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TESTING OF ROCK SAMPLES FROM OIL AND GAS FIELDS TO DETERMINE THEIR PHYSICAL AND MECHANICAL CHARACTERISTICS

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Annotation. Determination of the physical and mechanical properties of anisotropic limestone rocks is an important and urgent task, since carbonate deposits are very often found in oil and gas fields of the Mangistau region. The data show that limestone creates from 70% to 90% of all problems related to the stability of wells, which is due to the peculiarities of their physical and mechanical properties.

Experimental studies of the physical and mechanical properties of limestone have features both in terms of monolith selection and in terms of preparation of samples for research, and in the methods of conducting and processing experiments. These features are due to extremely low permeability, anisotropy of elastic and strength properties due to their layered structure. The experience of testing core samples of layered limestone is considered, tests are carried out on equipment under the program of consolidated-undrained loading in accordance with the standards.

As a result of experiments on core samples cut at an angle, along and across the layering, the anisotropic elastic properties of rocks, as well as their dependencies on geophysical parameters, were studied. The anisotropy of elastic properties has a significant effect both on the *stress-strain state when solving specific problems of continuum mechanics and on the design values of the* initial stress field as a whole. Taking into account the anisotropy parameters obtained in this paper will make it possible to solve Geomechanics problems in relation to layered limestones of the Sarmatian stage.

Keywords: geomechanics; anisotropy; strength; elasticity; foliation; limestone, experimental studies; monolith; core.

1. Introduction

The Dunga oil and gas field is located in the Tupkaragan district of the Mangistau region of Kazakhstan, 50 km from Aktau. The geological reserves of the field are estimated at 106 million tons of oil and more than 6 billion cubic meters of gas. The deposit was discovered in 1966.

The Dunga project is being implemented under the Production Sharing Agreement (PSA) dated May 1, 1994, concluded between Oman Oil Company Limited and the Government of the Republic of Kazakhstan. Currently, the project participants are Total E&P Dunga GmbH (60%), «Oman Oil Company Limited» (20%) и «Partex

Kazakhstan Corporation» (20%), collectively referred to as the Contractor. The operator of the project is Total E & P Dunga GmbH.

The Dunga field was put into trial production in 2000. In the period from 2004 to 2006, the field was developed as part of the Pilot Development project with the drilling of horizontal and vertical wells. From 2007 to the present, the Dunga field has been at the stage of full-scale development.

Within the boundaries of the deposit, deposits of the Sarmatian stage of the Neogene are developed, expressed by weathered limestone of hard consistency, with interlayers of shell limestone up to 30%, layer thickness from 0.2 m (well No3-52) to 2.5 m (well No8-06), loamy marl, limestone - shell rock, covered from the surface with a gypsum horizon, loam, sandy loam. Below there is a continuous massif of limestone-shell rock of low strength, with interlayers of weathered limestone up to 30%. The thickness ranges from 0.6 m (well No3-13) to 7.0 m (well No8-10).

The most important mechanical properties of rocks - elasticity, compressive and tensile strength, as well as plasticity - affect a number of processes occurring in the reservoir during the development and operation of oil and gas fields. For example, the redistribution of stresses in the reservoir during the operation of the deposit depends on the elastic properties of rocks and the elasticity of reservoir fluids. The reserve of elastic energy released by pressure reduction can be a significant source of energy, which is the driving force through which oil moves through the reservoir to the bottom of the wells.

In the process of field operation, it is also very important to know the compressive and tensile strength characteristics. These data, as well as the modulus of elasticity, are necessary in the study of the processes of artificial stimulation of the rocks of the bottomhole zone of wells (hydraulic fracturing, torpedoing), which are widely used in the oilfield business to increase oil recovery. When studying the physical properties of rocks, it should be taken into account that depending on the conditions of occurrence, the mechanical properties of the rock can change dramatically.

2. Literature review

Researchers have always been interested in the question of how the properties of rocks will change in an intact massif, which is in a bulk stress state. For this purpose, T. Karman developed one experimental setup that made it possible to test samples under triaxial equicomponent compression [1]. Loading in it was carried out using a piston, which compressed the working fluid (glycerin) and created lateral pressure. The first results on marble samples showed that with an increase in lateral pressure, the strength of the samples increased. T. Kármán's experiments were subsequently improved by O. Müller [2] under similar conditions, during which the results obtained for marble, sandstone, shale, and coal were confirmed.

In the works of the authors [3-5], it was experimentally proved that a similar tendency to increase the strength of samples with an increase in lateral pressure is also characteristic of other types of rocks.

At the moment, laboratory equipment for testing rock samples under conditions of triaxial compression has undergone a number of technical changes.

The loading capacity of the presses has increased, the number of parameters controlled and determined in the course of the experiment has increased, and it has become possible to create a three-axis unequal component load [6-15]. This made it possible to obtain new data on changes in the strength and deformation properties of rocks under conditions of triaxial compression [16–21]. For a number of rocks, it has been established that with an increase in lateral pressure, their tendency to fracture in a dynamic form decreases, and at high values of lateral pressure, such a tendency disappears altogether [21–23], i.e. the rocks pass into a state of plastic deformation.

Despite the significant groundwork in the field of studying the properties of rocks under loading under conditions of triaxial compression, there is a problem with obtaining experimental data. It is mainly associated with the high cost of testing equipment, as well as labor-intensive testing of samples. Nevertheless, the importance of this method lies in the fact that it allows you to determine how the properties of rocks change under conditions of triaxial compression, as well as to identify whether the tendency of rocks to fracture in a dynamic form will change with an increase in lateral pressure.

To date, the Rock Testing Laboratory of the Caspian University of Technologies and Engineering named after Sh. Yessenov has carried out quite numerous studies of the elastic properties of cores and has accumulated a significant amount of data on the physical and mechanical properties of rocks and methods of their testing [24–27]. One of the most common test methods is to load specimens in uniaxial compression mode. As a result, knowledge is obtained about the strength and elastic properties of rocks, the nature of their deformation. This type of testing is simple, it can be implemented on relatively inexpensive and accessible laboratory equipment. However, such a loading mode characterizes the limiting cases of fracture in the rock mass, when there are free surfaces and there are no lateral loads. This article presents the results of experimental studies of shell limestone samples (Dunga oil field) under uniaxial compression conditions. The main goal of the research is to obtain characteristics of anisotropy of elastic properties of rocks on the basis of experimental studies of core samples of layered limestone.

A review of publications in scientific sources on the topic under consideration shows its relevance, novelty and socio-economic significance not only for the region, but also for the economy of the republic as a whole. Therefore, it is necessary to formulate the formulation of the task, goal, area and subject of research.

Problem statement

The field of research is the Dunga oil and gas field in the Mangistau region,

the subject is its sustainable operation in the long term.

Laboratory and field surveys of the rocks of the deposit:

- drilling of 2-4 wells, depth h = 0.2 – 7.0 meters;
- extraction, storage of the natural integrity of the well core and delivery to the university laboratory;
- preparatory work for experimental research;
- comprehensive testing of rock samples of the deposit in the university laboratory;
- test results, their analysis and comparison with known, reliable, reference solutions. This article presents the results of comprehensive experimental tests of shell limestone samples.

Expected results of the study: on the basis of comprehensive tests of core samples of layered limestone, to obtain characteristics of anisotropy of elastic properties of rocks at the base of the Dunga oil field.

3. Purpose and objectives of the study

Objective: Experimental studies of the anisotropy parameters of the rocks of the Dunga oil and gas field in order to assess their strength, rigidity, stability and predict the stress-strain state of the foundation in the long term.

Tasks:

1. Test rock samples extracted from well No8-02 of the Dunga deposit.
2. To test rock samples extracted from well No8-06 of the Dunga deposit.
3. To test rock samples extracted from well No8-08 of the Dunga deposit.
4. Test rock samples extracted from well No8-10 of the deposit.

As a physical method for assessing strength anisotropy, a method widely used in geotechnics for determining the strength of soils is used - the method of uniaxial compression-tension of samples taken from the base at their different spatial orientation in the base, usually determined by the angle of inclination of the longitudinal axis of the sample to the vertical or to the isotropy axis, if its position is known in advance.

Scheme of orientation of the soil sample in the space of the foundation

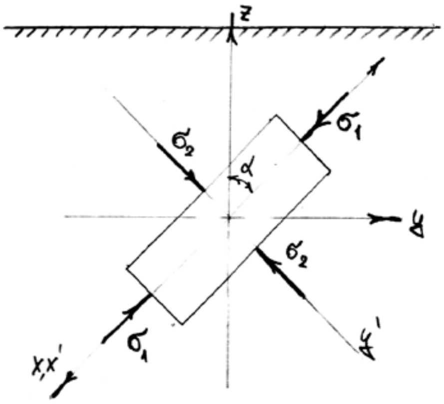

Figure 1

Methods for determining strain anisotropy.

Poisson's ratios are determined in the traditional way - for uniaxial compression of soil or rock samples. This method is considered in the work of V.A. Kuzmitsky. This method was then used in a number of works. The most complete results were obtained in the studies of V.P. Pisanenko, in which the determination of Poisson's coefficients was carried out on a setup made on the basis of the CTB stabilometer at different orientation of the samples. When it was used, from 8 to 12 indicators were used to measure transverse deformations, placed in the horizontal plane at intervals of 45° or 30°. When the isotropy plane of a transversal-isotropic medium coincides with the plane xoy, this medium is characterized by Poisson's coefficients $\nu_{xy}=\nu_{yx}=\nu_1$, $\nu_{zx}=\nu_{zy}=\nu_2$, $\nu_{xz}=\nu_{yz}=\nu$. The direction of action (stress application) is assumed to coincide with the longitudinal axis of the sample.

To determine the Poisson coefficients ν_{xy} , ν_{xz} the samples were cut so that the axis of the specimen was located in the xy plane (coinciding with the x-axis), for the coefficient ν_{xz} – the axis of the specimen coincided with the z-axis. In a monotropic body, any two directions inclined to the isotropy axis z (the vertical axis in Figure 2) at the same angle are equivalent. In this case, the two arbitrary orthogonal directions i, j are uniquely characterized by the Poisson's ratio $\nu_{\alpha i}$, $\nu_{\alpha j}$, where α_i, α_j are the angles of inclination of the directions i, j to z. The angles together with the orthogonality condition of the directions i, j completely determine the Poisson's ratio. For ease of notation, it is proposed $\nu_{\alpha i}$, $\nu_{\alpha j}$ to denote ν_{ij}. The coefficient ν_{ij} characterizes the expansion in the direction j of the specimen, the longitudinal axis of which coincides with the direction i, under the action of a load on the ends with the normal i. (There may be other notations and rational formulas).

The values of Poisson's ratios based on the results of uniaxial compression experiments are calculated according to the formula following the concept of this coefficient:

$$\nu_{ij} = \Delta\varepsilon_j / \Delta\varepsilon_i , \qquad (1)$$

where $\Delta\varepsilon_j$ is the relative strain increment in the cross-section in the direction j;

$\Delta\varepsilon_i$ - increment of relative strain along the longitudinal axis of the specimen aligned with the i-axis when a compressive pressure is applied along this axis.

In formula (1), total (accumulated) deformations from the applied load can be taken instead of increments.

The determination of the strain moduli from the experimental tests can only be carried out with known values of Poisson coefficients, even in the case of isotropic soil testing, the relationship $\varepsilon_1 = (\sigma_1 - 2\nu\sigma_3)/E$ between the deformation E_1 and the stress σ_1 measured in the experiment contains two unknown characteristics E and ν, if we assume that $\sigma_3 = \xi\cdot\sigma_1 = \sigma_1\nu / (1-\nu)$.

The method of processing the test results of an anisotropic sample differs markedly from that of an isotropic one. Assuming, as usual, the lack of friction between the reference and the sample stamps and uniform stress distribution in the sample, the longitudinal axis is parallel to the z axis, when tested according to the "crushing" have $\sigma_z=\sigma_1$; $\sigma_x=\sigma_y=\sigma_2=\sigma_3$; $\tau_{xy}= \tau_{yz} = \tau_{zx}=0$. In the general case of an anisotropic linearly deformable soil (with the existence of an elastic potential), deformations are determined by the dependencies:

$$\begin{aligned}
\varepsilon_x &= (a_{11}+a_{12})\sigma_3 + a_{12}\cdot\sigma_1\\
\varepsilon_y &= (a_{11}+a_{22})\sigma_3 + a_{22}\cdot\sigma_1\\
\varepsilon_z &= (a_{13}+a_{23})\sigma_3 + a_{33}\cdot\sigma_1\\
\gamma_{xy} &= (a_{16}+a_{26})\sigma_3 + a_{36}\cdot\sigma_1\\
\gamma_{yz} &= (a_{14}+a_{24})\sigma_3 + a_{34}\cdot\sigma_1\\
\gamma_{zx} &= (a_{15}+a_{25})\sigma_3 + a_{35}\cdot\sigma_1 .
\end{aligned} \tag{2}$$

In the case of fixing the end of the sample in the form of a parallelepiped, the dependences of the movements of the center of the upper end along the x, y and z axes after integrating expression (2) take the form:

$$\begin{aligned}
u &= [(a_{15}+a_{25})\sigma_3 + a_{35}\sigma_1]\cdot x\\
v &= [(a_{14}+a_{24})\sigma_3 + a_{34}\sigma_1]\cdot y\\
w &= [(a_{13}+a_{23})\sigma_3 + a_{33}\sigma_1]\cdot z ,
\end{aligned} \tag{3}$$

where x, y and z are the Cartesian coordinate system with the origin in the center of gravity of the lower end of the sample and the z axis coinciding with the longitudinal axis of the sample.

It follows from expressions (3) that the vertical axis of the sample changes its slope when it is loaded, while the rectangular faces of the sample turn into a parallelogram.

In the presence of symmetry of deformation properties, expressions for deformations and displacements are significantly simplified and they acquire the simplest form for samples from monotropic soil when they are selected parallel and perpendicular to the isotropy plane. In this case, the sample will not experience skew deformation during loading, since all the coefficients of mutual influence a_{ij} $(i\neq j)$) in forms (2) and (3) are zero.

The calculation formula for calculating the shear modulus of deformation in any direction in the space of an anisotropic base has a simple form:

$$E_\alpha=\Delta\sigma_{1,\alpha} / \Delta\varepsilon_{1,\alpha}, \tag{4}$$

where $\Delta\sigma_{1,\alpha}$ is the increment of the greatest main (axial) stress σ_1 in the sample taken from the base at an angle α to the axis of isotropy (the longitudinal axis of the s$\Delta\varepsilon_{1,\alpha}$ ample is inclined at an angleα to the axis of isotropy);

$\Delta\varepsilon_{1,\alpha}$ - is the increment of the relative axial deformation ε_1 of the specified sample.

In total, three samples are being tested. Module $E_{xx}= E_{//}$ and Poisson's ratios $\nu_{xy} = = \nu_{II,//}$, $\nu_{xz} = \nu_{II,\perp}$ determined by the compression of the sample, cut perpendicular to the z axis, i.e. the axis of the sample lies in the plane of isotropy. To determine transverse deformations, one pair of indicators is placed in the isotropy plane; the other is perpendicular to the first. The values E_{xx}, ν_{xy}, ν_{xz} are calculated directly using formulas (1) and (4). To find the module $E_{zz}= E_1$, the sample is selected so that its longitudinal axis is parallel to the axis of isotropy z.

The stress-strain state of transversally isotropic bases depends, along with other deformation parameters, also directly on the shear modulus Gxz = Gyz in planes parallel to the z-axis. The shear modulus Gxz can be determined through known deformation parameters in the isotropy plane, both theoretically and experimentally.

Some authors have proposed a technique for indirectly determining the shear modulus G_{xz} based on data from uniaxial compression of samples with free lateral expansion, while other deformability characteristics are determined. This technique is used for soils of foundation bases when lateral compression of soils can be neglected. To determine the Gxz module, in addition to the previous ones, a sample cut from the base at an angle of 45° to the z-axis of isotropy is tested. In the uniaxial compression test, E_{45° is determined by the formula (4). A dependency is used for the G_{xz} module:

$$G_{xz} = \frac{E_{xx} \cdot E_{45^\circ} \cdot E_{zz}}{4E_{xx} \cdot E_{zz} - E_{45^\circ}(E_{xx} - 2\nu_{zx} \cdot E_{zz} + E_{zz})}, \tag{5}$$

which substitutes the value ν_{xz} found from the ratio $\nu_{zx} \cdot E_{zz} = \nu_{xz} \cdot E_{xx}$, and E_{45° determined by the formula:

$$\mathrm{E}_{\alpha=45} = \frac{\cos^4 \alpha}{\mathrm{E}_{1(zz)}} + \frac{\sin^2 2\alpha}{4(G_{2(xz)} - 2\nu_{2(zx)} \cdot \mathrm{E}_{(zz)})} + \frac{\sin^4 \alpha}{\mathrm{E}_{2(xx)}} \tag{6}$$

The values of the elastic constants E_1, E_2, ν_1, ν_2 and G_2 do not quantitatively characterize the degree of elastic anisotropy of the array, allowing only a qualitative assessment of deviations from the theoretical ratios $E_1=E_2$, $\nu_1=\nu_2$ and $G_2=E_1(2+\nu_2)$. In general, the degree of anisotropy of rocks and soils is estimated by the deviation of the anisotropy parameter $n_{ij} = E_{i\alpha}/E_{j\alpha}$ from the isotropic rock parameter at $n_{ij}=1$. A complete analysis of the planar and generalized planar deformation of a transtropic rock requires anisotropy parameters of the types k, n and l. The degree of anisotropy in this case is estimated by the deviation of the numerical solutions of the anisotropy parameters from the parameters of the isotropic array: k = 1, n = 2, l = 1.

$$\begin{gathered} k = [(E_1 E_2^{-1} - \nu_2^2) / (1 - \nu_1^2)]^{1/2} \\ n = \{2K - [E_1 G_2^{-1} - 2\nu_2(1 + \nu_1)] / (1 - \nu_1^2)\}^{1/2} \\ l = [0.5 * E_2 / (1+\nu_1) G_2]^{1/2} \end{gathered} \tag{7}$$

5. The results of complex tests of rock samples of the base of the oil and gas field.

5.1 Test results of anisotropic rock samples extracted from well No. 8-02 of the Dunga deposit.

Lithological section of well No.8-02

Литологический разрез скважины №8-02

The strength of the samples was determined in three directions of rock stratification: perpendicular to the stratification of the sample (isotropy plane); parallel to the stratification; at an angle of 30°, 45°, 60° to the stratification.

The ultimate strength was determined by the formula:

$$\sigma_{разр.} = P_{разр.}/F \tag{8}$$

The proportionality limit was determined by the formula:

$$\sigma_{пц.} = P_{пц.}/F \tag{9}$$

The results of determining the physical and mechanical characteristics of rock samples in their natural state are shown in Table 1.

Table 1. Test results of shell limestone samples from well No.8-02

Strength tests									
No p.p	Length, cm	Width, cm	Height cm	Area cm^2	Volume, cm^3	Volumetric weight, t/m^3	Sample weight, g	Destruction. Load, kgf	Tensile strength, kg/m2
1	10,2	10,3	105	105	1080	1,85	2000	7100	67,6
2	10,5	10,3	108	108	1090	1,80	1960	9600	89,0
3	10,4	10,4	108	108	1080	1,80	1940	8100	75,0
4	10,5	10,5	105	105	1070	1,82	1950	6800	64,8
5	10,4	10,2	106	106	1070	1,82	1950	9700	91,5

In accordance with THE STATE STANDARD 4001-84, the average strength of the samples is $\sigma_{cp.}$ = 77.8 kg/cm^2, minimum strength - σ_{min} = 64.8 kg/cm^2, maximum strength - σ_{max} = 91.5 kg / cm^2, average destructive load is equal to P_{aver} = 8260 kgf.

5.2 Test results of anisotropic rock samples extracted from well No8-06 **of** the Dunga deposit.

Lithological section of well No.8-06

Table 2. Test results of shell limestone samples from well No.8-06

No p.p	Length, cm	Width, cm	Height cm	Area cm^2	Volume , cm^3	Volumetric weight, t/m^3	Sample weight, g	Destruction. Load, kgf	Tensile strength, kg/m2
1	9,4	10,0	9,7	94	912	1,61	1470	6100	64,8
2	9,3	9,2	9,4	85	800	1,52	1220	4200	49,4
3	9,7	9,5	10,0	92	920	1,67	1540	3950	50,0
4	9,1	9,9	10,1	90	909	1,69	1540	3950	43,8
5	10,1	9,7	9,2	98	901	1,76	1540	3600	36,7

In accordance with STATE STANDARD 4001-84, the average strength of the specimen is (σ_{aver} = 48.9 kg/cm^2, minimum strength - (σ_{min} = 36.7 kg/cm^2), maximum strength - (σ_{max} = 64.8 kg/cm^2, average breaking load is equal to P_{aver} = 4360 kgf.

5.3 Test results of anisotropic rock samples extracted from well No8-08 of the Dunga deposit.

Lithological section of well No.8-08

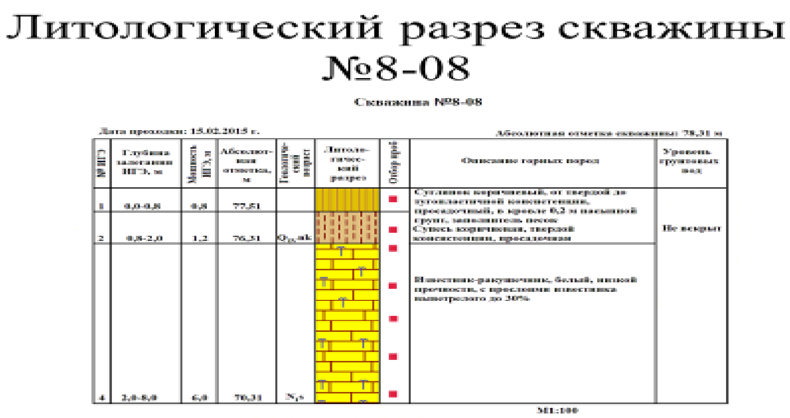

Table 3. Test results of shell limestone samples from well No.8-08

Испытания на прочность									
№ п.п	Длина, см	Ширина, см	Высота, см	Площадь, $см^2$	Объем, $см^3$	Объемный вес, $т/м^3$	Вес образца, г	Разруш. Нагрузка, кгс	Предел прочности, $кг/м^2$
1	10,0	9,7	9,7	97	941	1,36	1280	1200	12,4
2	9,4	9,7	9,7	31	883	1,42	1260	1000	10,9
3	9,3	9,7	9,6	89	854	1,37	1175	1600	17,9
4	9,7	9,3	9,4	90	846	1,34	1135	1100	12,2
5	9,9	9,2	9,9	82	812	1,29	1050	1300	15,8

According to STATE STANDARD 4001-84, the average strength of rock samples ($\sigma_{aver.}$ = 13.84 kg/cm^2, minimum strength - ((σ_{min} = 10.9 kg/cm^2), maximum strength ((σ_{max} = 17.9 kg/cm^2, average breaking load is P_{aver} = 1240 kgf.

5.4 Test results of anisotropic rock samples extracted from well No8-10 of the Dunga deposit.

Lithological section of well No.8-10

Table 4. Test results of shell limestone samples from well No.8-10

Strength tests											
No p.p	Length, cm	Width, cm	Height cm	Area cm^2	Volume, cm^3	Volumetric weight, t/m^3	Sample weight, g			Destruction Load, kgf	Tensile strength, kg/m2
						dry	dry	Wet w/w 48 hours	Wet w/w 96 hours		
1	5,2	5,1	5,0	265	1030	1,88	250	275	265	1700	64,2
2	5,3	5,2	5,2	276	1400	1,81	260	270	275	1240	45,0
3	5,4	5,2	5,3	281	1490	1,65	250	270	270	1080	38,0
4	5,0	5,0	5,2	250	1300	1,85	240	250	250	2200	88,0

5	5,3	2,3	5,5	281	1550	1,87	290	300	300	1600	57,0

In accordance with GOST 4001-84, the average wet strength of the specimen is (σ_{aver} = 77.8 kg/cm^2, minimum strength - (σ_{min} = 64.8 kg/cm^2), maximum strength (σ_{max} = 91.5 kg/cm^2, average breaking load is P_{aver} = 8260 kgf.6.

6. Discussion of the results of complex testing of rock samples of the base of an oil and gas field

Experimental studies of the elastic properties of the rocks of the deposit were carried out in several stages. At the first stage, the initial loads were determined, for which the strength limits of samples of representative rocks of the shelf were clarified.

For this purpose, samples of 100x100x100 mm in size were prepared from the rock that was used in the tests. Further, destructive loads were determined on samples with side dimensions of 50×50×100 mm. Before the start of the test, the sample mounted on a hydraulic press was preloaded to approximately a pressure of 50-60% of the average destructive load, followed by unloading.

To determine the elastic modulus and Poisson's coefficients, two complete cycles of successive loads and unloads were carried out. The load on the sample for all three types of layering orientation was given in steps after 200 kg. The loading and unloading speed was maintained constant, equal to 0.5-1.5 MPa/s, temperature fluctuations in the range of 2-3 ° C.

Deformations of the sample were measured both during loading and unloading. The measurement of deformations begins at some initial loading of the sample, equal to the natural pressure or at least 20% of the maximum destructive load, in this case P = 0.4 MPa.

The average values of the destructive load, stresses in the sample, Poisson's coefficients and modulus of elasticity of the samples are determined based on the results of their tests, when the load acts perpendicular, parallel and at some angle to the isotropy plane, the degrees of anisotropy are determined.

To determine the anisotropy of elastic properties, tests were carried out on adjacent samples sawn along and across the stratification, with similar properties and mineralogical composition. When performing this work, it was not always possible to cut out samples near each other. Based on this, the maximum distance between adjacent samples was assumed to be 0.15 m, and the similarity of samples in mineralogical composition was also assessed.

Quantitative and qualitative analysis of the degree of anisotropy of rocks in the study area shows that in dry and wet states, the studied rocks have a pronounced anisotropy.

7. Conclusion

Thus, based on the results of experimental studies of limestone samples under uniaxial compression conditions, their main strength and deformation properties were determined. It is shown that when the isotropy plane is positioned at an angle to the horizon and with increasing depth of occurrence, the strength limits of the samples of the studied rock increase. At angles of inclination up to 45 °, the strength increased on average by 2 times compared to the ultimate strength at angles of inclination equal to 0 °. With an angle of inclination of the isotropy plane of 90°, the tensile strength of shell limestone averaged 8.42 MPa, which is almost 4 times higher than the strength at angles of inclination equal to 0 °.

It has been established that shell limestone, of low strength, with interlayers of weathered limestone, has a pronounced anisotropy.

It has been established that, according to the Kaiser criterion and the energy criterion, limestone-shell rock under uniaxial loading is prone to destruction in a dynamic form, which is also confirmed by a number of other signs (a high value of the brittleness

coefficient, the elastic nature of deformation and brittle fracture of samples). Rocks lying at shallow depths have no potential for impact hazard.

Thus, based on the performed studies, it is shown that the values of the strength limits of rock samples can increase sharply at the angles of inclination of the isotropy plane from 45° to 90°. At 90, they reach the maximum. It has also been established that shell limestone is prone to dynamic destruction under uniaxial compression. It follows from this that when acting in an array of rocks of high stresses, limestone-shell rock can be impact-hazardous.

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ИСПЫТАНИЕ ОБРАЗЦОВ ПОРОДЫ ИЗ НЕФТЯНЫХ И ГАЗОВЫХ МЕСТОРОЖДЕНИЙ ОПРЕДЕЛИТЬ ИХ ФИЗИКО-МЕХАНИЧЕСКИЕ ХАРАКТЕРИСТИКИ

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Аннотация. Определение физико-механических свойств анизотропных известняковых пород является важной и актуальной задачей, поскольку карбонатные залежи очень часто встречаются на месторождениях нефти и газа Мангистауской области.

Данные показывают, что известняки создают от 70% до 90% всех проблем, связанных с устойчивостью скважин, что связано с особенностями их физико-механических свойств.

Экспериментальные исследования физико-механических свойств известняков имеют особенности как с точки зрения выбора монолита и подготовки образцов для исследований, так и с точки зрения методов проведения и обработки экспериментов. Эти особенности обусловлены чрезвычайно низкой проницаемостью, анизотропией упругих и прочностных свойств из-за их слоистой структуры. Рассмотрен опыт испытаний керновых образцов слоистого известняка, испытания проводятся на оборудовании по программе сводно-не дренируемого нагружения в соответствии с нормами.

В результате экспериментов на образцах керна, разрезанных под углом, вдоль и поперек слоистости, были изучены анизотропные упругие свойства горных пород, а также их зависимость от геофизических параметров. Анизотропия упругих свойств оказывает существенное влияние как на напряженно-деформированное состояние при решении конкретных задач механики сплошной среды, так и на расчетные значения начального поля напряжений в целом. Учет параметров анизотропии, полученных в данной работе, позволит решить задачи геотехники применительно к слоистым известнякам сарматского яруса.

Ключевые слова: геомеханика; анизотропия; сила; эластичность; слоение; известняк, экспериментальные исследования; монолит; основной.

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ТАСТЫҚТАР ҮЛГІЛЕРІН СЫНАУ МҰНАЙ ЖӘНЕ ГАЗ КЕҢІЛДЕРІНЕН ОЛАРДЫ АНЫҚТАУ ҮШІН ФИЗИКАЛЫҚ ЖӘНЕ МЕХАНИКАЛЫҚ СИПАТТАМАСЫ

Аннотация. Анизотропты әктас жыныстарының физика-механикалық қасиеттерін анықтау маңызды және кезек күттірмейтін мәселе болып табылады, өйткені карбонатты шөгінділер Маңғыстау облысының мұнай-газ кен орындарында жиі кездеседі. Мәліметтер әктас ұңғымалардың тұрақтылығына байланысты барлық мәселелердің 70%-дан 90%-ға дейін құрайтынын көрсетеді, бұл олардың физикалық-механикалық қасиеттерінің ерекшеліктеріне байланысты.

Әктастың физика-механикалық қасиеттерін эксперименттік зерттеулер монолиттік таңдау тұрғысынан да, зерттеуге үлгілерді дайындау тұрғысынан да, тәжірибелерді жүргізу және өңдеу әдістерінде де ерекшеліктерге ие. Бұл ерекшеліктер өте төмен өткізгіштікке, серпімділік анизотропиясына және олардың қабаттық құрылымына байланысты беріктік қасиеттеріне байланысты. Қабатты әктастың керн үлгілерін сынау тәжірибесі қарастырылды, стандарттарға сәйкес шоғырландырылған-дренажсыз тиеу бағдарламасы бойынша жабдықта сынақтар жүргізіледі.

Қабат бойымен және көлденеңінен бұрышпен кесілген керн үлгілерінде жүргізілген тәжірибелер нәтижесінде тау жыныстарының анизотропты серпімділік қасиеттері, сонымен қатар олардың геофизикалық параметрлерге тәуелділігі зерттелді. Серпімділік қасиеттерінің анизотропиясы континуум механикасының нақты есептерін шешу кезінде кернеу-деформация күйіне де, жалпы бастапқы кернеу өрісінің есептік мәндеріне де айтарлықтай әсер етеді. Бұл жұмыста алынған анизотропия параметрлерін есепке алу сармат кезеңінің қабаттас әктастарына қатысты геомеханика есептерін шешуге мүмкіндік береді.

Түйін сөздер: геомеханика; анизотропия; күш; серпімділік; жапырақтану; әктас, тәжірибелік зерттеулер; монолит; негізгі.