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Shallow Foundations for Low-rise Residential Buildings in Nigeria

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Abstract—The paper present the basic types of shallow foundations use for the construction of low-rise residential buildings in Nigeria, the predominant soil types on which these foundations are constructed, conditions and the processes of formationof these soils and their basic engineering properties. The bases for the design approach for these types of foundations, the methods and technology of their construction.

Keywords:*Bearing capacity, Residential building, Settlement, Shallow foundation,Tropical residual soil.*

I. INTRODUCTION

Nigeria is a developing country still battling to provide houses for its ever increasing population. The demands for buildings for both commercial and residential uses are high, particularly in the country's many states capitals and other major cities. While trying to meet up with this demand, sure is made in ensuring proper designs of the buildings components, thusensuring that the buildingsare able to perform their functions satisfactorily. The foundation systems must be able to support the applied loads through safe transfer of same to the underlying soil.

Foundation is an integral part of a building whose stability determines the stability of the entire structure. It acts as a medium through which loads are transmitted to the soil or rock below. The stability of a foundation depends on its proper design based on the structural loads of the building it carries, the geology of the area and condition of the subsoil base. Depending on the depth of load-transfer from the structure to the ground, foundations are classified as shallow and deep foundations. The definition of shallow foundations varies in different publications. While BS 8004 (1986) adopts an arbitrary embedment depth of 3 m as a way of defining shallow foundations, many consider shallow foundation as one in which the embedment depth of the foundation is less than or equal to its width [1]. Many recent studies conducted have shown that, for shallow foundations, D_f/B can be as large as 3 to 4 [2]-[4]). EAG [5] states that, foundation elements are considered to be shallow when the depth to breadth ratio is less than 5 (D_f/B<5).

Most residential buildings in Nigeria, especially the low-rise types are founded on shallow foundations, with the most widely used of them as strip and pad foundations. This is perhaps because of the prevalent types of residential buildings (bungalows) and the soil conditions i.e stable tropical residual soils. Understanding the rationale behind the prevalent usage of these types of foundations can therefore not be over emphasized. Traditional foundation design practice in Nigeria relies largely, on the British Code of Practice for Foundations BS 8004of 1986 [6], and a little of empirical rules formulated from local experience with foundations in weathered rocks. A thorough understanding of the geology and soil conditions of an area, in which foundation is to be sited, is a pre-requisite to the success of a foundation project.

II. CHARACTERISTIC SOIL CONDITIONS AND PROPERTIES OF SOILS IN NIGERIA

Nigeria is one of the African countries located within the tropical region of the world (fig. 1). 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. The country therefore, has characteristic hot and heavy rainfall climatic conditions which are typical of tropical region. The geology of Nigeria is dominated by sedimentary and crystalline basement complex formations which occur in almost equal proportions all over the country [7]-[9] (fig. 2). The sediment is mainly Upper Cretaceous to recent in age while the basement complex rocks are thought to be Precambrian. Sedimentary rocks found within Nigeria include: sandstones, shales and mudstone, limestones, siltstones, ironstone, e.t.c. While migmatite-gneiss-quartzite complex, younger metasediments, charnokitic-gabbroic and dioritic rocks, older granite suite and volcanics and hypabyssalrocks groups have been identified within the crystalline basement complex[8].

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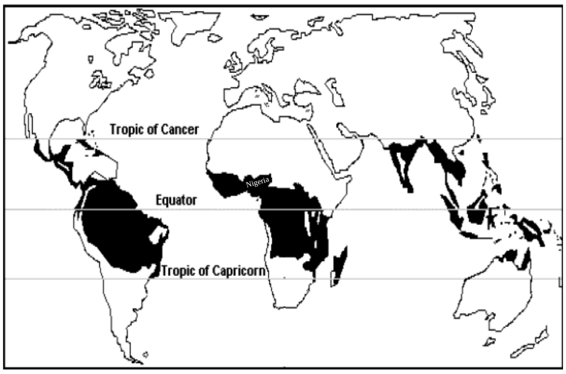

Fig. 1:*Regions with tropical climate [10]*

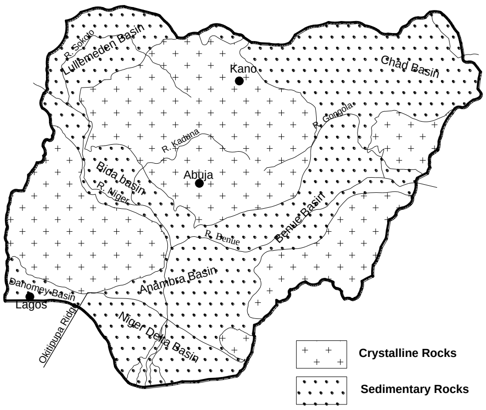

Fig.2: *Geological formation of Nigeria*

Due to the climatic conditions in the tropical region (Nigeria), soil formation from the parent rocks (igneous, sedimentary or metamorphic), is mainly by process of chemical weathering[11]. Although, mechanical process of weathering is also encountered within the tropics (Nigeria). The weathered material is untransported residue of both chemical and physical process of rock weathering. The most important end products are the clays and the resistant minerals, quartz. Other end products depend very much on the type of rock. In this part of the world, however, iron oxides are also common residues. They impart the reddish, brownish and yellowish coloration on the weathering residues, which are generally referred to as "laterite" [7]. Most abundant residual soils in Nigeria are mainly Ferruginous tropical soils and Ferralsols.

Under the humid tropical climate of Nigeria and the extensive gentle slopes of the terrain, deep in-situ weathering takes place. The depth of weathering, though variable, is generally about 30m below the surface, and may be greater in highly jointed and fractured rocks. In the more arid part of Northern Nigeria, the depth of weathering is reported to be less than 15m. The composition and characteristics of the weathered materials would depend very much on the parent rock from which they were formed [7].

In addition to the influence of parent rocks, residual soils in the tropics (Nigeria), have a vertical soil section, called the soil profile, which consists of a distinct layering, termed the soil horizons formed almost parallel to the ground surface. These genetically related horizons are a reflection of the weathering process. The soil profile also has a weathering aspect that gives rise to a vertical weathering profile that is a critical aspect from the engineering perspective. The weathering profile reflects the state of weathering along the soil profile or vertical soil section from the bedrock (unaltered parent rock) to the ground surface. It consists of materials that show progressive stages of transformation or "grading" from fresh rock to completely weathered material towards the ground surface. The weathering profile portrays considerable variation from place to place due to the local variation in rock type and structure, topography and rates of erosion because of regional climatic variation, particularly rainfall [11]. The entire weathering profile, generally, indicates a gradual change from fresh rock to a completely weathered soil as illustrated in fig. 3[12].

Residual soils are usually preferred to support foundations as they tend to have better engineering properties than transported soils [13].

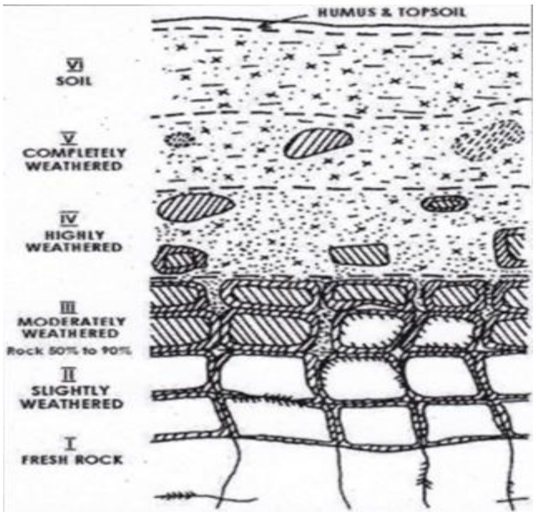

Fig.3: *Typical Tropical (Nigerian) soil profile*

In addition to the residual soils, weakly developed and hydromorphic soils are also found in Nigeria especially along rivers banks and coastal area, though in terms of coverage, but not necessarily in the order of significance, they are less in extent than the residual soils. Vertisol, which is also a tropical residual soil group, having distinct engineering properties are also found in the North-eastern part of Nigeria. Fig. 4 shows the major soil groups in Nigeria[14].

As shown on fig. 4, there are basically four major groups of tropical soils in Nigeria: Weakly developed soils, Vertisols, Ferrallitic soils and Ferruginous tropical soils. Of these, the ferruginous and ferrallitic tropical soils are the most abundant and most stable under engineering structures. The vertisols and weakly developed soils occur less in Nigeria and are generally weak bases for engineering structures, especially those founded on shallow foundations.

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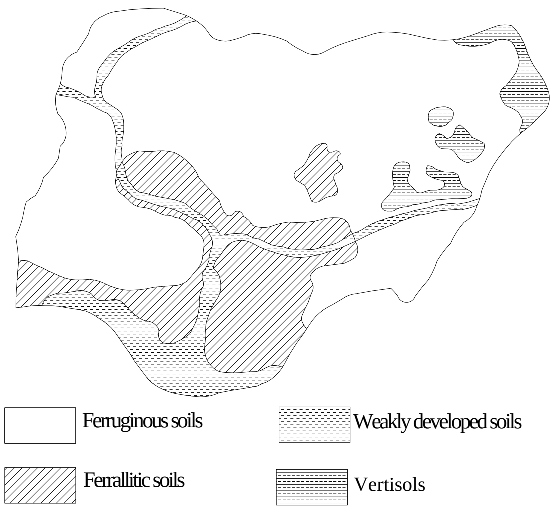

Fig. 4: *Soil groups in Nigeria*

A. *Weakly developed soils*

These are poorly developed soils, including young soils as well as lithosols on rocky areas and on recent deposits. Soils on recent deposit have no clear differentiation of soil horizons. There are two types; soils on alluvium at rivers and lake valleys and soils formed on mangrove swamps and marine alluvium. The first type is generally heterogeneous and they vary from sand to silty loam. They are soft and may be predominantly clayey in parts. They are found in valleys of many rivers and streams in Nigeria. The second type has similar granulometric characteristics as the latter. They differ in the presence of large quantities of humus and the high salt content. They have a high concentration of sulphides and even elemental sulphur.

Both groups contain sands in the form of quartz and a mixture of clays usually kaolinite and illite. The physical and engineering properties of weakly developed soils cover a wide range since they cover different genetic groups. The soils on recent deposits, which are the largest member of the group are soft and sometimes of considerable depth. Malomo[14] reported the following range of geotechnical properties for organic clay in Lagos area of Nigeria:Moisture content: 15-120%, Liquid limit-20-150%, Plastic limit-10-50%, Undrained shear strength- 31.4-314 kPa, Cohesion-3.14-31.4 kPa, Angle of shear resistance-0-7^o, Bulk density[15]-1600-1900kg/m^3.

B. *Vertisols*

These are heavy black clays associated with calcium rich parent rocks in the relatively dry savannah climate. They are also called black cotton soils. They characteristically have a black upper horizon, which is due to the presence of a black colored humus-clay complex. They have a heavy texture and a dominant montmorillonitic clay fraction.The engineering properties are dominated by its small particle sizes and the presence of the clay mineral montmorillonite. These properties impose the low permeability, high plasticity, expansiveness and shrinkage on the soils.

Ola [16] and Oritola and Moses[17] recorded the following ranges of properties for vertisols of the North-eastern Nigeria:Liquid limit-78-93%, Plastic limit- 21-31%, Plasticity index-47-72%, Linear shrinkage- 11-21%, Specific gravity-2.50-2.56, Free swell-50-90%, Swelling pressure-126.9 kPa, Bulk density [15] -1900-2100kg/m^3.

Building on vertisols using the types of foundation commonly employed for other types of soils, develop extensive cracks within a short period of time even with reasonable precautions taken.

C. *Ferruginous soils*

As shown in fig. 4, this soil group is most abundant in Nigeria. They are tropical soils with defined ABC profile. They frequently have marked separation of free iron oxides, which may either be leached out of the profile or precipitated within it in the form of spots of concretions (a process called laterization, which is common in the tropics). They contain mostly kaolinite, residual quartz and free iron oxides, which have been transformed to the inactive forms [14]. This group of soils is commonly referred to as red tropical soils.

The soils are of medium plasticity and inactive due the clay minerals present in them. S. Ola [18], Alhassan [19], [20], Alhassan and Mustapha [21] and Mustapha [22] reported the following ranges for the geotechnical properties of ferruginous soil profiles:Natural moisture content-6.55-38%, Liquid limit-36-50%, Plastic limit-18-44%, Plasticity index-6-26%, Specific gravity-2.53-2.70, Cohesion-24-140 kPa, Angle of shear resistance-18-26.5^o, Bulk density [15] -1700-2100kg/m^3.

D. *Ferrallitic soils*

They are formed in the humid to moist sub-humid parts and areas of dense vegetation in the southern Nigeria. The soils are often found as deep profile on a wide range of rock types. The horizons are slightly differentiated. They have little or no reserve of weatherable minerals. The clay minerals in them are predominantly of the 1:1 lattice type and mostly associated with large quantities of iron minerals.

This group of soil has almost similar engineering properties and color with the ferruginous tropical soils. These two groups are the most stable under foundation.

A generalized classification of subsoil bases in Nigeria, presented by Alhassan *et al.*[23], can serve as a guide for the selection of foundation type, depending on the soil condition.

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III. TYPES OF SHALLOW FOUNDATIONS USED IN NIGERIA

Most of the residential buildings in Nigeria are low-rise buildings founded mostly on shallow (pad, strip and raft) foundations. Statistically, more than 80% of these residential buildings are bungalows (building with single floor),which are mostly founded on strip foundations, while most of the few multi-floor low-rise residential buildings are founded on pad foundations. Only few rare cases occur, were residential buildings in Nigeria are founded on raft foundations, even in areas with extremely weak or very troublesome soils. The following are the different types of shallow foundations:

A. *Pad Foundation*

Pad foundations are used to support point loads from columns. There are a number of different types of pad foundations available in use in the country. They include the mass concrete for steel column, plain reinforced concrete, stepped reinforced concrete, etc. Types of pad foundations are shown in Fig.5.

Shallow mass concrete pad consists of a mass of concrete pad supporting point loads from columns and piers. They are used for varying conditions of soil layers where the suitable load bearing soils exist at shallow depth [24]. Shallow reinforced concrete pads are similar to the mass concrete pads but of a smaller thickness because of the usage of reinforcement on the tensile face of the pad which increases the pad resistance to bending moment. Combined pad footings are also used in cases were individual pad footing are much closed to each other.

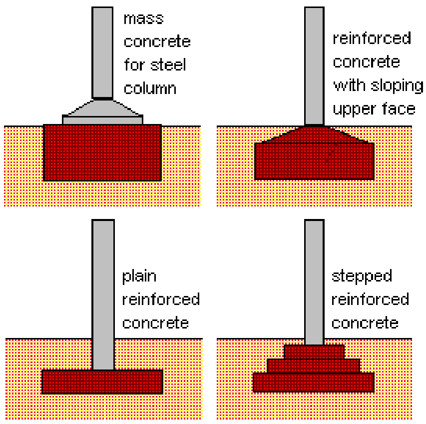

Fig.5a: *Types of pad foundations[25]*

Fig.5b: *Houses on pad foundations*

B. *Strip Footing*

Strip footings are used under relatively uniform point loads or mostly under walls. The strip distributes the concentration of the load sideways into an increased width of sub-strata to reduce the bearing stress and settlement to an allowable limit [24]. Strip footings are also used when rows of columns are spaced so closely that individual pad foundation will nearly touched each other. They are the most widely used shallow foundations in Nigeria for the construction of low-rise residential buildings.

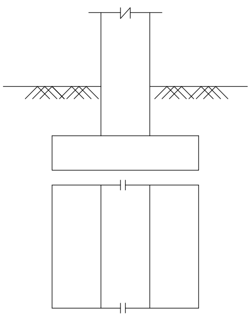

Fig.6 a: *Strip footing*

Fig. 6: *Houses constructed on strip footing*

C. *Raft Foundation*

Raft foundation is also known as mat foundation. It is a large spread footing that supports most of the structure loads. A raft foundation spreads the structural load over a large area to reduce the bearing pressure [26], [27]. It is more rigid and thus reduces the potential for excessive differential settlements. Raft has greater weight and is able to resist greater uplift loads. It distributes lateral loads into the soil more evenly and efficiently. Since most of the structures require a ground floor slab, it is always economic to incorporate it with the

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foundation into one element. The combination of floor ground slab and the foundation can be done by making the upper surface of the raft foundation coincides with the top surface of the floor slab[28].

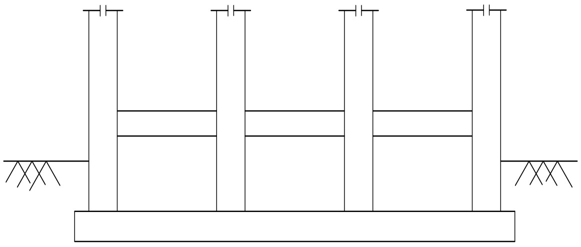

Fig. 7a:*Raft Foundation*

Fig.7b: *Construction of raft foundation*

IV. BASES ON SANDY SOILS

Shallow foundations are generally designed to satisfy bearing capacity and settlement criteria. The bearing capacity criterion stipulates that there is adequate safety against bearing capacity failure beneath the foundation, and a factor of safety of three is generally used on the computed ultimate bearing capacity. Settlement criterion is to ensure that the settlement is within tolerable limits[29]. According to Bowles [13], for foundations on sand and silts,the following requireconsiderations:

1. Bearing capacity.
2. Densification of loose deposits to control settlement.
3. Placing the footing at a sufficient depth that the soil beneath the footing is confined. If silt or sand is not confined, it will roll out from the footing perimeter with a loss of density and bearing capacity. Wind and water may erode sand or silt from beneath a footing that is too near the ground surface.

Foundations on silt or sand deposits may consist of spread (pad and strip) footings, mats or piles, depending on the density, thickness, and cost of densifying the deposit, and on the building loads. Spread footings are used if the deposit is dense enough to support the loads without excessive settlements. Rapid or immediate settlements occur on noncohesive silt or sand deposits.

It is poor practice to place foundations on sand deposits where the relative density is not at least 60 percent or to a density of about 90 percent or more of the maximum density obtained in a laboratory test. This dense state reduces the possibility of both load settlements and settlement damage due to vibrations from passing equipment, earthquakes, or the like.

Inorganic (nearly pure) silt in a saturated condition cannot be compacted. The compaction effort produces a wave in front of the compactor and the entire mass may quiver. When this type of deposit is encountered, the deposit must be excavated and replaced with competent soil or else excavated and dried to a water content that will allow compaction. Soil replacement is usually impossible so alternatives consist in drying the silt and encasing it in a geotextile to control water, mixing it with sand and gravel sufficient to produce a stable condition when saturated, or using piles to carry the load through the deposit to competent soil [30].

A. Bearing Capacity of foundations on sand

In proportioning shallow foundations parameters, the Terzaghi general bearing capacity equation as given by equation (1), is generally used.

$$q_{ult} = cN_c + qN_q + \frac{1}{2}\gamma B N_\gamma \quad (1)$$

where q_{ult}isthe ultimate bearing capacity, c is the unit cohesion, q is the surcharge ($D\gamma$), γ the unit weight of soil, D the depth of foundation, B is foundation width, $N_c, N_\gamma$and $N_q$are coefficients that depend on the effective friction angle of the soil, ϕ. It is commonly accepted that:

$$N_c = (N_q - 1)cot\phi \quad (2)$$

$$N_q = e^{\pi tan\phi}\, tan^2\left(45^o + \frac{1}{2}\phi\right) \quad (3)$$

However, for calculatingN_γ, different equations have been recommended. One of the most popular equations is that of Brinch-Hansen [26], [27], [30]:

$$N_\gamma = 1.5(N_q - 1)tan\phi \quad (4)$$

Values of $N_c, N_\gamma$and $N_q$are usually tabulated or graphically given against ϕ in literatures for easy reference.

For a granular, non-cohesive (c=0) material, the ultimate bearing capacity $q_{ult}$of the soil is given by:

$$q_{ult} = qN_q + \frac{1}{2}\gamma B N_\gamma \quad (5)$$

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The ultimate bearing capacity of foundations, q_{ult} in sand can also be determined from results of plate load test by the following equation:

$$q_{ult} = q_{up}\left(\frac{B_f}{B_p}\right) \quad (6)$$

where q_{up} is the ultimate bearing capacity of the test plate, B_f and B_p are foundation and test plate widths respectively.

Recognizing the uncertainties involved, factors of safety are applied to reduce the estimated ultimate bearing capacity from equation (5).The allowable bearing capacity q_{allow} is:

$$q_{allow} = \frac{q_{ult}}{FS} \quad (7)$$

The factor of safety (FS) is a function of the importance of the structure, the consequences of failure, and the uncertainty of the subsurface investigation.

Footings on granular soils are commonly proportioned by the use of Standard Penetration N values [26]. One of the empirical equations, which determine safe bearing capacity for a specified maximum total settlement in terms of N values, that is finding acceptance with geotechnical engineers in Nigeria, is *Bowles's correlation* [13], as presented by Rao and Ranjan[26]. This is a modification of *Meyerhof'scorrelation*.

$$q_{allow} = 0.73\, N\, R_{D1}\, S_{allow} \text{ kN/m}^2 \text{ for } B \le 1.2 \quad (8)$$

and

$$q_{allow} = 0.48\, N\, R_{D2}\left(\frac{B+0.3}{B}\right)^2 S_{allow} \text{ kN/m}^2 \text{ for } B \ge 1.2 \quad (9)$$

where N is corrected N values, B is foundation width, S_{allow} is permissible settlement in mm, while R_{D1} and R_{D2} are depth correction factors given by:

$$R_{D1} = 1 + 0.2\ \frac{D}{B} \le 1.2 \quad (10)$$

$$R_{D2} = 1 + 0.33\ \frac{D}{B} \le 1.33 \quad (11)$$

where D is depth of foundation in m.

B. Settlement of foundations in sand

The estimation of settlement of shallow foundations is an important topic in the design and construction of building and other related structures. In general, settlement of foundation consists of two major components: elastic settlement (S_e) and consolidation settlement (s_c). For a foundation supported by granular soil within the zone of influence of stress distribution, the elastic settlement is the only component that needs consideration [31].

It is commonly believed that the settlement criterion is more critical than the bearing capacity one in the designs of shallow foundations, especially for foundation width greater than 1.5 m, which is often the case. By limiting the total settlements, differential settlements and any subsequent distresses to the structure are limited [29]. Generally the settlements of shallow foundations such as pad or strip footings are limited to 25 mm [2].

The general equation for the calculation of elastic settlement S_e in sand is given as:

$$S_e = q_n B \frac{(1-\mu^2)}{E} I_f \quad (12)$$

where q_n is the net foundation pressure, B the width of foundation, E the modulus of elasticity of soil, μ the Poisson's ratio and I_f is the influence factor for settlement.

Terzaghi and Peck equation for the calculation of foundation settlement S_f in sand from the result of field plate load test is also commonly used:

$$S_f = S_p\left[\frac{B_f(B_p+0.3)}{B_p(B_f+0.3)}\right]^2 \quad (13)$$

Where S_p is test plate settlement, B_f and B_p are foundation and test plate widths respectively.

V. BASES ON CLAY SOILS

Clay soils may range from very soft, normally consolidated, to very stiff, highlyoverconsolidated deposits. Major problems are often associated with the very soft to soft, deposits from both bearingcapacity considerations and consolidation settlements. It should be noted that "soft" implies that the soil is very wet to saturated. Consolidation settlements occur in these deposits with high water contents. Most Nigerian residual clays are overconsolidated deposits.

In clay soil it is necessary to make a best estimate of the allowable bearing capacity to control a shear failure with a suitable factor of safety and to estimate the probable consolidation settlements. The bearing capacity is most often determined using the undrained shear strength as obtained from quality tube samples or from samples obtained from routine SPT. If the soil is highly sensitive, consideration are given to in situ strength testing such as the vane shear or the cone penetration test.

Consolidation tests should be made to determine the expected settlement if the structure has a relatively high cost per unit area. For smaller or less important structures, some type of settlement estimate based on the index properties might be justified.

In proportioning shallow foundation on clay, the net ultimate bearing pressure for vertical loads is normally computed using simplified Terzaghi, Meyerhof or Hansen equations. For ϕ=0, equation (1) becomes:

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$$q_{net} = C_u N_c \quad (14)$$

Since$N_c = 5.14$and $N_\gamma = 1$ from table of values of N_c, N_γ and N_q, when ϕ=0, therefore:

$$q_{net} = 5.14C_u \quad (15)$$

For the computation of consolidation settlement, the following equation is generally used for normally consolidated clays:

$$S_c = H\frac{C_c}{1+e_0}\log\frac{P_0+\Delta P}{P_0} \quad (16)$$

where H is the thickness of the clay layer,C_c is the compressive index from e-logP graph,e_0 the initial void ratio,P_0 is the effective overburden pressure and ΔP is the increase in the effective stress at the middle of the layer due to the foundation load.
For overconsolidated clays,
if$P_0 + \Delta P < P_c$

$$S_c = H\frac{C_s}{1+e_0}\log\frac{P_0+\Delta P}{P_0} \quad (17)$$

and if $P_0 < P_c < P_0 + \Delta P$

$$S_c = \frac{H}{1+e_0}\left[C_s\log\frac{P_c}{P_0} + C_c\log\frac{P_0+\Delta P}{P_c}\right] \quad (18)$$

whereC_s is swell index, and can be determined using the following empirical expression:

$$C_s = 0.0463\left(\frac{LL}{100}\right)G_s \quad (19)$$

where$LL$is liquid limit and G_s *is* specific gravity of the soil solids.

Compressive index C_c can also be computed using some empirical relationships with the soil index properties [13], [15]. For example:
for normally consolidated clay,

$$C_c = 0.007(LL - 10) \quad (20)$$

and for clay of low and medium sensitivity,

$$C_c = 0.009(LL - 10) \quad (21)$$

Foundation settlement in clay soils can also be estimated from the results of plate load test using the following equation:

$$S_f = S_p\left(\frac{B_f}{B_p}\right) \quad (22)$$

The maximum settlement allowed for foundations on clay soils is 25mm.

VI. TECHNOLOGY AND EQUIPMENT FOR THE CONSTRUCTION OF SHALLOW FOUNDATIONS IN NIGERIA

Foundation construction consists of a series of activities ranging from site preparation, foundation trench excavation and the actual construction or installation of the foundation.

Foundation construction for residential buildings in Nigeria is still been dominated by manual methods of construction, using local implements [32] and cast in-situ technology. This is perhaps because most residential buildings in the country are constructed by individuals, who have no sufficient capital to use modern methods and technology of construction. Only few cases occur where construction of foundation for residential buildings involves the use of *state-of-the-art* technology.

A. Site preparation

Although in Nigeria, manual methods of site preparation and foundation construction still predominate, thepresent-day foundation construction methods involve a high degree of mechanization. Optimum working speeds of plant are achieved only in clear working conditions giving maximum mobility for the plant and vehicles. Therefore, an efficient and well-maintained system of temporary roads is provided on extensive sites in order to achieve and maintain a rapid tempo of construction in all weathers. Equally important is attention to site drainage to give dry working conditions and to avoid unnecessary pumping[33].

It is equally important to make provision of good transportation system relatively clear of the foundation trench for easy movement of waste and construction materials. The form of construction of temporary roads depends, of course, on the subgrade soil conditions. On well-drained sandy or gravely soils, no construction will be necessary other than grading to levels and rolling to give a good running surface. Sandy surfaces are liable to rutting in very dry weather or during heavy rain. If required, increased stability can be obtained by rolling in quarry or industrial waste.

Construction traffic can run on a clayey or silty soil when it is dry. Thus, if it is certain that all construction requiring transport over the site can be completed in the dry season, site roads are unnecessary. However, if the construction programme requires work to continue through rainy weather, then some substantial form of temporary road construction is essential. It is also important to construct these temporary roads before the onset of wet weather[33].

B. Foundation trench excavation

Most construction sites in Nigeria for buildings that are to be founded on either pad or strip

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foundations, uses manual methods and simple equipment for the foundation trench excavation. The usual implements used for this operation are mostly diggers and shovels (fig. 10 a). After the site clearance and the removal of the top organic soil, the usual practice for foundation trench excavation, for the construction of either pad or strip foundations, is to pile the excavated materials on the unexcavated portions within the site (fig. 10: b). These materials are later on used for backfilling after the foundation construction. But excavating a trench for the construction of raft (mat) foundation, more comprehensive operations are required because of the large quantity of the excavated material that is usually involved.

a b

Fig. 10: *Excavation for strip foundation using diggers and shovels*

The choice of plant for bulk excavation is largely determined by the quantity and by the length of haul to the disposal point. If the tip area is close to the excavation, then the earth can be moved by loading shovel orbulldozer. Longer hauls require crawler or rubber-tyred tractor-drawn scrapers. However, the size and depth of the excavation and the soil conditions must be favourable for economical use of scrappers; they are unsuitable for deep excavations covering a small area since the ramp roads enabling the scrapers to climb in and out of the cut cannot be conveniently arranged. There must also be room for the scraper to turn in the cut (trench). These machines are best suited to fairly large areas of shallow excavation. They can excavate all soil types except soft clays and silts. If the haul distance for the excavated material exceeds about 800-1000 m, then excavators loading into tipping wagons are required [33].

To ensure the safety of the workers in the trench, stability of the trench's sides is seriously taken into consideration, especially for relatively dipper excavations in cohesionless soils. The sides of the trenches are usually protected by designed sheet piles.

C. Placement of Shallow Foundations

After the trenches are prepared, for plain concrete footing (and for reinforced concrete, the reinforcement arranged, fig. 11-12), the concrete is carefully poured to the designed dimensions. There still exist in Nigeria, especially for pad and strip footings, manual methods of mixing and placing concrete during foundation construction. For large scale foundation construction, mechanical methods of mixing and placements of the concrete foundations are used (fig. 13).

Fig. 11: *A pad footing under construction*

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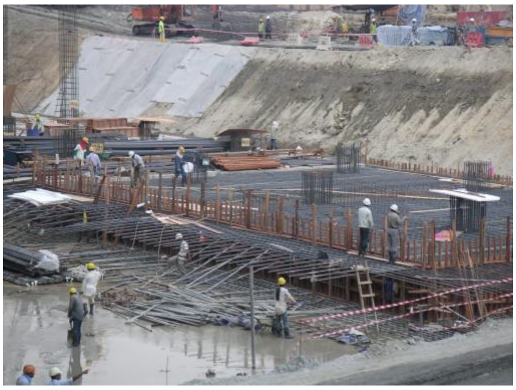

Fig. 12: *Strip/pad footings under construction* ***Fig. 13:*** *A raft Foundation under construction*

VII. CONCLUSION

Shallow foundations are widely used in Nigeria for the constructions of buildings for both commercial and residential purposes. Most of the low-rise residential buildings in Nigeria, which are mostly bungalows are founded on shallow foundations especially the strip type.

The selection and usage of these foundations depends to a large extent on the geological and soil condition of the area. Nigeria's territory is underlained by crystalline and sedimentary rocks, which on the surface have weathered to form mostly tropical firm residual soils. These geological and soil conditions of the country provide good bases for the use of shallow foundations to support most buildings in the country.

For the determination of shallow foundations' parameters, the Terzaghi bearing capacity equation, as modified by Brinch-Hansen, still remains the most often used equation in Nigeria.

Foundation construction for residential buildings in Nigeria is still been dominated by manual methods of construction using cast in-situ technology. This is perhaps because most residential buildings in the country are constructed by individuals, who have no sufficient means to use modern construction methods and technology.

REFERENCES

[1] K.Terzaghi, R. B. Peck &G.Mesri, "Soil Mechanics in Engineering Practice". (Third edition). John Wiley & Sons, New York. 1996.

[2] B. M. Das, "Shallow Foundations - Bearing Capacity and Settlement". CRC Press LLC, USA, pp. 2, 46, 1999.

[3] B.M. Das,"Principles of Foundation Engineering. 7th edition. CL Engineering, 2010.

[4] S.Shakiba rad, A. A. Heshmati and H.Salehzadeh, "Application of Adaptive Neuro-Fuzzy Inference System (ANFIS) to Predict the Ultimate Bearing Capacity of Shallow Foundation on Cohesionless Soil",*Electronic Journal of Geotechnical Engineering* (EJGE), Vol. 16, Bund.S,pp. 1459-1469, 2011.

[5] EAG,"Guidance on Detailed Engineering Evaluation of Non-residential buildings- Part 3 Technical Guidance Section 5 – Foundations". Engineering Advisory Group (EAG), Ministry of Business, Innovation and Employment (MBIE), New Zealand, pp. 1, 2012.

[6] BSI, "British Standard Code of Practice for Foundations (BS 8004: 1986)". British Standards Institution, London, 1986.

[7] B. Durotoye, "Geomorphology and Quaternary deposits of Nigeria": In Tropical Soils of Nigeria in Engineering Practice, Edited by S. A. Ola, A. A. Balkeda, Rotterdam.pp. 1-16, 1983.

[8] M. A. Rahaman and S.Malomo, "Sedimentary and Crystalline Rocks of Nigeria": In Tropical Soils of Nigeria in Engineering Practice, Edited by S. A. Ola, A. A. Balkeda, Rotterdam. pp. 17-38, 1983.

[9] K. A. Shitta, "Lithostratigraghy of Nigeria-An overview", Proceedings of thirty second Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California. 2007.

[10] http://www.nctwr.org.au/image/tropic-map.jpg,10/11/2012.

[11] B. B. k. Huat and F. Hj. Ali, "Foundation Engineering in Tropical Soils": In Foundation Engineering: Design and Construction in Tropical soils, Edited by Ali, F.Hj. Huat, B. B. K. Oma, H. and Singh, H., Toylor& Francis Group, LLc, London. pp. 1-11, 2006.

[12] A. L. Little, "The Engineering Classification of Residual Tropical Soils". Proceedings of Specialty Session on the Engineering Properties of Lateritic Soil, 7th International Conference on Soil Mechanics and

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Foundation Engineering, Mexico City. 1: 1-10, 1969.

[13] J. E. Bowles, Foundation Analysis and Design, McGraw-Hill Companies, New York. 1996.

[14] S.Malomo,"Weathering and Weathering Products of Nigerian Rocks-Engineering Implications": In Tropical Soils of Nigeria in Engineering Practice, Edited by S. A. Ola, A. A. Balkeda, Rotterdam. pp. 39-60, 1983.

[15] M.Carter and S. P. Bentley, "Correlation of Soil Properties", Pentech press, London, 1991.

[16] S. A. Ola, The Geotechnical Properties of the Black Cotton soils of Northeastern Nigeria: In Tropical Soils of Nigeria in Engineering Practice, Edited by S. A. Ola, A. A. Balkeda, Rotterdam. pp. 85-101, 1983.

[17] F.Oritola and G.Moses, "Groundnut Shell Ash Stabilization of Black Cotton Soil", *EJGE*, Vol. 15, pp.415-428, 2010.

[18] S. A. Ola, "Geotechnical Properties and Behavior of Some Nigerian Lateritic Soils": In Tropical Soils of Nigeria in Engineering Practice, Edited by S. A. Ola, A. A. Balkeda, Rotterdam. pp. 61-84, 1983.

[19] M.Alhassan, "Classification of Minna Laterite" Proceedings of the Papers Presented at the 7th Annual Engineering Conference, Federal University of Technology, Minna, Niger.pp. 40-44, 2006.

[20] M.Alhassan, "Effect of Bagasse Ash on Lime-modified Laterite", Mater Degree Thesis, Ahmadu Bello Unversity, Zaria, Nigeria. 2006.

[21] M.Alhassan and A. M. Mustapha, "Effect of Rice Husk Ash on Cement Stabilized Laterite" *Leonardo Electronic Journal of Practices and Technologies*, Romania.Issue 11.pp. 47-58, 2007.

[22] A. M. Mustapha, "Physical Properties of Residual Profile Found in Minna", *AU J.T.* 11(3), pp. 91-98, 2008.

[23] M.Alhassan, T. W. Adejumo, and I. L. Boiko, "Classification of Subsoil Bases in Nigeria", *Electronic Journal of Geotechnical Engineering (EJGE)*, Vol. 17 (J) pp. 1407-1413, 2012.

[24] W.G.Curtin, G.Shaw, G.I.Parkinson and J. M. Golding, "Structural Foundation Designer's manual, Blackwell.1994.

[25] http://strukts.com/wp-content/uploads/2012/06/pad1.gif,14/02/2013.

[26] G.Ranjan, and A. S. R. Rao, "Basic and Applied Soil Mechanics", New Age International Publishers Ltd, New Delhi. 2005.

[27] V. N. S. Murthy, "Soil Mechanics and Foundation Engineering", CBS Publishers &Distributots, New Delhi. 2009.

[28] J. H. Leow, "A Study of Building Foundations in Malaysia", Faculty of Engineering and Surveying, University of Southern Queensland.2005.

[29] B. M. Das, and N.Sivakugan, "Settlements of Shallow Foundations on Granular Soil - an overview",*International Journal of Geotechnical Engineering,* 1: pp. 19–29, 2007.

[30] Zekkos, D. P., Bray, J. D. and Der Kiureghian, A. (2004), Reliability of Shallow Foundation Design using the Standard Penetration Test, Proceedings ISC-2 on Geotechnical and geophysical Site Characterization, Viana da Fonseca &Mayne (eds.), Millpress, Rotterdam, pp. 1575-1582.

[31] Das, B. M., Atalar, C. and Shin, E. C. (2009), Development in the Elastic Settlement Estimation Procedures for Shallow foundations on Granular Soil, 2nd International Conference on New Development in Soil Mechanics and Geotechnical Engineering, Nicosia, Cyprus.

[32] A. M. O. Atolagbe, "An Evaluation of the Adaptability of Nigerian Indigenous Building Tools in Modern House Construction", *J. Hum. Ecol*, 32(1), pp. 63-68, 2010.

[33] M. J. Tomlinson and R.Boorman "Foundation Design and Construction", Pearson Education Ltd. London.2001.

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