International Journal of Rock Mechanics & Mining Sciences 46 (2009) 929–939

Contents lists available at ScienceDirect

International Journal of
Rock Mechanics & Mining Sciences

journal homepage: www.elsevier.com/locate/ijrmms

Deep weathering of a group of thick argillaceous limestone rocks near Three Gorges Reservoir, Central China

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A R T I C L E I N F O

Article history:
Received 15 April 2008
Received in revised form
16 February 2009
Accepted 18 March 2009
Available online 23 April 2009

Keywords:
Weathering
Argillaceous limestone
Three Gorges Reservoir
Urban development
Geohazards
Landslides
Sinkhole
Mountain environment
Rock mass characterization

A B S T R A C T

Rock mass characterization is one of the most basic and important tasks in rock mechanics and engineering. Literature review indicates that although there are many publications available on weathered rocks, there are few reports in English on weathered argillaceous limestone rocks and their chemical and mechanical properties. This paper presents a case study of characterizing a group of highly weathered thick argillaceous limestone rocks. Most importantly, they can be easily and quickly decomposed into soils after they are exposed due to excavation. Consequently, they would substantially lose their mechanical strengths. Geohazards such as landslides and sinkholes could occur in uncovered highly weathered argillaceous limestone rocks. The problematic weathered rocks were found during the development of a new town in upper mountains above the Three Gorges Reservoir on Yangtze River in Central China in the past 20 years. The factual data are presented on the changes of chemical compositions and mechanical properties of the weathered argillaceous limestone rocks due to chemical weathering. Some empirical correlations are given to quantify the changes in their uniaxial compressive strength and deformation moduli in terms of their contents of calcium carbonate. The data and findings presented in the paper can be useful to future urban development in geologically poor mountainous environments occupied by highly weathered argillaceous limestone rocks in the world.

1. Introduction

All rock engineering activities are conducted either on the surface of the Earth or within a relatively shallow depth beneath it. This thin mantle of the top crust is the zone where the processes of weathering, erosion, transportation and deposition are active [1]. Weathering significantly alters the chemical, mineralogical, and physical properties of the rocks exposed on the surface of the Earth and results in complicated spatial distribution of weathered rock masses with different properties. Quantitative characterization of weathered rock mass has been one of the most basic and important tasks in rock mechanics and engineering. It has been often reported that unforeseen poor geological conditions caused disasters during construction in weathered rocks [2,3].

Weathered rocks have been extensively examined in the fields of rock mechanics and engineering geology [4]. Such weathering of rocks has eventually resulted in the formation of a weathered rock profile on the surface of the Earth. This profile shows a spatial sequence of rock masses with varying compositions and physical and mechanical properties. It can be either thin or thick. Sometimes, it can be very thick [5,6]. According to ISRM and GB50021-2001 [7,8], the weathered rock masses can be scaled with the system of six grades. The six grades are fresh, slightly weathered, moderately weathered, highly weathered, completely weathered rocks and residual soils. In particular, although they still maintain the structure and fabrics of their parent rocks, the completely weathered rocks have completely lost their rock strengths and are basically soils. In other words, they can be broken into their constituents by hands.

A comprehensive literature review of the present study indicated that since 1955, a majority of the relevant studies on weathered rocks available in open publications in English and Chinese have been concentrated on igneous rocks including granites, granodiorite, ignimbrite, andesite and basalt, some on sedimentary rocks including sandstone, mudstone, kaolinite, pyrite, psammite and limestone, as well as a few on metamorphic rocks including schist, geniss and mylonite (Table 1). Furthermore, it seems that there were few publications in English available on weathered argillaceous limestone and marl rocks.

The objective of this paper is to present a case study of characterizing a group of highly weathered thick argillaceous limestone rocks. Most importantly, they can be easily and quickly weathered into completely weathered argillaceous limestone

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doi:10.1016/j.ijrmms.2009.03.006

Table 1
Weathering thickness of different rock types reported in open literature.

Rock type		References	Location	Formation	Age	Maximum weathering thickness (m)	Key points
Igneous rocks	Granite	Ref. [9]	Kowloon, Hong Kong (China)	?	Early cretaceous	>70	Contours of weathering front
		Ref. [6]	Nigeria (Australia)	?	?	100	Weathering geomorphology
		Ref. [10]	Uganda	?	?	100	?
		Ref. [11]	Queensland (Australia)	?	?	45	?
		Ref. [11]	New South Wales (Australia)	?	?	300	?
		Ref. [11]	Victoria (Australia)	?	?	80	?
		Ref. [11]	Western Australia (Australia)	?	?	40	?
		Ref. [12]	Hong Kong (China)	?	?	100 m or more	Engineering properties of fresh and decomposed igneous rocks
		Ref. [13]	Xiamen (China)	?	?	20–60	Engineering and geological characteristics of granite weathering profile
		Ref. [13]	Gannan (China)	?	?		
		Ref. [13]	Shenzhen (China)	?	?		
		Ref. [13]	Hong Kong (China)	?	?		
		Ref. [13]	Sanya (China)	?	?		
	(Coarse grained gray) biotite granite	Ref. [14]	Snowy Mountains (Australia)	?	?	30	?
	Granite	Ref. [15]	Hong Kong (China)	?	?	104	?
	(A light gray, two medium grained) two mica granite	Ref. [16]	Oporto (Portugal)	?	318 Ma	exceed 20–30	Characterizes the weathering products of the two mica Oporto granite
	Granite	Ref. [17]	Malanjkhand copper deposit (India)	?	Precambrian age	up to 90	Weathering effects on the strength and deformational behavior of crystalline rock under uniaxial compression state
	Granodiorite	Ref. [5]		?	?	120 or more	?
	Ignimbrite	Ref. [4]	East of the Kagoshima, prefecture in southern Kyushu island (Japan)	?	?	<15	The water infiltration behavior within weather profile of non-welded ignimbrite in relation to the generation of shallow landslides
	Ignimbrite	Ref. [18]	The Kagoshima prefecture (Japan)	?	780 ka	4–5	Weathering mechanisms and their effects on the landsliding of ignimbrite
	Andesite	Ref. [19]	Ankara (Turkey)	?	Miocene	2–3	Effect of weathering on the geomechanical properties of andesite
	Andesite	Ref. [20]	Ankara (Turkey)	?	Miocene	2–30	Field characteristics of weathered Ankara andesites
	Basalt	Ref. [21]	Southwest of Hamilton (New Zealand)	?	2.03 ± 0.03 Ma	66	Geomechanical and geochemical changes during early stages of weathering
Sedimentary rocks	Sandstone and conglomerate cemented by zeolite	Ref. [22]	Hokkaido, northern Japan (Japan)	?	Miocene	60	Chemical weathering mechanisms and their effects on engineering properties
	Mudstone with sandstone	Ref. [23]	Niigata (Japan)	Haizume formation	Pleistocene	50	Chemical weathering mechanism of mudstone
	Mudstone	Ref. [24]	Niigata (Japan)	Haizume formation	Pleistocene	About 36	Chemical weathering mechanism
	Sandy mudstone	Ref. [24]	Chiba (Japan)	Kakinokidai formation	?	About 4	Chemical weathering mechanism
	Sandstone and conglomerate	Ref. [24]	Hokkaido (Japan)	Toyonikawa formation	?	About 50	Chemical weathering mechanism
	Fine sandstone	Ref. [25]	Niigata (Japan)	Yamaya formation	?	Less than 30	Chemical weathering mechanism
	Kaolinite	Ref. [25]	Czechoslovakia	?	?	30	?
	Cretaceous sedimentary rocks	Ref. [26]	Queensland (Australia)	?	?	>100	?
	Pyrite	Ref. [5]	Rum jungle (Australia)	?	?	>200	?
	Psammite	Ref. [27]	Gaick area, Scotland (UK)	?	Predate the Devensian	17	The characteristics and significance of deep weathering
	Limestone	Ref. [28]	Istanbul (Turkey)	?	Devonian	8	Engineering aspects of limestone weathering
Metamorphic rocks	Schist	Ref. [7]	?	?	?	200	?
	Geniss	Ref. [5]	?	?	?	320	?
	Mylonite	Ref. [5]	?	?	?	120	?

Note: Symbol "?" stands for the date were not given in the references.