Some results of the study of rock properties of the Sulukta deposit

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Abstract. This article presents the results of research into the properties of physical and mechanical properties of rocks and their influence on the conditions of their occurrence in the coal-bearing massif, depending on the geological structure of a particular section of the rock massif and the relief of the area, to develop an experimental method of inspection of preparatory workings and the development of safety pillars. As a result of the research carried out, it was revealed that geological structures, tectonic stress fields, physical and mechanical properties of rocks and the relief of the earth surface of the deposit regularly reflect the values of shear angles, safe depth of development. These regularities can be used to forecast and estimate the boundary of the zone of dangerous influence of underground mining and the duration of the shear process. The physical and mechanical properties of rocks, determined by the depth of occurrence of rocks, tectonics and fracturing, humidity, relief of the surface of the deposit. The results of the research will allow to estimate the safe depth of underground workings, the nature and duration of rock shear processes, to reveal the zones of dangerous influence of underground workings, and will increase the efficiency of the method developed by the authors for inspection of preparatory excavations and mining of safety pillars in the conditions of the Sulukta lignite deposit. New values of physical-mechanical properties and dependences for rocks of Sulukta lignite deposit were obtained, which are valuable for designing and planning of safety pillars mining.

1 Introduction

The Sulukta lignite deposit is the main deposit in the Kyrgyz Republic where coal has been mined underground for over 100 years. The "F" seam is the main working coal seam at the deposit. The dip angle of the seam after the influence of tectonic compression forces varies from 10°-15° to 90°. The seam has a complex structure, consisting of two packs, with interlaced coal packs with interlayers of clays and coal shales. The lower 1.5÷2.5 m thick layer consists of shiny and semi-glossy very stable coal varieties, which are called "glassy" at the mines being worked. The workings passed through the lower pack are unstable and poorly preserved. The total thickness of the seam varies from 4.5 to 6.5 m. The useful...
The thickness of coal bundles varies within 4÷6.5 m. The rock interlayer between the coal bundles increases in thickness towards the eastern part of the Sulukta deposit. The immediate roof of the seam is represented by low-stable dense clay and shale. The main roof is composed of conglomerate and sandstone. Sandy pebbles and clays, which, when moistened, become highly fluid and friable, form the soil of the seam. The coal of the seam belongs to the class of humus brown coals prone to spontaneous combustion [1-4].

Surveys and observations in mine workings show that the collapse of more or less significant part of the massif is preceded by local fractures that change the stability of the outcrop as a whole. In the further development of local fractures, when their separate areas begin to merge, there are intensively growing deflections of outcrops, delamination of rocks, opening of existing cracks and the emergence of new ones, the mutual intersection of which cause the formation of differently shaped fragments that lose their connection with the massif, and their gradual or sudden collapse.

Collapse, shear, rockslides, outbursts, shooting and impacts in rocks are the forms of manifestation of rock pressure, the final stages of deformation and destruction processes. The regularities of development of these processes are associated with the solution of a large number of important practical problems of mining production [4].

Foci of land disturbance by underground mining operations and soil pollution from coal mining enterprises have formed in the vicinity of Sulukta town. Landslides and failures of the earth surface caused by underground mining operations occur here. Part of the lands disturbed by underground mining fall within the mining and land allotments of coal enterprises, and part goes beyond their limits. Adoption of appropriate measures to address these problems, envisaged in the Strategy for Sustainable Development of Industry of the Kyrgyz Republic for 2019-2023 (SDSI), include measures to explore opportunities to reduce the impact of coal mining on the environment [5].

Displacement of rocks and earth surface depends on the following factors: physical and mechanical properties of rocks, geological and hydrogeological conditions of the mine; presence of tectonic disturbances with and without continuity fracture; dip angle of rocks and coal seams; thickness and number of coal seams; depth of mining; mining system; speed of mining advance; disturbance of rocks by previous mining operations; relief of the earth surface; size of the cleaning workings.

The Sulukta lignite deposit is characterised by insufficiently studied nature and parameters of shear processes. The existing data have been received on the basis of generalisation of results of shearing on similar enterprises of coal deposits of Central Asia in the beginning of 70-s of the last century [6, 7]. Therefore, in order to determine the real parameters of the shear process corresponding to the deposit, it is necessary to determine first of all the physical and mechanical properties of rocks composing sections of the deposit massifs as a factor determining the form of manifestation of the shear process and to create a three-dimensional digital model of the deposit with previously passed mine workings to visualise the old mine workings, the structure and characteristics of rocks [2, 3].

2 Methods and materials

At present, the mines of the Sulukta deposit are reworking the coal seams by mining the previously left safety pillars, which significantly affects the course of the shear process during its repeated mining. In these cases, the shearing process is activated, i.e. the parameters characterising the shearing process differ from those of the initial mining. Thus, the subsidence value is larger, the shear angle is smaller in absolute value, and the deformations in the shear valley are slightly larger.
The structure and physical and mechanical properties of rocks have a significant influence on the nature and parameters of the shear process. Of the mechanical properties of rocks, the shear process is affected by their resistance to compression, tension, shearing and bending, and has a very significant effect on the magnitude of shear angles and discontinuities.

Carbonaceous massif of the deposit is composed of rocks, diverse in origin and composition. In the present work we will talk about coal and host rocks (slate carbonaceous, loamy shale, dense shale, clay shale).

The mentioned host rocks have the following main features of internal structure: it is a medium, heterogeneous in structure and properties both in space and in time. Indicators of physical properties of the massif, as a rule, are different in its different points, besides, in the same point there is anisotropy of manifestation and distribution of these indicators in space [8-14]. It should be noted that mechanical anisotropy is considered in this case.

Rock samples intended for the study were selected according to the requirements of instructions and guidelines. Special attention was paid to the issue of representativeness of the selected samples to the geological structure of the deposit, the number and size of the selected blocks, preservation of natural moisture content and in some cases their orientation relative to the bedding. The size of the blocks was not less than 40x30x30 cm. The quantity of the sampled material was sufficient for a full range of studies. Repeated extraction of samples was excluded. The parameters were investigated on samples of regular cylindrical shape, and in cases of difficulty some work was carried out on samples of semi-regular and irregular shapes.

The digital three-dimensional model of the Sulukta lignite deposit was made using the Micromine software complex, which provides reliable results and increment of information in spatial and temporal format, is important for practical use, taking the three-dimensional spatial structure of each section of the deposit as a modelling boundary.

3 Results and discussion

3.1 Study of physical and mechanical properties of rocks containing a coal-rock massif
All selected rock samples were tested in laboratory conditions, as a result, the natural moisture content, specific and volumetric weights, porosity, uniaxial compressive and tensile strength, internal friction angle, cohesion, Young's modulus, Poisson's ratio, longitudinal and transverse wave velocities, acoustic modulus, modulus of elasticity, modulus of all-round compression and shear modulus were determined and calculated on the basis of initial data (Table 2).

Table 1.

<table>
<thead>
<tr>
<th>Name of rock and place of sampling by field sections</th>
<th>Name of rock and place of sampling by field sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonaceous shale</td>
<td>Mine No. 18, immediate roof</td>
</tr>
<tr>
<td>Charcoal matt</td>
<td>Mine No. 18</td>
</tr>
<tr>
<td>Slate, clayey, dense</td>
<td>Mine No. 18, seam roof</td>
</tr>
<tr>
<td>Clay shale, dense</td>
<td>Mine No. 2/4, direct roofing</td>
</tr>
<tr>
<td>Clay slate</td>
<td>Shaft No. 2/4, seam soil</td>
</tr>
</tbody>
</table>

Table 2.

<table>
<thead>
<tr>
<th>rock no.</th>
<th>Natural moisture content, %</th>
<th>Specific weight, g/cm³</th>
<th>Rock volume weight, g/cm³</th>
<th>porosity, %</th>
<th>Tensile strength, kg/cm² value range</th>
<th>average value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.10</td>
<td>2.57</td>
<td>2.41</td>
<td>2.66</td>
<td>2.10</td>
<td>2.57</td>
</tr>
<tr>
<td>2</td>
<td>2.57</td>
<td>2.41</td>
<td>2.66</td>
<td>2.10</td>
<td>2.57</td>
<td>2.41</td>
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4 Construction of a digital three-dimensional model of the field

Both samples are taken in the reservoir roof. However, as can be seen from Table 2, the values of uniaxial compressive and tensile strength, internal friction angle and cohesion, they have different, different. The uniaxial compressive strength of sample No.3 is 2.2 times greater than that of sample No.4, and tensile strength of sample No.4 is 1.7 times greater and this increases the absolute values of shear and fracture angles along the strike in mine No.18 to the maximum, and in mine No.4 the shear angles decrease to the minimum than those accepted in [6]. At the same time, the angle of internal friction of sample No.3 is less than that of sample No.4 - by 1.3 times, and the cohesion, on the contrary, is greater by 2.4 times.
Fig. 3. Screen of the 3D model of the rock massif of the Sulukta brown coal deposit site in orthogonal projection: a - on the horizontal plane; b - on the vertical plane

The created digital three-dimensional model in its full form describes all factors influencing the process of rock shearing: physical and mechanical properties of rocks; geological and hydrogeological conditions of the deposit; presence of tectonic disturbances and fractures, and their influence stress-strain state of the coal-rock massif; dip angle of rocks and coal; thickness of strata; depth of development; system of development; speed of mining operations; disturbance of rocks by previous mining operations; relief of the earth surface.

The above factors, to some extent influencing the development of the rock shear process and the formation of a shear mulch, simultaneously affect the earth's surface and the objects on it that are in the shear zone.

5 Conclusions

As a result of this work, the methodology of surveying preparatory mine workings and mining of safety pillars was developed in the conditions of the Sulukta lignite field.
allowed to obtain the results of processing with high reliability and a detailed three-dimensional model of the rock mass of the areas of the surveyed preparatory workings. The data obtained on rock properties give a general idea of the physical state of the rocks studied and can be used to solve various engineering problems at certain stages of field operation design.

The methodology developed for experimental (field) work under the conditions of the Sulukta lignite deposit showed high productivity and high enough representativeness of the surveys conducted and sampling. It is recommended to be used by scientific, design, and production organisations in studying, monitoring underground mine workings, and forecasting of development of shifts and failures on the earth surface in time and space under the influence of mining operations, in similar conditions of other deposits. For use in different conditions of Sulukta lignite deposit, it is possible that adjustments, changes, and additions in the methodology are necessary, corresponding to the conditions of the investigated object depending on the task.

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