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Mechanical properties of material in a mine dump at the Shengli #1 Surface Coal Mine, China

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ABSTRACT

In-situ experiments were conducted to investigate the mechanical properties of the soil-rock mixture in the internal dump of the Shengli #1 Surface Coal Mine, China. Based on the experimental results, this study used comparative analysis and found that the shear strength of the soil-rock mixture in the dump was greater than the residual shear strength of the original rock. The results showed that the material presented in the dump as large blocks was the main factor affecting the strength of the soil-rock mixture. Numerical simulation was carried out for the analyses of three factors: different combinations of shear failure, rolling failure along with different large-block radius ratios, and mixture densities. The results illustrated that the cohesion and angle of internal friction of the soil-rock mixture are 12 kPa and 32.26°. However, in some cases the bench angle in the dump was controlled by a coupling relationship of rocks in the material. Finally, the stability of a soil slope showed a linear relationship with the large-block radius ratio and the bulk density.

1. Introduction

Waste dumps at surface coal mines can be divided into two type: internal dumps and external dumps. The dump is made up of a soil-rock mixture whose physico-mechanical properties are changed compared to the original materials. As such, its slope angle is dominated by these new properties. For internal dumps, a larger slope angle increases the area the waste dump occupied which may substantially increase the transportation distance. Due to the limitation of the land lease acquired by the mine, external dumps storage capacity is restricted mainly due to the slope angle [1–4]. Therefore, the physico-mechanical properties of the soil-rock mixture are of great significance for determining the operating cost and minimizing the footprint of surface mines [5].

The Shengli #1 Surface Coal Mine is located in the center of the Shengli Coal Field, Xilinhaote, Inner Mongolia autonomous region, China. It covers a total area of 37 km^2, which extends 6.84 km from east to west and 5.43 km from south to north. It is located in an area affected by ancient landslides and suffers from a high risk of future landslides due to a higher level of the water table [6]. Examples of landslides failure are shown in Fig. 1.

According to experiments run for previous geological and engineering investigations, the rock types and their mechanical properties in the Shengli #1 mine are summarized in Table 1.

At the mine, the overburden is stripped and broken into relatively uniform fragments [7,8]. These fragments are dumped at the internal dump, forming a slope of material of distinctly different sizes [9]. If a dump is made up of only coarse material, its overall strength is the same as the residual shear strength of the overburden. After long-term weight loading, the overall strength gradually increases due to the influence of water infiltration and vibration from mining activities [10]. Without the influence of water, this material would possess its original residual shear strength [11]. Therefore, to prevent slope failure when depositing new material on the internal dump, it is necessary to determine the shear strength of this mixed waste materials [12,13].

2. Mechanical properties determination

The stability of a mine waste dump mainly depends on the shear strength of its constituent materials [14]. The most important parameters for shear strength are cohesion, *C*, and internal friction angle, φ. Knowing these two parameters is necessary for optimizing the benches on dumps [15]. The most common methods for measuring geotechnical parameters are direct shearing

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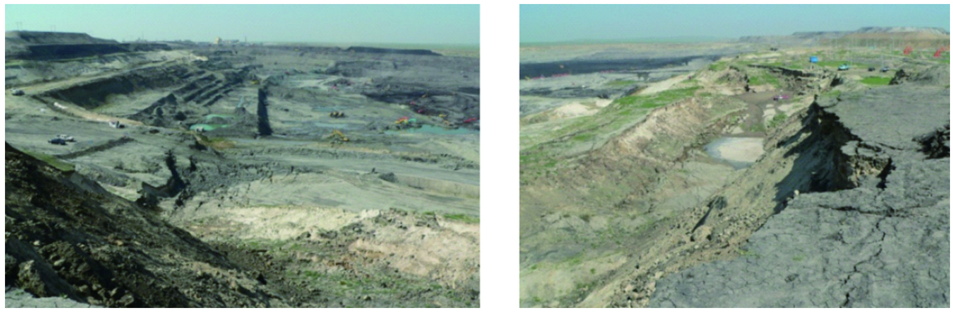

Fig. 1. Landslides in the Shengli Surface Coal Mine, Inner Mongolia, China.

Table 1
Rock types and physical parameters for rock units in the south slope at the Shengli #1 Coal Mine.

Name	Index	Specific gravity	Natural bulk density (kN/m^3)	Natural shear strength		Residual shear strength	
				C (MPa)	*Φ* (°)	*C* (MPa)	*Φ* (°)
Mudstone	Standard value	2.52	19.96	0.230	35.520	0.020	17.93
Carbonaceous mudstone	Standard value	2.22	18.97	0.120	26.860	0.010	12.11
Fine sandstone	Average value	2.59	21.00	0.377	40.333		
Coal	Average value	1.46	13.10	1.473	27.667		
Carbonaceous mudstone	Average value	2.14	18.95	0.170	29.000	0.015	13.25

tests, in-situ experiments, and the point load method (for measuring shear strength along a specific surface). Because the original stratigraphy and integrity of the original rock are all disturbed when the material is deposited on the dump, neither the direct shearing test nor the point load method are applicable [16,17]. Thus, the most suitable method to determine the shear strength of the soil-rock mixture on a dump is in-situ experiments. If an appropriate test location for the experiment can be identified, *C* and φ can be determined accurately [18].

2.1. In-situ experiments

Any in-situ experiments on a dump must be designed according to the specific features of the dump. For the Shengli #1 Surface Coal Mine internal dump, one site was chosen on Level 945 and two sites were selected on Level 960. The location coordinates for these sites are listed in Table 2.

The in-situ tests should be conducted according to the nine steps described below. A schematic diagram of the test site is shown in Fig. 2.

(1) Two vertical holes with 15 cm in diameter and 15 m in depth should be drilled adjacent to the testing point. The two holes should be 2.8 m apart and the midpoint of the line connecting the two holes' centers is the center of the sample.
(2) Grout two anchors to the two vertical holes to make sure they are firmly attached to the ground. The anchors should be installed vertically, and its length above the collars of the holes should not be too long.
(3) The midpoint between the two holes is the base point, and a trench with 30 cm in width and 1 m in depth should be excavated as a square shape around the base point. The inner side of each leg of the trench is 50 cm from the base point resulting in a 1 m^3 cube of rock to serve as the sample with a 30 cm trench around it (Fig. 2).
(4) One vertical surface of the sample should be designated as the testing surface. The testing surface should be coated with concrete, as well as the bearing surface facing it. Two 1 m^2 and 1 cm thick steel plates should be placed on these surfaces.
(5) Four evenly spaced identical hydraulic jacks should be placed horizontally in the bottom of the trench along the testing surface. The ends of the identical jacks should be in contact with the bottom of steel plates on the bearing surface and their heads on the testing surface. Dial indicators should be installed on the two end jacks with the dial indicators in direct contact with the steel plate. The upper parts of the steel plate at the top of the trench should be supported with wooden braces. An initial pressure should be applied to make sure the steel plates are in firm contact with the rock surface, and then the dial indicators should be set to zero.
(6) A horizontal joist should be installed on the anchors. A fifth jack should be placed between the joist and the sample so it can apply vertical pressure to the sample. This jack should be placed in the center of a steel plate placed on the top surface of the sample with its head touching the joist.

Table 2
Mine coordinate positions for the three sites tested in this study.

Position	Sample 1	Sample 2	Sample 3
X coordinate	75552.072	75161.864	75153.981
Y coordinate	21930.987	21986.568	21997.126
Height (m)	945.628	957.999	958.231

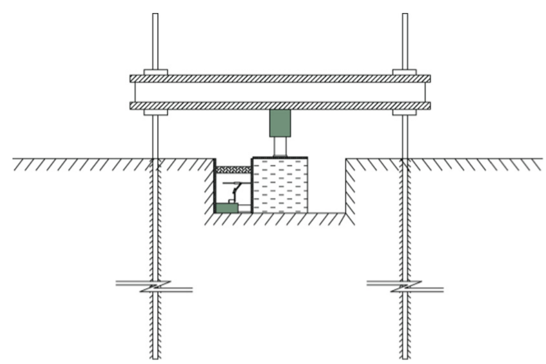

Fig. 2. Schematic diagram of the in-situ experiments.