ENGINEERING SOILS MAPPING IN THE TROPICAL TERRAIN: THE GHANA EXPERIENCE

CARTOGRAPHIE GÉOTECHNIQUE EN TERRAINS TROPICAUX: L'EXPÉRIENCE DU GHANA

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Abstract

Laterites and other products of weathering in the tropics are an important source of material for highway construction. For any extensive use such as has happened over the past two decades when there has been a lot of development, rehabilitation and maintenance of roads throughout Ghana, it became necessary to evaluate and map these materials.

Research into laterites and lateritic soils and other problem soils of Africa has been undertaken. Highway materials evaluation and mapping in Ghana has also been undertaken.

This paper appraises the methodology used in the evaluation, highlights the fieldwork, including sampling processes and limits of extrapolation of point profiles for the development of line profiles leading to the preparation of two types of maps:

(a) Area soils maps of selected areas;
(b) General engineering soils maps of Ghana:
   i. Lateritic and lateritic soils maps.
   ii. Saprolitic soils maps.

The quantitative evaluation is then undertaken using the map and various profiles, and problems encountered in doing this are discussed. Laboratory testing methods are discussed with problems, some of which are unique to the tropical situation, highlighted. The relevance of geology and soil forming factors to the prediction of occurrence and mapping of engineering soils is emphasized. The speed and economy inherent in the method is also shown.

1. Introduction

Over the past two decades during which Ghana has been accelerating communication improvement by undertaking design, rehabilitation and construction of roads and highways and their maintenance, the need was felt to find a way to predict the occurrence of various construction materials, evaluate and map them. The formation of materials is primarily dependent on geology, topography and climate. Their engineering and physical properties are mainly dependent on relative position within the catenary.

The formation of these materials is dependent on factors of weathering which in the tropics is carried further through laterization. Within a given climatic zone the distribution of laterites and lateritic materials is dependent almost exclusively on topography and drainage while the distribution of the non-lateritic weathered products is dependent on parent rock, topography and drainage.

With this background knowledge materials have been evaluated and mapped in Ghana primarily for highway construction and while exploitation has gone on for some time, information from the field has also come to enable appraisal of the methodology. The success of the method is above 80% on map scales of 1:63360 and above 40% on map scales of 1:1,000,000. It must be pointed out that where the relief is accurately shown on the base map the result of the material mapping becomes very accurate.

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2. Field occurrence of construction materials

Weathering in the tropics, which is usually variably influenced by the type of parent rock, topographical and drainage conditions is carried through to laterization. This leads to the formation of laterites, lateritic soils and saprolites. The wide variety of tropically weathered soils, red or reddish brown in colour, having slightly different chemistry and morphological and physical properties and with silica : sesquioxide ratio between 1.33 and 2.00 constitute the laterites and lateritic soils (BRRI/Lyon Associates 1971).

The laterites and lateritic soils are very different from the parent rock and all structural and textural features from the parent rocks are completely obliterated. In the tropics, lateritic soils are found over almost all types of rocks and in climates ranging from the savanna areas through the humid rainfall regions. They occur in well-defined and regular sequence of the soil catena which is related to relief. Efficient drainage coupled with factors like pH and oxidation potential of the environment determine the extent of leaching.

It however appears that, whatever the material from which laterites and lateritic soils are derived it is essential to obtain an adequate supply of sesquioxides. It has generally been observed that due to the ease of alteration of basic rocks, laterization processes on them are more intense and widespread than on acid rocks.

Drainage is the most important factor in the formation of laterites and lateritic soils and is also very closely related to topography. With these two factors as the basis for field reconnaissance, traverses are run mainly from the bottom up the hillside to the hillcrest. Sampling along such a line reveals the boundaries between the laterites and lateritic soils and the saprolites.

First, the saprolitic-lateritic soil boundary is marked. This point is then marked on the field sheets of 1 : 63360 maps. Two or three such uphill traverses are run. When the points thus obtained are marked on the map and joined as far as possible along contours the boundary is obtained between the laterites and lateritic soils on one side and the non-lateritic material which is invariably saprolite. The height of the point of the boundary is transferred on to a good 1 : 1,000,000 map. This is done in different climatic regions and in different topographical areas covering the country. The most important consideration at this stage, when the heights of the boundaries on the 1 : 63360 maps above become established, is to complete the 1 : 1,000,000 map. This is completed on the basis of about 18 field sheets of 1 : 63360 maps. When the map is drawn for the whole country on the basis of 1 : 1,000,000 scale, then detailed work could be done at 1 : 63360.

Three (3) types of maps are produced, namely:

(a) Laterite and lateritic soils maps
   1 : 1,000,000 (fig. 1a)

(b) Saprolitic soils maps
   1 : 1,000,000 (fig. 1b)

(c) Area soils maps
   1 : 63360 (fig. 1c & 1d)

3. Evaluation methodologies

For mapping and the evaluation of the chemical and physical properties, both disturbed and undisturbed samples were taken from the field. Where serial photographs existed these were studied before site visits to ensure selection of preliminary construction materials which would be checked in the field. Auger holes and pits were made during the study and it was from these that the representative soil samples were taken. Outcrops were also sampled for testing in the laboratory.

The quantitative and qualitative evaluation of construction materials is made by means of geophysical (seismic) traverses, boreholes, pitting and augering, examination of road cuts, borrow pits and laboratory analyses. From the geophysical traverses, where forward and reverse traverses are run, depth to bedrock could be ascertained and a correlation of the compressional wave velocities obtained with information from boreholes or pits made along or close to traverse lines. It is thus possible to delineate the lateritic and saprolitic horizons from the bedrock. From the compressional wave velocities the rippability could also be ascertained (Fig. 2). It has been found that the lateritic soils have compressional wave velocities of around 305 m/s which increased up to 460 m/s as the lateritic gravels become more compact, and well beyond this where induration had produced hardpans. When the dynamic modulus is obtained from geophysical traverses a first approximation of California Bearing Ratio (CBR) is obtained from correlations of dynamic modulus and CBR values of soils (Fig. 3). From the pits and road cuts, visual examinations of materials are made and samples taken. The vertical variation of materials in profiles with respect to texture and suitability for construction purposes are ascertained.

The quantitative and qualitative evaluation of lateritic gravels for construction have been based on simplified economic geology methods. Field traverses are run along grids. From point profiles (derived from these field traverses) extrapolations are made laterally and longitudinally to obtain line profiles, from which vertical and areal distribution and variability are determined through field traversing (Fig. 4a, 4b) so that area soils maps and general engineering soils maps are produced. The general engineering soils maps may be either a laterite and lateritic soils map or saprolitic soils map. Area materials maps showing clays, sands, gravels and quarriable rocks may also be produced.

The mode of occurrence of laterites and lateritic and saprolitic soils has been found to be the same in almost all areas of occurrence and the principles applied during exploration of materials were as follows:

- the principle of integrated exploration,
- the principle of gradual accumulation of data, and
- the principle of uniform degree of exploration.

This decision is based on the relatively simple structure, extensive areal distribution and the relatively low material depth variation of laterites, lateritic soils and saprolitic soils. A combination of four (4) main exploratory grids are used, namely: