THE GEOTECHNICAL PROPERTIES OF LATERITIC AND NON-LATERITIC SOILS OF SOUTHEASTERN NIGERIA AND THEIR EVALUATION FOR ROAD CONSTRUCTION

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Abstract

The soils within the entire length of the Port Harcourt - Enugu expressway consist of (1) concretionary laterite gravels (2) non-lateritic tropical sandy/clayey soils which are gravelly in some places and (3) silty to fat clays formed from shales. The particle size distribution and the plasticity of the majority of the soils indicate that by standard acceptance specifications they are unsuitable for base materials. Field compaction results revealed that the relative compaction of 95-100% can be easily achieved in the field using 10-12 ton vibratory rollers.

Although the pavement materials used for the expressway are inferior under conventional standards, mostly isolated rather than widespread pavement failures have so far occurred. Such failures are presumed to be more related to poor field compaction rather than the inferior quality of the construction materials. Where the troublesome weathered shale forms the subgrade, severe pavement failure usually occurs.

Resume

Les sols que l'on rencontre sur l'ensemble du trajet de la route express Port Harcourt-Enugu sont :
1. des graveleux latéritiques
2. des sols tropicaux sablo-argileux non latéritiques, parfois graveleux
3. argiles ou argiles limoneuses dérivées de schistes.

La granularité et la plasticité de ces sols les rendent inutilisables en tant que couches de base si l'on suit les spécifications en vigueur. Mais les mesures de compacité in situ ont atteint 95-100 % de l'O.P.M en utilisant des compacteurs vibrants de 10 à 12 tonnes.

Bien que ces matériaux soient donc hors spécification on n'a constaté jusqu'à présent que des dégradations très localisées des couches de chaussées. Elles sont d'ailleurs probablement dues à des défauts locaux de compactage.

Mais dans les zones où la couche de forme est faite en schistes altérés, on constate généralement des dégradations importantes des couches de chaussée.

Introduction

Lateritic and non-lateritic tropical soils occur abundantly in Nigeria and they are widely used for various earthwork engineering constructions such as pavements, embankments, earthdams. The degree of success in each case may be attributed to the geotechnical characteristics of the soils, design techniques, construction procedures, environmental factors and the specific function of the structure e.g. traffic in the case of roads.

In roads and other earthwork engineering structures, where very large quantities of construction materials are involved, economic constraint may not allow the use of construction materials other than those available locally even when these do not meet the material specifications of so-called conventional pavement materials which were originally designed for temperate countries. Various field observations have shown that it is often the conditions of the material, e.g. degree of compaction, thickness, traffic and climatic conditions, and not necessarily its nature that determines the performance on the road. Good performance can be achieved by conventionally inferior materials if careful attention is given to construction procedures and the traditional design techniques are modified to suit the nature of the soils and the prevailing environmental conditions. Therefore a major problem in the use of lateritic and non-lateritic tropical soils is the formulation of local design and construction control specifications to ensure their proper utilization. A number of specifications have been suggested by various authors and authorities (Wooltorton, 1954, 1968; Remillon,
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1955, USAID, 1971; Gidigasu, 1975, 1980, 1983) for lateritic and non-lateritic tropical soils but it must be emphasized that these could at best be regarded as guide lines since detailed geotechnical properties and environmental conditions may differ significantly from place to place.

Within the past decade, there has been a tremendous increase in the number of road construction projects in Nigeria both at Federal and State levels. Three important dual carriage expressways have been constructed within this period: these are: Lagos — Ibadan; Benin — Lagos and Port Harcourt — Enugu expressways. The three expressways which are all located in the southern part of the country have shown signs of pavement failures, ranging from mild to severe, in various sections. As mentioned earlier, such pavement failures may be attributed to a variety of factors.

The study reported herein was undertaken to examine the geotechnical properties of the soil materials used for the Port-Harcourt — Enugu expressway and to evaluate their suitability for road construction. The laboratory studies included particle size analysis as well as the determination of Atterberg Limits, linear shrinkage, and compaction characteristics. The extent of the breakdown of the concretionary lateritic gravels during compaction was also evaluated. Field studies included in situ density and vane strength tests, compaction using vibratory rollers and inspection of the sections where pavement failures have occurred.

Description of the study area and soils

The Port Harcourt — Enugu expressway is located in South-eastern Nigeria (Fig. 1). The area crossed by the expressway is underlain by Cretaceous and Tertiary sedimentary formations as well as Quaternary unconsolidated sediments and Coastal Plain sands of various thicknesses. The sedimentary formations are mostly sandstones and shales, usually alternating in most cases, and with varying properties of silt. The geomorphology of the southern segment consists of flat coastal and deltaic plains whereas the northern portion has a gently rolling and undulating landscape.

The area has a tropical climate, with distinct wet (April-October) and dry (November-March) seasons. The annual rainfall exceeds 2,500 mm towards the coast, but decreases steadily inland (Table 1).

Tab. 1: Annual rainfall of the study area.

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean annual rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Harcourt</td>
<td>2,950</td>
</tr>
<tr>
<td>Aba</td>
<td>2,500</td>
</tr>
<tr>
<td>Umuahia</td>
<td>2,300</td>
</tr>
<tr>
<td>Okigwe</td>
<td>2,250</td>
</tr>
<tr>
<td>Enugu</td>
<td>2,150</td>
</tr>
</tbody>
</table>

Genetically, two types of soils occur in the area namely: (1) Lateritic soils that are essentially residual and (2) Non-lateritic tropical soils that are transported in origin. The lateritic soils usually occur in the northern part of the area, i.e. north of Umuahia, and the profiles contain a gravelly lateritic crust. On the other hand, the non-lateritic tropical soils are mostly found in the southern segment and they occur over unconsolidated sandy-clayey substrate. The mineralogy of the soils is dominated by quartz and kaolinite with subsidiary proportions of goethite-limonite and smectite-expandable mixed layer clays.

Test methods

The various laboratory tests were generally carried out according to procedures specified by the American Society for Testing and Materials (ASTM, 1975) under the section of Soils and Rocks for Engineering Purpose (1289, 1975). However, the soil samples were subjected to special pretreatment during particle size analysis and Atterberg's Limits in order to break down the structural cementation and achieve complete separation of the individual particles.

The particles size analysis was carried out by soaking a known weight of the oven dried soil in a dispersing agent for 24 hr. The soil was then washed through ASTM Sieve No. 200 (0.074 mm) using sieve No. 4 to protect sieve No. 200 from the concretionary gravel particles. The soil was washed thoroughly until the unagglutinated individual particles were clearly visible and the aqueous mixture of the soil showed no cloudiness. A special advantage of starting with an exactly known oven-dried weight of the soil is that the solution passing sieve No. 200 need not be retained. This means that washing can be continued until there are no signs of fines in the soil. The percentage passing sieve No. 200 can be found from the difference between the