Journal of Engineering and Applied Sciences 12 (18): 4568-4572, 2017
ISSN: 1816-949X

Slaking Behaviour of Mudrocks at Precinct 5, Putrajaya and its Performance as Subgrade Material for Road Construction in Malaysia

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Abstract: One of the significant problems of clay-bearing rocks such as Mudrocks is their slaking behaviours when exposed to alternating cycles of drying and wetting when performing as geomaterial for a construction. Thus, it is important to study whether or not the slaked material can perform as subgrade material. This study investigates the durability of Putrajaya Mudrock through typical slaking test for clay-bearing rocks; jar slake test, slake durability test and slaking immersion test. Also in this study, the performance of Putrajaya Mudrocks as subgrade material for road construction in Malaysia is studied by conducting CBR test in reference to standard requirement for subgrade as stated by the Public Work Department (JKR) Malaysia. The results show that the Slaked Putrajaya Mudrock is suitable as subgrade for road construction, however, further study is required to investigate the settlement that it may cause due to change of moisture content.

Key words: Slaking, Mudrock, subgrade, putrajaya, moisture content, Malaysia, JKR

INTRODUCTION

Mudrocks, according to Oakland and Lovell (1985) and Czerewko and Cripps has important consequences on their behavior during geotechnical works since they are widely used in construction industry due to its abundance. Mudrocks are commonly used as subgrade, base course, aggregate and foundation (Aghamelu and Okogbue, 2011). According to Sharma *et al.* (2015) Mudrocks are sensitive against cyclic wetting and drying known as slaking and has given rise to numbers of construction problems including embankment failures. Similarly, Hussein and Mustapha (2004) has proven that the slope failure in Putrajaya which was happened on January 2001 was caused by the presence of soft clay layer that had cause the settlement of slope's fill. Since, Mudrocks are the most abundant of all lithologies (Hajdarwish and Shakoor, 2006) to investigate the engineering properties of Mudrocks are very important. However, Mudrocks behave intermediately between rock and soil and tend to change from rocklike to soil-like materials within relatively short time-frames (Sharma *et al.*, 2015). Thus, its slaking behavior is of the importance to study in order to evaluate its performance as construction material.

In Putrajaya, the public works department of Malaysia has conducted an investigation to determine the causes of slope failure. The failure has caused part of the road on the top of the filled slope to collapse. The case study conducted has also found that there was a rise in the groundwater level thus cause instability of the slope. Czerewko and Cripps has state that volume changes resulting from changes in moisture content cause the material to slake by breaking up along the existing discontinuities. Moreover, in less indurated Mudrocks, it has been found that a few cycles of wetting and drying of non-weathered material may cause rapid breakdown. However, according to Ekeocha and Akpokodje (2012) when highly indurated, clay-bearing rocks such as Mudrocks may be used as construction materials because of their intermediate hardness. The durability of Mudrocks is thus investigated in order to study the Mudrocks performance as subgrade material.

Research on the slaking behavior of Mudrocks have been widely studied (Sadisun *et al*., 2005; Sharma *et al*., 2015; Adewuyi and Festus, 2015). The slaking behavior of clay-bearing rocks is typically evaluated based on jar slake test (Santi, 2006), slaking immersion test and slake durability test (Sadisun *et al*., 2005).

This study describes the laboratory study conducted to evaluate the slaking behaviour of Putrajaya Mudrocks and its performance as subgrade material for road construction in Malaysia relevant to the standard requirement for subgrade as stated by Public Works Department (JKR) Malaysia. The experimental program includes California Bearing Ratio (CBR) tests to evaluate the bearing strength of Slaked Putrajaya Mudrocks.

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MATERIALS AND METHODS

The Mudrock samples were collected from Jalan P5A, Precinct 5, Putrajaya (N02°53'56.8". E101°41'59.2"). The study area is located along Lebuh Gemilang, the main road connection for the ease and convenience in obtaining samples. The area is included in the kajang-schist formation that the rocks consist of dark-grey to black carbonaceous quartz-muscovite schist interlayed within bands and lenses of orange to buff quartz-muscovite schist with minor intercalations of marble and phyllite with deposits of majorly silt, sand and gravel. Geological map of peninsular Malaysia interprets kajang-schist formation to be of upper silurian to devonian age because it overlies the carboniferous to permian kenny hill formation. Carboniferous-permian age that belongs to kenny hill formation comprises of monotonous clastic sequence of interbedded shale, mudstone and sandstone. According to Dick and Shakoor lithology is of the important key in order to understand Mudrock durability. As the deposits found in the area is majorly silt-sized grains thus this initiates the consideration made onto Mudrock; physically weak and is problematic. Engineering properties of the sampled Mudrock were measured in accordance with BS 1377 (1990) procedures (Table 1).

Based on classification used by Sibanda *et al*. (2013) soil with plasticity index in the range of 3-15 is classified as slightly plastic soil. Low plasticity index values indicate Mudrocks with lower percentages of clay-size material and fewer expandable clay minerals (Gautam, 2012).

Slaking tests:

Slake durability test: The procedure as outlined in ASTM D4644 is followed. Four sets of samples comprising of 10 rock lumps weighing 450-550 g is prepared. Each rock lump must weighed around 40-60 g. Lumps are made sure to be roughly spherical in shape and has no rough edges. This is to make sure that any disintegration occurred to the sample is because of the material itself, not the shape. In other words, to make sure that there will be no side factor of the disintegration that was going to happen. The sample is then placed into a clean drum before been oven-dried at temperature of 110°C for 6 h. The oven-dried sample is weighed and recorded as mass A. Immediately, the drum is set to the motor and tap water is poured to a level of 20 mm below the drum axis. The temperature of the water is recorded. The drum is rotated at 20 rpm. After 10 min, the oven-dry procedure is repeated and mass B recorded. Mass C is the mass of the sample that has undergone second cycle of the procedure.

Table 1: Summary of engineering properties of Putrajaya Mudrock

Engineering properties	Putrajaya
Moisture content (%)	8.310
Specific gravity	2.618
Liquid limit	41.600
Plastic limit	28.550
Plasticity index	13.050

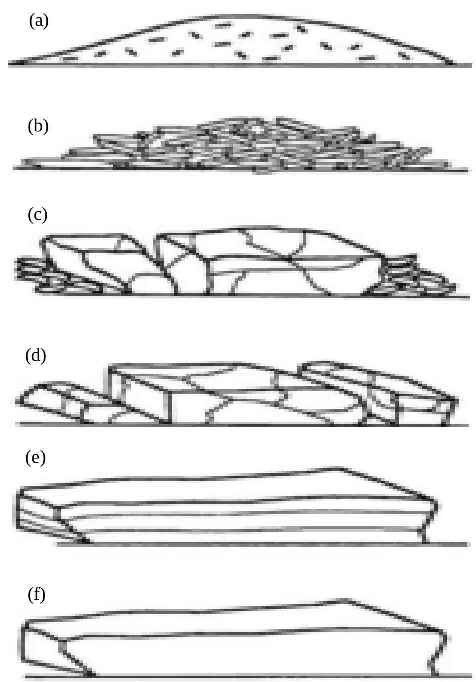

Fig. 1: The classification made by Santi (1998): a) Mud: degree to a mud-like consistency; b) Flakes: sample totally reduced to flakes original outline of sample not discernible; c) Chips: chips of material fall from the sides of the sample. Sample may also be fractured. Original outline of sample is barely discernible; d) Fractures: smaple features throughout, creating a chunky appearance; e) Slabs: sample parts along a few planar surfaces and f) No reaction no discernible effect

Jar slake test: The procedure that is outlined by Santi (1998) is followed. Two set of sample each containing one lump of Mudrock sample weighing 30-50 g. These samples are oven-dried at 110°C for 16 h and is allowed to cool for 20 min. After 20 min of cooling each sample is immersed in a jar containing distilled water. The samples should be fully immersed in the distilled water and been observed after 10-60 min of immersion. The changes in appearance of the samples is observed and recorded according to the classification made by Santi (1998). Figure 1 shows the classification used in this test.

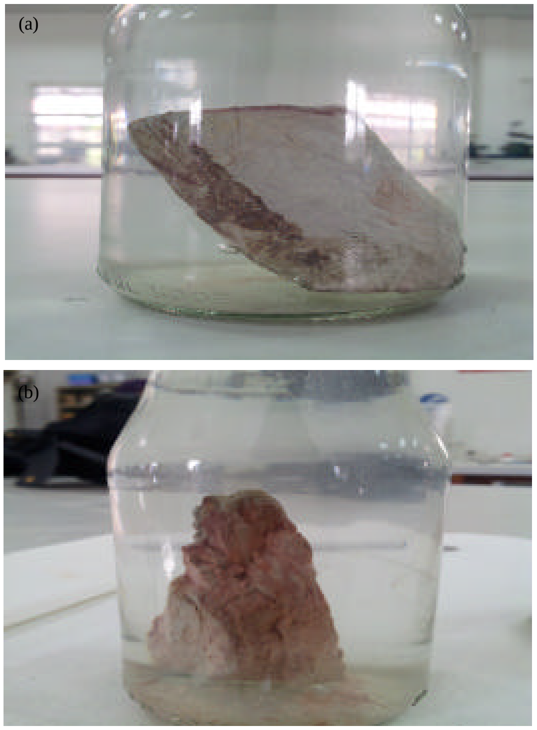

Fig. 2: From left; test 1 and 2 during jar slake test

Slaking immersion test: This test has been carried out by following the same procedure for sample preparation of jar slake test except that it was carried out until 24 h of immersion. The observation is made at constant time interval; 1-30 min, 1-24 h. After 24 h of immersion, the samples were exposed to room temperature for 24 h. The immersion procedure is repeated and observation is made.

CBR test: modified proctor compaction test that is in accordance to BS 1377-4: 1990 is carried out before CBR test to determine the optimum moisture content of the sample. CBR test is also carried out according to BS 1377-4: 1990 to evaluate the suitability of the sample to be used as subgrade material. All samples are conducted in two penetration sizes; 2.5-5.0 mm.

RESULTS AND DISCUSSION

Slaking tests:
Jar slake test: Table 2 shows the index classification observed on two different tests carried out on two samples in accordance to classification by Santi (1998). Based on Table 2, the samples experienced changes after 30 min the test been conducted. Both samples recorded its end at 4th class. Soil with this slaking behavior is stated by Santi (2006) as poor, yet durable for long term exposure to weathering. Figure 2 shows the condition of the sample after the test is completed.

Table 2: Summary of index classification observed for three jar slake tests

	Index classification	
Time (min)	Test 1	Test 2
10	5	5
15	5	5
30	5	5
60	4	4

Table 3: Summary of slake durability index exhibited from 2 wetting drying cycle

		Second cycle		
Sample	First cycle (Mass B (g))	Index, I_{d1} (%)	Mass C (g)	Index, I_{d2} (%)
1	3510	71.93	2720	55.74
2	3690	75.61	3080	63.11
3	3020	59.33	2370	46.56
4	3460	65.53	2970	56.25

Slake durability test: Table 3 shows the slake durability index exhibited from four samples subjected to two wetting-drying cycle in rotational motion. It is observed that after first cycle, the samples are in medium to high durability. Even after second cycle, samples 1-4 are still categorized in medium durability class, except for sample 3 which has exhibit the value of low durability class according to slake durability classification by Franklin. Soil in medium class durability is said to be susceptible to slump failures.

Slaking immersion test: Based on the observations at the first hour, all three samples experienced bubbles, slight cloudiness on the base, minor hairline crack and disintegrated. According to Sadisun *et al.* (2005) disintegration indicates that the samples has medium strength when examined by point load test. During the second hour, bubbles are still seen but there is no more new disintegration occurred, water is seen slightly cloudy but no collapsed particles are seen neither any precipitation. The cloudiness of water is closely related to the disintegration that occurred since there is no precipitation resulted. The scenario illustrates that the disintegrated particles has caused the water to be cloudy but is not easily precipitated. After 24 h, the sample experienced disintegration of about 5% and is seen with severe hairline crack. Czerewko and Cripps mentioned that these changes are associated with mineralogical changes which eventually influence the engineering properties of Mudrocks especially strength and durability. The condition of samples is shown in Fig. 3.

CBR test: The sample was soaked for 24 h and dried in order to liken the sample's condition to the samples that has undergone the slaking tests. The soaked and unsoaked CBR test has been conducted onto the sample and has passed 5% CBR value as shown in

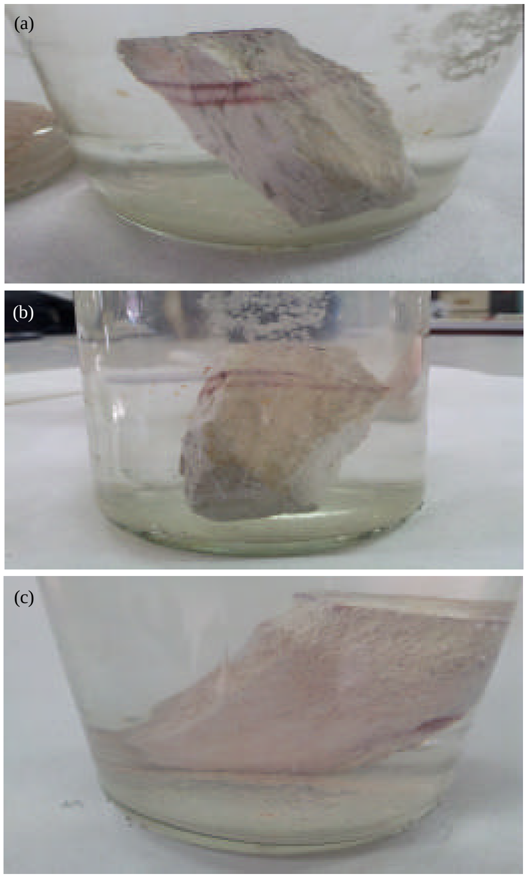

Fig. 3: The condition of samples through slaking immersion test: a) During first hour, minor hairline crack, tiny disintegration and bubbles are seen; b) During second hour, bubbles are still seen and water is seen slightly cloudy and c) After 24 h, the sample has been disintegrated of about 5%

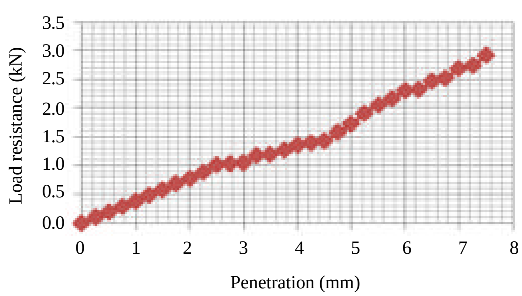

Fig. 4: Force Penetration curve of Soaked CBR test for Slaked Putrajaya Mudrocks

Fig. 4 and 5 in which the value obtained is 12.6 and 10.3%, respectively. This shows that the durability of weathered or slaked Putrajaya Mudrocks are in agreement with the requirement for subgrade material as specified by JKR standard. Therefore, Mudrocks of

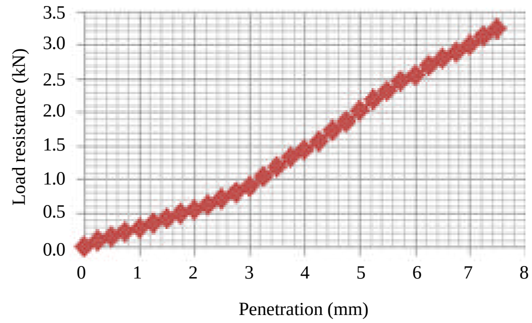

Fig. 5: Force penetration curve of Soaked CBR test for Slaked Putrajaya Mudrocks

Putrajaya that has exposed to drying and wetting is suitable as subgrade material for road construction in Malaysia. However, the settlement that it may cause is still a key of concern to researchers. Figure 5 shows the standard requirement stated by JKR.

Properties of sub-grade: Sub-grade is one of the most important factor in determining pavement thickness, comosition of layers and overall pavement performance. The magnitude and consistency of support that is provided by the sub-grade is dependent on soll type, density and moisture condition during construction and changes that may occur over the service life of a pavement.

For pavement design purposes, several parameters shall be use to categorise sub-grade support. Traditionaly, the California Bearing Ratio (CBR) has been widely used for this purpose. Mechanistic pavement design procedures require elastic medium. For this manual are shown in Table 2 along with the CBR values used as input values for selecting pavement structures from the catalogue.

A minimum CBR of 5% is recommended for pavement that have to support traffic volumes corresponding to traffic classes T1 though T5. If the sub-grade (cut of fill) dose not meet this minimum CBR requirment at least 300 mm of unsuitable sub-grade soill shall be replaced or stabillesed to ensure that the selected minimum CBR value is obtained under due consuderation of applicable moisture conditions and probility of meeting the design input value. For road pavements designed for large volume of (Traffic classes T4 and T5) a minimum sub-grade strength correspoding to CBR of 12% is recommended. For pavement design purposes, the use of average CBR or sub-grade modulus test results is not recommended; it would signify that there is only a 50% probability that the design input value is met.

CONCLUSION

Mudrock has often been encountered in engineering construction. Though Mudrock is considered problematic, this study has proved that Mudrock, particularly from Putrajaya when tested with soaked CBR test, may perform as subgrade material for high volume traffic whereas the sample that is tested with unsoaked CBR test, it shows that the sample may perform as subgrade material for pavement supporting low volume traffic.

The slaking causes particle size of Mudrocks reduces and shape changes with significant reduction in shear strength and increase in deformation. This study has attempt to investigate the performance of slaked Mudrock as subgrade material. The California Bearing Ratio (CBR) value obtained from soaked and unsoaked CBR test for Putrajaya Mudrocks is 12.6 and 10.3% respectively. Clearly, the CBR value obtained from this study has passed 5% as enlisted in JKR's requirement. It is proved that the exposure to drying and wetting process does not affect the sample to be non-durable in performing as subgrade material. Nevertheless, the sample's fragments may have been disintegrated while executing the slake durability test. Consequently, the fragments might have not passed through the drum mesh. Hence, it is recommended to have mesh with various opening size to be used for this test.

In order to be more sensitive at distinguishing the slaking classification, the jar slake test is a prospective test to be tested on large number of samples. The study proved that the Putrajaya Mudrock may serve well as subgrade layer of road since fulfilling the requirement of JKR. However, the term suitability and performance of subgrade requires wider view as sub-grade in real practice is prone to the environmental effect and its contact with overlying layer such as bases and sub-base at various traffic loading. Further investigation on the issue specially on settlement should be conducted to give more reliable outcome on the performance of sub-grade material.

ACKNOWLEDGEMENT

This research was supported in part by the Ministry of Higher Education of Malaysia under Fundamental Research Grant Scheme (Cost Center: 5524614)

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