n}{m} \quad \text{or} \quad e = \frac{n}{1-n}, \quad (13)$$

further

$$e = \frac{\rho_s - \rho_d}{\rho_d} \quad (14)$$

or, taking into account (8), we have

$$e = \frac{\rho_s(1+W)}{\rho} - 1. \quad (15)$$

From the determination of the coefficient of soil porosity may be obtained

$$n = \frac{e}{1+e} \quad \text{and} \quad m = \frac{1}{1+e}. \quad (16)$$

Porosity coefficient – is one of the most important parameter of soil, which is characterize the density of its structure (the smaller porosity coefficient, then density higher, and soil has better construction properties) and directly used in the calculations. For sand it is used as a classification index.

The concept of "porosity" and "humidity" of soil in some way related. We also introduce the concept of humidity that corresponds to full water saturation of the soil, therefore, when all pores are filled with water, – W_{sat}.

This value is usually called full **humidity of the soil**. Then according to (6) we obtain

$$W_{sat} = \frac{e\rho_w}{\rho_s}, \quad (17)$$

where ρ_w – water density, 1 g/cm^3.

The degree of soil pores filling by water is characterized by **water saturation coefficient** S_r, which is the ratio of the soil natural humidity to its full humidity

$$S_r = W / W_{sat}. \quad (18)$$

Substituting in place W_{sat} its value as (17), we find, that

$$S_r = \frac{W\rho_s}{e\rho_w}. \quad (19)$$

The coefficient of water saturation is measured in parts of the unit and it varies from 0 when soil is completely dry to 1 when soil pores is completely filled by water. The value of this parameter creates significantly impact on the changes in the properties of the sandy soil and it use as an indicator of their classification.

To calculate the weight of the soil using the following characteristics:

soil unit weight (N/cm^3 or kN/m^3)

$$\gamma = \rho g , \tag{20}$$

where g=9,81 m/s$^2 \approx$ 10 m/s^2 – acceleration of gravity;

solid particles unit weight (N/cm^3 or kN/m^3)

$$\gamma_s = \rho_s g ; \tag{21}$$

dry soil unit weight (N/cm^3 or kN/m^3)

$$\gamma_d = \rho_d g . \tag{22}$$

2. Classification of soils

According to “ДСТУ Б В.2.1-2-96”, the **classification of soils** includes such taxonomic units, which are allocated by groups of signs:

–*class* – by the general nature of structural relations;

–*group* – by the nature of structural connections (taking into account their strength);

–*subgroup* – by the origin and conditions of education;

–*type* – according to the material composition;

–*species* – by the name of the soil (taking into account the size of the particles and properties of the properties);

–varieties – by quantitative indicators of the material composition, properties and structure of soils.

The class of *natural rocky* soils includes soils with rigid structural bonds (crystallization and cementation).

The class of *natural dispersed* soils includes soils with water-colloidal and mechanical structural bonds.

The class of *natural frozen* soils includes soils with cryogenic structural bonds. The class of *technogenic (rocky, dispersed and frozen)* soils includes soils with various structural connections, formed as a result of human activity.

Engineering-geological characteristics of large-scale soils and sand. Unconventional soils are subdivided into varieties for: granulometric composition; coefficient of water saturation; degree of salinity D_{sal}; relative deformation ε_{fh}; temperature. Large-bay soils are divided into varieties by: the vibrational coefficient k_{wr}; coefficient of erasure k_{fr}; and the sands – according to the degree of heterogeneity of granulometric composition of C_u; coefficient of porosity; degree of density; relative content of organic substances I_r.

Varieties of large-scale soils and sand in *granulometric composition* can be determined from Table 2.

Table 2. **Varieties of large-scale soils and sand in granulometric composition**

Kind of soil	The size of grains, particles, *d*, mm	Factions content, %, from the mass
large-scale:		
boulder (with the vast majority of uncoated particles - deep)	> 200	> 50
pebble (with uncut faces – rubble)	> 10	> 50
gravel (at uncut faces - zhortvyyanny)	> 2	> 50
Sands:		
grave	> 2	> 25
coarse	> 0,50	> 50
medium coarse	> 0,25	> 50
grail	> 0,10	≥ 75
silty (dusty)	> 0,10	< 75

By the *coefficient of water saturation* S_r, unconnected soils are divided into varieties:

Low degree of water saturation	$0<S_r\leq 0,5$
Medium degree of water saturation	$0,5<S_r\leq 0,8$
Saturated with water	$0,8<S_r\leq 1,0$

By the *coefficient of porosity e* sands are distributed according to table 3.

Table 3. **Varieties of sands by the coefficient of porosity**

A variety of sands	Coefficient of porosity *e*		
	Sands are engraving, coarse and medium coarse	Grail sands	Sands are silty (dusty)
Dense	< 0,55	< 0,6	< 0,60
Medium density	0,55 – 0,70	0,60 – 0,75	0,60 – 0,80
Friable	> 0,70	> 0,75	> 0,80

Large sandy soils and sand, in general, are strong enough to absorb significant pressures from buildings and structures without losing strength (strength). The deformations of the same compression in them depend first of all on the degree of dispersion and the content of clay particles. The higher they are, the greater and more compression. Some large soils are practically inconsolable.

The settling of structures on such bases usually passes quickly and stabilizes with the completion of construction. As the density of these soils increases, their strength increases and compressibility decreases. When wet, their characteristics change slightly, with the exception of dusty sands, which often acquire pouring properties.

Engineering-geological characteristics of clay soils. Thixotropic-coagulation and crystallization-condensation (cementation) structural bonds exist between their mineral particles. The strength of these bonds depends on the degree of soil dispersion, their mineral composition, density, humidity, composition of the cementitious substance and other factors. Strength of structural connections is characterized by clutch.

Clay soils are divided into varieties for: number of plasticity; yield index; relative strain of swelling without load; relative deformation of subsidence; relative content of organic substances; degree of salinity; relative deformation of eating; temperature.

Clay soils according to the *plasticity index* I_P are distributed on:

Loamy sand	I_P=1-7
Loam	I_P=7-17
Clay	I_P>17

According to the *liquidity index* I_L, clay soils are distributed to:

Loamy sand:	
hard (stiff)	I_L<0
plastic	I_L=0-1
fluid (yielding)	I_L>1
Loam and clay:	
hard (stiff)	I_L<0
semisolid	I_L=0-0,25
low-plasticity	I_L=0,25-0,50
high-plastic	I_L=0,50-0,75
fluid-plastic	I_L=0,75-1
fluid (yielding)	I_L>1.

Compressibility of clay soils also varies widely. In addition, this process is much longer than in sandy and large-scale soils. Therefore, the settling of structures on such bases is usually not stabilized during the construction period, and continue during the period of operation, sometimes even decades.

It should also be added to this that the structural properties of clay soils are very significantly influenced by the rate of their fluidity – with different values of I_L they have different strength and deformability characteristics.

8. Fundamentals of soil science. Part 2

1. Phases of the stress state of the soil

Consider **ground deformation process of the soil massif from action of local workload growing.** For this purpose ground hard stamp (foundation) place, under which from the foundation base ground pressure is transmitted on the soil massive σ (Fig. 1, a). Under stamp influence subsidence S is occur.

On fig. 1, *b* shown soil deformation curve of on the action local growing workload $S=f(\sigma)$. There is possible to divide three parts (phases): *oa, ab, bc*. While external pressure did not exceed the structural strength of soil σ_{str}, soil sensate small (elastic) deformations. After pressure exceeds σ_{str} under the stamp soil consolidation occurs by reducing its porosity. With load increasing, soil has consolidating in the increasing area (Fig. 1, c). Impact of the tangential stresses τ is almost unnoticed. Soil grains moving down with insignificant deviation away from the vertical axis. Area of the soil deformations extends to significant depth, much larger than the width of the stamp. Bigger density of the soil lead to the bigger area of the soil grains moving. Soil deformations $S=f(\sigma)$ correspond to the section *oa* (Fig. 1, b). Depending from pressure on soil and deformations is directly. In the same time in soil under the edges of the stamp where concentration of stresses, there is developing plastic deformation (shifts deformation). Depending $S=f(\sigma)$ is going to be curve line. But still with relatively low pressure, which is usually under the foundation base, this graph

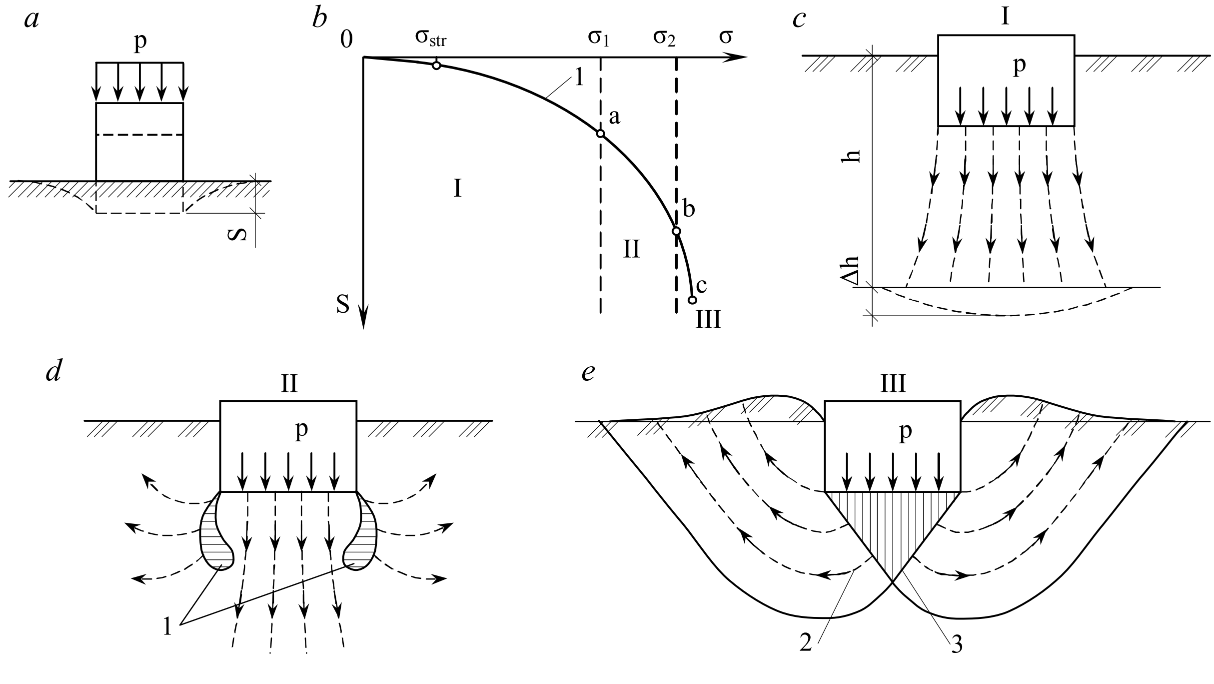


Fig. 1. Scheme of the deformation development in soil massive from action of the local workload growing: *a* – test of the soil by stamp; *b* – graph of stamp subsidence from pressure under foundation base; *c* – phase of the consolidation and local displacements; *d* – phase pf the development the intensive deformation shifts and consolidations; *e* – phase soil bulging 1 – area of shift; 2 – slide line; 3 – consolidated core

can be approximated by a straight line. This phase of the soil base stress state has call **local shifts and soil consolidation phase**.

From the soil strength point of view this phase – is safe, because soil gets bigger structural density, and subsidence development is reducing in time. In practical needs depending *S=f(σ)* usually is taken as straight line. This give an opportunity for calculation of stresses and subsidence, in the phase of soil consolidation, theory of linear deformities environment apply. The pressure corresponding to the border between phases I and II, it is call **the first critical pressure**.

Further increasing of the load on stamp lead to the plastic deformations areas development outwards and soil consolidation around these areas (Fig. 1, d). Shift areas increasing.

This is – **intensive shifts deformation development and soil consolidations phase**. Section *ab* corresponding to this phase. Some of the shift areas gradually connected, it create solid sliding surface under the stamp.

Compacted core is full formatted when soil attain maximal bearing capacity (Fig. 1, e). Core has started to formatted under the stamp during the two previously phases. Further core is constant. It is moving with stamp, it is working as wedge, core moving soil outwards and it is lead to the great stamp subsidence. Pressure that is correspond to the border of the II and III phases, is – **second critical pressure** or **soil base bearing capacity limit.**

Finally, under some pressure stamp sharp subsidence happened with soil outwards and upwards bulging. Almost vertical section *bc* appear on the curve *S=f(σ)*. It is correspond to the **soil bulging (destruction) phase**. In this stress state lateral displacement of particles is dominating, solid sliding surface develop, soil massive stability loss is happened (Fig. 1, e).

On practice soil bulging usually occurs sharply and it has catastrophically character. Soil base destruction occurs, foundation and over ground structures receives emergency deformations. For great eccentricities is possible soil unilateral bulging on surface and significant buildings lurch. Transkonsyi elevator failure is a classical example (Fig. 2).

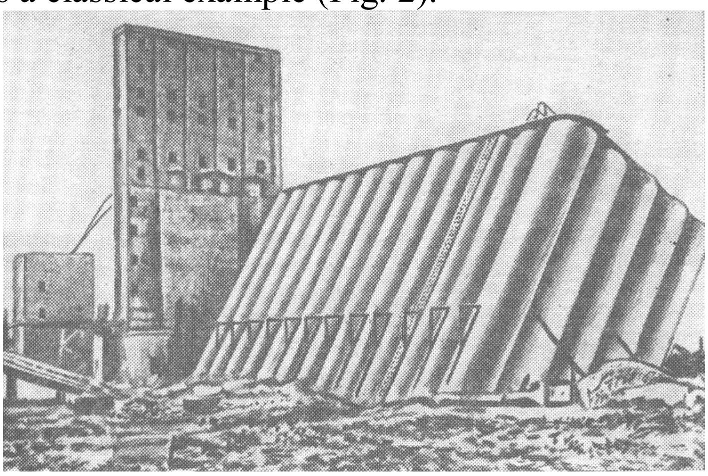


Fig. 2. Transkonsyi elevator failure by unilateral boundary subsidence 8.4 m in complete loss of stability of foundations (III phase – bulging)

2. Mechanical properties of soils

General characteristics of the soil mechanical properties. Calculations of the deformations, strength and stability estimations of the soil bases and foundations is possible to provide only by definition of the **soil mechanical properties**. Mechanical properties of soil are – properties that determine soil behavior as a mechanical system. It is explain mechanical movements of the soil massive and its parts in space and time under the influence of various external factors. The indicators of mechanical properties are directly determine the amount of deformation and strength of soils. It is called characteristics **deformability (compressibility) and strength**.

Compressibility is – the most characteristically property that separate soil from solids material. Compressibility is conditionally by reasons: consolidation under loading, which is lead to reducing of the porosity coefficient; elasticity of the crystal lattice of mineral particles; changes in the physical state (drying, coagulation, etc.). Normal stresses lead to deformation and changes in pores volume in disperse soils. **Consolidation (compression) law** is describing these processes. Lateral extension occurs in the soil (as in the solid bodies) under normal stresses

Soil strength – is property to accept influence of external forces without complete destruction. **Ultimate strength** – is the limit, above which almost complete destruction occurs. Soil can't accept an additional force that is applied to it. Soil satisfies strength condition, if **forces** are lower than the strength limit. **Shearing** forces lead to shearing deformations (shift). Shear resistance at the limit stress state is most important to the designer. It is characterizes soil strength and its carrying load (bearing capacity). It is determined in accordance with the law of soil shear resistance (**Coulomb's law**).

Compressibility properties determination. Soil consolidation is combines, pores volume changing, particles, water, gas compression; deformation of the consistent water; gases dissolving in the water; relative displacement and destruction of the structural units and other. But for engineering practice compression deformation occur **only by reducing of the soil pores volume**.

In the laboratory soil compressibility is usually determined by their consolidation under static loading without the possibility of lateral extension (steel ring). Under such load deformations are developing only in one direction. Research is performing in **compression device (odometer)** (Fig. 3).

Soil element 1, in ring 2 is installed on the bottom 3. On the top of the sample is stamp. Load transfer through the stamp in 5 steps F, which is lead to the compressing stresses $\sigma=F/A$, where A – area of the ring cross section. Thin holes are in the bottom. It is for the pores water flowing out during. Or, conversely, it is used for water direction to the soil if necessary (For example in the collapsible properties of the soil studying).

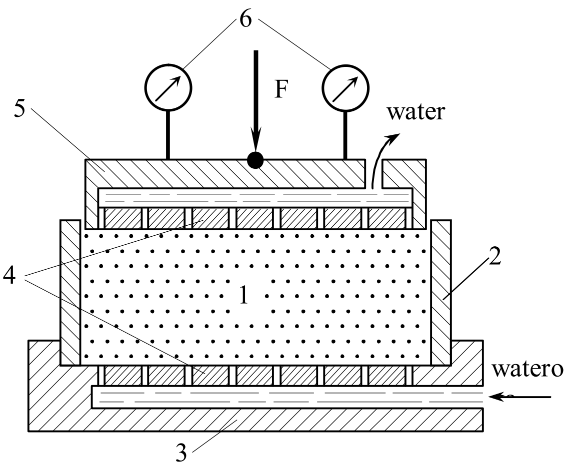


Fig. 3. Odometer for soil compression tests: 1 – soil sample; 2 – steel ring; 3 – bottom; 4 – thin holes; 5 – stamp; 6 – indicators of deformations

Under force *F* stamp is vertically moving. – it is consolidations. Indicators 6 are definition it's value. Diameter of the ring should exceed its height in three times, to reduce influence of the friction force on the walls of the soil sample rings.

Experiments is performing by pressure applying in stages, usually $\Delta\sigma$ = 0,01-0,1 MPa (depending on the natural state of the soil).

Load on every stage is stand to the conventional deformations stabilization "ДСТУ Б В.2.1-4-96": 0.01 mm for the last 4 hours for sand, 16 hours – for clay soils.

Because the sample in the ring is unable to lateral expansion, changing its porosity Δn_i under pressure p_i, distributed in area *A*, find the expression

$$\Delta n_i = \frac{\Delta hA}{hA} = \frac{\Delta h}{h}, \quad (1)$$

where *h* – soil height; *Δh* – deformation from compression p_i (Fig. 4, *a*).

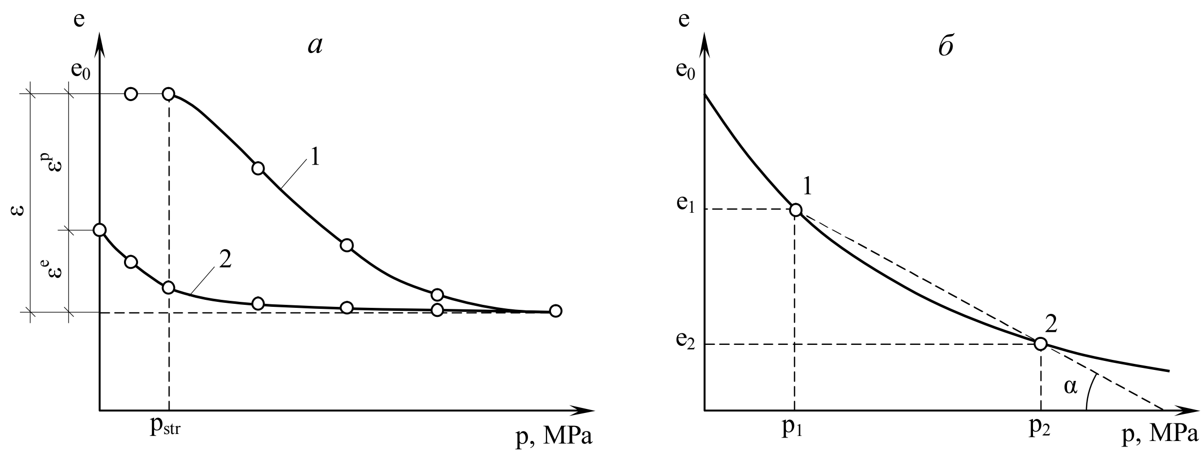


Fig. 4. Compression curve: a – general view (1 – loading; 2 – unloading); б – calculation model for determining the relative compressibility coefficient

The volume of solid particles in the soil sample before and after deformation remains almost unchanged. Because existing tension can not significantly change the amount of mineral particles. This volume per unit volume of soil sample is

$$m = 1/(1+e_0), \quad (2)$$

where e_0 – initial porosity coefficient .

By dividing of the equation (1) on (2), we obtain formula for determining porosity coefficient changing Δe_i from pressure p_i

$$\Delta e_i = \frac{(1+e_0)\Delta h_i}{h}. \quad (3)$$

Excluding Δe_i from initial porosity coefficient e_0, we will find e_i – porosity coefficient under pressure p_i

$$e_i = e_0 - \frac{(1+e_0)\Delta h_i}{h}. \quad (4)$$

By this formula you can count porosity coefficient for any applied pressure. After receiving of the experiment values e_i for different pressure p_i receive depending $e_i=f(p_i)$. It is **compression curve**. General view is on the Fig. 4, a. During pressure growing porosity coefficient is reducing (**loading curve (compression**) – curve 1 on Fig. 4, a). If pressure reducing then porosity coefficient is partially growing (**unloading curve (decompression**) – curve 2 on Fig. 4, a). Initial sample height *h* after decompression would not be fully restored, because during the decompression only elastic deformations ε^e is restored, and final deformation ε^p is irreversible.

There is section of the compression curve on the Fig. 4, a, where depending of the porosity coefficient from pressure is close to linear. It is specially to the clay soils. It's limit corresponds to the **structural strength of soil** p_{str}, it is caused by bonds between the particles of the soil skeleton. It is provides ability to withstand a certain load before the destruction of its skeleton. Under pressure lower then p_{str}, in soil occur only elastic deformations. Sharp break of the compression line corresponds to the structural strength of soil. Its value usually 0,01-0,05 MPa for weak saturated clay soils; 0,15-0,20 MPa for unmoisture collapsible soil.

If we restrict ourselves small changes in pressure (p=0,1-0,3 MPa), which usually occurs in the foundations of buildings, then the pressure range compression curve conditionally replace straight (Fig. 4, b). Its tangent of its angle to the axis of the pressure *p* is a quantitative measure of the soil compressibility – **coefficient of compressibility** m_0

$$m_0 = tg\alpha = \frac{e_1 - e_2}{p_2 - p_1}, \quad (5)$$

or

$$e_1 - e_2 = m_0(p_2 - p_1). \quad (6)$$

By differentiating equation (6), we obtain

$$de = -m_0 dp\,. \qquad (7)$$

Equation (7) is very important for soil mechanics, and its basic provisions, such as the principle of linear deformation and soil consolidation. It reflects the law of soil consolidation, **infinitesimal change in soil pore volume is directly proportional to the infinitely small change in pressure**.

In calculations of soil subsidence also often use **relative compressibility factor** m_v

$$m_v = m_0 /(1+e_0)\,. \qquad (8)$$

Parameters m_0 and m_v meet the conditions of soil compression without the possibility of lateral expansion. But, in fact, soil foundations have opportunities for horizontal movements. Therefore, to reduce the impact of this inconsistencies on the accuracy of the subsidence foundations designers use compression **deformation modulus**, which is determined by the expression

$$E = \beta / m_v \quad \text{or} \quad E = \frac{1+e_0}{m_o}\beta\,, \qquad (9)$$

where β – coefficient which takes into account absence of the transverse expansion in soil compression device, it is calculated by the formula

$$\beta = 1 - \frac{2\nu^2}{1-\nu}\,, \qquad (10)$$

where ν – **coefficient of the soil transverse deformation (Poisson's ratio)**, it is ratio of transverse and longitudinal deformations absolute values for one axial compression of the sample without lateral expansion limitation. It is determined by the results of tests in three-axis compression devices. In the absence of experimental data Ukrainian normative document “ДСТУ Б В.2.1-4-96” allow to take ν: 0,30-0,35 – for sand and sandy loam; 0,35-0,37 – for loam; 0,2-0,3 for I_L<0; 0,3-0,38 for 0≤I_L≤0,25; 0,38-0,45 for 0,25<I_L≤1,0 – for clays. Lower value of ν takes at higher values of the soil density.

For ordinary soil E=5-50 MPa, for a weak soils E< 5 MPa.

Most real stress-strain state in the soil massive corresponds to the test in a **three-axis compression device (tri-axial).** Soil samples have cylindrical (sometimes cubic) form. Model of the **tri-axial** shown in Fig. 5, a, stress state of the soil sample in the **tri-axial** – in Fig. 5, b. Cylindrical soil sample (1) with highness h is in rubble cover (2). Firstly it is subjected to the lateral compression of the liquid 3. Water is filling the working chamber of the device, creating in soil side pressure $\sigma_2=\sigma_3$.

After from piston rod 4 to stamp 5 is applied vertical load F in steps. Pressure creating normal tensions σ_1 in the sample. Pressure measurements in the chamber of tri-axial perform by manometer, absolute vertical deformation Δh_i of the sample measures by indicators.

Tension σ_1 is **maximal main**, σ_2 and σ_3 **minimal main.** Increasing σ_1, we can achieve the destruction of the sample. Accordingly to the soils test results in the tri-axial is possible to determine deformability and strength characteristics.

Soil sample cross-section is changing A_i during the test, it is determine by formula

$$A_i = A/(1-\varepsilon_1), \qquad (11)$$

where A – initial cross-section area; ε_1 – the vertical relative deformation of soil sample, which is $\varepsilon_1 = \Delta h_i / h$.

Tension value σ_1 is determined as

$$\sigma_1 = \frac{F}{A} + \sigma_3(1 - \frac{A_c}{A}), \qquad (12)$$

A_c – piston rod cross-section area.

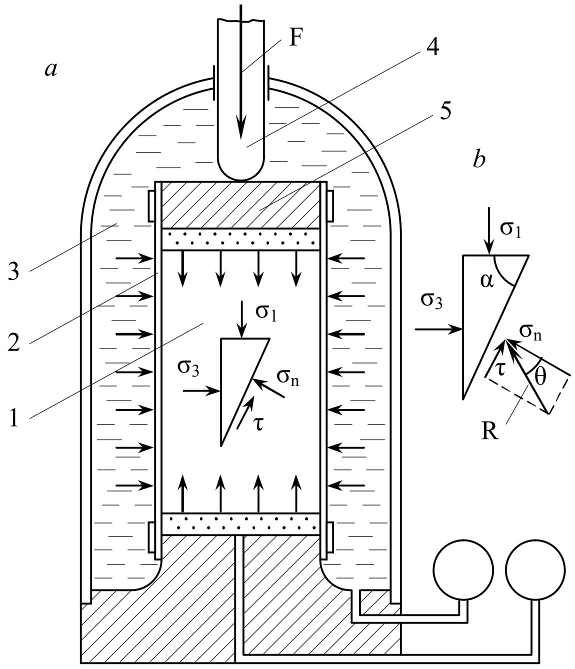


Fig. 5. Model of the three-axis compression device (a), the stress state of the soil sample (b)

Graph of the relative vertical deformation ε_1 of the sample from the tension σ_1 is building. As example Fig. 6 there is a graph linear *OA* and nonlinear *AB* area. Point *A* coordinates $\Delta\sigma_1$ and $\Delta\varepsilon_1$. Soil deformation modulus in the conditions of the tri-axial stress is

$$E = \Delta\sigma_1 / \Delta\varepsilon_1, \qquad (13)$$

and coefficient of the soil transverse deformation (Poisson's ratio),

$$\nu = \Delta\varepsilon_3 / \Delta\varepsilon_1, \qquad (14)$$

where $\Delta\varepsilon_1$ and $\Delta\varepsilon_2$ – increasing of the soil sample relative normal and lateral deformations

$$\Delta\varepsilon_3 = (\Delta\varepsilon_v - \Delta\varepsilon_1)/2, \qquad (15)$$

where $\Delta\varepsilon_v$ – increasing of the soil sample relative volume deformation (the relative volume deformation of the sample is $\varepsilon_v = \Delta V / V$, where ΔV – absolute volume deformation; V – initial volume of the sample).

The most accurate but costly method of soil deformation characteristics determining is field testing by static loads in the pits is stamp with 2500-5000 cm^2 area, or in the boreholes by screw stamps with area 600 cm^2 stamps. Fig. 7 shows the tool for static testing of soil in the of the pits anchor design by stamps.

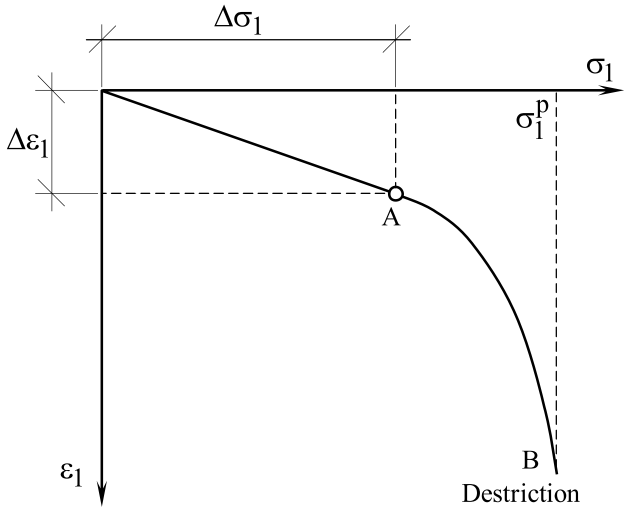


Fig. 6. Graph of the soil sample relatively vertical deformation ε_1 from stresses σ_1 on the results of soil tests in triaxial

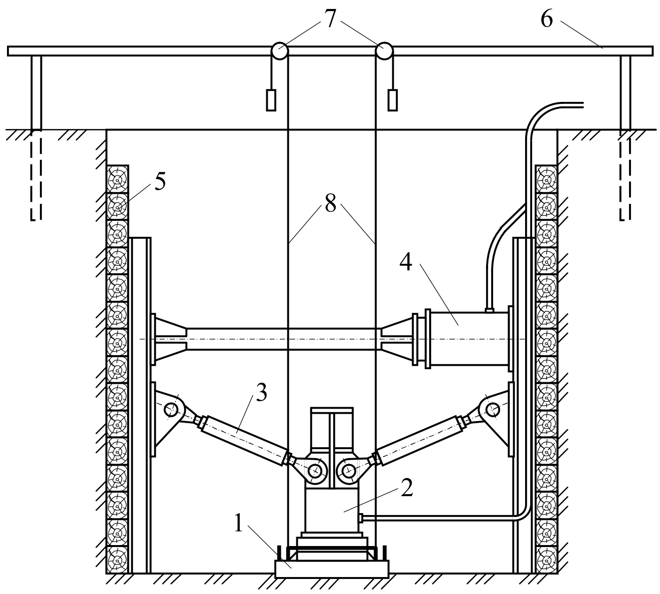


Fig. 7. Model of the tool for soil stamp test in the anchor design pits: 1 – stamp; 2 – jack for stamp loading; 3 – screw supports; 4 – jack for expansion-support; 5 – support of the top; 6 – geodesic system; 7 – tool for deflection measurement; 8 – rod

Soil test by static load is performed by pressure creating in few steps. Steps value accept from 0,025 to 0,1 MPa in accordance with soil type and its state. Each pressure step stands until stamp settlements are stabilizing. The stabilization is reached, if the settlements increasing for 1 hour for sandy soils and 2 hours for clay are less than 0,1 mm.

During the experiment, the value of stamp settlements measure with two deflection measure tools. Measure tools connect to the stamp with help of the rod with diameter near to 0,3 mm. arithmetic mean from two measurements take for calculations. Therefore, build graph of the settlement from pressure (Fig. 8). Deformation modulus is determined in the section where is a linear dependence of the settlement from the pressure

$$E = \omega(1 - \nu^2)b\frac{\Delta p}{\Delta S}, \qquad (16)$$

where ω – dimensionless coefficient adopted for round stamp 0,8; ν – lateral expansion coefficient; b – stamp diameter, cm; Δp – pressure increasing, MPa, $\Delta p = p_n - p_1$; ΔS – stamp settlements increasing, cm, $\Delta S = S_n - S_1$.

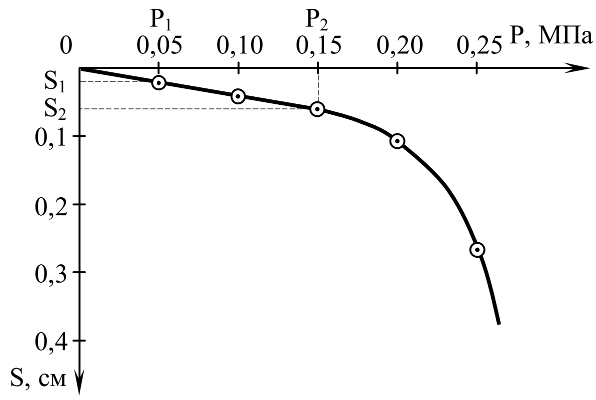


Fig. 8. Graph of the stamp subsidence from the pressure

Strength properties. Coulomb's law. In the laboratory conditions in accordance to the "ДСТУ Б В.2.1-4-96" strength properties determined by **tests for direct shearing** in the corresponding device (Fig. 9). This is the same compressive device (Fig. 3).

In device metal ring is divided into upper part, which can move under the influence of horizontal (shearing) force *Q*, and a lower, fixed, part. Between these parts of the ring set period 0.5-1 mm, there giving the plane on which will shearing the moving parts from a fixed sample.

Similarly, to the compression test, on the sample in the ring, through the stamp pass compressive (normal) force *F*. Horizontal movement of the upper part of the sample Δℓ is record by indicator, which is installed on top of the device (Fig. 9).

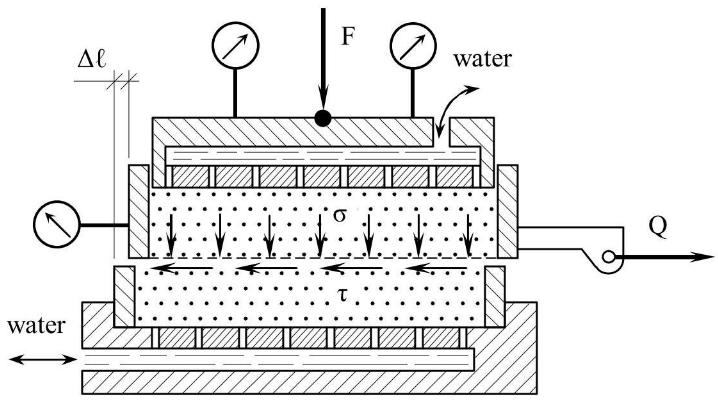


Fig. 9. Model of the device for testing soils for direct shift

To establish the relationship between the shear resistance $\tau=Q/A$ and vertical tensions $\sigma=F/A$, where A – cross sectional area of the sample, experiment conducted at several vertical stresses that is standing fixed for the one experiment. Load Q is applied in steps, until shearing (or movement $\Delta\ell$ does not exceed 5 mm). After the test we can build graph in the coordinates "shear resistance τ – movement (displacement) $\Delta\ell$" (Fig. 10, *a*). This graphic determine the limiting shear resistance τ and the results of a test series is data to build another graphic in coordinates "shear limit resistance τ – vertical stress σ" (Fig. 10 b).

Researches to sandy soils shows that in the usual borders of the stresses under the foundation ($\sigma\leq$0,3…0,5 MPa), depending between shear resistance τ – vertical stress σ is possible to approximate in the straight line from the coordinates origin (Fig. 10 b). Then this depending is represented by the next equation

$$\tau = \sigma tg\varphi, \qquad (17)$$

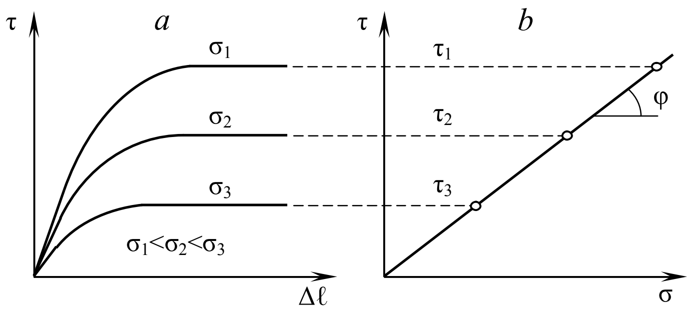


Fig. 10. Graphics of the sandy soil shear resistance: a – deformations under shearing; b – limit resistance under shear

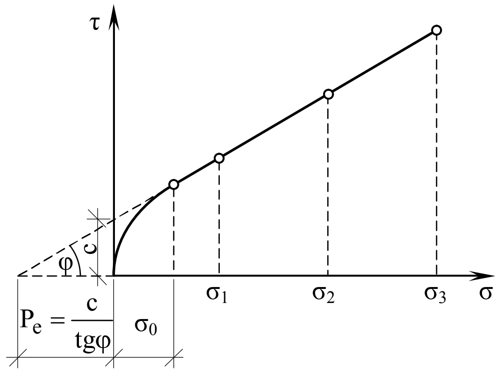


Fig. 11. Graphics of the clay soil shear resistance

where $tg\varphi$ – **coefficient of internal friction** sandy soil; φ – **angle of internal friction of the soil**.

Depending (17), is the law of **the sandy soils shear resistance**: *ultimate (limit) shear resistance of the sandy soils is directly proportional to the external normal pressure*. This is **Coulomb's law for the sandy soils**.

Researches for the clay soils have some complicated curve depending. Especially it is characteristically at the initial stage σ_0. Depending $\tau=f(\sigma)$, presented at the Fig. 11.

But for stresses σ=0,05…0,5 MPa depending is almost straight, so we obtain

$$\tau = \sigma tg\varphi + c, \qquad (18)$$

where c – **specific clutch of soil** – it is part, which straight line is cross at the axis τ (Fig. 11, *b*).

Parameters φ and c is mathematical parameters of the experimental depending for the specific soil and its only conditionally called **angle of internal friction of the soil** and **specific clutch of soil.**

Equation (18) is **Coulomb's law for the clay soils.** *Ultimate (limit) shear resistance of the clay soils is directly proportional to the external normal pressure, after full consolidation completion.*

In the engineer practice model of the test for direct shear is most relevant to the foundation and adjacent soil shear from soil base under horizontal shear forces. Especially shear is possible for the one part of the soil after another in the presence of a fixed fracture surfaces, such as the weak layer.

Because of the simplicity this scheme is the most common in the research practice.

Results of the soil tests in the three-axis device (Fig. 5) are useful to determination of its strength properties. From graph of the depending $\varepsilon_1 = f(\sigma_1)$ value of the sample destruction stress σ_1^p are determining. Also there is determining maximal main stress value σ_1', for this test $\sigma_1' = \sigma_1^p + \sigma_3$.

To determinate strength properties of the sandy soils there is necessary to make one test and build just one More circle (Example of its building is on the (Fig. 12, *a*). Its diameter is $\sigma_1' - \sigma_3$.

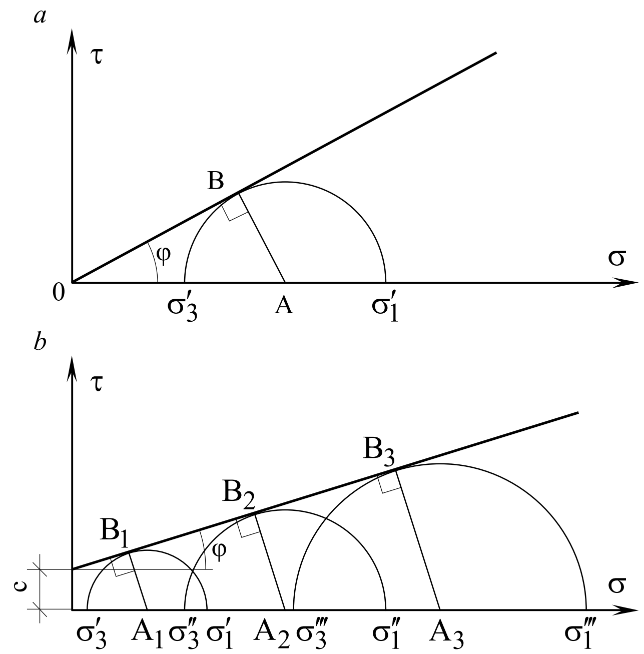


Fig. 12. Determining of the soil strength characteristics. From the test results of the soil samples in the three-axis compression device:
a – More circle for sandy soil;
b – More circle for clay soil

Tangent OB to a More's circle is drawn through the coordinate origin, OB is determining the angle of soil internal friction φ. Analytical expression for this case has the form (19)

$$sin\varphi = \frac{\sigma_1' - \sigma_3}{\sigma_1' + \sigma_3}. \quad (19)$$

For the clay soils make more than two tests under different values of the main and minimal stresses σ_3: σ_3', σ_3'', σ_3'''. In the result corresponding values of the main maximal stresses are obtaining: σ_1', σ_1'', σ_1''' and: $\sigma_1' < \sigma_1'' < \sigma_1'''$.

Further there are building more than two More's circles (Fig. 12, b).

Tangent to More's circles is determining angle of internal friction of the soil φ and specific clutch of soil c. Analytical equations are further:

$$sin\varphi = \frac{(\sigma_1'' - \sigma_3'') - (\sigma_1' - \sigma_3')}{(\sigma_1'' + \sigma_3'') - (\sigma_1' + \sigma_3')}; \quad (20)$$

$$c = \frac{\sigma_1'' tg^2(45^\circ - \varphi/2) - \sigma_3''}{2tg(45^\circ - \varphi/2)}. \quad (21)$$

9. Experimental-theoretical preconditions of soil mechanics

1. General imagination about soil and development of soil mechanics

We know already, that soil is continuous (grainy and dispersible), porous, three-phase material which:

1) at deformation in most cases is not resilient, because him remaining deformations considerably anymore from resilient;

2) after certain limits loses property of linear dependence between tensions and deformations;

3) becomes deformed not instantly, but in time;

4) has specific features of deformation, caused external influence, for example: by kinds, values, connections of loadings, by the temperature and moist mode of external environment, and others like that – and numerous physical and mechanical by properties each of types of soils;

5) practically does not work on a stretch and leans only squeezing and moving efforts.

In 1919 K. Tercagi created the complex of devices for research of compressibility and durability of soils. He executed the tests, mainly, with homogeneous clay pastes and with ideal friable soils, which remove not all properties of the real soils far. Without regard to it, the got results allowed him in 1925 to formulate the row of positions which made the base of *classic mechanics of soils* and promoted it to subsequent development.

Before appearance of works of K. Tercagi soils examined as *continuous, homogeneous, monophase materials*, it was considered that closeness and humidity them in the process of deformation does not change practically. K. Tercagi discovered that the basic phenomena which are observed in the conduct of soil on-loading depended on the change of quantitative correlation of phases of soil in the process of deformation and from mechanical co-operation of phases.

Advantage of classic mechanics of soils is simplicity of it mathematical models. K. Tercagi considered that through complication of description of mechanical properties of the real soils in swingeing majority of practical tasks was sense to be limited to only the approximate decisions, and if they can not be attained simple facilities which do not need difficult mathematical vehicle, it is in general impossible to get them.

He considered that in similar tasks major is a not receipt of the most exact decision, but determination of influence of different possible rejections of natural terms, from accepted in a calculation.

To the lacks of classic mechanics of soils it follows to take that it did not decide the most important problem of determination of the tense state of soils outside the linear resilient stage of deformation. With the special sharpness imperfection of row of methods of classic mechanics of soils appeared, when at the report of modern buildings and buildings, sensible to uneven deformations of basis, there was a necessity of the use under building of territories with unfavorable geological terms. From it a coming to a head necessity of expansion and clarification of theoretical base of mechanics of soils, and also strengthening of its connections, is with engineering geology, what calculation models can not be perfected without.

A step in this direction was become by principle of conditional calculations of M. Gersevanova. After him it was allowed de bene esse to give calculation models ideal properties are certain, as, for example, supposition about the even distributing of tension after the horizontal cuts of basis the surface of which is natively high-usage. Thus models must answer two obligatory conditions: 1) to represent the most substantial factors which determine work of building; 2) to put building in less favorable, than at reality, condition of work.

Insufficient in many cases reliability of decisions of classic mechanics of soils was one of reasons of that in 1948 by the group of engineers at the head with V. Keldishem the new going was offered near planning, is *principle of the maximum states*. In relation to bases this principle in the first time was formulated in 1948 D. Pol'shin. In particular, at determination of loadings on bases it was suggested to go out from the maximum possible for this building settling and fully to give up the groundless method of standard “possible pressurei” on soils. Deformations of bases not must exceed maximum possible for normal exploitation, but them bearing strength must be sufficient, that a loss of firmness or destruction of basis was not.

Oversea norms of planning of bases, though are not based on principles of the maximum states, but, beginning from the formula of K. Tercagi with clarifications of Meyergofa, Kako-Kerizelya, Khansena et al, contain expressions in the complement of which empiric coefficients i, λ, d, N, that does depend on the corner of internal friction φ.

Now at planning more frequent all apply the *separate calculation of bases and buildings*. At first expect building and determine loadings which are passed on basis so, as though it is absolutely hard and intractable. Then after these efforts, using the simplified normative rules, deformations of foundations, which compare to maximum possible, determine.

The complete use of advantages of principle of the maximum states is possible with passing to the method of *compatible calculation of work of basis, foundations and buildings*, on the whole, which a redistribution of efforts which operate on the array of soil is as a result of. It is thus desirable to take into account spatial work of constructions, geometrical and physical non-linearity, anisotropic, plastic and reologichni properties of materials and soils, possibility of change of their properties, in the process of report (including technology and sequence of report of buildings, and also rates and building chart) and exploitation of buildings.

Bringing in of these factors to the weekend given approaches a prognosis tensely deformed to the state of basis to reality. Yes, at *planning of objects on the stages*: tearing away of foundation pit; report of foundations and underground part of building; change of water-table; building of above-ground part; exploitation of building – it is set that efforts in constructions grow in once or twice and can change the sign on opposite. Thus to a full degree taken into account variant of both structural and technological, decision of report of buildings, including factor of time, and also deformation of adjoining territory and surrounding buildings. From here possible optimization of technology of report of buildings.

The modern tasks of mechanics of soils are very various and have a practical orientation, in particular: determination of tensions is in the ground layer; calculation of deformations and prognosis of settling of foundations of engineering buildings; finding of bearing strength of ground array cells (round foundations, piles, underground buildings); determination of pressure of soils and mountain breeds is on retaining walls and other non-load-bearing buildings; calculation of firmness of hay-crops; prognostication of deformations at formation of the underground making, underflooding, frosty thrusting out, underground explosions, and others like that. Their decision is impossible facilities of mechanics of soils without the wide use of achievements of theories of resiliency, plasticity, creep, hydromechanics, mechanics of destruction, mathematical physics and other. Such tasks decide presently, as a rule, only by numerical methods with application of modern computers.

2. General rules about distribution of stress and strains in a point of soil massif

Pressure from loading, enclosed to the ground array, for example, through the sole of foundation or side and edge of pile, is passed in soil particles or structural aggregates through the points of contact, distributed after a depth on an all greater area. Tensions diminish here. There is a process of dispersion or fading of tensions after a depth and with a removal in sides.

By the measure of quantitative estimation tensely deformed there are *stress, deformations and moving* which arise up in him from the action of external (loading is from buildings) and internal (own weight of soils) forces the state of array of soils. These concepts answer general determination of mechanics of continuous environment.

In the system of rectangular co-ordinates the stress state of elementary volume of soil it is possible the aggregate of operating in him stress: σ_z – vertical normal stress, which operates in the direction of axis z; σ_y – horizontal normal stress, which operates in the direction of axis y; σ_x – horizontal normal stress, which operates in the direction of axis x; τ_{xy}, τ_{yx} – the tangents of stress, which operate under verges, to parallel wasp of z, are identical between itself in accordance with the rule of "evenness of stress" (τ_{xy}=τ_{yx}); τ_{zx}, τ_{xz} – identical between itself tangent stresses, which operate under verges, to parallel wasp *y* (τ_{zx}=τ_{xz}); τ_{yz}, τ_{zy} – identical between itself tangents of stress, which operate under verges, to parallel wasp *x* (τ_{yz}=τ_{zy}). As soils, as a rule, very badly work on a stretch, in mechanics of soils unlike mechanics of continuous environment squeezing stresses accept a "plus" with a sign, and tensile – with a sign "minus".

If loading is up-diffused after a bar (in theory endless length), such task (or problem) has the name of *two-dimensional or plane* (Fig. 1, a). In this case the constituents of stresses change only in directions of two co-ordinate axes, keeping a permanent value in direction one. In the case of action of loading, up-diffused after the ground of the limited sizes in all directions, the stress state of array is characterized the change of constituents of stresses in directions of three co-ordinate axes. Unlike flat *a three-dimensional task (or problem)* in mechanics of continuous environment is named spatial (Fig. 1, b).

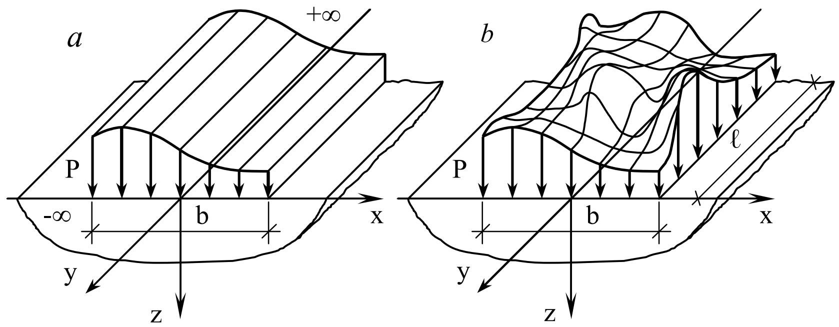


Fig. 1. Charts of loadings for: a – plane problem; b – three-dimensional problem

In classic mechanics of soils for determination of stresses and deformations apply the theory of the linearly-deforming medium. For the use of its conclusions to any body necessary inhibition of linear dependence between stresses and deformations, whether submission of material of body mathematical dependence, to analogical the law of Guka. Thus fully to proceed in the presence of property of resilient bodies the form after unloading not obligatory, if only the question is about the *non-permanent loading*. In the theory of the linearly-deforming medium use mathematical dependences of theory of elasticity, but, unlike the last, in it examine non-elastic, linearly-deforming medium bodies at their non-permanent loading.

For the use in classic mechanics of soils of the approved decisions accept some suppositions and limitations, for example: calculations conduct only in the interval of loadings within the limits of which soil can be considered arcwise deformed, and also consider soil a continuous, homogeneous and isotropic environment. The theory of resiliency does not represent deformations of soils in time.

3. Models describing the state of soil

For the decision of tasks of mechanics of soils usually limited to the study only of the mechanical phenomena and distracted from physical and chemical and other processes which take place in soils. Thus, mechanics of soils deals not with the real mountain breeds, as with natural and historical bodiesbodies, and with their certain mechanical *models* – bodies with the considerably simplified properties by comparison to actual soils.

Hem of *continuous models*, usual for mechanics of continuous environment, it is possible to conduct after many signs, in particular: *models of the linearly-deforming medium; models of theory of maximum equilibrium; models resiliently plastic medium and theories of plastic flow; models which are based on conception of critical condition of soil*, and others like that.

The models of the linearly-deforming medium – most widespread in engineering practice of classic mechanics of soils. In opinion of scientists, they yet will compete with more difficult models, especially in the calculations of mass building. In these models, except for the valid for one occasion load of soil and linear dependence between stresses and deformations, at loading examine only general deformation without dividing into elastic and plastic constituents. The first supposition is provided by possibility of the use for the calculations of stresses in the array of soil of vehicle of theory of elasticity, and second – at known stresses of determination of eventual deformations of basis.

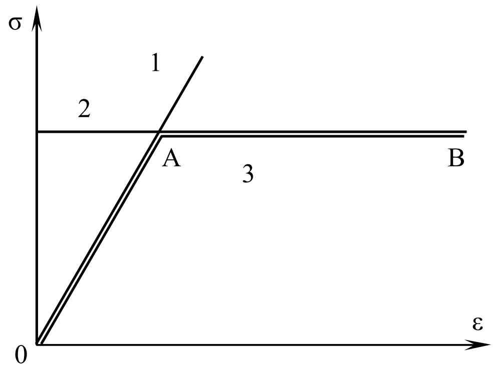


Fig. 2. A typical type of charts of dependence is between stresses (σ) and deformations (ε) of models of soils: 1 – the linearly-deforming medium; 2 – hardly plastic bodies; 3 – resiliently plastic bodies (diagram of Prandtly)

Consequently, the models of the linearly-deforming medium are answered by all not curve of *0c* deformation of soil, but only its area of *0a*. That *application of theory of linear deformation of soil is required by establishment of limit of its use*. By this limit in the calculations of stresses and settling (or settlements) of bases mainly middle pressure serves under the sole of foundation to achievement of which dependence of $S=f(\sigma)$ is near to linear. A failure to observe of this limitation usually results in understating of size of settlements of bases in comparison with their actual values. Typical for the model of the linearly-deforming medium type of chart of dependence between stresses and it is given deformations on fig. 2 (line 1). Limit of linear deformation of this model of soil is a limit of proportion (point A).

Equalizations of the state of model of theory of linear deformation write down as the *generalized law of Guka*.

The criterion of application of model of the linearly-deforming medium to the ground massifs is accept the degree of development of areas of the maximum stress state (maximum equilibrium). If such areas absence or the small by comparison to the sizes of foundation uses of this model consider possible, in opposite case – no. In particular, now is the use of model of the linearly-deforming medium assumed in the calculations of bases of buildings and buildings, if the depth of development of areas of the maximum tense state does not exceed approximately ¼ width of sole of foundation (for strong soils and hard buildings this depth can be megascopic).

Line 2 on Fig. 2 represents a model hardly plastic bodies. Assume that linear (resilient) part of his moving (deformations) very had by comparison to a plastic constituent. Physical equalizations describe the maximum tense state (maximum equilibrium). The task of calculation of such body is decided as statically certain. Moving does not find, because this model does not contain correlations which would link stresses and deformation.

A calculation is directed on determination, as a rule, one parameter – index of bearing strength: maximum loading (forces, to the moment and others like that).

Rational application of theory of maximum equilibrium are calculations of firmness of buildings and bases, hay-crops, slopes, pressure of soil, on a protection.

Models resiliently plastic medium and *theories of plastic flow* are a set of equalizations, which determine limit of resilient conduct of environment and connection of deformations and stresses after a limit a resilient area. They are based on differential between the stresses and by deformations and can take into account conformities to law of change of mechanical properties of soil both in the process of experiment and in model terms.

For this purpose in the system of equalizations resiliently plastic deformations enter functions, which take into account variables after motion of experiment of value of the modules of change, by volume deformation, general deformation, Poisson's coefficient. All these variants of resiliently plastic medium attribute to the *deformation theories*.

The components of deformations and stresses in these models divide into elastic and plastic constituents (linear) and angular deformations. The elastic constituents of deformations describe the above-mentioned differential equalizations of equilibrium, equalizations of unbreak, physical equalizations of theory of resiliency. Plastic constituents describe differential correlations of deformations and stresses.

Line 3 on Fig. 2 an enough widespread model represents properties *ideal resiliently plastic bodies* (diagram of Prandtly), which are connection of equalizations of linearly-deforming medium and hardly plastic bodies. In this model of limit of proportion, fluidity and durability, coincide (point A).

Dependence of *OAB* (Fig. 2) answers the forms of physical non-linearity, which show up in unimpeded deformation at the maximum tense state: fluidity, creep, one-sided copulas.

Ministry of education and science of Ukraine
Poltava National Technical Yuri Kondratyuk University

JOURNAL

For laboratory work by engineering geology

for students of specialty
192 construction and civil engineering,
Educational level „bachelor” (full-time study)

Surname and initials of the student ___________________

Group ___________________

Evaluation of the test ___________________

Poltava 2019

INTRODUCTION

The journal contains reference, graphical, tabular and factual material, as well as concise recommendations for laboratory work by engineering geology for students of specialty 192 construction and civil engineering, educational level „bachelor" (full-time study)

Attention:

1. The implementation of laboratory work is preceded by listening to lectures on "Engineering Geology", as well as non-auditing work of students over relevant sections of the course.
2. Laboratory work is an important form of educational process that is aimed at assimilating and consolidating students' learning material and acquiring skills to perform practical tasks.
3. In order to obtain a credit for laboratory work, you must have a well-designed journal on laboratory work, signed by a teacher, as well as a complete picture of the exercises performed during the training sessions.

Laboratory work № 1

THE MOST IMPORTANT ROCK-FORMING MINERALS

Using Methodical instructions for laboratory work "The most important rock-forming minerals and rocks" (compiler – professor Yu. Vynnykov), and auxiliary materials and accessories, carefully read the properties of the three samples of minerals. After examining the external characteristics of minerals should refer them to the appropriate class and set the name.

Sample № 1

Signs of

1. Hardness ________________ 2. Luster ___________________________________
3. Color ____
4. Cleavage ____
5. Fracture____
6. Habit ____
7. The species in nature ____
8. Special features ____
9. Using in production ____
____

Conclusion

1. Name of class ____
2. Name of mineral ____

Sample № 2

Signs of

1. Hardness ________________ 2. Luster ___________________________________
3. Color ____
4. Cleavage ____
5. Fracture____
6. Habit ____
7. The species in nature ____
8. Special features ____
9. Using in production ____
____

Conclusion

1. Name of class ____
2. Name of mineral ____

Sample № 3

Signs of

1. Hardness ______________ 2. Luster ________________________________
3. Color ____
4. Cleavage ____
5. Fracture____
6. Habit ____
7. The species in nature ____
8. Special features ____
9. Field of application____
____

Conclusion

1. Name of class ____
2. Name of mineral ____

THE MOST IMPORTANT ROCKS

Using Methodical instructions for laboratory work "The most important rock-forming minerals and rocks" (compiler – professor Yu. Vynnykov), and auxiliary materials and accessories, carefully read the properties of the three samples of rocks (magmatic, metamorphic and sedimentary). After examining the external characteristics of rocks should refer them to the appropriate class and set the name.

Sample № 1

Signs of

1. Color ____
2. Structure ____
3. Texture ____
4. Mineral composition ____
5. Special features ____
6. Peculiar properties ____
7. Field of application____
____

Conclusion

1. Name of genetic species ____
2. Name of rock____

<u>Sample № 2</u>

Signs of

1. Color ____
2. Structure ____
3. Texture ____
4. Mineral composition _______________________________
5. Special features ___________________________________
6. Peculiar properties _________________________________
7. Using in production ________________________________

____

Conclusion

1. Name of genetic species ______________________________
2. Name of rock______________________________________

<u>Sample № 3</u>

Signs of

1. Color ____
2. Structure ____
3. Texture ____
4. Mineral composition _______________________________
5. Special features ___________________________________
6. Peculiar properties _________________________________
7. Using in production ________________________________

____

Conclusion

1. Name of genetic species ______________________________
2. Name of rock______________________________________

The most important rock-forming minerals and rocks

Each group of students selects 3 samples of minerals and conducts research characteristics as follows:

1. Determine sample hardness on the Mohs scale (1 – 10)
2. Determine luster surface sample split view (metallic, glassy, silky)
3. Determine sample color
4. Determine mineral cleavage
5. Determine appearance of fracture
6. Determine sample form
7. Determine special features
8. After examining the external characteristics of minerals should refer them to the appropriate class and set the name

9. All features and properties recorded in the log of laboratory work
10. Record of the form in the nature and field of application

Each group of students selects 3 samples of rocks: magmatic, metamorphic and sedimentary. Conducts research characteristics as follows:

1. Determine the sample color
2. Determine the structure of rocks
3. Determine the texture of rocks
4. Determine the mineral composition
5. Determine the special features and properties
6. After examining the external characteristics of rocks should refer them to the appropriate class and set the name
7. All features and properties recorded in the log of laboratory work
8. Write the field of application

The table to determine rock-forming minerals

Name of mineral	**Loadstone(magnetite)**	**muscovite**	**gypsum**
Name of class	oxide	silicate	sulfate
hardness	5.5-6.5	2-3	1,5-2
luster	metallic	glassy, nacreous	glassy, nacreous
color	black, not transparent	colorless, green, yellow	colorless, white, yellow
mineral cleavage	-	perfect in one direction	perfect in one direction
appearance of fracture	acinose, grainy	-	even, acinose, grainy
specific weight	45-53	27-31	23
sample form	cubic octahedron	in the form of stacks of thin plates	as crystals
form in the nature	Dense masses, granular inclusions	In igneous rocks, gneisses, schists	In the form of layers of sedimentary rocks
special features	Magnetic properties	divided into thin, elastic leaves	
field of application	ironstone	In the electro-technical industry	As a binder

The table to determine rocks

Name of rock	**granite**	**limestone**	**shale**
group	magmatic	sedimentary	metamorphic
color	grey, yellow, pink	white, light-grey, yellow	black, grey, green
structure	Fully-crystalline	Various	Incomplete-crystalline, fine-grained
texture	massive	massive, porous	shale
mineral composition	feldspar, quartz, biotite	calcite, dolomite	Clay minerals, biotite, muscovite, quartz
special features	Acidic rock mainly deep quartz 25-30%	Boil on weak solution of hydrochloric acid HCl	Matte luster, structure thin-slate
properties	R = 100-200 MPa	R = 7-200 MPa	γ = 26-28 kN/m^3 R = 20-60 MPa
field of application	Facing material, rubble	Production blocks and slabs. Raw material for lime production	Refractory products

Laboratory work № 2

CONSTRUCTION OF GEOLOGICAL SECTION

1. Draw a geological section area using geological map (Fig. 1).
2. The section is done at millimeter A4 paper.
3. We use the following scale: Horizontal – 1:25000; vertical – 1:5000.
4. Geological section plotted by segment AB that is given to each map (Fig. 1) individually.
5. From below making retreat 5 cm and draw a line base.
6. On the left side of doing retreat 1 cm and draw a scale heights in scale (step 100 corresponds to 2 sm). Maximum horizontal mark is 900, minimum – 500. So draw a scale from 400 to 1000.
7. plotted on the line base segment AB on the scale of 1: 25000. As the scale of the map is the same, the cut segment measure ruler (Fig. 1) and carry each other.
8. Next plotted points on the cut segment AB corresponding to its intersection with the horizontal. Sign them.
9. We transfer point of the cut line base up according to the scale heights.
10. We connect points consistently smooth line profile.
11. Then on our geological section we need to locate geological elements. On the geological map we transfer point of intersection of geological elements. Denotes those points on the line profile numbers.
12. Starting from the top profile connecting points with the same geological elements smooth lines.
13. The geological elements that are found only on one side have no exit on the surface profile. We connect them with line base.
14. Then we are hatching (shading) geological elements according to the legend. Draw conventional signs to the right of the geological section (Fig. 1).

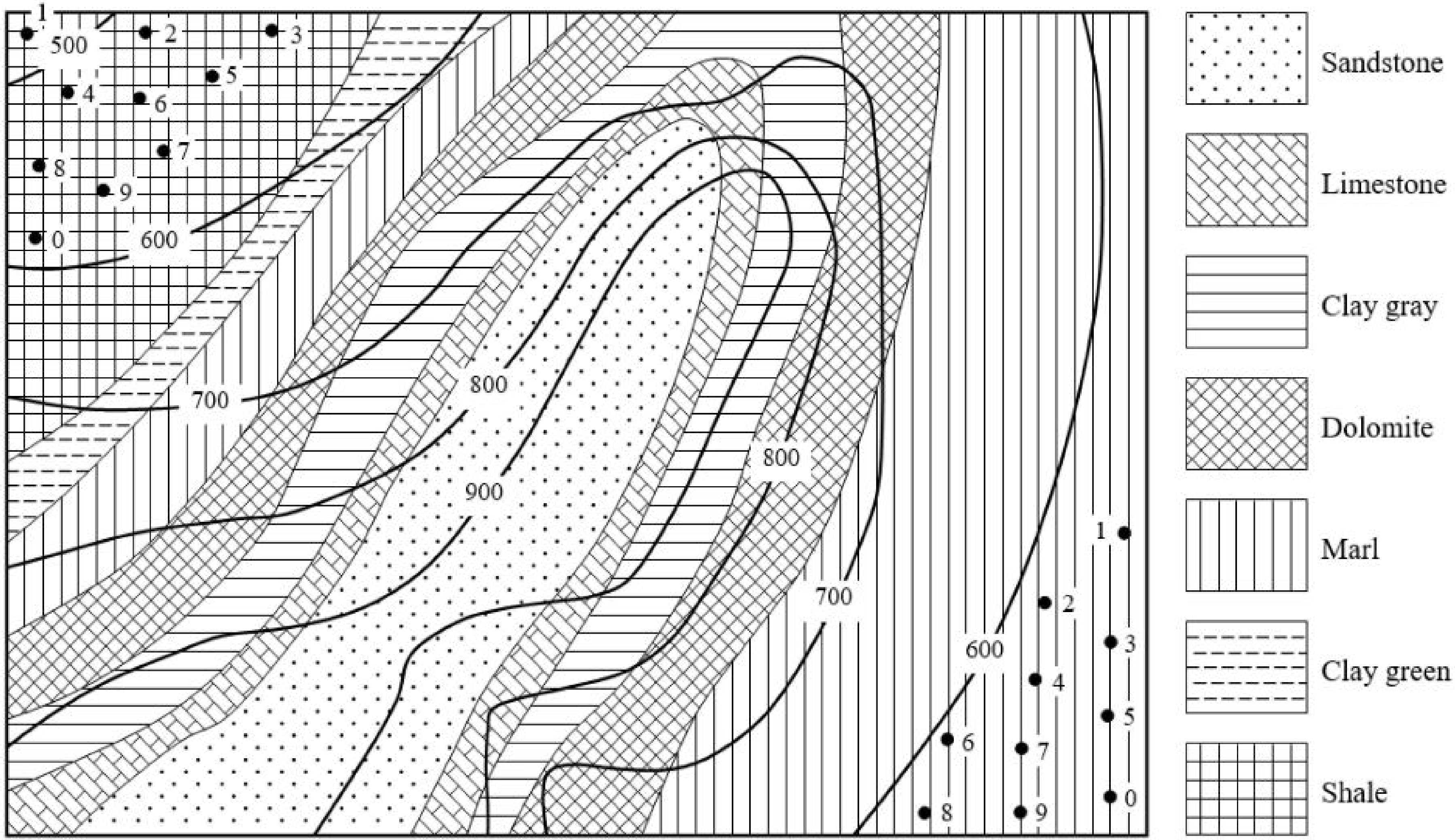


Fig. 1. Geological map of the area M 1:25000

Laboratory work № 3

DRAW MAP THE SURFACE OF GROUNDWATER IN THE HYDROIZOHIPS

1. Information about the features of the relief area, the depth of the location of groundwater, the distance between wells where groundwater identified given in Table 1. Soil permeability aquifers rocks and the average thickness of the aquifer are shown in Table 2. They are chosen on the variants individually.

2. Drawings performed on a piece of graph paper.

3. Drawings performed on a piece of graph paper. Start with drawing a grid of nine wells located in the corners of the squares of the distance ℓ (80 m) in the scale of 1: 1000 (Scheme Fig. 1).

4. At each well record its number, the absolute mark of mouth (the ground) in the numerator and the absolute mark the groundwater level in the denominator (the calculation). Mark the groundwater level is marked as the difference between the ground and the depth of GWL (Table 1).

5. For mapping the topography and GWL use measuring grid. Find the highest and lowest mark surface and draw a parallel line to measuring grid at 1 m. Sign them.

6. First found on the sides of squares and diagonals integer values (at 1 m) marks the surface with a measuring grid (or interpolation).

7. Further, connecting identical in size marks smooth curves by pencil. So get horizontal system.

8. Then, using the same measuring grid squares on the sides and the diagonals are integer values (at 1 m) marks GWL, and then, connecting the same in size marks smooth curves blue paste is prepared hidroizohips system.

9. Continuous arrows on the map indicate the direction of general flow of groundwater.

10. On the map, select a segment perpendicular the lines hidroizohips to determine the hydraulic pressure.

11. Determine the hydraulic pressure for GWL marks at the ends of the segment in the direction of general flow of the expression

$$I = \frac{H_1 - H_2}{L}, \tag{1}$$

where H1 and H2 – RGV mark; L – length of the segment, m.

12. Determine the amount of water that is filtered in unit time through unit area of section flow (A=1 м^2)

$$q = I \cdot k_f \cdot A. \tag{2}$$

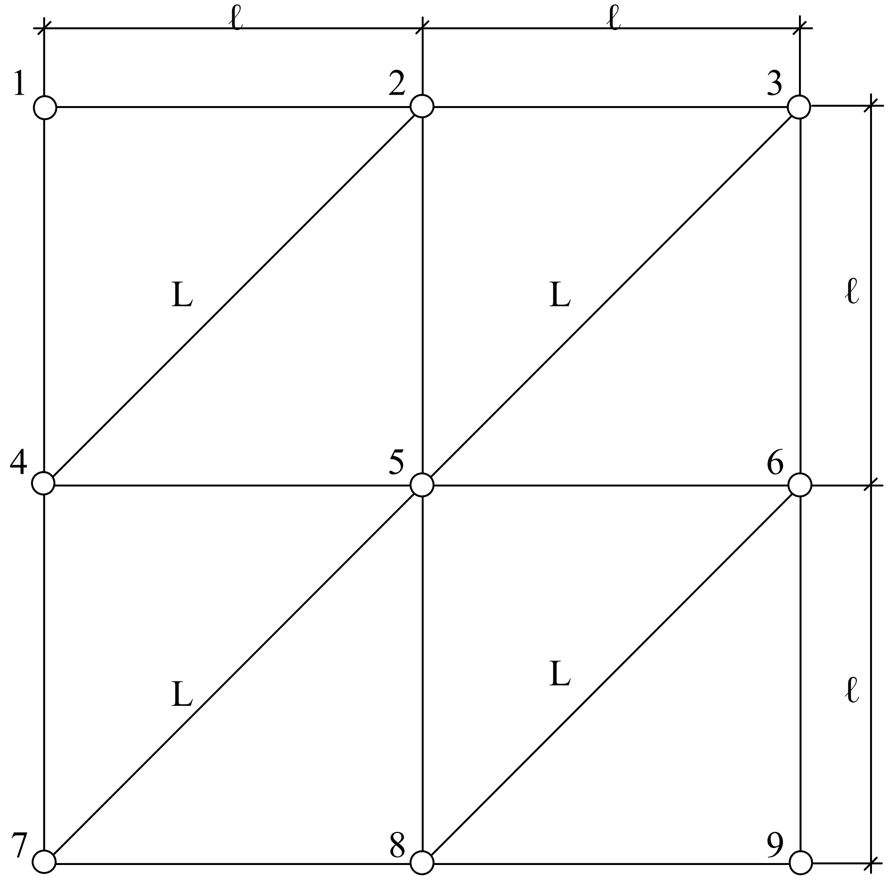


Fig. 1. Location of wells Scale 1:1000.

13. Determine the expense flow groundwater flat 1 m wide with an average thickness of the aquifer ($A = h \cdot 1{,}0$)

$$q_n = k_f \cdot A \cdot I. \quad (3)$$

Table 1

Numbers of wells									The distance between wells ℓ, м
1	2	3	4	5	6	7	8	9	
$\frac{78{,}2}{2{,}5}$	$\frac{77{,}6}{1{,}6}$	$\frac{77{,}5}{2{,}0}$	$\frac{79{,}5}{2{,}4}$	$\frac{79{,}4}{1{,}8}$	$\frac{79{,}2}{2{,}5}$	$\frac{81{,}3}{1{,}7}$	$\frac{80{,}5}{0{,}8}$	$\frac{80{,}3}{2{,}3}$	80

Table 2

№ variant	1	2	3	4	5	6	7	8	9	10
Soil permeability, k_f, m/day	7,9	14,0	8,5	11,3	7,8	13,4	10,5	9,7	12,2	8,6
The average thickness of the aquifer, *h*, m	6,3	7,0	6,8	5,8	5,6	7,3	6,5	6,0	5,5	7,5

Laboratory work № 4

CONSTRUCTING GEOTECHNICAL SECTION

1. Geotechnical sections are important documents geotechnical investigations. They give a visual representation of the nature of the occurrence of soils and hydrogeological conditions. Geotechnical sections build on pioneer excavations (pits and wells). They are placed on the area of the distance between them from 20 to 100 m. The construction of geotechnical section performing at least three pioneer wells.

2. Figure 2 shows the location of wells. Table 1 shows the horizontals marks, wellhead and distance between wells. Indicates the data in Figure 2.

3. The construction of geotechnical section performed on graph paper.

Table 1

The horizontals marks, m			The distance between wells, m	The wellhead marks, m		
a	*b*	*c*	*ℓ*	*w.1*	*w.2*	*w.3*
72,00	72,50	73,00	30,0	72,30	72,70	73,10

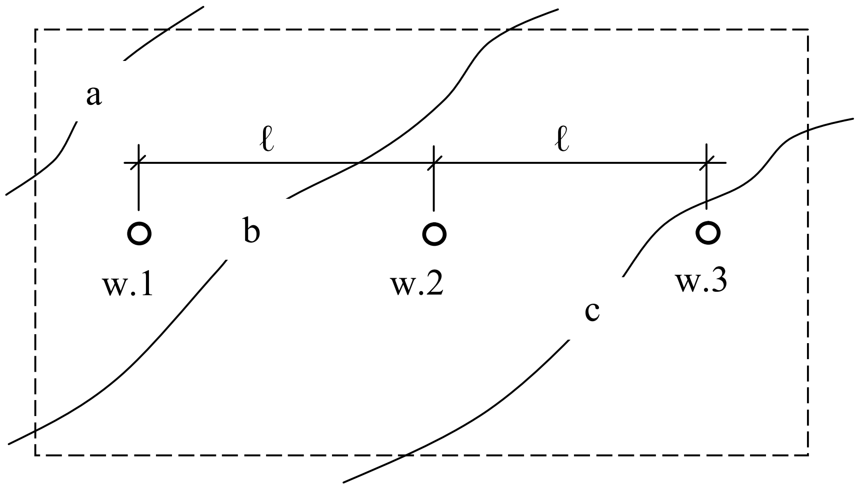


Fig. 2. Location of wells

4. Table 2 given thickness of 3 engineering-geologic elements (EGE). Using data from Table 2, determine the thickness of three engineering-geologic elements and depth of groundwater. Having added thickness of 3 layers get an array depth 10 m.

Table 2

Wells									depth of groundwater, m
№ 1			№ 2			№ 3			
The thickness of EGE, м									
topsoil	EGE-2	EGE-3	topsoil	EGE-2	EGE-3	topsoil	EGE-2	EGE-3	
0,50	2,85	6,45	0,45	2,90	5,85	0,55	2,75	6,05	2,50

5. On a scale of 1: 100 plot line marked on graph paper. Below retreat 7 cm, left – 6 cm. Marks on the scale markings 10 from 64 to 74 m.

6. From the scale retreat 1 cm and draw well №1. The width of the well is 5 mm. Mark wellhead is in Table 1.

7. From the well №1 in scale 1: 500 plotted the well №2 and №3. The distance between wells is 30 m, the scale is 6 cm.

8. Connecting the top of wells straight lines.

9. From each wellhead plotted the thickness of the first layer - topsoil. Thickness EGE given in the Table. 2.

10. Connecting points between the first layer wells straight line.

11. Draw a second layer thickness (EGE-2) from the end of the first layer in each well. Also, connect a straight line.

12. Similarly plotted thickness of the third layer (EGE-3).

13. Signs thickness of each layer from the surface of the section. The first layer of each well rewrite of Table 2. Then gradually add each layer and record the result at each well.

14. Lays groundwater level in the section. The depth of the groundwater is 2.5 m. From wellhead marks subtract depth of groundwater and lay on the scale of the section.

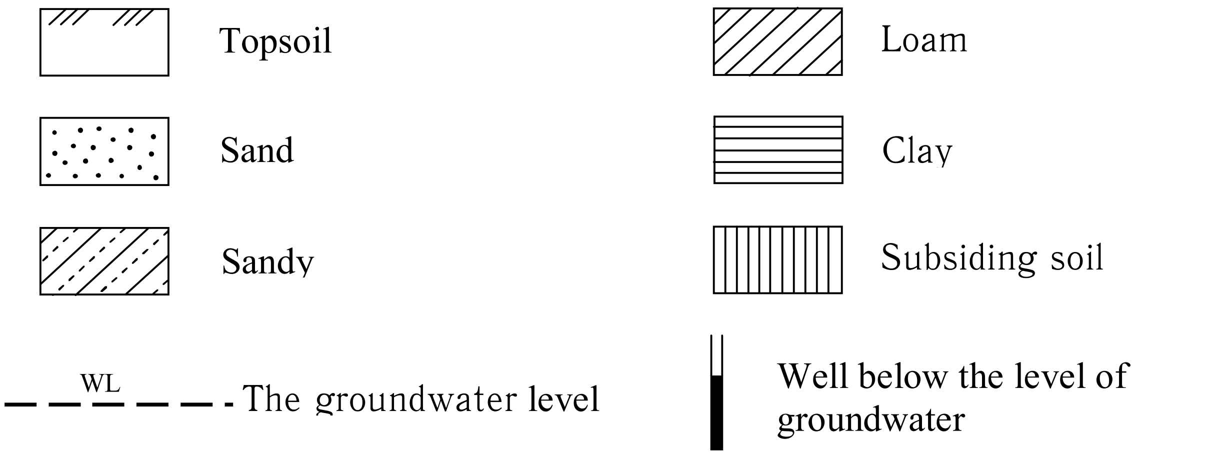
15. Connecting point of groundwater straight dotted line, write down the depth groundwater.

16. Indicates soil layers numbers. Hatchin under the legend. EGE-2 – loam, EGE-3 – sand.

17. In engineering-geological section showing the legend:

18. Under the engineering-geological sections placing table 3.

19. The slope is determined by the ratio of the difference marks wellhead to the distance between them *(w.1-w.2)/l.*



Legend

Table 3

№ of the well	1	2 3
The wellhead marks	72,30	72,70 73,10
The distance between wells	30,00	30,00
The groundwater mark	69,80	70,20 70,60
The slope	0,013	0,013

Laboratory work № 5

DETERMINATION GRAIN-SIZE COMPOSITION OF SANDY SOIL

1. Grain-size composition is determined the sandy soil by sifting soil sample through a sieve column. Sandy soil take weight 100 g
2. Weight of each sieve written on it.
3. Weighted sand is placed on a top sieve and close the lid.
4. Sifting sand are horizontal vibrations of the column sieves on the table for 1 min.
5. Then the sieve with a sand is weighing. Subtracted weight of empty sieve and record the results in table 1 (paragraph 1)
6. The total mass of residues must different from the mass of sample no more than 1%. The difference is added or subtracted from the mass fractions in proportion to their share so that the total mass fractions was 100%. Results also placed in Table 1 (paragraph 2).
7. Д Then write down amount of mass fractions in Table 1, paragraph 3. For this mass fraction "> 1,00" rewrite in 1 column. Then add mass fraction "1-0,5" and written in the second column. Next to the sum of mass the first two fractions add mass fraction "0,5-0,25" and write in the third column. The last value – is the sum of the all mass fractions and it is 100%.
8. In the fourth paragraph of Table 1 write down sum of mass fractions in reverse order. Determine similarly the third paragraph, but start with the last value fraction "<0.10" and added consistently mass of each fraction from right to left.
9. According to Table 1 (point 4) depicting the total curve the grain-size composition of the sandy soil in semi-logarithmic scale (Fig. 1) On a vertical is the factions content in percent. In the horizontal – size fractions.

Table 1

	Parameter	The diameters of holes sieves *d*, mm				
		1,00	0,50	0,25	0,10	pallet
		The dimensions of the fractions, mm				
		>1,00	1-0,50	0,50-0,25	0,25-0,10	<0,10
		1	2	3	4	5
1	The mass fractions, g					
2	factions content, %					
3	The amount of mass fractions ↑					
4	The amount of mass fractions ↓					

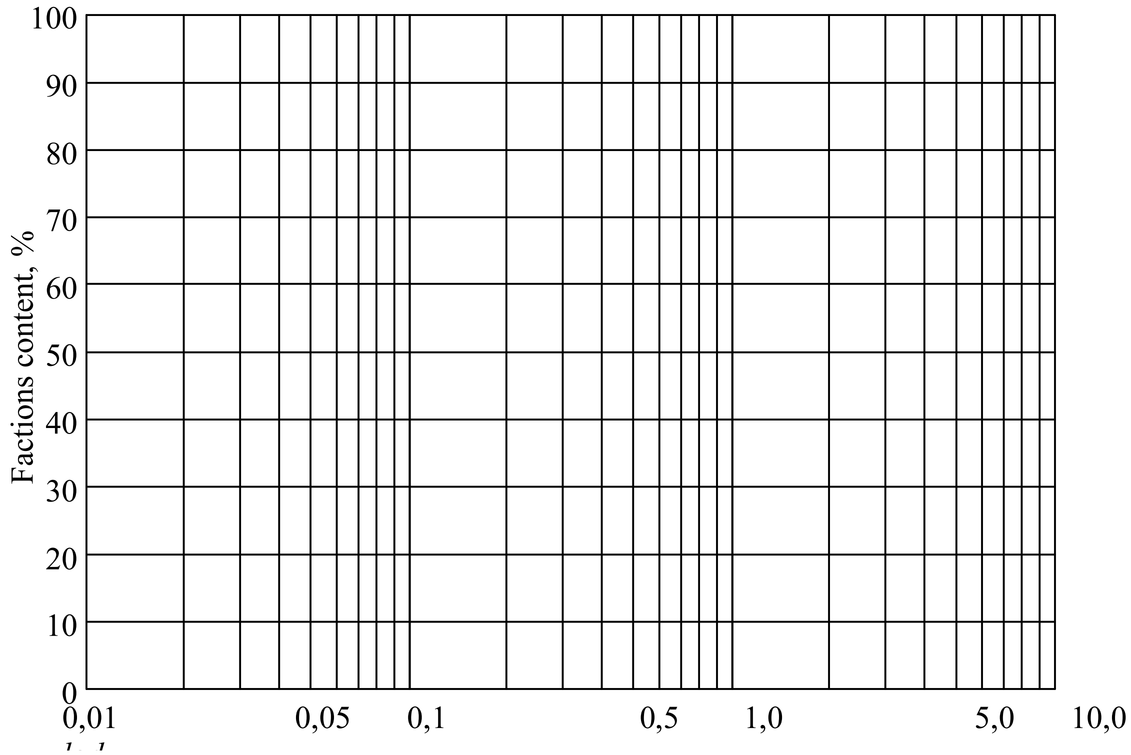


Fig. 1. The total curve the grain-size composition of the sandy soil in semi-logarithmic

10. Determine d_{60}, d_{10} – particle diameter, mm, less than in the soil which contained respectively 60% and 10% of the particles (by weight), using a graph of grain-size composition (Fig. 1).

11. Set the degree of heterogeneity of grain-size composition

$$C_v = d_{60} / d_{10}\ . \qquad (1)$$

If $C_v \leq 3$ – sand homogeneous, if $C_v > 3$ – inhomogeneous.

12. From Table 2 specify the sand

Table 2

Sand	The size of grains, particles, *d*, mm	factions content, %, from the mass
grave	> 2	> 25
coarse	> 0,5	> 50
medium coarse	> 0,25	> 50
grail	> 0,10	≥ 75
silty	> 0,10	< 75

13. For the 3rd paragraph of Table 1 tested the conditions percentage contents particle fractions. Sieve diameter> 2 we didn`t use because the sand grains of this diameter were not. So sand isn`t gravel.

If the mass fractions diameter> 0.5 less than 50%, the condition is not satisfied, and the sand is not the medium coarse. Proceed to the next check fraction sand.

If the condition is met, then write the appropriate name sand.

Full name of sand is ____ .

Laboratory work № 6

DETERMINATION OF PLASTICITY INDEX AND LIQUIDITY INDEX OF CLAY SOIL

Determination humidity at the yield limit W_L:

1. For the work first prepare a paste of clay soil. Dried soil triturated in mortar, sifting it through a sieve with holes of 2 mm and kneaded with distilled water until creamy state. Pasta filled with metal cup and spatula leveling the soil surface.

2. On the surface paste quietly dipped Vasilyev cone balancer weight 76 g. If the cone dipped into the soil to a depth of 1,0 cm (the mark) for 5 seconds, humidity of the soil is at the yield limit W_L.

If the cone during this time immersed to a depth of less than or more than 1.0 cm, in the soil accordingly add water or dry soil and after mixing experiment is repeated until the cone to plunge into risk.

3. To determine the humidity first weighed empty weighing bottle (q_1). Then in the weighing bottle are placed more than 10 g of soil paste, weigh it (q_2). Next, dried in the drying oven at 110 degrees (for laboratory work is allowed to dry on an electric hot plate) to constant weight when the humidity is 0 (q_3).

Determination humidity at the plasticity limit W_P:

4. To determine humidity of the soil at the plasticity limit take a piece of soil and roll it into a glass to cord with a diameter of 3 mm. In training purposes you can roll on paper. When the soil begins to break up into separate pieces (length 3-10 mm), believe that its humidity is at the plasticity limit W_P.

5. To determine the humidity first weighed empty weighing bottle (q_1). Then in the weighing bottle are placed more than 10 g of soil paste, weigh it (q_2). Next, dried in the drying oven at 110 degrees (for laboratory work is allowed to dry on an electric hot plate) to constant weight when the humidity is 0 (q_3).

The experimental results are entered in Table 1.

Table 1

Humidity	№ weighing bottle	Weigh empty weighing bottle q_1, g	Weigh weighing bottle with soil paste q_2, g	Weigh weighing bottle with dry soil q_3, g	Humidity of the soil $W = \frac{q_2 - q_3}{q_3 - q_1} 100\%$
yield limit W_L					
plasticity limit W_P					

6. By the formula to calculate the humidity at the yield limit W_L and humidity at the plasticity limit W_P (Table 1). Humidity is expressed as a percentage or share units.

7. Name of clay soil is determined by the **plasticity limit** (in percentage):

$$I_P = W_L - W_P. \tag{1}$$

sandy loam	$1 \le I_P \le 7$
loam	$7 < I_P \le 17$
clay	$I_P > 17$

If I_P=____________________ the soil is ________________________

8. **Liquidity index** is determined by the formula

$$I_L = \frac{W - W_P}{W_L - W_P}, \tag{2}$$

where W – Humidity soil in the natural state.

9. Determine the type of clay soil for the liquidity index I_L.

Table 2

Loam and clay	**Liquidity index**	**Sandy loam**
hard	$I_L < 0$	hard
semisolid	$0 \le I_L \le 0{,}25$	plastic
low-plasticity	$0{,}25 < I_L \le 0{,}50$	
high-plastic	$0{,}50 < I_L \le 0{,}75$	
fluid-plastic	$0{,}75 < I_L \le 1{,}0$	
fluid	$I_L > 1{,}0$	fluid

Conclusion. Soil is ____

____

Laboratory work № 7

DETERMINATION OF SAND FILTRATION COEFFICIENT

A. <u>By the approximate Hazen formula.</u>

on the results of determine heterogeneity sand:

$$k_f = C \cdot d_{10}^2 \cdot \tau, \text{ m/day}, \quad (1)$$

where C – empirical coefficient, which for homogeneous sand taken as equal 1000 and for heterogeneous – 600;

d_{10} – particle diameter, which establish the curve of sand grain size (l.w. № 5);

τ – temperature coefficient determined by the formula

$$\tau = 0{,}7 + 0{,}03 \cdot t°, \quad (2)$$

$t°$ – water temperature °C.

B. <u>With universal tube "KF":</u>

1. Fill the cutting cylinder dry sand, set metal grid and close the lid.

2. Set Telescopic device to the mark of 0.6 (corresponding hydraulic gradient I = 0.6), and lower in the middle of the cutting cylinder.

3. The cylinder is filled with water to full water saturation sand. Withstand 2-5 min., then drained excess water.

4. In a glass measuring cylinder (Mariotte vessel) pour water and gently set it down a hole in the net.

5. Determine the time T when from the scale graduated cylinder filter off 25-50 cm^3 of water. For gradient I = 0.6 experiment is repeated twice and the results recorded in Table 1.

6. Lift the upper part of the telescopic device on gradient I = 0.8 and perform two similar experiments.

Then do the same with I = 1.0.

7. Filtration coefficient at a given temperature t ° water determined by the formula

$$k_f = \frac{864 \cdot Q}{T \cdot A \cdot I}, \text{ (m/day)}, \quad (3)$$

where Q – the volume of water that filter off during T, cm^3;

864 – dimensional factor for transfer k_f from cm/sec to m/day;

T – time filtration, sec;
A – sectional area of the cutting cylinder, A=25 cm^2;
I – hydraulic gradient.

8. To determine the coefficient of filtration water at standard temperature t = 10 ° C using the formula

$$k_f^{10} = {k_f}/{\tau}, \text{ (m/day).} \quad (4)$$

Table 1

The results of determination k_f using tubes "KF"

№ p/p	hydraulic gradient I	the volume of water that filter off Q, cm^3	time filtration T, sec			Filtration coefficient k_f, m/day		
			experiments		middle	separate	middle	by t°=10°C
			1	2				
1	0,6							
2	0,8							
3	1,0							

Table 2

Comparison of determination k_f

Name of sand	Filtration coefficient k_f, m/day	
	By the formula Hazen	By the results of the experiments

Conclusion: filtration coefficient of the sandy soil k_f = m/day.

Laboratory work № 8

DETERMINE THE DENSITY AND HUMIDITY OF UNCONSOLIDATED SEDIMENTS BY CUTTING RINGS

This method can be used for sedimentary rocks – clay, loam, sandy loam, sand, from which you can cut the sample by the cutting ring.

1. Using calipers measure the inner diameter and height of the cutting ring and determine its volume V (cm^3). Weigh the ring on the scales to the nearest 0.01 g and get weight rings g_1 (g). In this work we use the ring with already known mass and volume.

2. Ring set the sharp side to the tipped and leveled surface rock monolith. With a sharp knife carefully cut column of rock whose diameter of 1 mm more than the internal diameter of the ring. Ring gradually imposed on a column of rock. Excessive rock trimmed by the cutting edge of the ring. After column rock ledge above the upper edge of the ring, excessive rock cut flush with the bottom and top edge of the ring.

3. Ring with rock weighed at technical scales and get weight g_2. Defining rock weight $g = g_2 - g_1$, calculate its density (g/cm^3)

$$\rho = \frac{g}{V}. \qquad (1)$$

4. To determine the humidity of rock, you put part of it (at least 10 grams) in a weighted weighing bottle, weigh this weighing bottle with soil, then dried soil in the oven at a temperature of about 105 ° C to constant weight it (see. L.W. № 6).

Determine the humidity by the formula

$$W = \frac{q_2 - q_3}{q_3 - q_1} 100\%. \qquad (2)$$

5. The density of the soil skeleton (or the density of dry soil) ρ_d (g/cm^3) determined by the formula

$$\rho_d = \frac{\rho}{1 + W}. \qquad (3)$$

6. The results of the determination of the rocks density and humidity recorded in Table 1.

Table 1

№	№ ring, № weighing bottle	Weight empty rings (weighing bottle) g_1 (q_1) g	Weight ring (weighing bottle) with the soil g_2 (q_2), g	Weight the sample of rock, g, g	Weight the weighing bottle with dry soil q_3, g	The volume of ring, V, cm^3	The density of the sample, ρ, g/cm^3	The density of the skeleton sample, ρ_d, g/cm^3	Humidity of the soil W, %
1					-				
				-		-			
2					-				
				-		-			
3					-				
				-		-			
4					-				
				-		-			
5					-				
				-		-			
6					-				
				-		-			
7					-				
				-		-			
8					-				
				-		-			

LITERATURE

1. ДСТУ Б В.2.1-2-96. Ґрунти. Класифікація / Державний комітет України у справах містобудування і архітектури. – К.: МНТКС, 1997. – 43 с.
2. ДСТУ Б В.2.1-17: 2009. Основи та підвалини будинків і споруд. Ґрунти. Методи лабораторного визначення фізичних властивостей.
3. ДСТУ Б В.2.1-8-2001. Ґрунти. Відбирання, упакування, транспортування і зберігання зразків.
4. ДБН А.2.1-1-2014. Інженерні вишукування для будівництва. – К.: Мінрегіонбуд України. – 2014. – 128 с.
5. Чаповский Е.Г. Лабораторные работы по грунтоведению и механике грунтов. – М.: Недра, 1975. – 304 с.
6. Інженерна геологія. Механіка ґрунтів, основи та фундаменти: Підручник/ М.Л. Зоценко, В.І. Коваленко, А.В. Яковлєв, О.О. Петраков, В.Б. Швець, О.В. Школа, С.В. Біда, Ю.Л. Винников. – Полтава: ПолтНТУ, 2004. – 568 с.

Ministry of education and science of Ukraine
Poltava National Technical Yuri Kondratyuk University

Geological Surveying Log

for students of specialty
192 construction and civil engineering,
Educational level „bachelor” (full-time study)

Poltava 2019

Ministry of education and science of Ukraine
Poltava National Technical Yuri Kondratyuk University

Geological Surveying Log

Student of .... group civil engineering faculty

Crew

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____
7. ____
8. ____
9. ____
10. ____

Chief of practice ________________________________

____

The practice was carried out
since ____________________________
till ____________________________

Content

INSTRUCTIONS FOR THE EXECUTION, LOGGING AND PROTECTION OF THE REPORT ON ENGINEERING GEOLOGICAL PRACTICE. THE ORDER OF CARRYING OUT THE OFFSET

The purpose of the engineering-geological practice of students of the second year of the above-mentioned specialties studying in the direction of "Construction" is the consolidation of knowledge from the course "Engineering Geology", as well as their mastery of practical skills and techniques for the detection of signs in the field of adverse geological processes and engineering-geological phenomena, determination of indicators of physical and mechanical properties of soils and their analysis.

In practice, students study geological and engineering-geological features of the practice area, gain experience in selecting, preserving, transporting soil samples, using some field and laboratory methods for determining the physical properties of soils. During the work, trainees use equipment and instruments that are intended for engineering and geological exploration.

Before the beginning of practice, as well as in its process, the chief conducts the surveying safety training.

The log on engineering geological practice is being filled in during its implementation and must have a brief description of the objects or works that were observed during the passage of the tour or other work practices of practice. The log should have clear diagrams, drawings, scemes or photographs.

If necessary, you can stick additional sheets to the magazine for further filling them with text or illustrations.

In the course of the training, the team brings to the chief a completed, high-quality log, and crew answer the questions about works that were carried out during practice.

1. EXCURSIONS

Date ....

The following pages of the log provide a detailed description of the routes of excursions and works that were observed during their passage. To do this, use the information that students received from the chief, as well as from literary sources.

The section includes sketches or photographs of natural debris, ravines, landscaping circuses, river valleys, buildings and structures that have undergone deformation through manifestations of exogenous geological processes and dangerous engineering-geological phenomena, etc.

2. STUBBLE WORK AND SELECTION OF SOIL SAMPLES OF BROKEN OR UNDAMAGED STRUCTURE

Date ....

Aim – ....
....
Tools ………………………………………………………………………….....
....
....

Selection of samples of broken and undisturbed structure. Conservation of samples and monoliths (*painted and signed*).

Information on the main set of instruments of field express laboratory of prof. I.M. Litvinov, FLL-9 (paint or photograph and sign).

Selection of samples of undisturbed structure with the equipment of the basic set of laboratory FLL-9 (painte or take pictures).

Soil samples in compression rings or beaks are weighed in a stationary laboratory with accuracy up to 0.01 g, and the results are entered in the table. 4 (p.18). After weighing, the samples are dried in a drying cabinet.

Log

Work initiated ...., completed ....
Location ....

Top marker ....
Location ....
Cross section ....
Depth .... m.

Table 1

Sample #	Features of breeds (color, density, humidity, presence of inclusions, impurities, etc.)	Depth of sampling, m	Layer depth, m		Layer length, m	Water level, m, after	
			from	to		appear	setting

3. DRILLING AND SAMPLING OF WELLS

Date ....

The purpose of drilling works in engineering geological surveys – ....
....
....
....

Equipment used for drilling operations.

A. Manual drilling.

Depth .... Well diameter ....

Technique ....

Components of a hand-made storm (draw or photograph, to sign).

Б. Mechanized drilling using the search drilling set (SDS-15).

Depth .... Well diameter ....

Technique ....

Components of a drilling set (draw or photograph, to sign).

Drilling log

Well # .... Top marker ....
Location ....

Depth .... m. Diameter .... mm.
Work initiated ...., completed ....

Table 2

Sample #	Features of breeds (color, density, humidity, presence of inclusions, impurities, etc.)	Depth of sampling, m	Layer depth, m		Layer length, m	Water level, m, after	
			from	to		appear	setting

4. DETERMINATION OF SAND FILTRATION COEFFICIENT IN FIELD CONDITIONS

The date of the experiment...............................

The purpose of establishing the soil filtration coefficient is – ....
....
....

Equipment for determining the soil filtration coefficient is device PVN (Painted or photographed and signed).

The sequence of fieldwork (*Write down*)

Field journal to study the filtration properties of the soil

Table 3

№	Time		Time interval between measurements		The amount of water spilled over the time taken, l	Water consumption	
	hour	min	hour	min		l/min	m^3/day
1							
2							
3							
4							
5							
6							
7							
8							

Notation: 1 day = 1440 min.; 1 m^3 = 1000 liters.

Graph of dependence of filtering water consumption on time (*Vertical axis - filtration water consumption, m^3/day; gorizontal – hour, min.*)

5. CAMERAL WORKS

The date of the experiment...............................

A. Determination of the density of mineral soil particles

Devices and materials

1. A pycnometer.
2. Glass funnel.
3. Scales technical.
4. Electric hot plate.
5. Distilled water.
6. Samples of air-dry soil.
7. Stump.
8. Sieve № 1.

To prepare the experiment, the soil samples are crushed in a porcelain stump and sifted through a sieve with apertures of 1 mm.

The sequence of the experiment (*Write down*)

Output data and calculation

Mass of empty pycnometer g_n ....g.
Mass of pycnometer with a weight of soil g_{n2} ....g.
Soil mass $g_1 = g_{n2} - g_n$ ....g.
Mass of pycnometer with soil and water, poured to the mark g_2 ....g.
Mass of pycnometer with water, poured to the mark g_3 ....g.
Incorporation of correction for hygroscopic moisture (the value of hygroscopic moisture (W_2) is given by the teacher)

$$g_0 = \frac{g_1}{1 + W_2} = \text{-------------------------} = \qquad \text{g.}$$

The density of mineral soil particles

$$\rho_s = \frac{g_0}{(g_0 + g_3) - g_2} \cdot \rho_w = \text{---------------------} = \qquad \text{g/cm}^3.$$

$\rho_w = 1{,}0$ g/cm^3 – water density.

B. Determination of granulometric composition of clay soil by field method (Rutkovskii)

B.1. Determination of the composition of clay particles (diameter $\leq 0{,}005$ mm)

Devices and materials

1. Measuring cylinder capacity 50 cm^3.
2. Mixer (metal or glass rod with a rubber tip).
3. Coagulator (solution $CaCl_2$).
4. Prepared powder of clay soil.
5. Water.
6. Capacity for fusion water.

The sequence of the experiment (*Write down*)

Output data and calculation

Initial volume of soil $V_0 = 5{,}0$ cm^3.
Volume of soil after swelling $V_1 =$ .... cm^3.
To increase the volume by 1 cm^3 of the original value

$$K = \frac{V_1 - V_0}{V_0} = \text{-------------------------} = \qquad .$$

The content of clay particles $F = 22{,}7 \cdot K =$ .... %.

B.2. Determination of the composition of sand particles (diameter $\geq 0{,}05$ mm)

Devices and materials

1. Measuring cylinder capacity 100 cm^3.
2. Mixer (metal or glass rod with a rubber tip).
3. Stopwatch.
4. Prepared powder of clay soil.
5. Water.
6. Capacity for fusion water.

The sequence of the experiment (*Write down*)

Output data and calculation

Initial volume of soil $V_0 = 10\ \text{cm}^3$.
Sediment volume after complete clarification of water $V_1 =$ .... cm^3.
Each cubic centimeter of soil that is introduced into the measuring cylinder corresponds to 10% of the soil. Therefore, the amount of sand particles is determined after multiplying the amount of sediment by 10%

$$Y = V_1 \cdot 10\ \% = \text{................................}\ \%.$$

B.3. Determination of the composition of dust particles
(diameter by 0,005 to 0,05 mm)

To calculate the composition of dust particles it is necessary to subtract from the 100% total amount of clay and sand particles:

$$Z = 100\ \% - (F + Y) = \text{..}\ \%.$$

Thus, according to the classification V.V. Ohotina, soil belongs to...................
(for reference: sandy loam $F \le 10\ \%$; loam $F = 10 \div 30\ \%$; clay $F > 30\ \%$).

C. Determination of indicators of physical properties of the soil
C.1. Soil density calculation

Using samples taken from the technical (shell or well) through the cutting rings, the density of the soil is determined as

$$\rho = \frac{G_1 - G_á}{V} = \text{------------------------------} = \qquad \text{g/cm}^3,$$

where G_1 – sample mass with a ring (weighing bottle), g;
$G_á$ – mass of a ring (weighing bottle), g;
V – Ring volume, sm^3.
The calculation results are entered in column 9 of table 4.
Note. The volume of the compression ring from the set of the express laboratory of Litvinov is $V = 50\ \text{cm}^3$.

C.2. Determination of soil moisture

After drying the samples in the drying cabinet drying oven at $t = 105^\circ$ C the samples are weighed on technical scales and calculate the soil moisture by the formula

$$W = \frac{G_1 - G_2}{G_2 - G_á} = \text{----------------------------} = \qquad ,$$

where G_2 – Mass of dried sample with a ring (weighing bottle), g.

If necessary, the moisture of the soil can be determined as a percentage.

The calculation results are entered in column 10 of table 4.

C.3. Calculation of the density of the dry (skeleton) soil

The density of dry soil ρ_d is calculated according to the following expression, using already established values ρ and W:

$$\rho_d = \frac{\rho}{1 + W} = \text{----------------------------} = \qquad \text{g/cm}^3.$$

The calculation results are entered in column 11 of table 4.

C.4. Determination of the porosity coefficient of the soil

The coefficient of soil porosity is calculated according to one of the formulas:

$$e = \frac{\rho_s}{\rho} \cdot (1 + W) - 1 = \text{---------} \cdot (1 + \qquad) - 1 = \qquad \text{or}$$

$$e = \frac{\rho_s - \rho_d}{\rho_d} = \text{----------------------------} = \qquad .$$

The density of mineral soil particles ρ_s is taken on the basis of the results of the cameral work A. The results of the calculation are made to column 12 of Table 4.

C.5. Calculation of the water saturation coefficient of the soil

The water saturation coefficient of the soil is determined by expression

$$S_r = \frac{\rho_s \cdot W}{\rho_W \cdot e} = \text{----------------------------} = \qquad .$$

The constituent formulas are taken separately for each sample according to preliminary calculations. The results of calculations are added to column 13 of table 4.

Table 4

Determination of basic and derived indicators of physical properties of the soil

№ hole	Depth of selection, m	№ ring (weighing bottle)	mass of a ring (weighing bottle), $G_á$, g	mass of a ring (weighing bottle), g		mass of a soil, g		Soil density ρ, g/cm³	Humidity W	density of the dry soil ρ_d, g/cm³	Porosity coefficient e	Water saturation coefficient S_r	Notes
				wet G_1	dry G_2	wet	dry						
1	2	3	4	5	6	7	8	9	10	11	12	13	14

LITERATURE

1. ДСТУ Б В.2.1-2-96. Ґрунти. Класифікація / Державний комітет України у справах містобудування і архітектури. – К.: МНТКС, 1997. – 43 с.
2. ДСТУ Б В.2.1-17: 2009. Основи та підвалини будинків і споруд. Ґрунти. Методи лабораторного визначення фізичних властивостей.
3. ДСТУ Б В.2.1-8-2001. Ґрунти. Відбирання, упакування, транспортування і зберігання зразків.
4. ДБН А.2.1-1-2014. Інженерні вишукування для будівництва. – К.: Мінрегіонбуд України. – 2014. – 128 с.
5. Чаповский Е.Г. Лабораторные работы по грунтоведению и механике грунтов. – М.: Недра, 1975. – 304 с.
6. Інженерна геологія. Механіка ґрунтів, основи та фундаменти: Підручник / М.Л. Зоценко, В.І. Коваленко, А.В. Яковлєв, О.О. Петраков, В.Б. Швець, О.В. Школа, С.В. Біда, Ю.Л. Винников. – Полтава: ПолтНТУ, 2004. – 568 с.

CONTENT

ЗОЦЕНКО Микола Леонідович
ВИННИКОВ Юрій Леонідович
МІРОШНИЧЕНКО Ірина Володимирівна

Engineering Geology and Soil Mechanics Starter.
Навчальний посібник

Комп’ютерна верстка Ю.Л. Винников
І.В. Мірошниченко

Відповідальний за випуск Л.Г. Щербінін

Підп. до друку 18.06.2019 р. Формат 60х84 1/16.
Папір офсет. Друк ризограф.
Ум.-друк. арк. – 8,84. Обл.-видав. арк. – 5,10.
Тираж 300 прим. Зам. №42.

Видавець і виготовлювач –
поліграфцентр Полтавського національного технічного
університету імені Юрія Кондратюка
36011, Полтава, Першотравневий проспект, 24
Свідоцтво про внесення суб’єкта видавничої справи
до державного реєстру видавців, виготовників
і розповсюджувачів видавничої продукції
Серія ДК, № 3130 від 06.03.2008 р.
