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Experiment on stabilized swelled mudstone reinforced with geocell

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ABSTRACT: Mudstone has the property of argillization. When it is exposed to a very humid working environment or immersed in water, it will become weaker, softer, and when subjected to dynamic loading, it'll swell in just a few hours. In coal mining engineering, such argillization occurs on excavated roadway floor, and form a muddy roadway, which is considered as a natural disaster. In order to stabilize this muddy roadway floor and make use of this waste muddy soil and coal dust mixture instead of removing them from the tunnel, the approach of lime-fly ash stabilizing the swelled mudstone and geocell reinforcing the stabilized mixture is proposed. And many experiments had been done. This paper focuses on the properties of lime-fly ash stabilizing swelled mudstone and coal dust mixture at optimum mixture and the effect of geocell parameter on the unconfined compressive strength of geocell reinforcing stabilized muddy soil mixture. The results show that the lime-fly ash treated muddy mixture can be used as geocell fill material, and with provision of geocell, the unconfined compressive strength of treated muddy mixture increases more than two times that of unreinforced stabilized mixture. Such treatment method can meet with the stress requirement of heavy axes load. The treatment not only is a cost effective roadway floor remediation method, but also eliminated the need of removing muddy mixture, and therefore reduces the construction time.

1 INTRODUCTION

Mudstone has the property of argillization. When it is exposed to a very humid working environment or immersed in water, it will become weaker, softer; and when subjected to dynamic loading, it'll swell in just a few days (Fu-Shu Jeng, et.al. 2000). In coal mining engineering practice, it was reported that argillization occurred on the excavated mudstone on roadway floor just in several hours under dynamic load after being exposed to a very humid environment. Such an unfavorable condition hinders from coal mining and is considered as a natural disaster at Shendong Coalfield in Inner Mongolia Autonomous Region in Northwest of China.

In order to stabilize this muddy roadway floor, an approach of lime-fly ash stabilizing the swelled mudstone and geocell reinforcing the stabilized mixture was proposed. The Class C fly ash used in this study was taken from local Daliuta Thermal Power Plant in this coalfield. Given that the strength of stabilized muddy mixture is not enough to meet the requirement of stress level of coal mine haul road; it is determined to use geocell to reinforce it. Geocell, as a kind of geosynthetics, has been widely used in geotechnical engineering to improve soil strength, bearing capacity of structure, reduce the different settlement by means of its confining system mechanism and membrane effect.

In fact, it is important to find alternate uses for swelled mudstone on roadway floor in coal mining engineering and fly ash, the two important byproduct of coal industry, so that their disposal without adverse environmental effects becomes possible. Realizing the economic and environmental consequences, efforts have recently been made to study engineering properties of stabilized swelled mudstone. Thereby, the disaster of swelled mudstone roadway floor in excavated tunnel will be cured using lime-fly ash stabilized swelled mudstone as the fill material of geocell reinforcement for coal mine haul road, instead of removing them out of the tunnel.

This paper focuses on the geotechnical properties of lime-fly ash stabilizing swelled mudstone and coal dust mixture at optimum mixture and the behavior of geocell reinforcing stabilized muddy soil mixture. So laboratory tests have been conducted to determine standard Proctor compaction characteristics of untreated and stabilized muddy mixture and unconfined compressive strength of stabilized mixture specimens and geocell reinforced stabilized mixture. Parameter research has also been done in this paper. The details are discussed herein.

2 TESTING METHODS

2.1 *Standard proctor compaction tests*

These tests were conducted on the swelled mudstone passing 25 mm Sieve following the Chinese Code: Standard for Soil Test Method (GB/T 50123-1999) for determination of the moisture density relationship. These tests were also performed on the swelled mudstone specimens stabilized by varying amounts of lime-fly ash mixtures.

2.2 *UCS tests*

Unconfined compressive strength (UCS) tests were conducted on lime-fly ash stabilized soil mixtures samples and geocell reinforce treated soil samples. The specimens for tests were prepared at optimum water content as determined from standard Proctor compaction tests. The samples measured 39.1mm in diameter and 81mm in height. Samples stabilized with lime-fly ash were cured for 7days in humid condition at a temperature of 20 ± 2°C.

3 TEST RESULTS AND DISCCUSION

3.1 *Grain size distribution*

The samples of the swelled muddy mudstone mixture were taken from the in-site of excavated roadway floor in tunnel. Some unusually big chunks of unswelled mudstone were removed before tests for sieve and the hydrometer analysis. The grain size distribution analysis shows that the curvature coefficient is 1.154 and the uniformity coefficient C_u is 26.0. The specific gravity of the muddy mixture is 2.71. The size distribution curve indicates that the swelled dried muddy mudstone mixture samples were well graded.

3.2 *Compaction behavior*

Standard Proctor compaction tests were conducted following Chinese Code: Standard for Soil Test Method GB/T 50123-1999 to determine the maximum dry density and its corresponding optimum water content of the dried Yujialiang swelled mudstone muddy mixture (YM) and stabilized mixture with varying amount of lime (L) and fly ash (FA). The fly ash content starting at 10% of the dry weight of the mixture with an increment of 5% was mixed with the swelled muddy soil while the lime content is 10% of the dry weight of the mixture. Each blend of the lime-fly ash soil mixture was compacted per the standard Proctor test method. The test results are presented in Fig. 1.

Figure 1 presents typical results of the dry density versus water content of the swelled mudstone samples and lime-fly ash stabilized muddy mixtures. The measured maximum dry density of the swelled mudstone mixed with coal dust was 1703.3 kg/m^3 and its corresponding optimum water content was 11.6%. Fig. 1 also presents the compaction results of lime-fly ash stabilized mixtures consisting of lime, fly ash, and the swelled mudstone in proportions of 10:20:70, 10:15:75 and 10:25:65 by dry weight, respectively. A comparison of these data indicates that an addition of 10% lime and 20% fly ash yields the best performance of compaction in terms of the maximum dry density. The maximum dry density of it is 1680.2 kg/m^3 at water content 13.8%. Therefore, these percentages of lime and fly ash should be considered as the optimum mixture design for the swelled mudstone mixed with coal dust.

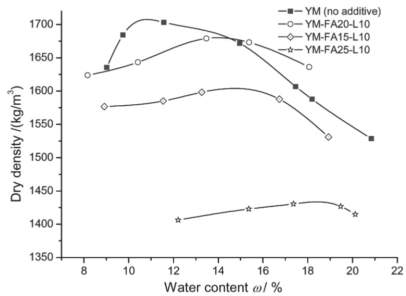

Figure 1. Water content-dry density curves.

3.3 *UCS Tests on stabilized mixture*

At the optimum water content, a series of specimens were compacted in three layers in a split mold with a collar using a standard manual compaction rammer. All the samples were wrapped with plastic membrane and allowed to cure at 22 ± 2°C and more than 80% relative humidity for the periods of 1, 3, 7 and 28 days. After the curing periods, they were tested for unconfined compressive strength according to the procedures suggested by GB/T 50123-1999. These results can also be used to evaluate whether the stabilized soil is suitable to substitute the geocell fill materials in terms of its strength. The test results of samples at different curing periods are presented in Fig. 2.

Figure 2 shows that UCS of the mixture stabilized with lime-fly ash is time-dependent. The UCS of stabilized mixture increased from 330 kPa after 1day curing to 1120 kPa after 7days curing. The UCS reached 1780 kPa after 28 days curing time. It can be concluded that the stabilized soils have significantly higher compressive strength than the untreated muddy soil mixture. Resilient Modulus Tests also show that

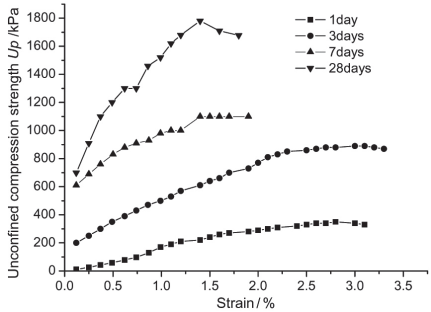

Figure 2. Relationship of axial stress vs. axial strain of stabilized mixture at different curing time.

the resilient modulus of this kind of stabilized mixture is on the order of 210 to 400 MPa after 7 days curing time.

3.4 *UCS tests on geocell reinforced mixture*

In order to utilize the stabilized mixture as structural layer material for heavy haul roads, this mixture must have enough strength and modulus. The geocell reinforced stabilized soil mixture is proposed as the structural layer of the haul road to support tires pressure with the contact pressure up to 1.027 MPa. The following section assesses the feasibility of using geocell reinforced stabilized soil as structural layer.

To evaluate the feasibility, another series of compression tests were conducted to determine the behavior of geocell reinforced stabilized soil. The sketch of the test for the geocell reinforced stabilized soil is presented in Fig. 3. Similar experiments setup had been used by Rathurst and Crowe (1994), and Rajagopal et al (1999). Geocell used in these tests are made of high density polyethylene (HDPE), whose

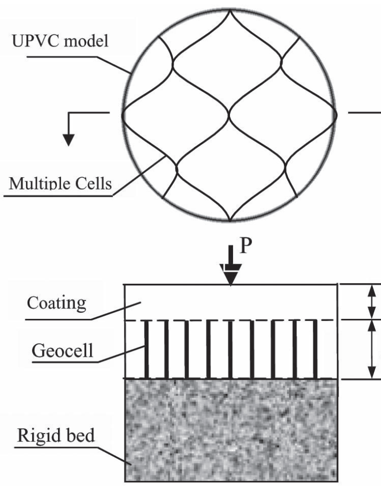

Figure 3. Sketch of geocell reinforcing the stabilized soil in compaction tests.

properties are given in Table1. The cylindrical unplasticised polyvinyl chloride (UPVC) container has the diameter of 200 mm and the height of 200 mm as the model. It was cleaned and its interior wall was oiled before adding materials. A circular concrete platform with the height of 80mm was placed at the bottom of this UPVC container to simulate a rigid bed. Inside the UPVC model, the geocell reinforced lime-fly ash stabilized mixture layer was compacted. This stabilized mixture was prepared at the optimum water content obtained in the lab. After sufficient mixing, the mixture was poured into the geocell pockets and compacted in three layers by rodding. After careful trimming, this sample was kept in a relative humidity of 80%, temperature 22 ± 2°C and allowed to cure. It was removed from the container after 2 days through a stripper machine and wrapped with plastic membrane. The sample was returned to the moist room until the date of testing (7 days).

A parametric study was conducted to investigate the geocell reinforcement effect. The fill material and the variables in this study are also listed in Table 1.

The UCS tests results are given in Table 2. The average UCS of samples in T1 series is 2.368 MPa and that of samples in T2 series is up to 2.551 MPa. The UCS of the geocell reinforced lime-fly ash stabilized muddy mixture is 2.13 to 2.30 times that of the unreinforced stabilized lime-fly muddy mixture. It is also shown that with the same geocell types (in T1, T3 and T4), the reinforced common fill material (gravel and sand) had the maximum reinforcement strength of 2.73 MPa, the reinforced sand had the lowest strength of 0.55 MPa, and the geocell reinforced stabilized muddy mixture had a acceptable strength of 2.37 MPa. The strength of sample stabilized with lime fly ash is about 86.8% the strength of geocell reinforced gravel and sand and 4.3 times that of the geocell reinforced sand. Therefore, the gravel plus sand and the lime fly ash stabilized mixture are suitable for the geocell fill material.

This parametric study also shows that the seam strength of geocell, the ultimate tension strength, and the sheet thickness of geocell material are the important factors. They play a comprehensive effect on the reinforcement. The strength of test series T1, T2 and T5 verified such influences. As for T1 and T2, when the aperture opening shape and the height of geocll are the same, and the thickness, seam strength and ultimate tension strength of T2 is larger than those of T1, the reinforced strength of T2 is larger than that of T1. And the parametric study results show that the seam strength of geocell is a key factor. And as for T2 and T5, due to the global stiffness of T5 less than that of T2, the samples of T5 are failure due to large deformation and its strength less than that of T2.

Generally, the intended use of construction material as geocell fill material, emphasis is given to determinate its mechanical characteristics including

Table1. Properties of geocell and reinforcement types used in the tests program.

Type of geocell	Reinforcement Type (fill material)	Height of Geocell (mm)	Thickness (mm)	Seam Strength (kNm)	Aperture opening shape & size (cm)	Ultimate tensile strength (kN/m)
DTGS-10 (white)	T1 (stabilized soil)	10	0.8	7.50	Diamond, 7 × 7	18.0
DTGS-10 (black)	T2 (stabilized soil)	10	1.2	13.72	Diamond, 7 × 7	24.0
DTGS-10 (white)	T3 (sand)	10	0.8	7.50	Diamond, 7 × 7	18.0
DTGS-10 (white)	T4 (gravel +sand)	10	0.8	7.50	Diamond, 7 × 7	18.0
DTGS-5 (black)	T5 (stabilized soil)	5 × 2 layers	1.2	13.72	Diamond, 7 × 7	24.0

Table 2. UCS tests for geocell reinforcement.

Reinforcement Type	T1	T2	T3	T4	T5
UCS (MPa)	2.37	2.55	0.55	2.73	1.53

strength, resilient modulus and permeability. Based on the elastic half theory, the maximum anticipated stress level for a particular layer of the roadway floor should be less than maximum tire contact pressure. For every layer of the haul road, the bearing capacity of it is much larger than its corresponding stress level. The test of determination of the resilient modulus of the geocell reinforced lime-fly ash mixture is under way now. However, owing to geocell can provide confinement, it is expected that the resilient modulus of the reinforced stabilized soil mixture would be increased much. Also due to the cellular confinement, poor-quality granular fills can be used as the surface or near-surface material of access road where driving speeds are relatively slow and ride quality is not a major concern (Presto Products Company 2000).

In order to avoid further argillization of roadway floor, the stabilized material should have the property of low hydraulic conductivity. As for this, Sanjeev Kumar et al (Kumar, et al 2001) had conducted similar tests on lime-fly ash stabilized coal mine refuse. His results suggested that lime-fly ash treatment reduces the hydraulic conductivity value of fine coal refuse. He also suggested that if both the strength improvement and reduction in leachate flow are required, treatment of coal refuse with lime (2.5% to 5%) and fly ash (10 to 20%) may provide the required effect. Form these research results, a primary conclusion could be drawn that the present treated swelled muddy mixture could hinder the seepage and therefore could hinder mudstone from argillization.

So, we can drawn conclusions that the geotechnical properties of lime-fly ash stabilized swelled mudstone muddy mixture meet the requirements of geocell fill material primarily. And it is suitable to use as the geocell reinforcement fill material. And the geocell reinforced lime-fly ash stabilization mixture could meet the stress requirement of ultra-heavy axel load of on coal mining roadway floor.

4 CONCLUSIONS

The following conclusions can be drawn:

1. Standard Proctor tests indicate that the optimum mixture design between lime and fly ash is 10:20 by the dry weight of mixture so as to effectively stabilize the swelled mudstone mixture on roadway floor. The stabilized mixture, whose UCS reach 1780 kPa after 28 days' curing period, can be used as a geocell fill material in haul road remediation.
2. The geocell reinforcement tests show that the strength of geocell reinforced lime-fly ash stabilization of mixture is more than two times that of unreinforced stabilized mixture. As a result of the favorable strength, permeability and resilient modulus of the geocell reinforcement, the proposed approach is a feasible roadway floor remediation method. The geocell reinforcement mattress can be used as structural layer of haul road to support heavy axes load with 1.027 MPa contact pressure.
3. Although gravel and sand satisfy performance criteria as a geocell fill material and could be used at Shengdong Coalfield, they are not located near mines and have to be hauled from other locations. However, lime-fly ash stabilized muddy swelled mudstone is a cost-effective roadway floor remediation method. Because it eliminated the need of removing muddy mixture and discharge out of tunnel and reduced the construction time. As a result, it is a time-saving remediation method.

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