VOL. 12, NO. 14, JULY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

UNIAXIAL COMPRESSIVE STRENGTH OF MALAYSIAN WEATHERED GRANITE DUE TO CYCLIC LOADING

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ABSTRACT

For the stability evaluation of rock structures, it is important to reveal the deterioration characteristic of rocks under repeated stress as rock structures may not only subjected to static loads but also affected by dynamic loads. Literature studies showed that there are significant reductions of rock strength due to cyclic loading. However absence of research involving the effects of cyclic loading on the strength parameter has led to improper knowledge and fundamentals. Therefore this research work is to assess and determine the effects of cyclic loading on the uniaxial compressive strength of weathered granite. With the use of advance GCTS Triaxial RTX-3000 machine, it is now possible to apply a fixed number of cycles to the rock specimens. The rock specimens used for the characterization purpose were classified into Grades II, III, and IV, and free from any fractures, joints and faults. All of the specimens were loaded up to 50 % loading amplitudes under frequency of 1 Hz and the number of loading cycle was limited to 100 cycles as the limitation. Considering the effects of cyclic loading, the maximum percentage reduction of strength for Grade II, Grade III, and Grade IV granite were recorded as 13.50 %, 15.15 %, and 16.30 % respectively. Conclusively, the approximate average 15 % strength reduction is due to the increase of bulk compressibility and accumulated permanent strain damage resulting from cyclic loading, thus reducing compressive strength of weathered granite.

Keywords: weathered granite, uniaxial compressive strength, and cyclic loading.

INTRODUCTION

It is well-known that most materials deteriorate due to repeated stress and can reach failure below its maximum stress level [1]. Failure due to repeated stress is generally known as fatigue and it could occurs in many of rock material as well [2]. Most of rock structures, such as bridges, buildings, traffic tunnels, and mining galleries, were affected by repeated stress in their use and operation [2]. It is therefore important to investigate the deterioration of rocks under repeated stress over the long term for the stability evaluation of many rock structures.

Up to date the investigation on the behavior of rock under cyclic loading has been generally neglected [3]. However considerable efforts have been made to study the effect of cyclic loading parameters that could affect the strength of rock. It has been proved that the deterioration of rock strength due to cyclic loading greatly depends on types of rock [4-5]. Haimson [4] stated that strength deterioration for 100 numbers of cycles was within the range of 35% to 85% of static strength. Lee *et al*. [6] revealed that the fatigue failure of rock fall between 70% to 82% stress level. Under maximum number of cycles, fatigue strength was typically between 50% and 70% of the static strength of rock [7]. Ray, Sarkar and Singht [8] reported that uniaxial compressive strength decrease with increasing applied stress level and the number of cycles.

Although previous studies found that the variation of fatigue life for the maximum number of cycles varied between 60 % to 80 % of the respective UCS [6, 9], it should be kept in mind that different materials have different behaviors when subjected to severe loading conditions [10]. As reported by Liang *et al*. [11], different rocks have different inner structure and mineral grains that makes it response to different loading paths in different way. Badge *et al*. [12] then concluded that fatigue of rock was very complex and unpredictable.

In Malaysia, determination of fatigue strength is still highly variable and generally unreliable due to the tropically weathered rock formation. The absence of data regarding the effects of cyclic loading on the strength parameter of these weathered rocks has led to improper knowledge and fundamentals. As the possible solution this primary investigation is mainly focuses on the effects of cyclic loading on the uniaxial compressive strength of weathered granite. Behavior of rock specimens under cyclic loading will be assessed and the possible effects on the uniaxial compressive strength will be analyzed.

METHODOLOGY

This study is primarily a laboratory experimental works on tropically weathered granite rocks. More than 30 specimens were required for this research purpose. The rock samples used in this study were collected from Bukit Rahman Putra Sungai Buloh. The granite rocks samples were classified based on Grades II, III and IV. In order to study the effects of cyclic loading on the uniaxial compressive strength of weathered granites, two testing were selected namely uniaxial compression strength test, and cyclic loading test. A summary of the research framework are then presented as in Figure-1.

The uniaxial compression test was divided into two tasks, namely first monotonic loading test (without cyclic loading) and secondary monotonic loading test (with cyclic loading history). There were 14 groups of weathered granite samples tested under uniaxial compressive strength test. Each group consists of both primary specimen and secondary specimen. Figure-2 then shows principle of primary and secondary monotonic loading in performing laboratory strength test.

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Based on previous literature on cyclic loading test, most of the researcher stress rock specimens cyclically using a loading machine [13] and it was found that fatigue characteristic of rock material were greatly depends on the maximum stress level, amplitude, loading waveform and frequency. Therefore, assessments of the effects of cyclic loading on hard rocks are mostly done in laboratory test where prismatic or cylindrical specimen would be subjected to cyclic loads based on the standard GCTS-RTX 3000 recommended procedure. Figure-3 then shows the installation of rock specimens into the GCTS-RTX 3000 for cyclic loading test. All of the specimens were loaded up to 50 % loading amplitudes under frequency of 1 Hz and the number of loading cycle was limited to 100 cycles as the limitation.

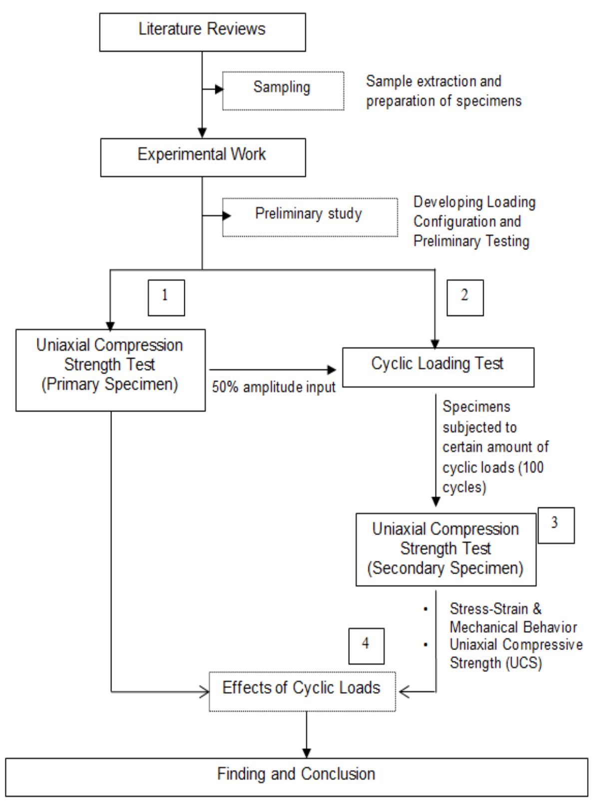

Figure-1. Research framework.

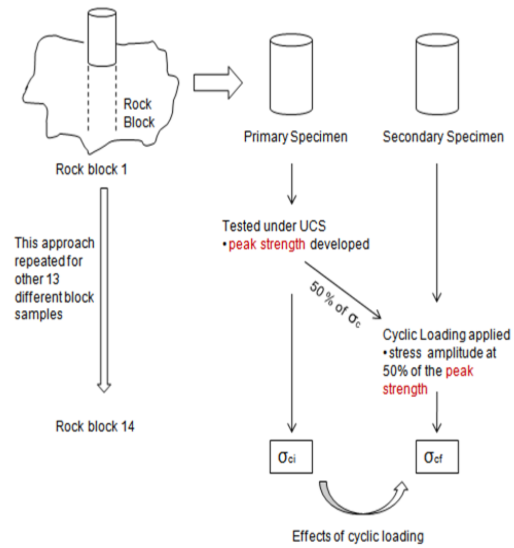

Figure-2. Laboratory process on primary and secondary specimens.

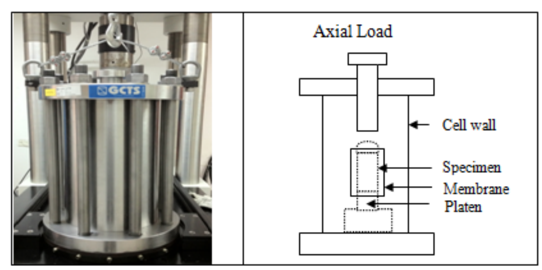

Figure-3. Installation of rock specimen into triaxial GCTS-RTX (Cyclic loading test).

RESULTS AND DISCUSSIONS

Figure 4 depicts the value of uniaxial compressive strength before and after cyclic loading. It shows the reduction of strength of all specimens from Grade II, Grade III, and Grade IV of weathered granite. The maximum percentage reduction of strength for Grade II, Grade III, and Grade IV were recorded as 13.50%, 15.15%, and 16.30% respectively. The differences of strength reduction in all weathering grades are not so obvious since all specimens show variation of strength reduction from 5 % to 15 %. Then it can be deduce that 50% amplitudes of cyclic loads could reduce uniaxial compressive strength of weathered granite up to 15% average.

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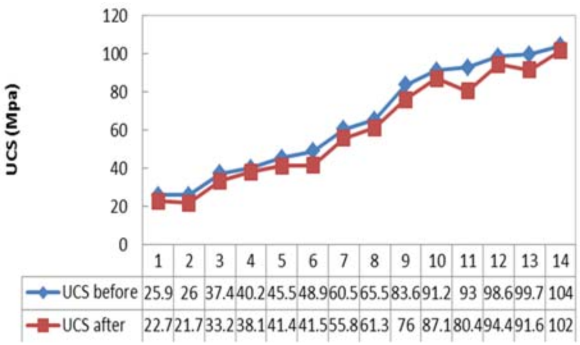

Figure-4. Reduction of strength of weathered granite due to cyclic loading.

Figure-5 then shows a typical hysteresis curve under actual cyclic stress-strain curve during cyclic loading test. The result shows that the curves of stress-strain for loading and unloading were hysteresis loops. It is common to have a large hysteresis loops in the first few cycles followed by a narrowing of loops in the following groups of cycles.

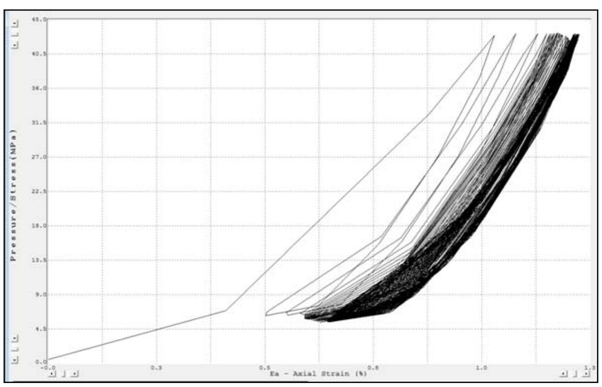

Figure-5. Typical hysteresis curve under cyclic loading test.

The presented result supported previous findings by Mingli *et al*. [14]. It was noticed that as the number of cycles increase, hysteresis loops moved to the direction of increasing axial strain and become denser. From the observed behavior, it was believed the large hysteresis in the first few cycle was due to initial compaction from cyclic loads while the observed "densening loading portion" in the following group of cycles was due to the effects of permanent strain damage accumulate due to micro cracking process from successive cyclic loads.

CONCLUSION AND RECOMMENDATION

From the results, the maximum percentage reduction of strength for Grade II, Grade III, and Grade IV granite were recorded as 13.50 %, 15.15 %, and 16.30 % respectively. Considering the stress-strain characteristic, the large hysteresis in the first few cycles can be related to the fact that loose or weathered rock are simply more compressed due to cyclic loads, while the observed densening loading portion in the following group of cycles was due to the permanent strain damage resulting from microcracking process from successive cyclic loads.

Such observation could explain that the average 15 % reduction of strength due to cyclic loading is highly influenced by the accumulated deformation from initial compaction and permanent strain damage from cyclic loading history. In conclusion, it was found that the effects of axial residual strain resulting from cyclic loads could be a better option to describe the effects of cyclic loading on uniaxial compressive strength of weathered granite. The following are some suggestions for further study;

- Since different material has different capability behavior to resist load under different loading conditions, different types of rock are suggested for future research under cyclic loading test.
- Cyclic loading test consists of many variables such as number of cycles, frequency, loading waveform and amplitudes. It is therefore recommended to test a cyclic loading test under different types of loading condition. (In this study, configuration test are only limited to 100 cycles, 1Hz of frequency and sinus loading waveform condition)
- Instead of uniaxial compressive test, the triaxial compressive test is suggested in order to observe the influence of confining pressure.

ACKNOWLEDGEMENT

The research is supported by Universiti Teknologi MARA (iRAGS) under grant number 600-RMI/IRAGS 5/3 (48/2015) and indirectly supported by Dana Kecemerlangan Universiti Teknologi MARA Sarawak under grant number 600-RMU/DANA 5/3 (1/2016). I am very thankful for this support. Sincere thanks are extended to those who have contributed directly or indirectly for all their valuable comments, guidance, assistance in laboratory work and suggestion during preparation of this research.

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