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Technical note

# On the reliability of the strength retention ratio for estimating the strength of weathered rocks

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ABSTRACT

This technical note examines the validity of the strength retention ratio ($R_s$) as a criterion for estimating the strength of weathered rocks. Although $R_s$ has been widely used for classification purposes, it seems to significantly underestimate the strength of slightly weathered (SW) rocks. To better understand the limitations within which $R_s$ can be used, a series of point load and slake durability tests were performed on weathered rocks of three types. The obtained correlations between the point load and slake durability indices were used as a basis to refine the current method of determining $R_s$. Using this new procedure, the available data from the literature were revisited, and $R_s$ was re-calculated providing a better match between the quantitative and qualitative description of weathered rocks.



## 1. Introduction

Weathering of rock materials has a strong effect on the stability of rock masses. A number of studies have been performed in the past few decades to provide qualitative description of weathered rock materials and rock masses (Irfan and Dearman, 1978; Irfan and Powell, 1985; Tugrul and Gurpinar, 1997; Basu et al., 2009; Marques et al., 2010) and quantitative (Gupta and Rao, 2000, 2001; Kim et al., 2015a, 2015b) information about weathered rocks, resulting in several criteria and indices which are currently used for rock classification.

From an engineering point of view, changes in the strength of weathered rocks will be of great importance for design purposes and the prediction of long-term stability of natural and engineering structures (Tating et al., 2013). To address this issue, Gupta and Rao (2001) proposed a "strength retention ratio" ($R_s$) to describe the strength of weathered crystalline rocks. $R_s$ is defined as the ratio of the uniaxial compressive strengths (or point load index) of weathered to the fresh intact rock specimens, and its value starts at 100% for fresh rocks decreasing with progressive weathering.

Although $R_s$ has become a popular tool to classify the degree of weathering of granitic rocks (Heidari et al., 2013; Momeni et al., 2015) and rock mass (Ramamurthy, 2004), there are still some concerns regarding its use. In particular, a) the value of $R_s$ strongly depends on the strength of fresh rocks. However, published lab data suggest that the strength of fresh rocks can vary significantly. For example, Dagdelenler et al. (2011) indicated that the unconfined compressive strength (UCS) of fresh Koprukoy granite can range from 77.1 MPa to 143.6 MPa while Baczynski (2001) reported a wide variation of point load strength index (from 1 to 3.1 MPa) for Brisbane argillite. b) In addition, $R_s$ seems to significantly underestimate the retained strength of slightly weathered (SW) crystalline rocks. For example, for SW granites (Gupta and Rao, 2001), $R_s$ can drop as low as 52%, which indicates a significant difference in strength between fresh and slightly weathered rocks. However, this doesn't seem to fit in the ISRM (1981) description of SW rocks which states that SW rocks "may be somewhat weaker than in its fresh conditions" (Table 1). It also contradicts the classification of

**Table 1**
Weathering degrees: qualitative description and ranges of slake durability index ($I_{d2}$).

| Grade of weathering | Qualitative description (after ISRM, 1981) | $I_{d2}$, % |
|---|---|---|
| Fresh (F) | No visible sign of weathering; perhaps slight discoloration on major discontinuities surfaces | 98–100 |
| Slightly weathered (SW) | Rock may be discoloured and may be somewhat weaker than in its fresh conditions | 95–98 |
| Moderately weathered (MW) | Less than half of the rock material is decomposed and/or disintegrated to a soil. | 85–95 |
| Highly weathered (HW) | More than half of the rock material is decomposed and/or disintegrated to a soil. | 60–85 |
| Completely weathered (CW) | All rock material is decomposed and/or disintegrated to soil. | <60 |

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**Table 2**
Summary of lab data.

| No. | Point load strength index, $I_{s(50)}$ (MPa) | Slake durability index, $I_{d2}$ (%) | Weathering grade |
|---|---|---|---|
| *Rock type: Sandstone* | | | |
| 1 | 1.42 | 99.20 | F |
| 2 | 1.04 | 98.70 | F |
| 3 | 1.83 | 98.10 | F |
| 4 | 1.93 | 97.20 | SW |
| 5 | 2.71 | 97.07 | SW |
| 6 | 3.90 | 97.00 | SW |
| 7 | 1.50 | 96.71 | SW |
| 8 | 2.07 | 96.69 | SW |
| 9 | 1.55 | 96.60 | SW |
| 10 | 1.64 | 96.30 | SW |
| 11 | 2.36 | 96.00 | SW |
| 12 | 1.35 | 95.57 | SW |
| 13 | 0.92 | 95.50 | SW |
| 14 | 0.66 | 94.18 | MW |
| 15 | 1.47 | 93.20 | MW |
| 16 | 0.75 | 92.40 | MW |
| 17 | 1.30 | 92.31 | MW |
| 18 | 1.34 | 91.71 | MW |
| 19 | 1.09 | 91.08 | MW |
| 20 | 1.33 | 91.05 | MW |
| 21 | 0.61 | 91.10 | MW |
| 22 | 0.84 | 90.70 | MW |
| 23 | 1.17 | 90.60 | MW |
| 24 | 0.93 | 90.57 | MW |
| 25 | 0.60 | 89.38 | MW |
| 26 | 0.86 | 89.00 | MW |
| 27 | 0.68 | 88.20 | MW |
| 28 | 1.05 | 87.14 | MW |
| 29 | 0.73 | 86.40 | MW |
| 30 | 0.57 | 85.60 | HW |
| 31 | 0.62 | 84.00 | HW |
| 32 | 0.83 | 83.00 | HW |
| 33 | 0.58 | 79.37 | HW |
| 34 | 0.50 | 73.51 | HW |
| 35 | 0.26 | 69.76 | HW |
| 36 | 0.33 | 69.06 | HW |
| 37 | 0.17 | 59.30 | HW |
| 38 | 0.10 | 57.40 | CW |
| 39 | 0.17 | 50.00 | CW |
| *Rock type: Shale* | | | |
| 40 | 0.99 | 98.38 | F |
| 41 | 2.26 | 98.06 | F |
| 42 | 1.67 | 97.86 | SW |
| 43 | 1.20 | 96.34 | SW |
| 44 | 1.25 | 96.00 | SW |
| 45 | 1.20 | 93.50 | MW |
| 46 | 0.86 | 90.57 | MW |
| 47 | 0.90 | 86.93 | MW |
| 48 | 0.95 | 83.90 | HW |
| 49 | 0.78 | 80.64 | HW |
| 50 | 0.58 | 78.50 | HW |
| 51 | 0.62 | 72.31 | HW |
| 52 | 0.21 | 64.92 | HW |
| 53 | 0.38 | 58.08 | CW |
| 54 | 0.19 | 45.15 | CW |
| *Rock type: Tuff* | | | |
| 55 | 2.40 | 97.80 | F |
| 56 | 1.40 | 93.20 | SW |
| 57 | 2.04 | 93.16 | SW |
| 58 | 0.85 | 81.80 | HW |
| 59 | 0.80 | 75.20 | HW |
| 60 | 0.28 | 63.70 | HW |
| 61 | 0.21 | 55.80 | CW |
| 62 | 0.30 | 48.70 | CW |
| 63 | 0.28 | 43.70 | CW |
| 64 | 0.18 | 40.30 | CW |
| 65 | 0.13 | 33.60 | CW |
| 66 | 0.05 | 24.80 | CW |

Note: F — fresh, SW — slightly weathered, MW — moderately weathered, HW — highly weathered, CW — completely weathered.

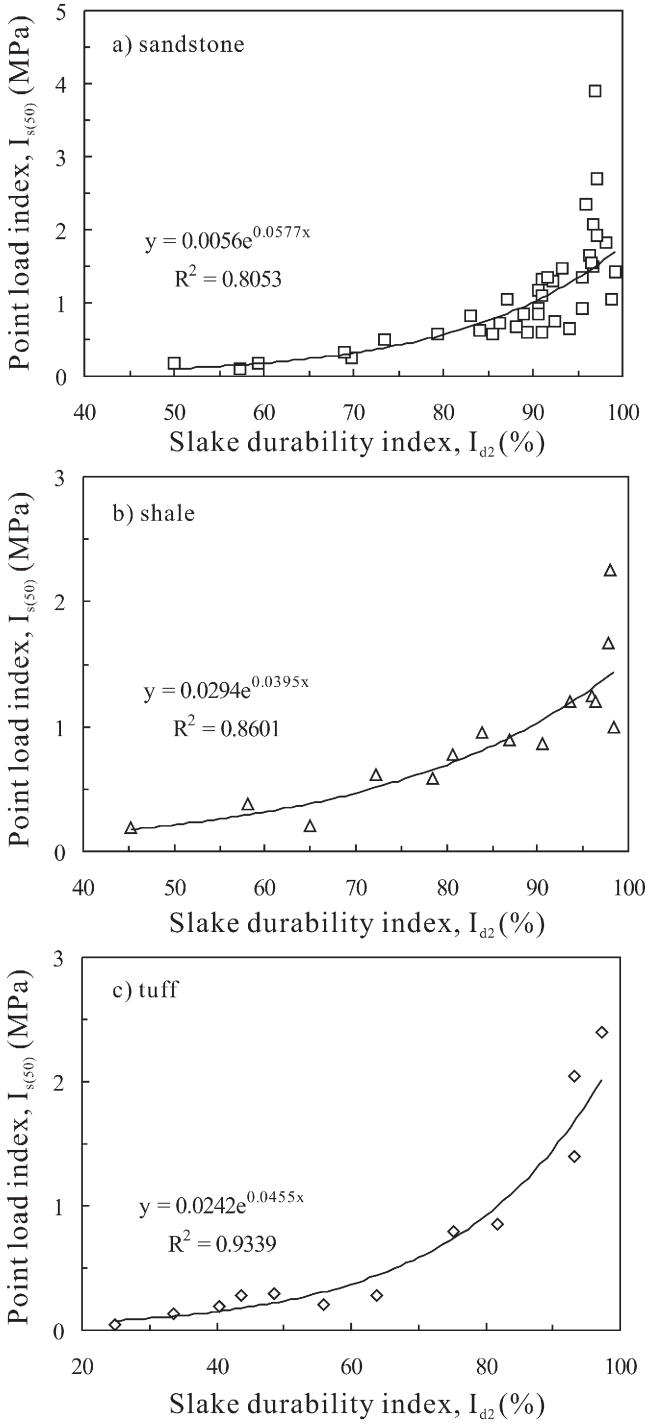


**Fig. 1.** Results of point load and slake durability tests obtained for sandstone (a), shale (b), and tuff (c).

SW rocks given by Australian Standard AS1726 (1993), which describes SW rocks as "little or no change of strength from fresh rock".

This study seeks to critically assess the use of $R_s$ as an indicator of weathered rock strength. In particular, this technical note presents the data from a series of point load and slake durability tests performed on three different types of rocks from the Gold Coast area (Queensland, Australia) to establish the correlation between the rock strength and its resistance to weathering. Based on the obtained results, the use of $R_s$ is critically analysed and some adjustments to the current procedure of determining $R_s$ are proposed. Finally, the available literature is reviewed to discuss the use of $R_s$ for a variety of rock types.