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# Impact of Weathering on Geotechnical Properties of Metamorphic Rocks on part of the Kurunegala - Kandy Expressway

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**Abstract**
Weathering is an irreversible naturally occurring phenomenon that negatively affects the structural integrity and geotechnical parameters of rocks. This study aims to understand how weathering influences the physical parameters of tropical metamorphic rocks, by testing three types of gneissic rocks — Granitic Gneiss, Quartzo-Feldspathic Gneiss and Biotite Gneiss — collected along the Pothuhera – Galagedara Section of the Central Expressway, Sri Lanka. Rocks were tested under three main degrees of weathering for each rock type, using UCS, Brazilian tensile strength, slake durability, AIV, and LAAV. Results show that Biotite Gneiss deteriorates the fastest under weathering and is the most vulnerable to wear. Consequently, although Granitic Gneiss has the highest strength initially, it declines rapidly. Comparatively, Quartzo-Feldspathic Gneiss has lower initial strength than the other two rock types, but retains it more effectively as weathering progresses.

**Keywords:** Index tests, Intermittent Wet Zone, Strength tests, Weathering Profile Analysis

## 1 Introduction

Weathering is a natural process by which minerals and rocks are physically broken down and chemically decomposed when they are exposed to near-surface or surface environmental conditions. This phenomenon alters the geologic, mineralogic, and mechanical properties of rocks, which significantly impacts their engineering behavior [1], [2], [3]. Weathering is an important parameter in geotechnical engineering as it controls the strength, durability, and stability of rock masses. Therefore, it is an extremely critical factor to be monitored when considering the rock for a given engineering purpose, as the degradation as well as the behavior of strength parameters of the rock may differ due to numerous external and internal factors. Weathering is also important for determining the slope stability of rock mass, as stated in several studies [4] [5].

## 2 Background of the Study

### 2.1 Types of Weathering

Weathering is commonly classified into three groups. These are physical, chemical, and biological. Physical weathering refers to the mechanical breakdown of rocks without chemical alteration. Freezing and thawing, wetting and drying, exfoliation, and thermal expansion are some of the usual processes of physical weathering. Chemical weathering is the disintegration of minerals by chemical alteration through processes such as hydrolysis, carbonation, and oxidation, which normally give rise to the formation of secondary minerals such as clays. Biological weathering occurs by the action of plant roots, microorganisms, and organic acids, which cause and accelerate both physical and chemical breakdowns.

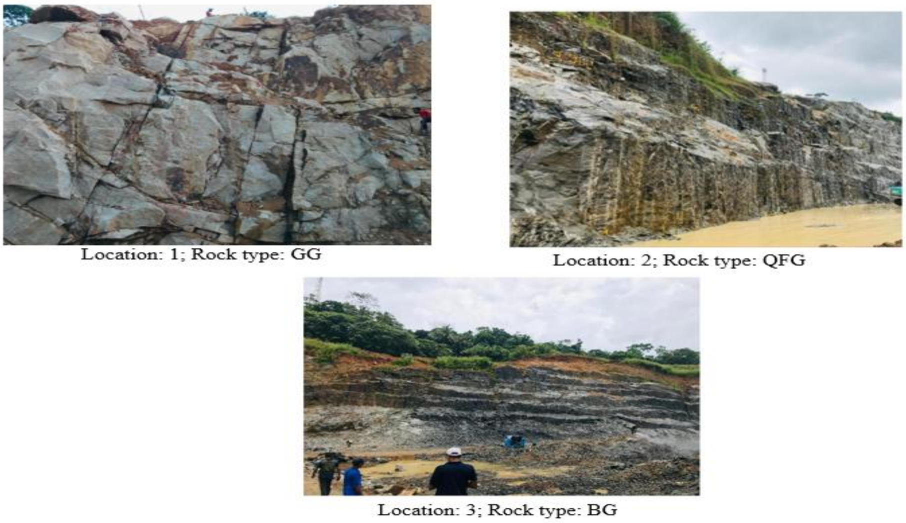


Figure 1: Sample collection locations along Central Expressway, Section 03 Trace

### 2.2 Weathering Profiles

A weathering profile is a vertical cross-section through the Earth's surface that reveals progressive changes in rock and soil prompted by weathering. This extends from the surface up to the bedrock, in the absence of discontinuities such as faults and joints. The upper portion of the profile most often includes weathered rock and residual soil and as the depth of profile increases, the degree of weathering will decrease gradually or rapidly, depending on environmental, geological and several other deciding factors.

Weathering profiles provide insight into geological characteristics and the formation of the rock, which is crucial for engineering projects.

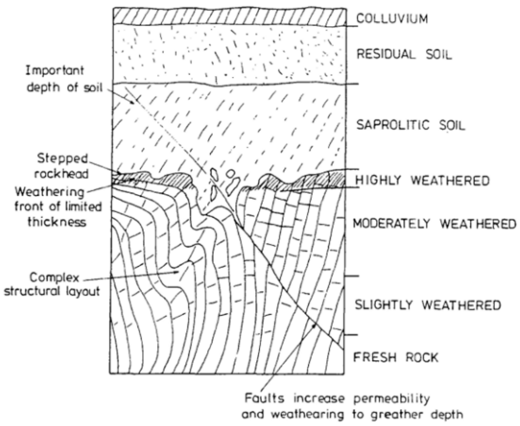


Figure 2: Typical weathering profiles at gneissic rocks in tropical climate [6].

## 3 Sample Collection

Samples were collected along the Pothuhera – Galagedara Trace (Section 03) of the Central Expressway, Sri Lanka (See Figure 2).

Fresh rock, weathered rock and residual soil samples were collected from three types of gneissic rocks: Granitic Gneiss (GG), Quartzo-Feldspathic Gneiss (QFG) and Biotite Gneiss (BG), as depicted in Figure 3. The sample collection was done immediately after the area was excavated to begin the road construction.

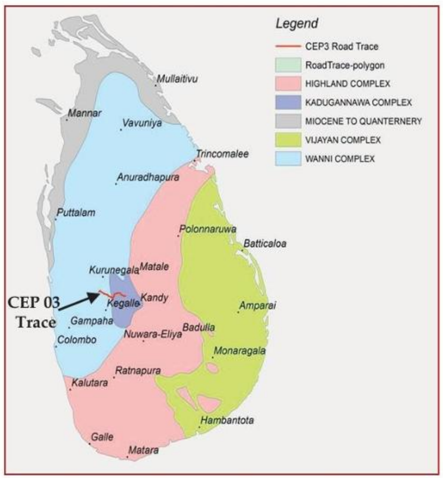


Figure 3: Central Expressway Sample Area - Section 3 Trace [7].

### 3.1 Sample Preparation

For UCS tests, fresh rock samples of NX-type were prepared using drilled cores obtained from the chosen location, following the dimensions mentioned in ASTM D2938 – 95 (2002) standard. Disc specimens of dimensions suggested in ASTM D3967 – 95 (2002) standard were prepared for the Brazilian tensile strength test.

Aggregate Impact Value (AIV) test was conducted using the samples prepared as instructed in IS: 2386 (Part IV) — 1963 standard for weathered and fresh rock. As for the Los Angeles Abrasion Value (LAAV) test, samples for weathered and fresh rock were prepared as instructed in ASTM D C 131 – 03 standard. Weathered rock and fresh rock samples of each rock type were prepared for Slake Durability (SD) test by following the directions as mentioned in ASTM D4644−16 standard.

As an additional confirmation of the strength parameters, rebound hammer test was also conducted for every rock sample according to D5873 – 14 standards.

test, and Brazilian Tensile Strength test are the two tests conducted under this category.

The UCS test depicts the maximum uniaxial stress that a rock can bear under compressive conditions without failure. This is a direct implication of rock strength and can be observed declining with increased degree of weathering.

Brazilian Tensile Strength test is an indirect test that measures the maximum tensile force that a rock can withstand without failing. Usually, this value is much lower than the UCS, so it should be measured with higher accuracy, and considered more critically [8].


Figure 4: Collected fresh and weathered rock samples

## 4 Sample Testing

Rock samples were categorized as fresh rock (core samples) and weathered rock. This categorization was done visually on site based on appearance, colour, texture and toughness. UCS, AIV, LAAV, and SD tests were done for all fresh and weathered rock samples the three rock types. Brazilian Tensile Strength tests, were also initially conducted for fresh rock samples: however, they were not successful, as the actual values were below the minimum detected range of the machine.

### 4.1 Strength Tests

Strength tests done for rocks primarily determine the strength of rock samples and provide an understanding of the structural integrity and stability. Uniaxial Compressive Strength (UCS)

### 4.2 Index Tests

Index tests provide indirect measures of mechanical behavior and durability that can then be used to make informed conclusions on the strength of rock sample. Under this category, AIV, LAAV, and SD tests were conducted for rock samples covering the three selected rock types.

AIV test measures the resistance to continued impacts. This is important in identifying the suitability of the chosen rock for aggregate purposes in the construction sector. Alternatively, the LAAV test evaluates the resistance to abrasion of a given material in aggregate form, which is also a selection criterion for construction materials [9].

Determining Slake Durability Index of a sample reflects its durability under consequent wet and dry cycles. This test may be ideal for estimating the durability of tropical rocks given the simulation of similar climatic patterns [10].

Rebound hammer test is a quick and non-destructive test that can give a rough estimate of surface hardness of the rock, and it can be used as a precursor to measuring UCS of the rock. However, rebound hammer values may not be entirely accurate, as it measures the surface based hardness, not actual rock strength. Therefore, is recommended only for comparative assessment, not exact strength measurement [11].

## 5 Results and Discussion

Table 1 shows the variations of some physical properties of rock with the degree of weathering.

Figures 5 – 8 depict the graphical representations of results obtained for the individual tests.

The largest difference in AIV is noted in GG, where AIV changes from 12.53% to 46.86% with weathering. BG shows the least difference in AIV, going from 12.26% to 33.55% as weathering progresses. This implies that BG has the highest impact resistance among the tested samples and GG has the lowest.

Similarly, the most significant change in LAAV is observed in BG, which suggests that BG is more susceptible to abrasion, compared to QFG and GG, both of which show similar resistance to abrasion according to Table 1.

As for the SD test, BG shows the highest decline, suggesting the least durability among the three tested rock types. In contrast, Table 1 shows the least decline in Id2 for GG, which states that GG has the highest durability among the three rock types. Notably, the durability indices (Id2) observed are higher than expected in all slightly weathered samples, suggesting that early-stage weathering does not immediately compromise rock integrity for any of the selected rock types.

UCS values obtained for fresh rock samples show the highest value for GG and the lowest value for QFG. Nevertheless, the UCS results obtained for fresh core samples are relatively low compared to the expected outcome. This may be attributed to micro-fracturing within the rock matrix. Unfortunately, BTS tests were not successful due to the maximum bearable tensile force of any sample not being within the measurable range of the machine.

Upon analysis, it was observed that GG indicates least impact resistance, moderate abrasion resistance in addition to the highest durability and UCS among the tested samples. Meanwhile, QFG has the lowest UCS but the highest resistance to abrasion, and moderate durability and resistance to impact. Lastly, BG shows the highest resistance to impact, least resistance to abrasion and durability, and moderate UCS. These assessments imply that while GG is the strongest as fresh rock, QFG retains its physical strength better. Conversely, BG loses its strength faster than the other two rock types.

Figures 5 – 7 show the variation of physical properties of each rock types with increasing depth and subsequently, degree of weathering for each individual rock type.

***Table 1: Results for physical property testing***

| Location | Rock Type | Degree of Weathering | AIV (%) | LAAV (%) | Id2 (%) | UCS (MPa) |
|---|---|---|---|---|---|---|
| 1 | Granitic Gneiss (GG) | FR | 12.53 | 18.43 | 98.95 | 52.40 |
| | | SWR | 17.87 | 20.68 | 95.47 | N/A |
| | | RS | 46.86 | N/A | N/A | N/A |
| 2 | Quartzo-Feldspathic Gneiss (QFG) | FR | 12.75 | 18.96 | 98.9 | 29.90 |
| | | SWR | 16.43 | 22.75 | 94.4 | N/A |
| | | RS | 36.62 | N/A | N/A | N/A |
| 3 | Biotite Gneiss (BG) | FR | 12.26 | 24.23 | 97.82 | 45.64 |
| | | SWR | 22.87 | 53.93 | 88.85 | N/A |
| | | RS | 33.55 | N/A | N/A | N/A |

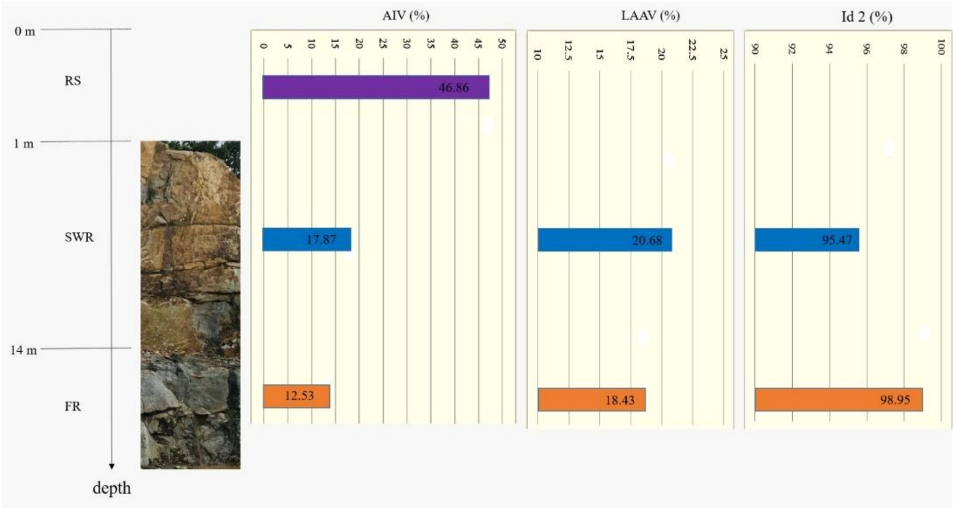


Figure 5: Weathering profile analysis of GG

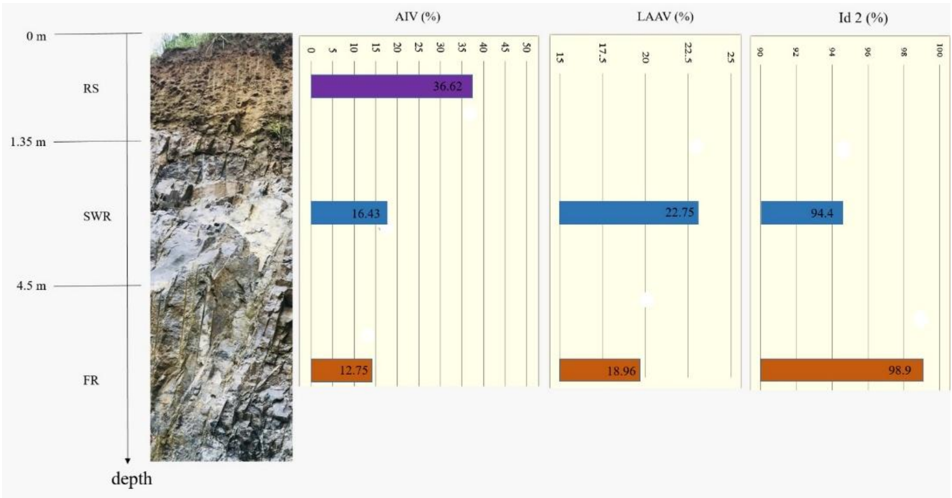


Figure 6: Weathering profile analysis of QFG

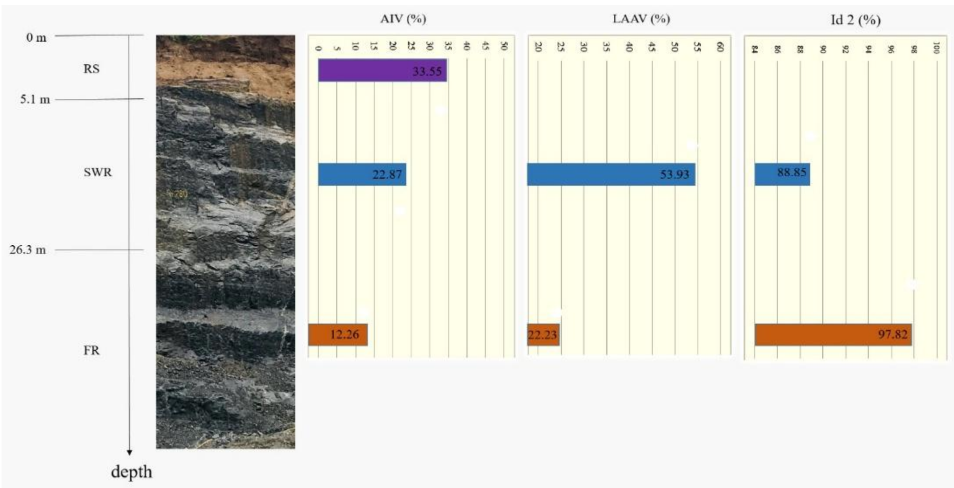


Figure 7: Weathering profile analysis of BG

## 6 Conclusion

The preliminary findings of this study underscore the progressive impact of weathering on the geotechnical properties of metamorphic gneissic rocks in the intermittent wet zone of Sri Lanka. This research uniquely investigates three specific types of gneissic rocks—Granitic Gneiss (GG), Quartzo-Feldspathic Gneiss (QFG), and Biotite Gneiss (BG) present in a tropical setting.

Based on the results obtained in the course of this study, GG seems to be highly strong and durable in static conditions but highly affected by impacts. Therefore, it is not recommended in dynamic load bearing conditions. QFG appears to be physically resilient, but weaker structurally. Therefore, it may be optimum for surfacing and drainage purposes but not for high stress zones. Finally, BG shows the highest sensitivity to wear and is the most vulnerable among the tested rock types and therefore is suitable for dynamic load environments. However, it is important to acknowledge that this study was conducted with limited number of working samples under a resource-constrained environment and therefore requires additional sample testing for more definitive conclusions.

Further comprehensive studies are recommended to determine the eligibility of these rocks for certain projects, and to determine the slope stability of the inherent rock mass present in Pothuhera – Galagedara section of the Central Expressway.

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