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Identification and Investigation of Residual Soils and the Associated Weathering Profile

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SUMMARY Soils resulting from in situ weathering of rock are different in many respects from transported soils, and require a more flexible and sophisticated approach in investigation and testing programmes.

Firstly, whilst weathered in situ materials may be as variable in their physical properties as similar transported soils, such variability is usually related to the structure of the original rock rather than to history of transportation and relationship with source materials, as is the case in transported soils.

Secondly, most correlations between various soil properties have been developed for transported soils, and may not apply to the weathered in situ soils.

Thirdly, standard methods of sampling, sample preparation and testing which are suitable for the transported soils may alter the structure of a weathered in situ soil, resulting not only in erroneous results, but in masking the true origin of the soil.

The potential for development of a significant profile of weathered in situ materials may be recognised from a knowledge of the existing and ancient environments at a particular location. Differentiation between weathered in situ materials and transported soils derived from the residual soil and completely weathered rock can be problematic but is not impossible.

1. INTRODUCTION

Completely weathered rock and residual soil is that material which may be classified as an engineering soil, but which is also amenable to classification as a product of the weathering of rock. The rock weathering classification referred to is that proposed by a working party of the Engineering Group of the Geological Society of London (Anon, 1970), which in turn is based on a scheme developed for the Snowy Mountains Authority (Moye, 1955). It is summarised in Table I.

It is clear that the relevant weathering grades are V and VI, the completely weathered rock and the residual soil.

2. IDENTIFICATION OF V AND VI MATERIALS

2.1 The Importance of Identification

The identification of materials which have been weathered in situ can be important for a number of reasons:

- weathered in situ materials can be expected to vary in their physical characteristics in a different manner to similar transported soils. The composition and physical properties of a weathered in situ soil will generally be strongly dependent upon the mineralogy and structure of the source rock, whilst for the transported soils the means and duration of transportation and deposition will be more important.
- in situ material of weathering grade VI or V must, by definition, be underlain by material of a similar or lesser weathering grade, which implies that the physical properties of the underlying materials will be similar or better. In a transported soil, underlying material could have similar, better, or worse engineering characteristics.
- in general, weathered in situ materials can be expected to have significantly better engineering characteristics compared to material of similar origin which has undergone transportation.

Differentiation between materials which are the result of in situ weathering and those which have been transported can be approached on two levels. On the large scale it is possible to determine if such materials are likely to be of widespread and significant occurrence, and on the small scale a number of means exist whereby the weathered insitu materials may be differentiated from similar but transported materials.

2.2 Identification on the Large Scale

An examination of the available literature concerning an area of interest will often indicate the potential for the development of extensive deposits of weathered in situ material, as it is apparent that climatic factors play a significant role in the development of major weathering profiles. Tropical climates appear to be particularly important, the high rates of both physical and chemical weathering resulting from the high rainfall, evaporation and ambient temperatures of these areas all combine to produce deep weathering profiles and significant occurrences of V/VI material. The high rainfall also produces high rates of run-off and erosion, and it is in such conditions that the differentiation between transported and weathered in situ materials can be particularly important. However, prevailing climatic conditions at a specific location should be viewed with caution, as gross climatic changes are known to have occurred over geologically short time periods. For instance, over much of the Yilgarn Block of Western Australia, tropical and sub-tropical climatic conditions were succeeded by an arid climate in the late Miocene. This arid climate has persisted to the present day, although the weathering profiles developed during the warm and humid period have been preserved. (Smith, 1983).

It can therefore be seen that other factors which can aid in the recognition of the potential for the development of a significant weathering profile include a knowledge of the geological history of an area. For instance, major changes in geomorphology can result from environmental events such as marine transgressions, or glaciations and other climatic variations. The submergence of a previously terrestrial landscape might tend to preserve its pre-existing form, due to a reduction in rates of physical and chemical weathering, while a glaciation would produce a major re-working of the landscape, involving the removal of pre-existing weathered in situ material, and the development of new weathering profiles, by periglacial action. Where climatic conditions alter to a more arid state, an existing weathering profile might suffer erosion due to deflation and the loss of the stabilising influence of vegetation. That this has not occurred to any significant degree in Western Australia is thought to be largely due to the indurated nature of the upper portion of the weathering profile over large areas of the Yilgarn Block.

The recognition of near-surface engineering soils as either weathered in situ or transported materials will be aided by as complete an understanding as possible of the environmental conditions leading to their development and/or deposition.

2.3 Identification on the Small Scale

The identification, on the scale of typical hand specimens and samples, of weathered in situ material is usually directly related to features which are remnants of the parent rock, and which do not survive transportation. This means that weathered metamorphic and igneous rocks will be more readily discernible from similar transported material than will weathered sedimentary rocks, as by their nature the material comprising sedimentary rocks has been transported prior to lithification, whereas igneous and metamorphic rocks are composed of material which has undergone at least some degree of mineral formation or alteration at the site of lithification. In the case of most igneous and metamorphic rocks, this means that they were formed or altered to their current composition at temperatures and pressures far in excess of those currently existing. For instance, where crystallisation or re-crystallisation has taken place, well-formed and angular crystals may be produced. Erosional processes leading to exposure of such materials will be accompanied by stress relief, often resulting in fracturing of the individual crystals in the rock material. Where such angular, or cracked crystals are seen in an engineering soil, their presence may indicate the weathered in situ nature of the material, as transporation would tend to result in disaggregation and rounding of the crystals.

However, even weathered sedimentary rocks may be differentiated from transported soils, as the weathered in situ materials may display remnant features resulting from their past lithification. For instance, jointing may usually be taken as evidence of a significant past stress

TABLE I

ROCK WEATHERING CLASSIFICATION

Weathering Grade	Alternative	Designation	Description
IA	FR	Fresh	No visible sign of weathering
IB	FRST	Fresh with stained joints	Weathering limited to the surface of major discontinuities
II	SW	Slightly Weathered	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.
III	MW	Moderately Weathered	Weathering extends throughout the rock mass but the rock material is not friable.
IV	HW	Highly Weathered	Weathering extends throughout the rock mass and the rock material is partly friable.
V	CW	Completely Weathered	Rock is wholly decomposed and in a friable condition but the rock texture and structure are preserved.
VI	RS	Residual Soil	A soil material with the original texture, structure and mineralogy of the rock completely destroyed.

history and may be recognised as a planar discolouration or even a parting plane not parallel to bedding in an engineering soil. This would generally be indicative of the fact that no re-working of this soil has occurred since its in situ weathering.

3. INVESTIGATION OF RESIDUAL SOIL/CW ROCK

The full suite of geotechnical sampling and testing techniques is available for weathered in situ material, but the specific properties of the material mean that some methods are particularly relevant. Whilst it is often assumed that the weakest soils are most sensitive to sample disturbance effects, it is not generally recognised that the relatively strong weathered in situ materials are also often at risk. This is due to the fact that they often have a degree of physical strength imparted by the residual effects of rock structure. 'Normal' 'undisturbed' sampling can destroy the bonds of this residual structure, and whilst there might be little or no discernible effect on the soil in hand specimen, the strength of the soil can be significantly reduced. In fact, if it is not possible to compare truly undisturbed samples (such as might be obtained from a trial pit, or bulk excavation) with samples from borings, the overall physical quality of a soil could be significantly underestimated. Any well planned large scale site investigation should therefore include a variety of techniques for sample recovery and laboratory testing, and in situ testing. It is then often possible, by comparison of the results of in situ and laboratory tests for the same parameters, to determine if sample disturbance is a significant factor.

Specifically, weathered in situ soils are susceptible to significant structural breakdown when subjected to shock loading. For instance, a thin walled sampler driven by the steady application of hydraulic force can be expected to produce a sample more representative of the in situ state than one which has been driven by repeated hammer blows. Similarly, if the material to be sampled is of sufficient strength to resist 'push' sampling, the steady application of sampling force by a rotating bit will again be preferable to the more abrupt force of the drop hammer techniques. This line of argument might logically be advanced to the elimination of the actual sampling operation, sample retrieval, packaging and transportation, and laboratory preparation. This may be achieved by relatively sophisticated in situ testing, utilising equipment such as the static cone penetration test and the pressuremeter.

While most residual soils or completely weathered rocks might be expected to suffer a decrease in strength due to sample disturbance, as might soft and sensitive clays, loose sands may suffer densification, with an apparent overall increase in values of material properties. It is therefore vital that laboratory and in situ dynamic tests be interpreted in the light of an understanding of the origins and history of the soil, and preferably with the aid of relatively sophisticated in situ testing.

4. CONCLUSIONS

It can often be difficult to distinguish between transported soils and those that are weathered in situ, particularly where the former are derived wholly or in part, from the latter. Although the distinction can be difficult to make, it is an important one, in that the engineering properties of the two soil types can be significantly different.

The likely presence of completely weathered rock and residual soil can often be inferred from a literature review of the area of interest, as specific conditions, both climatic and geomorphological, favour the development and retention of deep weathering profiles. In the field, the weathered in situ soils may be distinguished from their transported counterparts by various methods, although it is often impossible to be positive about a problematical soil's genesis without review of a wide range of samples and test results.

5. REFERENCES

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