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Chemical and geotechnical assessment of low organic foundation soils across the coastal area of Southwestern Nigeria

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ABSTRACT

Pressure on land use has caused great site development along the coastal area of south western Nigeria. However, research works for the purpose of evaluating appropriate depths of foundations in the area were without cognizance of engineering challenges that may ensue as a result of the organic content, and associated factors of the soils. This paper evaluates the compositional effects of the soils on foundation materials, and a phenomenological model of compressibility of fines during design and construction of problem-free foundations in the area. Thirty (30) disturbed soils were analysed for moisture content, grain size distribution, consistency limits, chloride, pH and sulphate, while the oedometer consolidation test was carried out on another 30 undisturbed soils. The stratigraphic sequence in the profile comprises medium dense to coarse grained silty clayey sand to 16.80 m depth, below loose grey organic silty clayey sand from the surface. Results show in most cases, that the foundation soils contain insignificant percentages (0.95–5.8%) of organic solids. Moisture content (44–70%), chloride (74.9 ppm), sulphate (420 ppm) ions concentration and pH (8.96) could enhance the corrosive potential of the soils. It is recommended that Portland cement concrete will be suitable in the environment. Foundation settlement with respect to surface area ($0.028 \leq m_v \leq 0.434 m^2MN^{-1}$ at 200 kNm^{-2}; $0.038 m_v \leq 0.776 m^2MN^{-1}$ at 400 kNm^{-2}; $0.038 \leq m_v \leq 0.879 m^2MN^{-1}$ at 800 kNm^{-2}) ranges from low to medium compressibility with respect to consolidation pressure. Therefore, footings load need be spread over the soils, and foundation design need be based on site-specific soil information.

1. Introduction

Increasing urbanization and rapidity in urban population have resulted into rising utilisation of coastal part of Southwestern Nigeria. Presently, a great development of building sites is emerging along this marginal ground. A wide range of the subsurface probe conducted by Malomo and Oloruniwo (1983), Ajayi (1983), Farrington (1983), Adesunloye (1987), Onwuka (1990), Oyedele (2011) and Bolarinwa (2011) in the area revealed that the subsoils are sandy silt with clay-sized particles and organic matter. Organic matter could detrimentally influence properties of a foundation soil on foundation materials such as corrosion of metals and weak strength of concrete (Bhattarai, 2013).

It is apparent that the subsoils in the coastal area of Lagos vary widely in their composition with depth. However, a study which quantifies the organic content and measures the compressibility range of the soils that serve as foundation material in the area soils is yet to be a subject of research. This is important in order to assess their probable challenges to engineering performance of structures. This study therefore, focuses on the corrosive and weak strength potentials of the soils on foundation materials in the coastal during the service life of structures.

2. Geology

The study area falls between a longitude range of 3°15' - 4°15′E and a latitude range of 6°25' - 6°30′N, in the Dahomeyan Miogeosyclinal Basin of Southwestern Nigeria (Fig. 1). The Basin combines inland and coastal with offshore parts stretching from Southeastern

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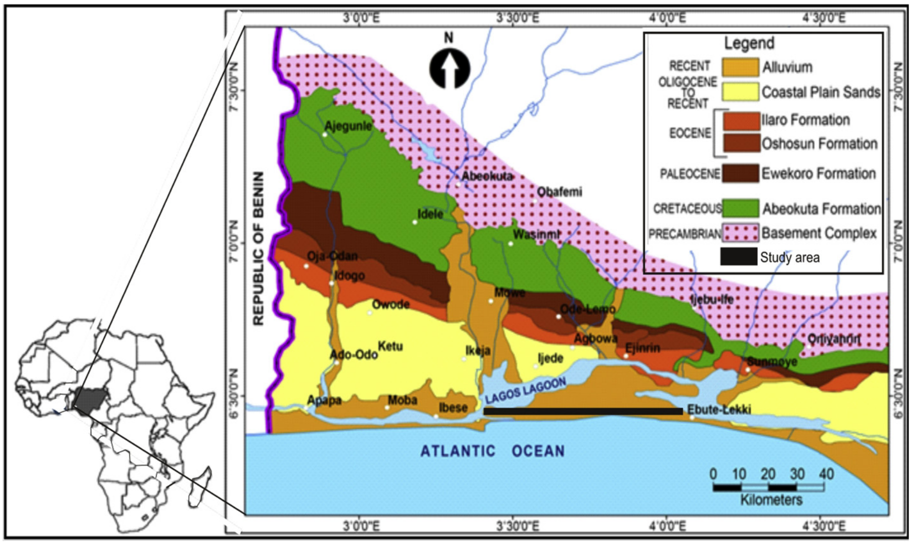

Fig. 1. Geological map of the part of Southwestern Nigeria showing the study area (Adapted from Boboye and Omotosho, 2017).

Ghana through Togo, and the Republic of Benin to Southwestern Nigeria. 'The Okitipupa Ridge' (a subsurface basement high) separated it from the Niger Delta (Boboye and Omotosho, 2017).

According to Obaje (2009) the Late Cretaceous marine shales correlated with the Nkporo Shale Formation, while the marine beds nearer the coast and offshore are older. The Paleocene Ewekoro Limestone Formation and the Eocene phosphatic Oshosun Formation, which are Lower Tertiary marine units have been exposed at various quarries in Ogun State, and in neighboring Benin Republic. Although the younger Tertiary ljebu Formation, Afowo Beds are exposed along the coast are non-marine, marine Miocene deposits in the offshore subsurface.

The subsurface stratigraphic information provided by Jones and Hockey (1964), Omatsola and Adegoke (1981) and Agagu (1985), shown in Table 1 revealed that some basement blocks partly underlain the basin are displaced towards the NNE-SSW basin axis as well as towards the offshore. Adegoke et al. (1980) identified five important physiographic units in the area. These include (i) the Abandoned Beach Ridge complex, which comprises coast parallel savannah-grassed sand ridge; (ii) the Coastal Creeks and Lagoons which occur as a belt of nearly 1000 km between Abidjan and the western flank of the Niger Delta; (iii) the Swamp Flats which commonly border the lagoon; (iv) the Forested River Flood Plains which constitute a geomorphic form (See Fig. 2), and dissected the Benin Formation; and (v) the Active Barrier Beach complex consisting of a continuous line of wave-washed white to brownish sand with abundant mollusc shells. Analysis of strata in the area revealed clayey silty gravelly sand and peat, with vegetated freshwater deposits of Recent-Quaternary alluvium above the Ilaro Formation (Malomo and Oloruniwo, 1983; Onwuka, 1990).

3. Material and methods

Thirty (30) representative disturbed were collected with hand auger, and 30 undisturbed soil samples were retrieved at various depths across the area. The American Society for Testing and Materials ((ASTM 2004)) standard designation 420–4914 was employed in specifying both the chemical properties and the geotechnical characteristics of the foundation soils.

The organic content of the soils was calculated from the ratio of the mass of organic matter in a given mass of the soil to the mass of the dry soil solids percent. Moisture content in the soils was determined as the weight of water to the dry weight of the soil percent, while gravimetric method was used to estimate the sulphate content of each soil sample. Chloride content was determined by titration in the 1:2 soil-water suspensions of soil suspension against silver nitrate solution with potassium chromate as indicator. The *pH* of the soils was measured using a Cole-Palmer Digi-Sense digital pH/millivolt/oxidation reduction potential (pH/mV/ORP) meter.

Cognisance of the distinction between coarse and fine particles was made at 75 μm for particle-size analysis. The coarser particles were separated in a sieve analysis portion through progressively smaller meshes to determine its gradation. The finer particles were analyzed with a hydrometer using the rate of sedimentation to determine particle gradation. The percentage passing of soils was

Table 1
Stratigraphy of the Dahomey basin.

ERA	Jones and Hockey (1964)		Omatsola and Adegoke (1981)		Agagu (1985)	
	Age	Formation	Age	Formation	Age	Formation
Quaternary	Recent	Alluvium			Recent	Alluvium
	Pleistocene-Oligocene	Coastal Plain sands	Pleistocene-Oligocene	Coastal Plain Sands	Pleistocene-Oligocene	Coastal Plain Sands
Tertiary	Eocene	Ilaro	Eocene	Ilaro Oshosun	Eocene	Ilaro Oshosun
	Paleocene	Ewekoro	Paleocene		Paleocene	Akinbo Ewekoro
Late Cretaceous	Late Senonian	Abeokuta	Maastrichtian Neocomian	Araromi Afowo Ise	Maastrichtian Neocomian	Araromi member Afowo member Ise member
Basement Complex						