CHARACTERISTICS OF SOME TROPICAL RESIDUAL SOILS ON WEST JAVA

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Abstract

Laboratory tests were carried out using standard and modified procedures. The British Standard methods were applied to almost all of the laboratory testing, the modifications applied being those which distinguish the characteristics of tropical soils compared with conventional temperate soils for which standard testing procedures have been devised.

From the comprehensive laboratory test programme it was found that there were some significant differences between results obtained using standard procedures compared with the modification applied. Comparison was also made with earlier work conducted in the 1970's.

The effect of drying on tropical residual soils was found to decrease liquid limits, the plasticity index, and the percentage passing in the hydrometer test. Optimum moisture content in compaction testing was lowered with corresponding increase in maximum dry density. Engineering characteristics were examined using index test results and it was found that the effect of drying on tropical residual soils could make some difficulties in the prediction of likely engineering performance involving these soils.

I. Introduction

The engineering behavior of soils, whether formed under arctic, temperate or tropical conditions is determined by physical characteristics designated as engineering properties. These physical characteristics can be examined by laboratory experiments.

Soils are formed of materials which have undergone a combination of physical and chemical weathering processes. Physical weathering agents include freezing and thawing, temperature changes, erosion, and the activity of plants and animals including man. Chemical weathering decomposes the minerals in the rock by oxidation, reduction, carbonation, and other processes. Generally, chemical weathering is much more important than physical weathering in tropical soil formation (HOLTZ and GIBBS, 1954).

In Indonesia, which is a tropical country, the soils are largely derived by the chemical weathering process. In West Java, studies carried out by WESLEY (1973) have shown that many soils of this region are tropical residual soils.

The three procedural standards for testing of soils, which are of greatest familiarity to the geotechnical engineer are those presented by the British Standard, AASHTO and ASTM. These procedures were developed largely for soils, which were derived by the process of weathering in temperate climates, and which tend to be "sedimentary" in origin.

These well-established testing procedures for temperate soils are not always suitable for evaluating tropical residual soils. For example, even partial drying at moderate temperatures may change the structure and physical behaviour of tropical residual soils. These soils may also possess a significant macroscopic and microscopic fabric which is susceptible to destruction during sampling and testing such that the modelling of in situ behaviour in the laboratory becomes difficult.

Therefore there is a need to examine the validity of standard testing procedures and gaining early clues towards understanding the potential engineering behaviour when these soils are subjected to different stress conditions, e.g. in strength, swelling and collapse. This is particularly for so tropical residual soils, such as can be found in West Java

II. Tropical Residual Soil

Soils are formed by the natural process of disintegration of rock and decomposition of organic matter. This means that the physical properties and behaviour of soils are greatly influenced by their origin, formation history and the weathering process involved.

Weathering or disintegration of rock can be by physical or chemical processes. Physical weathering includes the effects of such mechanical processes as abrasion, expansion, and contraction, and produces end products such as angular blocks, cobbles, gravel, sand, and silt. The mineral constituents of all these products are the same as those of the original material. Chemical weathering results in the decomposition of rock and the formation of new minerals. The various processes of this weathering include hydration, hydrolysis, solution, oxidation, and reduction. The water is a key chemical agent involved in the weathering process. Chemical weathering is favored in warm humid climates, and tropical regions with abundant rainfall and high temperature are most susceptible to chemical alterations (MORIN & TODOR, 1975), such as shown in Figure II.1.

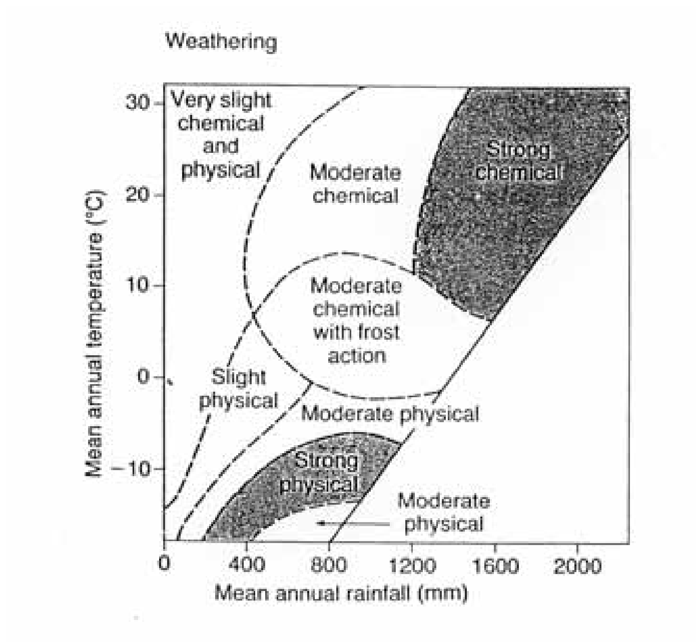
The state of weathering of any rock mass may be reported in the following standard terms (ANON., 1990).

1. Fresh, no weathering visible to the naked eye.
2. Slightly weathered, some partial discoloration, but no significant loss in strength.
3. Moderately weathered, general discoloration, with significant loss in strength.

4. Highly weathered, considerable change both in appearance and strength; still rock but very weak.

5. Extremely weathered, shows soil properties, though the texture of the original rock is still evident.

A schematic diagrammatic representation of a typical weathering profile is shown Figure 11.2. The Tropical Residual Soils Working Party of The Geological Society Engineering Group (ANON., 1990) have adopted a classification of tropical residual soils based on DUCHAUFOUR (1982). This classification is based on the relative intensity of weathering and so provides the logical basis on which to develop an engineering classification. An illustration of the general relationship is given in Figure II.3.



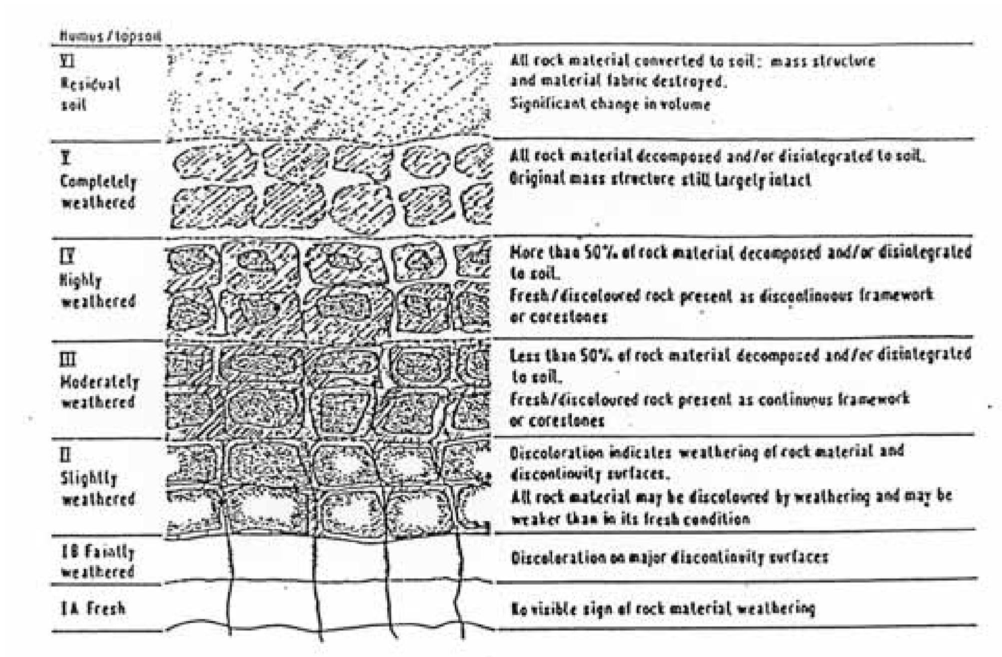


Figure II.2. : Schematic Representation of Tropical Weathering Profiles (description based on geological Society Engineering Group Working Party Report)

ENGINEERING WEATHERING GRADES		EXPLANATORY TERMS	ADOPTED TEMINOLOGY
VI	Residual Soil	Solum	TROPICAL RESIDUAL SOIL
V	Completely Weathered	Saprolite	
IV	Highly Weathered		
III	Moderately Weathered	Weathered Bedrock	
II	Slightly Weathered		
I	Fresh	Bedrock	

Extensive weathering within these zones causes major mineralogical changes associated with processes of solution transportation in solution and precipitation (Pedogenetic transformation)

ADOPTED PEDOLOGICAL CLASSIFICATION (DUCHAUFOUR 1982)	
FERSIALITIC SOILS	Increasing Intensity of weathering
FERRUGINOUS SOILS	
Ferrisols (transitional)	
FERRALLITIC SOILS	

Figure II.3. : Relationship between Weathering and Pegogenesis

Residual soils are the products of the intensive in-situ weathering of igneous, sedimentary and metamorphic rocks, and they include the group of iron-rich materials, usually described as laterites or lateritic soils which are very common in tropical areas. The different stages of weathering during lateritic soil formation and the accompanying property changes, according to TUNCER and LOHNES (1977) , are shown in Figure II.4.

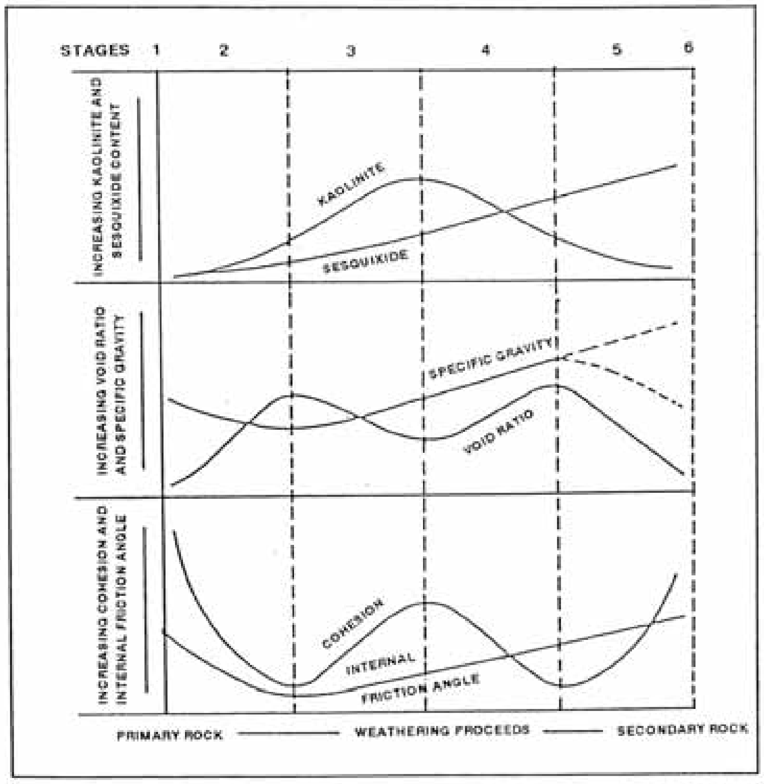


Figure II.4. Variation in Engineering Properties of Basalt Derived Lateritic Soils During Weathering (Tuncer et al., 1977)

Weathering leads in tropical climates to formation of clay minerals principally of four main groups . kaolinite, halloysite, montmorillonite and illite. Sequences in the formation of volcanic clay materials (GONZALES DE VALLEJO et al., 1981), are shown on Table II.1.

Table 11.1 : Sequences in The Formation of Volcanic Clay Material (GONZALES DE VALEJO et al., 1981)

<u>South Pacific Island</u>

Volcanic Ash/Glasses
↓
Allophanes
↓
Halloysites
↓
Metahalloysites

<u>Cameroon</u>

Volcanic Rock
↓
Allophanes
↙ ↘
Halloysites → Metahalloysites → Gibbsites
Kaolintes → Gibbsites

<u>Kenya</u>

Volcanic Ashes
↓
Montmorillonites
↓
Halloysites
↓
Kaolinite

Based on geotechnical classification, tropical residual soils can be divided into two behavioural groups.

i. Red tropical residual soils

ii. Black tropical residual soils

Soils grouped within the red tropical residual soils category can be divided into three types:

- *Ferruginous soils*

  These are those soils which have been the subject of the tropical weathering process to the extent that they are dominated by a clay mineral assemblage comprising kaolinite and the sesquioxides of iron (Fe) and aluminium (Al). Their behaviour in engineering works may be expected to be reflected by their behaviour in laboratory tests.

- *Fersiallitic Andosols*

  These are soils which contain appreciable quantities of halloysite and allophane, and are sensitive to test preparation procedures.

- *Ferrallitic soils*

  These are soils which contain sufficient quantities of sesquioxides of iron (Fe) and aluminium (A1), and are sensitive to test preparation procedures.

In terms of their engineering behaviour Black Tropical Residual Soils can be classified into non - expansive or potentially expansive depending on the basis of a series of simple index tests, which include Atterberg Limits, Linear Shrinkage, Free Swell and Colloid Content (ANON., 1990).

III Work program

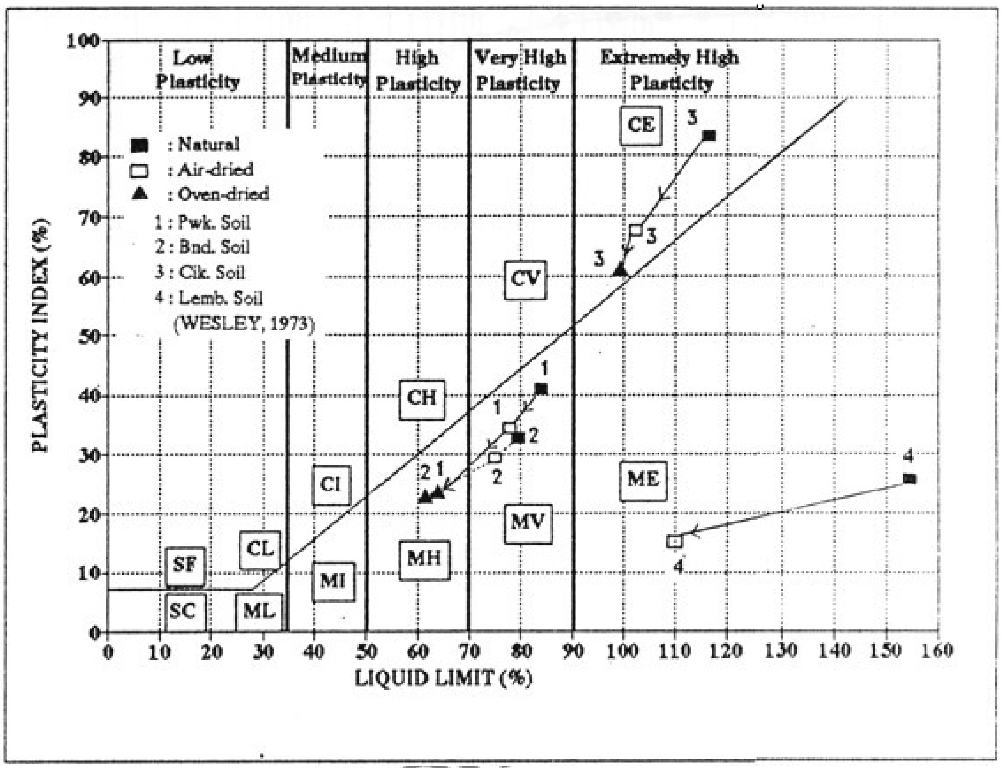
Undisturbed and disturbed samples have been collected at three sites i.e. Cikampek, Cikalong and Lembang. Both undisturbed and disturbed samples were tested using standard methods i.e. British Standard and modified standard procedures with consideration given to the effect of drying temperature (room temperature, 30oC, 50oC, 100oC, 110oC) and effect mixing time (5 min, 15 min, 45 min) on index properties. Unconsolidated undrained strength test was carried out using triaxial apparatus and ASTM test procedure was adopted (ASTM D 2850). All samples were tested for different water content values at natural dry density.

IV Test Results and Discussion

4.1 Effect of drying on water content

4.2 Effect of mixing time on Atterberg limits

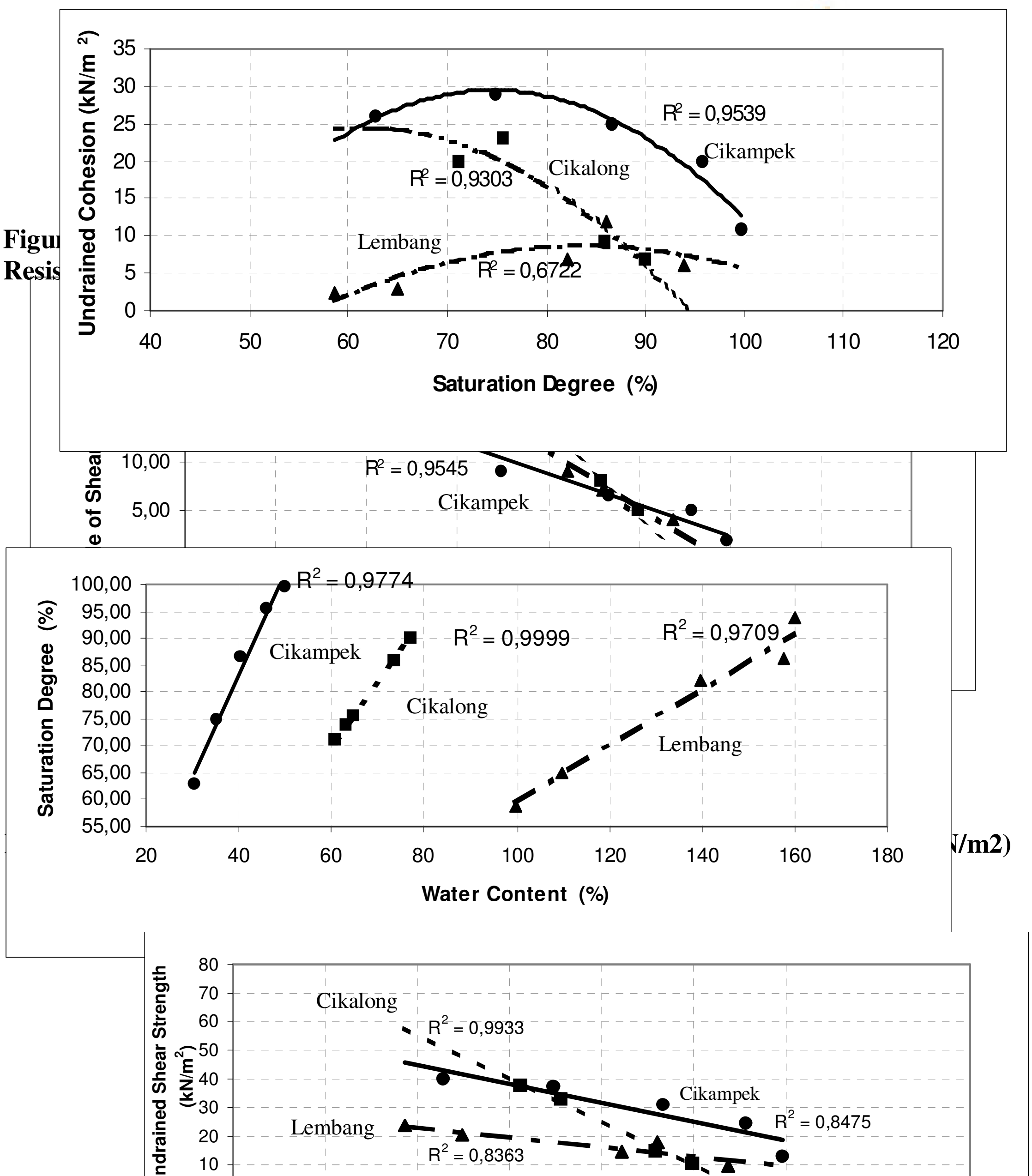
4.3.Classification of tropical residual soil



4.4. Strength characteristics

The summary of The triaxial test results for all soil for shear strength as a function of water content are presented in Figure 3 to 6., respectively.

Figure 3 : Relationship Between Water Content (%) and Saturation Degree (%)



Because soil placed as fill undergoes mechanical working, the remoulded undrained shear strength of a soil is considered to be of more relevance to assessing the suitability of the soil in an embankment than the undisturbed strength. Embankment stability depends on the support that can be provided by a soil and the remoulded undrained shear strength must therefore influence the suitablity of cohesive soils as fill material.

From Figures 3 and 5 it can be seen that the degree of saturation always increased with increase in water content, while the angle of shearing resistance decreased. At a degree of saturation of 100% the angle of shearing resistance in undrained testing became zero (∅ = 0 Concept, Lambe 1979). The undrained cohesion increased as water content increased up to a value near the optimum water content, after which it started to decrease with increase in water content. The maximum undrained cohesion occurred at the point of inflection on the "Water Content - Undrained Cohesion" curve.

Figure 6 shows that the remoulded undrained shear strength always reduced with increase in water content and some typical results of undisturbed and remoulded shear strength characteristics of tropical residual soils are indicated. It is observed that the undisturbed soil exhibited larger shear strength compared with that remoulded at natural water content. The difference in values between undisturbed and remoulded shear strength were in the other of 10% for Cikampek soil, 12% for Cikalong soil with the highest difference of 40% being shown by Lembang soil. All the soils had low sensitivity, with the first two being relatively insensitive, in line with previous studies on Java Soils.

V Conclusions

1. Shear strenght parameters (Cu and ∅) and shear strength varied with variations in water content:
    - The angle of shearing resistance decreased with increase in water content.
    - The undrained cohesion increased as the water content increased up to a value near to the optimum water content, whereafter the undrained cohesion started to decrease with increase in water content.
    - The maximum undrained cohesion and point of inflection on the water content – cohesion undrained curve were close to the optimum water content.

The shear strenght decreased with incerease in water content

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