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A Comparison and Review of the Field Logging Standards and Guidelines in Australia and New Zealand

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ABSTRACT

With the increased need for a flexible work force, labour mobility between regions and countries has become a necessary and normal practice for many geotechnical professionals. Engineers and geologists are required to work to country specific standards for the logging of soil and rock cores. The Australian Standard, AS1726-1993 aims to standardise logging procedures in Australia, and like many other countries, New Zealand has their own guidelines for logging, which differs from AS1726-1993. The purpose of this paper is to outline the similarities and differences between the Australian Standard AS1726-1993 and the New Zealand Logging Guideline, "Field Description of Soil and Rock, New Zealand Geotechnical Society, 2005". These comparisons are discussed both from a review of the standard and guideline, and further based on the author's experience of geotechnical field investigations in both Australia and New Zealand. The need for these variations is explained and any potential impact of these differences on the overall geotechnical interpretation and subsequent design is evaluated. Some advice is given to help practitioners easily adapt their logging style between the two countries.

Keywords: weathering, rock material strength, defect discontinuity spacing

1 INTRODUCTION

A comparison of significant descriptors outlined in the Australian Standard, AS1726-1993 and in the "Field Description of Soil and Rock, New Zealand Geotechnical Society, 2005" will be made. Due to changes being made to the current Standard AS1726-1993, a review of the draft standard (AS1726-2016 (DRAFT)) will also be made (at the time of publication of this paper, only a draft revision was available). In this draft revision there has been a shift from the Australian Standard being used as a "guideline", to a mandatory standard. This change in emphasis has been achieved by moving the majority of the content of the appendices into the main body of the text. The New Zealand guidelines have been prepared with the intention of reducing the 'subjective' use of terms, with an emphasis on the "describing properties that are for engineering significance" (NZGS-2005). Both publications have been written with the intention of an assessment of material classifications to be made in the field.

Not all aspects are able to be addressed in this paper; therefore what is believed to be some of the key descriptors used in engineering interpretation will be reviewed. This includes a review of rock weathering, rock strength, and discontinuity spacing. References to other literatures will be included in this paper, for comparison and therefore a more informed assessment may be made of the publications being reviewed.

2 COMPARISON OF FIELD DESCRIPTIONS

2.1 Rock Weathering

Rock weathering classification is an important descriptor for distinguishing changes to the rock fabric. Weathering describes the process of alteration of the rock's structure, (Geological Society Engineering Group Working Party Report, 1995), caused by physical, chemical and biological processes. The dominant process is dependent on the stage of weathering and type of rock; such processes are often governed by the presence of water (Clayton et al. 1995).

Chemical weathering involves the breakdown of minerals by the action of chemical agents, such as acids in the air or water (Blyth et al. 1984). As such the process is dependent on the solubility of the rock type and presence of water. Physical or mechanical weathering process involves the breakdown of rocks into smaller particles by temperature, rain, ice and abrasion, and is therefore dependent on the weather or climatic conditions (Blyth et al. 1984). Biological weathering includes the changes made to the ground through the activities of animals and plants (Blyth et al. 1984).

Weathering is best described by its visible effects which include changes in colouring, overall staining, staining along joints and changes in strength to the rock. Often strength changes in a rock can be used as an indication of the degree of weathering; on assessment this is often the case, but should not necessarily be assumed. Before making a full assessment of the weathered state of a section of rock it is helpful to see the rock in its unweathered or fresh state. This allows the geotechnical professional to make a more informed assessment by using the rock's unweathered state as a benchmark for the remainder of the strength and weathering classification. If possible, observations from outcrops in the vicinity of the site should be investigated.

The New Zealand Guideline, NZGS-2005, outlines the weathering terms and a corresponding description that can be used in the field to interpret the weathered state of the rock. A grade number is also given for each term (see Table 1). The rock mass weathering has been described as a scale. The definition of a scale is a number or amount, used to measure or to make a comparison from a reference level. This means that a reference point, in this case the rock's unweathered state, is required in order to make a more confident assessment of the corresponding weathered state. The descriptions refer to changes in rock strength, discolouration, defect aperture width and defect spacing. This can be used to assess the process of weathering that has taken place, for example physical processes in moderately weathered rock, chemical processes in highly weathered rock and physical and chemical in completely weathered rock.

Table 1. Extract from NZGS-2005 (Table 3.1 Scale of Rock Mass Weathering)

Term	Grade	Abbreviation	Description
Unweathered (Fresh)	I	UW	Rock mass shows no loss of strength, discolouration or other effects due to weathering. There may be slight discolouration on major rock mass defect surfaces or on clasts.
Slightly Weathered	II	SW	The rock mass is not significantly weaker than when unweathered. Rock may be discoloured along defects, some of which may have been opened slightly.
Moderately Weathered	III	MW	The rock mass is significantly weaker than the fresh rock and part of the rock mass may have been changed to a soil. Rock material may be discoloured, and defect and clast surfaces will have a greater discolouration, which also penetrates slightly into the rock material. Increase in density of defects due to physical disintegration process such as slaking, stress relief, thermal expansion/ contraction and freeze/thaw.
Highly Weathered	IV	HW	Most of the original rock mass strength is lost. Material is discoloured and more than half the mass is changed to a soil by chemical decomposition or disintegration (increase in density of defects/fractures). Decomposition adjacent to defects and at the surface of clasts penetrates deeply into the rock material. Lithorelicts or corestones of unweathered or slightly weathered rock may be present.
Completely Weathered	V	CW	Original rock strength is lost and the rock mass changed to a soil either by chemical decomposition (with some rock fabric preserved) or by physical disintegration.
Residual Soil	VI	RS	Rock is completely changed to a soil with the original fabric destroyed.

In comparison, Table 2 outlines the Australian Standard's, AS1726-1993, weathering terms that are to be used, which have been referred to as a classification. The definition of classifications is the act or process of dividing things into groups according to their type. Some of the definitions for the weathering terms rely on the understanding and definition of a soil. This is defined as 'it either disintegrates or can be remoulded in water'. A soil description and rock description is often given for the XW term, due to the material behaving more like a soil then a rock. Staining, discolouration and strength are also descriptors used to define a weathered state. Unlike NZGS-2005 there are no terms used in the Australian Standard to describe the weathering processes (physical, chemical, biological), but these are implied in some of the descriptions. AS1726-1993 differs from NZGS-2005, by using the terms XW and DW. In comparing the descriptions, it can be seen that XW can be equated to CW, as both terms describe the 'rock mass changed to a soil' or as 'having soil properties'. The DW term, is essentially a combination of HW and MW, as both are described as having significant changes in rock strength. It has however been observed that both the highly and moderately weathered terms are often used in Australia, over the distinctly weathered term, due to this being a broad descriptor. The new revision to AS1726 incorporates both the highly and moderately weathered terms, giving the geotechnical professional the option to distinguish between the two. There is no reference made to discontinuities, in the rock material weathering definitions, as this is only assessed in the rock mass weathering grades.

Unlike NZGS-2005, AS1726-1993 gives a separate table for rock mass weathering grades; with grade separation from I-VI. This is convenient for use and classification on large scale excavations. Rock mass weathering grade considers the rock mass as a whole, taking into account the effect of the individual discontinuities and how the whole block is weathered. This differs from the rock material weathering classification; the classification looks at the rock and intact material weathering. The draft revision to AS1726 has kept the table for rock mass weathering grades.

Table 2. Extract from AS1726-1993 (Table A9 Rock Material Weathering Classification)

Term	Symbol	Definition
Residual soil	RS	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.
Extremely weathered rock	XW	Rock is weathered to such an extent that it has 'soil' properties, i.e. it either disintegrates or can be remoulded, in water.
Distinctly weathered rock	DW	Rock strength usually changed by weathering. The rock may be highly discoloured, usually be ironstaining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Slightly weathered rock	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh rock	FR	Rock shows no sign of decomposition or staining.

AS1726-1993 and NZGS-2005 use different descriptors for the weathering of rock; a classification compared with a scale. The fundamental difference between these two concepts is that a scale describes the degree of the weathering, but the classification requires the geotechnical professional to choose one category to describe the weathering. It is observed that each publication has listed the terms in opposite orders; AS1726-1993, lists from a residual soil to fresh rock, whereas NZGS-2005 lists the terms from unweathered to residual soil. Nonetheless both publications rely on an understanding of the unweathered state of rock before an accurate assessment can be made.

The understanding of soil-rock boundary interface is an important factor, especially for design implications. The draft revision to AS1726 includes an important change, by incorporating both the HW and MW terms, as many projects rely on distinguishing MW rock, as this is often taken as the level for competent rock for foundation design purposes. NZGS-2005 also outlines that "in very general terms the boundary between a rock mass being more 'rock like' than 'soil like' is the boundary between moderately weathered and highly weathered."

Weathering is an important factor in assessing the geotechnical properties of rock, as it encompasses strength changes, fabric and colour changes. Care should be taken to understand the difference between describing the material weathering and the rock mass weathering. Although it is not detailed in the publications, an understanding of the type of weathering processes that are likely to have occurred on the rock unit and an understanding of the processes that would have occurred to the rock resulting in its current weathered state may both help with the assessment.

2.2 Rock Material Strength

Field strength descriptions are important and necessary to provide a complete representation of the in situ strength of the rock material. Any testing, over and above field descriptions, is only carried out in discrete locations and is not necessarily representative of the rock material strength. Overall in a highly fractured rock the behaviour may be governed by discontinuities (Clayton et al. 1995), but is important that the rock material strength is described and care should be taken not to describe the rock mass strength, which encompasses the strength loss due to discontinuities.

As presented in Table 3, the guidance from NZGS-2005 is to use the terms weak and strong, to describe the rock material strength, as the terms of high or low strength are felt to be indications of the rock mass strength. The field identification indicators use simple techniques to distinguish between the terms which include using your thumb, pocket knife and a geological hammer on the rock core. Strength indicators for unconfined compressive strength (UCS) and point loads are given, however correlations made should be site, rock type and weathering grade specific. These relationships are significant for design implications.

Table 3. Extract from NZGS-2005 (Table 3.5 Rock Strength Terms)

Term	Field Identification of Specimen	Unconfined uniaxial compressive strength q_u (MPa)	Point load strength $I_{s(50)}$ (MPa)
Extremely strong	Can only be chipped with geological hammer	>250	> 10
Very strong	Requires many blows of geological hammer to break it	100 – 250	5 – 10
Strong	Requires more than one blow of geological hammer to fracture it	50 – 100	2 – 5
Moderately strong	Cannot be scraped or peeled with a pocket knife. Can be fractured with single firm blow of geological hammer	20 – 50	1 – 2
Weak	Can be peeled by a pocket knife with difficulty. Shallow indentations made by firm blow with point of geological hammer	5 – 20	< 1
Very weak	Crumbles under firm blows with point of geological hammer. Can be peeled by a pocket knife	1 – 5	
Extremely weak *(also needs additional description in soil terminology)*	Indented by thumb nail or other lesser strength terms used for soils	< 1	
Note: No correlation is implied between q_u and $I_{s(50)}$			

The Australian Standard, AS1726-1993 has based the strength description on a scale and point load correlation, outlined in Table 4. It is suggested that a correlation to point loads should be undertaken to provide more credibility to the field descriptions. Guidance for the field indications includes using hand tests or a knife and a pick on the rock core. The use of a hammer for a sound description when hit should also be used to give an indication of the rock's material strength. As for NZGS-2005, the descriptions relate to the rock material strength and not the rock mass strength.

Table 4. Extract from AS1726-1993 (Table A8 Strength of Rock Material)

Term	Letter symbol	Point load index (MPa) $I_{s(50)}$	Field guide to strength
Extremely low	EL	≤0.03	Easily remoulded by hand to a material with soil properties
Very low	VL	>0.03 ≤0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces ≤ 3cm thick can be broken by finger pressure

Term	Letter symbol	Point load index (MPa) $I_{s(50)}$	Field guide to strength
Low	L	>0.1 ≤0.3	Easily scored with a knife; indentations 1mm to 3mm show in the specimen with firm blows of the pick point; has dull sound under hammer. A piece of core 150mm long 50mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling
Medium	M	>0.3 ≤1.0	Readily scored with a knife; a piece of core 150mm long by 50mm diameter can be broken by hand with difficulty
High	H	>1 ≤3	A piece of core 150mm long by 50mm diameter cannot be broken by hand but can be broken by a pick with a single firm blow; rock rings under hammer
Very high	VH	>3 ≤10	Hand specimen breaks with pick after more than one blow; rock rings under hammer
Extremely high	EH	>10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer

In the 2016 draft revision of AS1726, the extremely low strength boundary has been removed and the user is advised that any material considered to have less than a 'very low' strength should be described as a soil. It is noted that in NZGS-2005 the boundary between soil and rock is often taken as being between very weak and extremely weak. It is further noted that the British Standard, BS5930-2015, makes use of the terms weak and strong, with similar indicators as those used in NZGS-2005.

Care should be applied when switching between publications, NZGS-2005 and AS1726-1993, as the terms and boundaries used to describe the rock material strength do not align, and there is a difference between the field descriptions for classifying material strength. For example in the two upper strength boundaries for both publications; in NZGS-2005 for the extremely strong boundary, the rock material can only be "chipped at", however in AS1726-1993, for the extremely high strength boundary, the rock material can be broken with "much force". This demonstrates different upper bounds, with NZGS-2005 having a higher strength boundary.

2.3 Defect Discontinuity Spacing

Varying definitions of discontinuity spacing exist depending on the publication, and before making an assessment of this property it is important to understand the assumptions of the definition to be used. NZGS-2005 defines discontinuity spacing as the perpendicular distance between adjacent discontinuities. The terms used by the New Zealand guidelines to group spacing sets are outlined in Table 5. In cases where there are a number of parallel discontinuities it is the expectation that these are grouped into sets. It should be noted that there are other terms to describe bedding spacing, which has not been discussed in this paper.

Table 5. Extract from NZGS-2005 (Table 3.7 Spacing of Defects or Discontinuities)

Term	Spacing
Very widely spaced	>2m
Widely spaced	600mm – 2m
Moderately widely spaced	200mm – 600mm
Closely spaced	60mm – 200mm
Very closely spaced	20mm – 60mm
Extremely closely spaced	<20mm

The Australian Standard, AS1726-1993 does not present such a table with spacing terms, and advises against the use of descriptive terms. The definition that AS1726-1993 gives to describe discontinuity spacing is simply the 'spacing of defects', without advice of where this measurement should be taken from. It suggests that sets may be grouped, but does not give any clear advice on how to do so or how to determine the appropriate spacing boundary. AS1726-1993 also advises to use other indirect indicators for discontinuity spacing, such as rock quality designation (RQD). Caution is also advised in this standard, indicating that boreholes only provide one dimensional data on spacing.

In the 2016 draft revision for AS1726 the guidance has changed from the previous version to indicate that the measurements of discontinuity spacing are to be made perpendicular to the joint set and a suggestion is made that these spacing's can be grouped into appropriate numerical categories, but leaves it to the engineer or geologist to decide what grouping is appropriate for the project requirements.

It is presumed that AS1726-1993 recommends against the use of subjective descriptive terms, as geotechnical professionals can have different perceptions of what might constitute 'widely spaced' over other terms. As a comparison, the British Standard, BS5930-2015, has also chosen, like NZGS-2005, to use descriptive terms from '*extremely closely'* up to '*extremely widely'* spaced. There is also some important advice in BS5930-2015, which aligns with the caution given in AS1726-1993; that consideration of the distribution of discontinuities in three-dimensions should be made, which cannot be interpreted from a cored rock sample.

Discontinuity spacing is a measure of the degree of fracturing of a rock mass (Clayton et al.1995). Different descriptive terms have been developed in the context of different codes of practice, with varying emphasis and boundary definitions for the grouping of discontinuity spacing into sets. Regardless of the country, in all cases the investigation purpose should be understood and the use of discontinuity spacing for engineering purposes appreciated to allow a judgement to be made by the geotechnical professional as to the most appropriate way to communicate the discontinuity spacing as well as the level of detail required.

3 CONCLUSION

There are many aspects of field logging, both of soil and rock, which have not been covered in this paper, which would equally benefit from a close assessment. However, as demonstrated in this paper, switching between the Australian Standard and New Zealand Guidelines, requires careful consideration of all aspects, and may require geotechnical professionals to reconsider their interpretation of geological conditions to ensure records conform to the relevant standard or guideline.

With regard to the descriptions of rock weathering, rock material strength and defect discontinuity spacing, there are some differences between the publications which must be understood before commencing field logging. These differences are of particular importance when field descriptions are used as a basis for design, as misunderstandings would introduce margins of error in the interpretation. It is important to understand what is to be described; characteristic from the rock mass or rock material. It is always advised, when possible, to see the rock in its unweathered state to ensure a more accurate reflection of the weathered state. Whichever standard or publication the geotechnical professional is logging to, the professional must be consistent in their logging style and manner to avoid any confusion or misinterpretation, remembering that the data presented is a key input into associated designs. When the geotechnical professional is using a standard or guideline that they are not familiar with they should ensure they consider the publication carefully and not have a bias towards their more accustomed standard or guidelines. They should also use their professional judgment as to the level of detail required for the design.

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