Strength Assessment of Enclosing Rocks from the Coal Deposits of South Yakutia Via the Point Load Method

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Abstract. The paper presents some results of comparative tests for the strength properties of enclosing rocks from the coal deposits of Southern Yakutia. For example, the ultimate compressive strength of fine-grained sandstones from the Chulmakansky coal deposit was determined in two ways. In the former case, the authors determined maximum collapse pressure for cylindrical samples. In the latter case, arbitrary-shaped samples were tested by loading a sample with opposing indenters of conical shape. As a result, it was established that the difference in rock strength characteristics determined in the above-mentioned ways, does not exceed 20%. When determining rock strength by loading arbitrary-shaped samples with opposing indenters of conical shape, overestimated values are obtained as compared to the classical test. Nevertheless, point load method can be used in order to promptly determine the strength characteristics of sandstone in the course of mining operations provided the number of test samples in a series is increased.

1. Introduction

An important component of carrying out laboratory studies in the course of engineering geological survey, mining operations and their planning consists in the determination of rock strength characteristics [1, 2]. The need for a large number of high-quality tests requires the use of procedures and methods that would allow these tests to be carried out in the shortest possible time and with minimum labour costs [3]. At present, one of the main types of laboratory testing of soils having rigid structural bonds of a crystallisation or cementation type is the determination of their strength using the uniaxial compression method. Depending on the shape of test samples, one can distinguish between two main ways of determining the strength of rocky soils. The former involves measuring the maximum collapse pressure for cylindrical and prismatic test samples (procedure is described in detail in GOST 21153.2-84 [4]). The latter consists in the destruction of irregularly-shaped samples using opposing indenters, mainly spherical or conical (for example, GOST 24941-81 [5]). This way of testing rocks is of most interest as it is not time-consuming. The method allows you to test rock samples without prior preparation: sawing, facing, grinding, etc. [6-11].

The authors carried out comparative tests to determine the ultimate strength of overburden from deposits of the South Yakutian coalfield under uniaxial compression, using methods indicated above. The tests were aimed at finding correlations between data obtained via a “classical” test (according to
GOST 21153.2-84) and using the point load method (according to the standards of the American Society for Testing and Materials – ASTM D5731-08 [12]).

2. Methods
The South Yakutian coalfield is located in the south of Yakutia, extending for 750 km in a latitudinal direction [13]. Mesozoic coal-bearing strata, having an area of 25,000 km², form a series of isolated coal areas: Usmunsky, Aldan-Chulmansky, Gonamsky and Tokinsky. Aldan-Chulmansky area covering about 8,300 km² is the most studied one [14]. The coal-bearing deposits of the area in question are mainly represented by terrigenous rocks, among which sandstones of various particle size predominate. Siltstones, argillites, gritstones and conglomerates are limited. Coal banks and layers were established in the cross-section. The total thickness of Aldan-Chulman coal-bearing complex amounts to 3200–3400 m.

For carrying out laboratory tests, enclosing rock samples (sandstone) were selected from the borehole core of the eastern section of the Chulmakansky coalfield, located in the southeastern part of the Aldan-Chulman coal-bearing complex (Figure 1). Depending on the state of core, two groups of samples were formed from the selected material. For the first group, cylindrical samples were prepared using stone-cutting equipment. The second group consisted of fractured core products – irregularly-shaped fragments (Figure 2). The identical character of samples in the groups was controlled using ultrasonic scanning in accordance with GOST 21153.7-75 [15].

![Figure 1. Location of the Chulmakansky coalfield on the map of the Sakha Republic (Yakutia), Russia (indicated by the blue arrow).](image)

The uniaxial compressive strength of cylindrical samples (first group) was determined using a Petromechanics soil testing unit (EcogeosProm, http://ecogeosprom.ru). The strength was calculated using the following formula

\[
\sigma_{\text{com}} = K \times \frac{F}{S} \times 10, \tag{1}
\]

where \(F\) – destructive force applied to the sample, kN; \(S\) – cross-sectional area of the sample, cm²; \(K\) – dimensionless coefficient depending on the ratio of height and diameter of the sample; \(\sigma_{\text{com}}\) – uniaxial compressive strength, MPa.
Figure 2. Preparation of fine-grained sandstone samples for laboratory testing: 
a – core, selected at the site of mining operations in the Eastern section of the Chulmakansky field; 
b – cylindrical samples made of core; c – arbitrary-shaped rock samples, tested using the point load method.

The strength characteristics of sandstone samples of irregular shape (second group) were determined using a Point Load Tester-100 (https://www.gcts.com) according to the procedure described in [16, 17] and, partially, in [5]. During the first stage, we determined the equivalent diameter of the sample, which characterises the location of indenters on its surface when applying load

$$D = \sqrt{4lh/\pi},$$  \hspace{1cm} \text{(2)}$$

where $l$ – average width of the sample, m; $h$ – sample height, m, $D$ – central diameter, m. (Figure 3).

Then, the rock strength index $I_s$ and the strength index $I_{50}$ (corrected for the standard equivalent diameter $D=50$ mm) were calculated, reduced to the standard equivalent diameter $D = 50$ mm:

$$I_s = \left(\frac{F}{D^2}\right),$$  \hspace{1cm} \text{(3)}$$

where $F$ – destructive force applied to the sample, kN; $D$ – central diameter of the sample, m.

$$I_{50} = \left(D/0.05\right)^{0.45} \times \left(F/D^2\right) = \left(D/0.05\right)^{0.45} \times I_s.$$  \hspace{1cm} \text{(4)}$$

The relationship between the uniaxial compressive strength and the rock strength index is determined as follows [12, 17]

$$\sigma_{com} = q_u \times I_{50},$$  \hspace{1cm} \text{(5)}$$

where $q_u$ – correlation coefficient; $\sigma_{com}$ – ultimate strength of the rock sample, MPa.
3. Results
The results of determining the strength of sandstones from the eastern section of the Chulmakansky coal deposit are given in Tables 1, 2 and Figure 4.

Table 1. Results of determining the ultimate compressive strength of cylindrical samples using a Petromechanics soil testing unit.

| Sample No. | Linear dimensions | F | K | \(\sigma_{\text{com}}\) |
|------------|-------------------|---|---|------------------|
|            | Height, mm        | Diameter, mm |   |                  |
| 1          | 49.5              | 47.2          | 75 | 35.2             |
| 2          | 50.3              | 47.3          | 98 | 45.7             |
| 3          | 50.2              | 47.4          | 65 | 30.2             |
| 4          | 50.8              | 47.3          | 88 | 41.1             |
| 5          | 50.6              | 47.3          | 98 | 45.8             |
| 6          | 50.1              | 47.3          | 100| 46.7             |
| 7          | 50.1              | 47.2          | 110| 51.5             |
| 8          | 50.4              | 47.3          | 79 | 36.9             |
| 9          | 50.2              | 47.3          | 135| 63.1             |
| 10         | 50.4              | 47.4          | 88 | 40.9             |
| 11         | 50.8              | 47.4          | 75 | 34.8             |
| 12         | 50.8              | 47.3          | 100| 46.6             |

Average in a series \(43.2\)

*\(F\) – destructive force, kN; \(K\) – coefficient taking the ratio of the sample height to its diameter into account, MPa; \(\sigma_{\text{com}}\) – uniaxial compressive strength, MPa.

Table 2. Results of determining the ultimate compressive strength of samples via the point load strength test (with opposing conical indenters) using a Point Load Tester – 100°.

| Sample No. | Distance between indenters, mm | F | Is | \(I_{50}\) | \(\sigma_{\text{com}}\) |
|------------|-------------------------------|---|----|--------|------------------|
| 13         | 40.4                          | 6.7| 2.7| 2.7   | 34.9             |
| 14         | 35.6                          | 11.5| 7.5| 6.7   | 87.4             |
| 15         | 28.7                          | 2.8| 1.9| 1.7   | 22.3             |
| 16         | 56.5                          | 9.2| 2.8| 3.0   | 38.4             |
| 17         | 63.1                          | 8.3| 3.7| 3.6   | 46.6             |
| 18         | 48.8                          | 25.0| 6.2| 6.9   | 89.7             |
| 19         | 45.9                          | 13.7| 3.1| 3.5   | 46.0             |
| 20         | 22.8                          | 4.9| 2.6| 2.4   | 31.4             |
| 21         | 45.6                          | 11.7| 2.9| 3.2   | 42.0             |
| 22         | 39.7                          | 26.3| 6.1| 6.9   | 89.7             |
| 23         | 69.1                          | 17.5| 2.4| 3.1   | 40.3             |
| 24         | 85.9                          | 15.0| 2.7| 3.2   | 42.2             |

Average in a series \(50.9\)

*\(F\) – destructive force, kN; \(Is\) – uncorrected point load strength index, MPa; \(I_{50}\) – corrected point load strength for the standard equivalent diameter (D=50 mm), MPa; \(\sigma_{\text{com}}\) – uniaxial compressive strength, MPa.
Figure 4. Strength of sandstone samples from Chulmakansky coal deposit, determined in various ways:
I - cylindrical samples loaded with flat slabs;
II - arbitrarily-shaped samples loaded with opposing conical indenters.

4. Conclusions
As a result of comparative tests of determining the strength of fine-grained sandstone from the Chulmakansky coal deposit, it was found that the method for destroying arbitrary-shaped samples with opposing indenters gives overestimated values of rock strength as compared to the classical test [18, 19]. Difference between rock strength values obtained via the above-mentioned methods does not exceed 20%. Testing rock formations by loading them with opposing indenters can be used for a prompt assessment of sandstone strength when conducting mining operations in the coal deposits of South Yakutia. However, laboratory tests require a greater number of samples, as compared to measurements of the maximum collapse pressure applied to the flat ends of a regular cylindrical or prismatic sample through flat steel plates.

5. References
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