MINERALOGICAL CONTROLS OF MUDROCK DURABILITY

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ABSTRACT: The effect of mineralogy on slake durability of 36 mudrock samples was investigated. Samples were obtained from six different sites with distinct lithologies that included 12 mudstones from two sites, 14 mudshales from two sites, 6 clayshale and 4 siltstones. Slake durability tests were continued to fifth cycle to study the effect of different cycles on durability of mudrocks. The highest value of slake durability was measured for siltshale and the lowest for clayshale.

The slake durability results of this study also indicate that there is no single parameter that can be used to predict the durability of mudrocks. The results show that durability is closely related to the quantity of clay minerals. Therefore, it can be concluded that variation in durability within mudrocks is controlled predominantly by mineralogy. A decrease in the slake durability was associated with an increase in clay content. It seems that other geological parameters such as fabric and weathering also affect the durability of mudrocks.

INTRODUCTION

Mudrocks are very fine-grained argillaceous sedimentary rocks in which more than 50% of the clastic grains are smaller than 0.06 mm diameter (Blatt et al., 1980). Durability is the most important engineering property of mudrocks in projects that involve exposure of mudrocks to the weathering environment. It has value for many applications, such as for using mudrock as a construction material or as a foundation material.

Many studies on slaking mechanisms have been done (Terzaghi and Peck, 1967; Taylor and Spears, 1970). Vallejo et al. (1993) reported that the predominant slaking mechanism of mudrock is pore air compression, which takes place when the mudrocks are immersed in water and is the result of capillary suction pressures. However, the mechanisms causing slaking breakdown are far from completely understood.

Slake durability is widely used in testing mudrocks and these materials are characterised by a wide variation in their engineering properties, particularly their resistance to short term weathering by wetting and drying. One of the most common forms of breakdown in mudrock is slaking and it has value in many applications, because these rocks are seriously affected by wetting and drying. For example, some mudrocks slake almost immediately in moist air (Underwood, 1965, Dick et al., 1994), while others can withstand many cycles of wetting and drying. They take years of exposure before showing any signs of deterioration, and are roughly as durable as sandstone or limestone. Because of this problem, the durability of mudrocks is a major concern in engineering construction and has been the focus of mudrock research. Franklin (1983) reported that perhaps the most important mechanical characteristic of a mudrock, which distinguishes it from other rocks, is its general lack of durability.

SAMPLING

Thirty six mudrock specimens were taken from different sites that represent a variety of depositional environments. The majority of the samples was obtained from fresh excavations. Other samples were

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obtained from borehole coring. In order to minimize the effect of weathering on the durability test results, great care was taken to obtain relatively fresh samples. The sampled mudrocks range in age from Upper Ordovician to Upper Carboniferous.

According to the ISRM (1981) suggestion, ten representative mudrock lumps, roughly spherical in shape and with rounded corners, each with a mass in the range of 40 to 60 grams, to give a total sample mass of 450 and 550 grams, were prepared for each slake durability test.

MINERALOGY

To determine the influence of the mineralogy of mudrocks on durability the bulk mineralogy of different mudrock samples was analysed. The test was performed on a Hilton Books DG2/Philips X-ray diffractometer. The samples were scanned from 3° to 80° 2θ with at steps of 0.02° at speed of 0.02°/s.

The mineralogy of 36 different samples of mudrocks (5 samples from the Ashfield shale, 6 samples from Queenston shale and 25 samples from the Coal Measures mudrocks) was examined by means of X-ray diffraction of bulk rock material. The means of the resulting mineralogical data are summarised in Table 1. It shows a variation in composition of these rocks. These results are discussed below.

Table 1 Results of mineralogical analysis of clay and quartz fractions for tested mudrocks.

Rock type	Geological sequence	No.	Quartz (%)	Clay (%)	Type of clay
Mudshale	Ashfield	5	57	43	ill, kao
Mudstone	Queenston	6	47.8	45.3	chl, ill, kao
Mudshale	Coal Measures	7	53.7	39.6	kao, ill, chl
Mudstone	Coal Measures	8	47.1	50.3	kao, ill, chl
Clayshale	Coal Measures	6	26	71.7	kao, ill
Siltshale	Coal Measures	4	66.3	18.3	kao, chl
All samples		36	49.4	45.7	kao, ill, chl

ill = illite, kao = kaolinite, and chl = chlorite.

The X-ray diffraction analysis of the Ashfield shale shows that this rock contains no chlorite, no mixed-layer clays, and no smectite. The analysis of the less than 2 μm fraction of the Ashfield shale indicated that illite and kaolinite are dominant clay minerals, and that on average kaolinite is more abundant. Quartz is the major component of the non-clay constituent of this shale (generally 50% to 60%).

From the results in Table 1 it can be seen that the Queenston shale contains about 45% clay minerals, of which illite and chlorite are dominant with no mixed-layer clays and no smectite. Minor amounts of expansive montmorillonite are reported in occasional samples from the Queenston formation by Franklin (1983). Quartz is a major component of the non-clay constituent of these rocks with calcite and dolomite grains and intergranular cement contributing also to their mechanical competence.

The Coal Measures mudrock includes different types of mudrock with a wide range of clay content. The X-ray diffraction analyses of this mudrock show no mixed-layer clays and no smectite. The X-ray trace at less than 2 μm shows that kaolinite and illite are the dominant clay minerals in the Coal Measures mudrocks except siltshale. Chlorite can be seen in a minor amount of clay fractions of these rocks. Quartz is the major non-clay constituent in the Coal measures mudrocks.

In general, the results of the X-rays have shown that tested mudrocks vary in quartz and clay minerals contents. Based on the range of quartz and clay minerals contents the samples studied can be classified in the range from siltshale to clayshale based on the proposed geological classification.

SLAKE DURABILITY TEST

There are many test procedures for estimating the slake durability of mudrock. Almost all methods essentially consist of cycles of drying and wetting by water. Franklin (1970) and Taylor and Spear (1970) discussed the results of different methods of durability testing. The slake durability index (Id) test developed by Franklin and Chandra (1972) is recommended by the International Society for Rock Mechanics (ISRM 1979) and the American Society for Testing and Material (ASTM 1990). They used the two-cycle slake durability index (Id2) to classify mudrocks. Hopkins and Deen (1984) used two 25 min cycles for the slake durability classification of Kentucky shales. Russell (1982) suggested that a three-cycle, rather than a two-cycle test, is more likely to produce a constant value for the mudrock durability index of UK Coal Measures mudrocks.

In this research, the slake durability test, developed by Franklin and Chandra (1972) was used to characterize mudrock durability. Tap water and in some tests distilled water at room temperature were used as the slaking fluid. There was not any significant differences between the results of slake durability using tap water or distilled water.

TEST RESULTS AND DISCUSSION

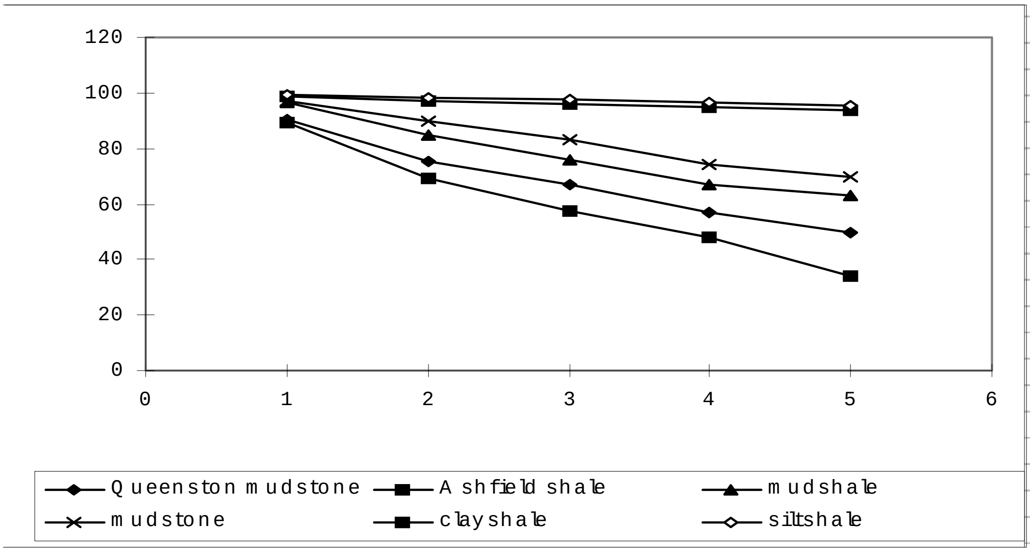
Slake durability was calculated as the percentage ratio of the amount of mudrock remaining after each cycle to the initial dry sample weight as follows:

$$I_{d2} = \frac{C - D}{A - D} \times 100 \tag{1}$$

where:
I_{d2}= slake durability index
C = the weight of drum plus the retained portions of sample
D = the weight of drum brushed clean
A = the weight of drum plus sample.

All slake durability tests in this study were continued to the fifth cycle to study the effect of different cycles on the durability of tested samples. The results of different cycles of durability are shown in Fig. 1.

Many studies on slaking mechanisms have been done (Terzaghi and Peck, 1967; Taylor and Spears, 1970). Vallejo et al. (1993) reported that the predominant slaking mechanism of the mudrocks is pore air



compression, which takes place when the mudrocks are immersed in water and is the result of capillary suction pressures. However, the mechanisms causing slaking breakdown are far from completely understood.

The results of this research show that there is no single parameter that can be used to predict the durability of mudrock. Different factors affect the slake durability of this type of rock. Mineralogy is a major parameter that control variation in mudrock durability. A decrease in slake durability of tested mudrock was associated with an increase in clay content.

Dick and Shakoor (1990) found that slake durability of mudrocks is closely related to the rock fabric as expressed by void ratio and absorption. Ghafoori (1994) and Tugrul and Zarif (1998) reported the influences of weathering on durability. Hence this test is also a good indicator for evaluating the weathering resistance of mudrocks. According to Van Eekhout (1976), the presence of montmorillonite indicates that a mudrock material will slake more rapidly. Moon and Beattie (1995) reported that the amount of clay-size material in mudrocks provides the most direct control on durability.

The slake durability results of this study show that there is no single parameter that can be used to predict the durability of mudrocks. The results indicate that durability in mudrocks is closely related to the quantity of clay minerals.

CONCLUSIONS

This research investigated the slake durability of mudrocks. One of the most common forms of breakdown in mudrock is slaking and it has value in many applications. These rocks are seriously affected by wetting and drying. The results indicate that no single parameter can be used to predict durability of all types of mudrocks. For those mudrocks that are similar in age, depositional environment and stress history but different in composition (such as Coal Measures mudrocks), increasing slake durability was associated with increasing quartz content and decreasing clay content.

It seems that other geological parameter such as fabric and weathering also affected durability The mudrocks used in this study were relatively fresh. Since mudrocks of varying degrees of weathering are often encountered in engineering projects, it is important to consider the effects of weathering on durability behaviour.

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