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Classification of Subsoil Bases in Nigeria

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ABSTRACT

The paper presents classification of Nigerian subsoil bases. Numerous subsoil investigation reports from across the country were collected, studied and analyzed. The study laid much emphasis on the numbers of soil strata and the variation of their bearing capacities and settlement characteristics in relation to the types of foundations recommended in each of the reports. Based on the study and depending on the complexity of the soil strata, subsoil bases in Nigeria were grouped into three: Simple, Less Complex and Complex.

KEYWORDS: Subsoil bases; soil profile; bearing capacity; settlement characteristic.

INTRODUCTION

Investigation of the underground conditions at a site is prerequisite to the economical design of the substructure elements. It is also necessary to obtain sufficient information for feasibility and economic studies for a proposed project. Geotechnical soil investigation is an integral component of any civil engineering project. This is because the safety, durability and economic usage of the intended structure depend on the proper analysis and understanding of the ground on which it will sit. Geotechnical soil investigation provides this needed information. The extent of soil investigation work depends on the importance and foundation arrangement of the structure, the complexity of the soil conditions, and the information which may be available on the behaviour of existing foundations on similar soils (Tomlinson and Boorman, 2001). Site investigation generally provide among others, the following basic information (Bowles, 1997):

1. Information to determine the type of foundation required (shallow or deep).

2. Information to allow the geotechnical consultant to make a recommendation on the allowable load bearing capacity of the foundation.
3. Sufficient data/laboratory tests to make settlement predictions.

A component of site investigation report that provides simple pictorial explanation or summary of the subsoil condition is the soil profile. A number of geotechnical engineers, reviewing a geotechnical soil investigation reports, are usually at first glance, attracted to the soil profile portion of the report. This is because soil profile gives a summarized explanation of the soil, rock strata and ground-water conditions within the zones affected by foundation bearing pressures and construction operations, or of any deeper strata affecting the site conditions in any way.

Many countries and regions of the world have been able to compile documents (guides, codes, standards, etc.) which serve as guides and handbooks to geotechnical engineers, especially those concerned with field work. Nigeria, as a developing country has no such compilations for its geotechnical engineers. It has over the years relied on adapting codes of practice from Britain and a few other countries. Therefore this paper is intended to serve as a little guide to geotechnical engineers concerned with field work in Nigeria. It is also intended to serve as a stimulant for the formation of a code (guide) for the practice of geotechnical engineering in Nigeria.

GENERAL INFORMATION AND THE GEOLOGY OF NIGERIA

Nigeria is one of the West African countries located within the tropical region of the world. The country lies close to the equator between latitude 4^o N and 14^o N and longitude 2^o E and 15^o E. Politically the country borders Niger republic to the north, Lake Chad to the northeast, Republic of Cameroon to the east, Benin republic to the west and to the south is Atlantic Ocean. The country is geologically bounded on the south by the gulf of Guinea and on the north by the southern edge of the Sahara desert. The country has a surface area of 923,768 km^2 and a total population of about 167 million.

The climate is typified by hot tropical condition, which is humid in the south and semi-arid in the north. Seasonal rainfall results from the influence of the wet south westerly monsoon winds from the sea and the hot dry dusty north east trade wind from the Sahara, known locally as the hamattan. The geomorphology and the quaternary history of Nigeria have evolved under the remarkable changes brought about by the intensity and periodicity of rainfall in the past. Wetter periods have been termed pluvial and drier periods are termed inter-pluvial.

The geology of Nigeria is dominated by sedimentary and crystalline basement complex formations which occur in almost equal proportions all over the country (Durotoye, 1983; Rahaman, 1983, McCurry, 1989; Rahaman, 1989; Shitta, 2007) (Fig. 1). The sediment is mainly Upper Cretaceous to recent in age while the basement complex rocks are thought to be Precambrian.

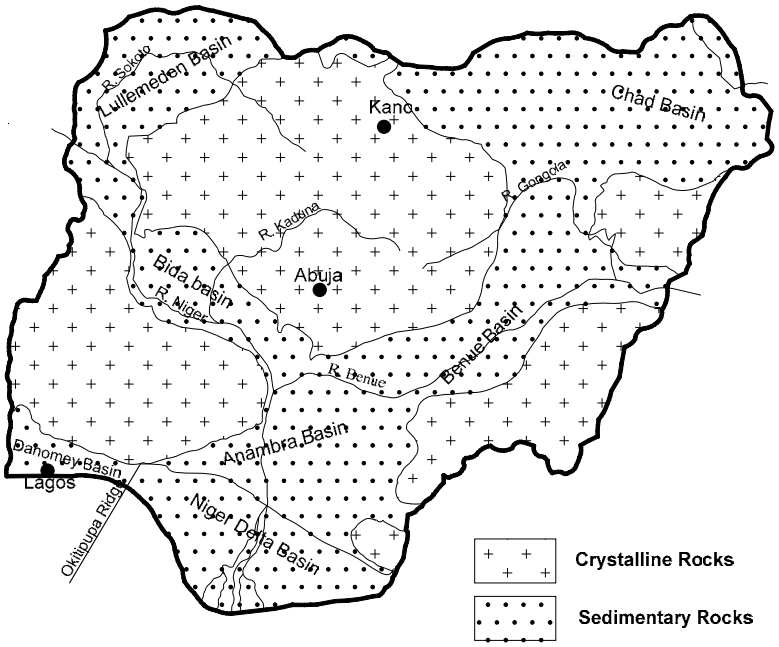


Figure 1: Geological formation of Nigeria

Weathered Rock

Generally, the weathered in-situ rock overlies the unweathered bedrock except in areas of outcrops and in exceptional cases where the Quaternary deposits overlie the bedrock directly. The contact between the weathered and unweathered bedrock is known as the basal surface of weathering. The depth of the basal surface is highly variable depending on the type of rock. In sedimentary rock regions, the basal surface of weathering may not easily be discerned, especially when the rocks are not very consolidated. But on the crystalline rocks, this boundary is very distinct because of the remarkable transformation, involved in the chemical weathering of primary rock forming minerals, like feldspars and the ferromagnesians, into secondary clays and iron oxides (Durotoye, 1983). Products of weathering in Nigeria are generally grouped into four main basic groups (fig. 2): the Ferruginous soils, the Ferrallitic soils, the weakly developed soils, and the Vertisols, which is localized to the North-eastern part of the country (Malomo, 1983).

Geomorphology

The Characteristic landforms on the crystalline rock Basement Complex and the Younger Granites of the Jos Plateau are the extensive dissected pedi-plains above which rise prominent steep sided residual hills. These hills range in height from a few metres to over 600m.

About half of the total area of Nigeria is covered by sedimentary rocks (Fig. 2). The characteristic landforms consist of extensive dissected flat to very gentle sloping plains of a lower pediment level above which rise remnants of flat lateritic capped hills of a higher pediment level. The lateritic capped hills, dissecting the flat plains are of various heights, with height up to 300m been recorded (Durotoye, 1983).

Residual hills are obviously the resistant remains left after the weathering and erosion of

surrounding rocks under humid tropical conditions, and there is a remarkable tendency for them to concentrate on the interfluves of large rivers. Rocks with high residual hill forming potentials are the Older Granites, the Younger Granites, and the Quartzites.

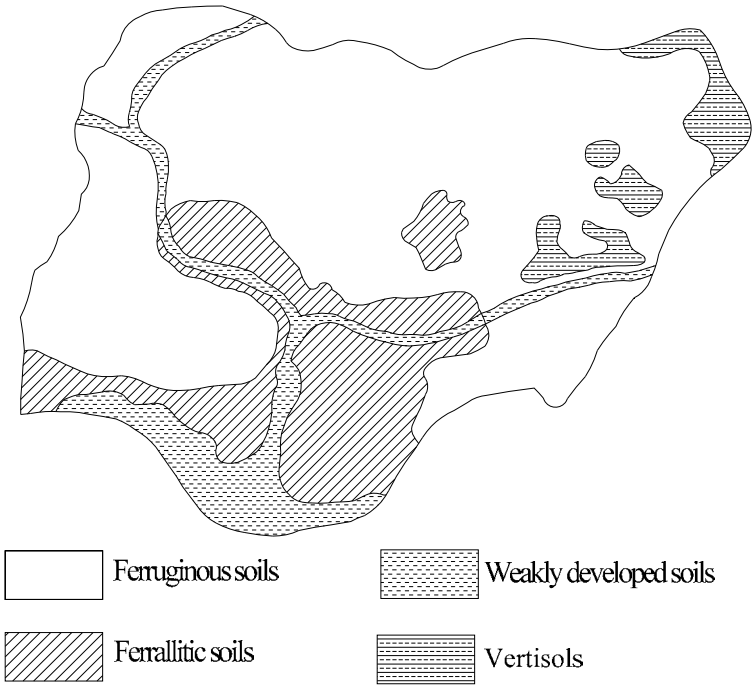


Figure 2: Soil groups in Nigeria

METHODOLOGY

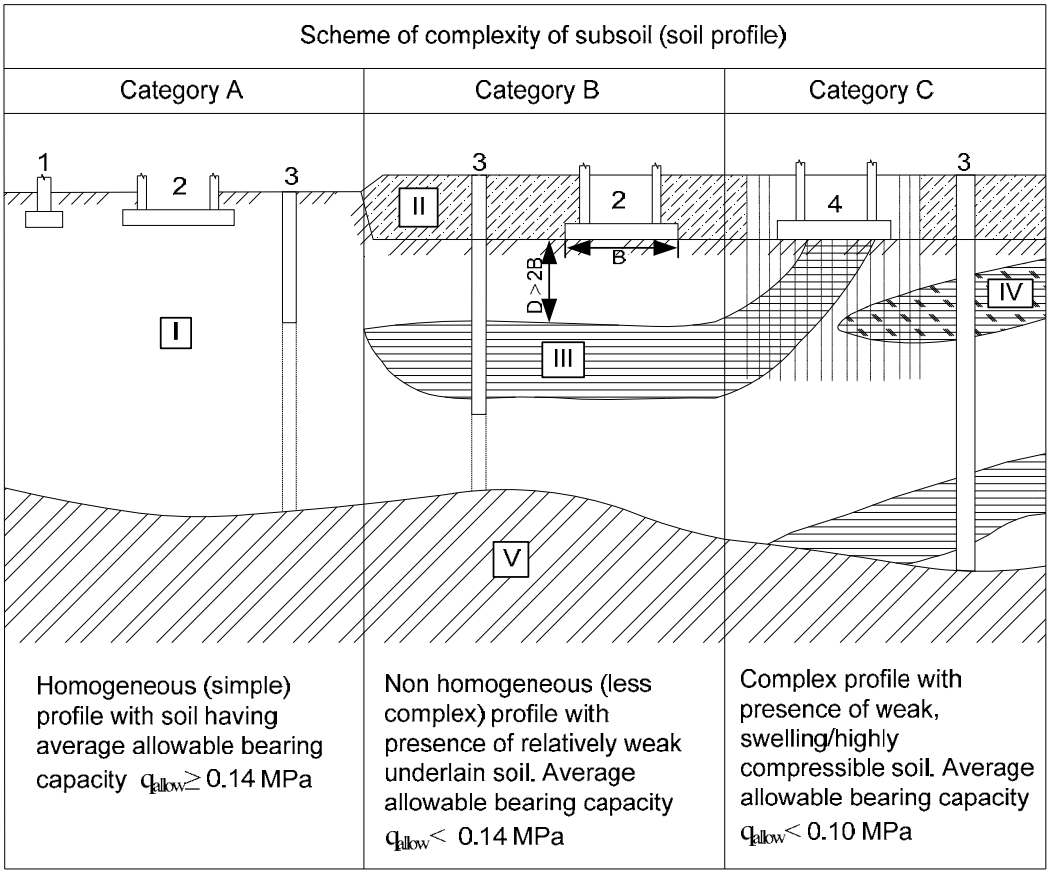
The methodology employed for this research work involves collection of several geotechnical and or subsoil investigation reports from around the country. These reports were studied and their subsoil bases (soil profiles) were classified in relation to the recommended foundations. Reports of investigation conducted for buildings purposes were given more attention, although a number of those conducted for the purpose of road construction were also considered. For the latter, portions concerning bridges were specifically considered because of the depths of exploration. A total of 500 soil reports were selected and studied taking into considerations of the main soil groups in the country. 250 reports from Ferruginous region were studied, 100 each from area with Ferrallitic and weakly developed soils and 50 from area with Vertisols dominance. That is a 5:2:2:1 ratio was used in the number of reports studied for Ferruginous soils, Ferrallitic soils, weakly developed soil and Vertisols respectively. More emphasis was laid on variations of soil strata and how the engineering properties (especially bearing capacity and settlement characteristics) of these strata vary with depth. Soil strata with average allowable bearing capacity $q_{allow} \geq 140$ kN/m^2 and modulus of deformation E > 8 MPa were considered adequate, considering the predominant types of buildings in Nigeria i.e. low-rise, with bungalows constituting greater percentage of them. The classification was based on the presence and arrangement of these strata

with other strata having less of these properties. The presence of soil strata with swelling/high compressibility characteristics was seriously considered, especially in the area (region) dominated by vertisols. Generalised foundation types were recommended for these classifications.

RESULTS

From the result of the study, Nigerian subsoil bases can generally be classified into three categories as shown in Table 1.

Table 1: Classification of complexity of Nigerian subsoil and recommendable foundation types



Soil: I — soil of average allowable bearing capacity- $q_{all} \geq 0.14$ MPa and average modulus of deformation- E > 8 MPa; II — Filled soil; III— weak soil of less strength; IV — weak swelling/highly compressible soil; V — bed rock: 1–3 — Types of foundations, accordingly: 1— Pad and Stripe at shallow depth; 2 — Raft ; 3 — Pile; 4 — Raft on piles, filled or reinforced bases.

DISCUSSION

From Table 1, category A is described as Simple Profile. This category consists of relatively homogenous soil strata having average allowable bearing capacity not less than 140 kN/m^2 and modulus of deformation E not less than 8 MPa. One major characteristic of this category is that

bearing capacity of the strata increases with depth to the bedrock. Shallow foundations are mostly recommended for use in this type of soil profile, although deep foundations are also used depending on the type and magnitude of the load from the structures e.g. bridges.

The second category, category B is described as Less Complex Profile. This category is characterised by non-homogenous soil strata, starting with (or without) filled soil layer at the top and relatively weak strata, having average allowable bearing capacity and modulus of deformation E less than 140 kN/m^2 and 8 MPa respectively, sandwiched within the profile. One major characteristic of this category is that the bearing capacity of the strata varies along the profile. Basement foundations are used to increase the bearing capacity and reduce settlement potentials in these circumstances. The foundations are located at depths such that the weak soil layer is below the influence zone or the seat of settlement, which is defined as the stress zone beneath a foundation within which the stresses induced by the structures load are large enough to cause significant orders of settlement. Outside this zone, the stresses are so small that they do not contribute to any significant settlement (Ranjan and Rao, 2005; Murthy, 2009). Deep (pile) foundations are also used to transfer the structural loads through the weak soil layer(s) to firm strata or bed rock below.

The third category- category C is described as Complex Profile. This category is characterised by both vertically and horizontally non-homogenous soil strata. The horizontal variability in the properties of soils in this type of soil profile makes it complex. The presence of expansible and or highly compressible layer(s) of clay, having low bearing capacity, adds to the complexity of the profile. Shallow foundations are only founded on this type of profile upon either modification, stabilization and in some cases replacement of the soil below the foundation. Deep (pile) foundations are also used depending on the safety and economic analysis of the intended structure and the foundation construction work involved.

CONCLUSION

-The geological formation of Nigeria mainly consists of crystalline and sedimentary rock basements, which are distributed almost equally across the county's territory.

-Weathered materials found within the territory of Nigeria, consist basically of Ferruginous Soil, Ferrallitic Soil, weakly developed soil and vertisols. These are mostly underlain by unweathered rocks.

-The subsoil bases (soil profiles) in Nigeria can be grouped into three groups: Category A (simple profile), Category B (less complex profile) and Category C (complex profile).

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