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A UNIFIED ROCK DEFORMATION MODEL INCORPORATING THE DEVELOPMENT OF UNIQUE STRAIN ENERGY METHOD (USEM) AND NORMALISED STRESS-STRAIN PATH CRITERION

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ABSTRACT

Weathering of rocks in a wet tropical climate gives a significant impact on the disintegration and the strength reduction of rock. Researchers have proposed various methods to express rock deformation characteristics, however, due to different nature and complex formulation, these criteria are not easy to be employed. The most common approach has neglected to account for the role of shear strength properties, a shortcoming addresses by this thesis. Moreover, there is an almost complete lack of data in the literature considering the impact of weathering on a tropical granitic rock, which necessitates further laboratory work on rock triaxial test, including basic mechanical properties, shear strength, and stress-strain analysis. Therefore, this study aims to fill these research gaps and produce a unified rock deformation model that can characterize the complete shear strength and stress-strain behaviour of tropical granitic weathered rock under any confining effect. This can be achieved by innovating a single stress-strain UCS data to project a complete deformation characteristic in terms of the shear strength model and stress-strain model. The normalised strain – rotational multiple yield surface framework (NS-RMYSF) was utilised to evaluate the intrinsic shear strength properties. At the same time, a spreadsheet program was designed to analyse the nonlinear H-B failure criterion. Then, the stress-strain predictive model applying NS-RMYSF and H-B material constant, m_b was developed. A new simplification was then introduced to improve the stress-strain model that is known as normalised stress-strain path criterion. However, these criteria are fully dependent on the peak stress and peak strain prediction. Therefore, a unique strain energy method (USEM) was proposed to infer the relationship between the stress, strain, and total strain energy, U_T. The development of U_T was observed based on stress-strain trapezoidal rules and the potential of USEM was investigated. The results and analysis confirm that single UCS data can be used to demonstrate the independent shear strength model, m_b using the proposed USEM parameters. Also, the proposed USEM relationships can be used to predict the peak stress and peak strain that significantly contribute to the development of an independent stress-strain model based on the proposed normalised stress-strain path criterion. The developed and validated shear strength model and stress-strain model were further verified against other rock types to check their reliability. Finally, the complete unified rock deformation model was conclusively established as the model was improvised in terms of additional parameters that can be used to suit any deformation characteristic of any rock type. The most influential finding and contribution of this study is the ability to utilise single UCS stress-strain data to predict complete shear strength and stress-strain profile irrespective of any confining pressures. It is very significant to researchers, consultants, and engineers as it informs our theoretical understanding regarding the importance of stress-strain as the most powerful and basic fundamental in rock deformation analysis. The role of possible intrinsic shear strength interaction and the innovative unique strain energy method (USEM) were also highlighted as the main knowledge contribution.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

In general, rock failure and deformation are related as the failure of rock under compression which is considered as deformation [1]. The complete stress-strain curves, on the other hand served as the most reliable tool for characterising rock failure and deformation [2]. As mentioned by [3], the stress-strain analysis provide significant information about the deformations characteristic.

The complete stress-strain curves of a rock sample provide a detailed understanding of rock deformation and failure behaviours [2], [4], [5]. However, the course of stress-strain characteristics differs for each rock type depending on numerous factors [6].

Rocks cannot be linearly deformed [6], [7]. It is well known that there are several stages of strain in nonlinear stress-strain rock deformation. According to previous studies [8]–[11], the mechanical responses of the heterogeneous microstructures primarily lead to heterogeneity in the distribution of stress and strain within a rock volume that causes the nonlinear response of the rock under external stress. The stress-strain curves of all types of samples could be divided into five common stages consisting of pore-fissure compaction, elastic deformation, crack initiation and propagation, strain softening and post-peak failure [12]–[16].

At present, the rock strength criterions based on stress or strain are widely used to evaluate the mechanical properties of the rock [10]. For example, [16] conducted the uniaxial compressive strength (UCS) test to investigate the mechanical properties and deformation failure modes of low-strength rock samples. Based on their observation, the stress-strain of low strength rock samples usually show ductile behaviour compared to brittle behaviour that is usually found in high strength rock sample. On the other hand, [4] revealed that the elastic stress-strain relationship can successfully reflect the weakening and anisotropy of the mechanical properties of the rock mass. This observation further indicated that the discontinuities are the main factor that weakens the elastic modulus of rocks.

Apart from UCS and elasticity, the shear strength of rock plays an important