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ISOPLETHS OF SUBGRADE SOIL PROPERTIES FOR JIGAWA AND KANO STATES OF NIGERIA

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Abstract

An engineering classification map and isopleths are produced for the subgrade soils of Jigawa and Kano States of Nigeria. Usage is made of historical and existing results of soil and materials investigations in the area, with a view to harnessing these resources and reducing the efforts, time and money to be expended in carrying out preliminary investigations in connection with future planning, design, location and construction of road projects in the area.

1. Introduction

Generally, the preliminary investigations of subgrade soils that are carried out in the planning, location and construction of road projects are often laborious, costly and time-consuming. Unfortunately, this whole process has to be repeated even in areas where previous projects had been done earlier, often resulting in unnecessary duplication of efforts and expenditure of time and money. To ameliorate this situation, highway authorities have over the years focused their attention on producing engineering geological maps to act, during preliminary investigations, as invaluable tools to the design engineer in providing an overview of site conditions and an insight into the likely nature of the physical terrain and the soils to encounter on the site. Such maps, if available, will be a source of primary information and general reference for the use and guidance of consulting and practicing engineers. They will constitute an invaluable aid to road planners, designers, etc., not only in preliminary route location but also in the preparation for further detailed field work in the area of interest by eliminating the cost and drudgery of a preliminary investigation, especially in an area with potential for rapid infrastructural development and limited previous exposure.

2. The study area

The study area comprises Jigawa and Kano States, the two states constituting the erstwhile Kano State, of Nigeria. The area lies wholly between latitudes 10º30′N and 13º00′N and longitudes 7º40′E and 10º35′E. It shares borders with the Niger Republic and Yobe State of Nigeria on the north, the Bauchi State on the east, the Kaduna State on the south and Katsina State on the West.

Geologically, the north-eastern half of the study area consists mainly of sedimentary rocks falling within the south-western section of the Chad sedimentary basin, while the south-western half lie within the crystalline basement complex of north-central Nigeria. The exposed sediments of the south-western part of the Chad basin range from Palaeocene to

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Recent but over large areas are mainly Quaternary. The rock types present in the basin are sandstones, grits, gravels and shales. This area is bounded to the south-west by the rocks of the Precambrian basement complex consisting mainly of undifferentiated basement complex rocks, mainly gneiss, with high level intrusions of the younger granites and basalt into the basement complex (Matheis, 1975; Rahaman and Malomo, 1983).

The climate of the study area is fairly uniform, with the temperature being continually high (20-30ºC) throughout the year. The soil temperatures are also very high, with the mean monthly soil temperatures measured being higher than the corresponding mean monthly air temperatures. The mean monthly soil temperatures, measured to a depth of 1.2 metres in the rainy season, vary between 27.2ºC and 32ºC (Malomo, 1983). The rainfall is low with a few wet months (the duration of the rainy season being between 110 and 160 days), and the mean annual rainfall between 50 and 100 cm (Soladoye, 1965; Barbour et al., 1982). The seasonal rainfall results from the influence of the west southwesterly Monsoon winds from the sea and the hot dry dusty North East trade winds from the Sahara known locally as the harmattan. In brief, the climate is typified by hot, semi-arid tropical conditions.

Water is required in the process of weathering. Besides its role as an agent in chemical reactions, it is also required as a carrier of the weathered products away from the sites of mineral breakdown. Also, the quantity of water leaching through the weathering environment is the most important single factor controlling the rate of breakdown of parent materials and the genesis of specific secondary products. The nature of the rainfall (heavy, concentrated and of short duration) in humid climatic environment would enhance leaching and the formation of laterites and lateritic soils. The hot, semi-arid tropical conditions in the study area would favour dehydration and aggregation and enhance the formation of ferruginous soils.

The morphology of the area of study within the Chad sedimentary basin is similar to the characteristic pediment found in the sedimentary rock areas of Nigeria. In the Chad Basin, these flat pediments dominate the topography. Within the basement complex area, the morphology is marked by extensive flat pediments on a lower level above which rise prominent steep-sided flat-topped laterite-capped residual hills on an upper pediment level (Durotoye, 1983).

The vegetation of the area closely follows and is derived from its climatic conditions. The vegetation is mainly the sudan savannah. The sudan savannah consists of a more or less continuous cover of short, featherless grasses, with isolated trees. Both fine-leaved thorny trees (Sahel variety) and broad-leaved trees (Guinea variety) are found.

3. Past engineering geological maps

A review of previous works done with regard to engineering geological maps revealed that maps showing engineering properties of soils do not exist as such, and neither do maps depicting areas with well-defined range of variation in engineering properties (Lawrance, 1989). In Great Britain, the method used to compile soil maps is that of Land Classification and Terrain Evaluation. It has been standard technique for land resources study for a long time. It has been applied by the Overseas Unit of the Transport and Road Research

Laboratory (TRRL) for route location and materials survey in Nepal, road design in Malawi, and an engineering resource inventory in Ethiopia (TRRL, 1978). Soils are delineated and classified through remote sensing techniques after which representative values of engineering and other soil properties are assigned to the identified soil types.

In the United States of America, soil map units are delineated on the basis of land use and vegetation pattern, as a first step in demarcating the boundaries of soils with uniform properties. Efforts are then made to associate values of the engineering properties of interest, presented in tabular form, to the soil types so identified (USDA SCS, 1980).

In Nigeria, the Nigerian Building and Road Research Institute has since 1982 been involved in the development of an Engineering Soil Subgrade Map of Nigeria. This is a comprehensive programme in which the subgrade soils in each state are to be systematically investigated one after another. For this purpose, soil samples are collected at different locations in the state. The locations are determined by means of a grid network, which is followed as much as physically possible. This is to ensure that soil sampling is uniformly distributed over the whole state. Laboratory tests are then carried out on each soil sample to determine their particle size distribution, consistency limits, compaction relationships and CBR values. Using these properties to classify the samples in the Unified Soil Classification System, a simple engineering subgrade soils map showing the distribution of the various soil types is then drawn for the state. However, no attempt is made to present in map form the actual values of the engineering properties of the soils. A few such maps have been produced for some geographical entities in Nigeria (see Omange and Aitsebaomo, 1988; Omange and Aitsebaomo, 1989; Omange et al., 1988; Omange et al., 1987).

4. Engineering subgrade maps for the current study

For this study, the engineering properties relevant to highway engineering planning, design and construction, have been investigated and evaluated. Instead of the Unified Soil Classification grouping of the soils, the engineering geological map depicting the AASHTO soil grouping of the area of study has been plotted (Figure 1).

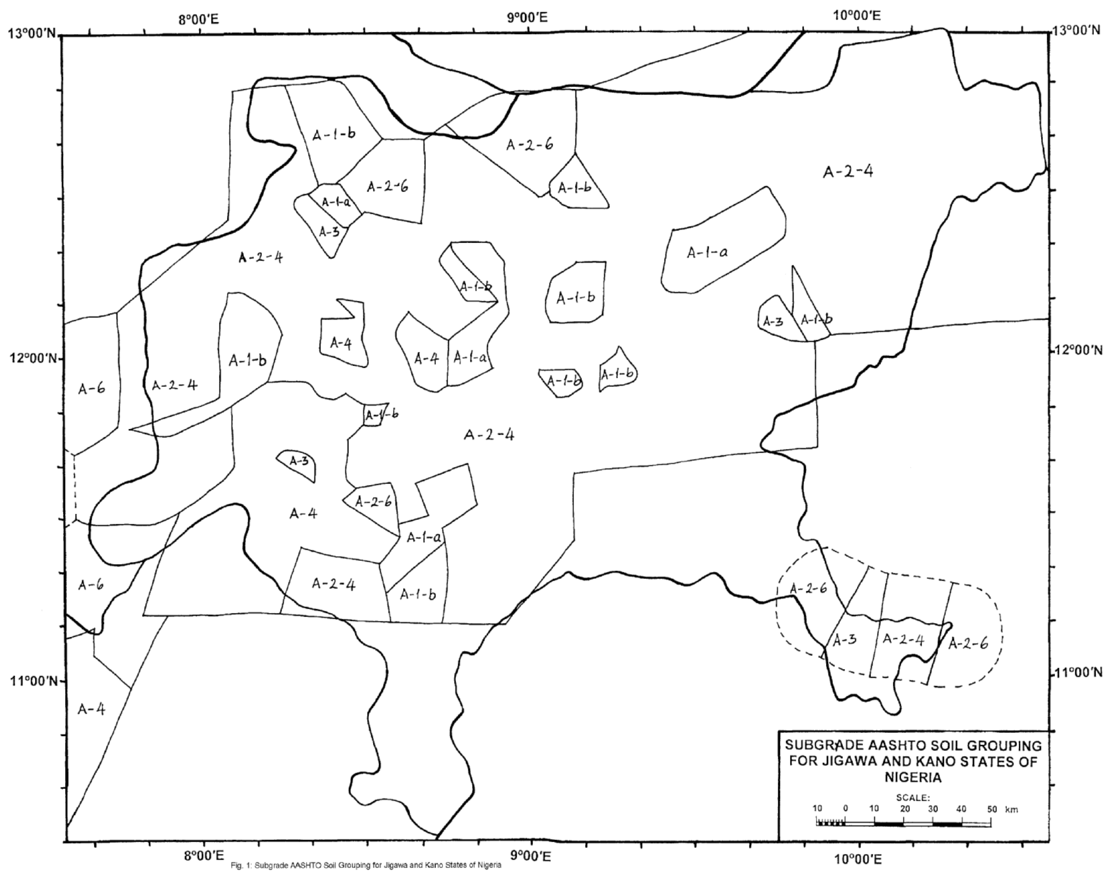

Figure 1: Subgrade AASHTO soil grouping for Jigawa and Kano states of Nigeria

Furthermore, eleven other maps (Figures 2-12), depicting the variation of the other relevant engineering soil properties, have also been presented. These properties are namely the Subgrade Group Index, the Subgrade Gravel Content (percentage retained on the 2.36 mm sieve), the Subgrade Sand Content (percentage passing the 2.36 mm sieve and retained on the 0.075 mm sieve), the Subgrade Fines Content (percentage passing the 0.075 mm sieve), the Subgrade Liquid Limit (%), the Subgrade Plastic Limit (%), the Subgrade Plasticity Index(%), the Subgrade Maximum Dry Density (kg/m^3), the Subgrade Optimum Moisture Content (%), the Subgrade Unsoaked California Bearing Ratio (%) and the Subgrade 96-Hour Soaked California Bearing Ratio(%).

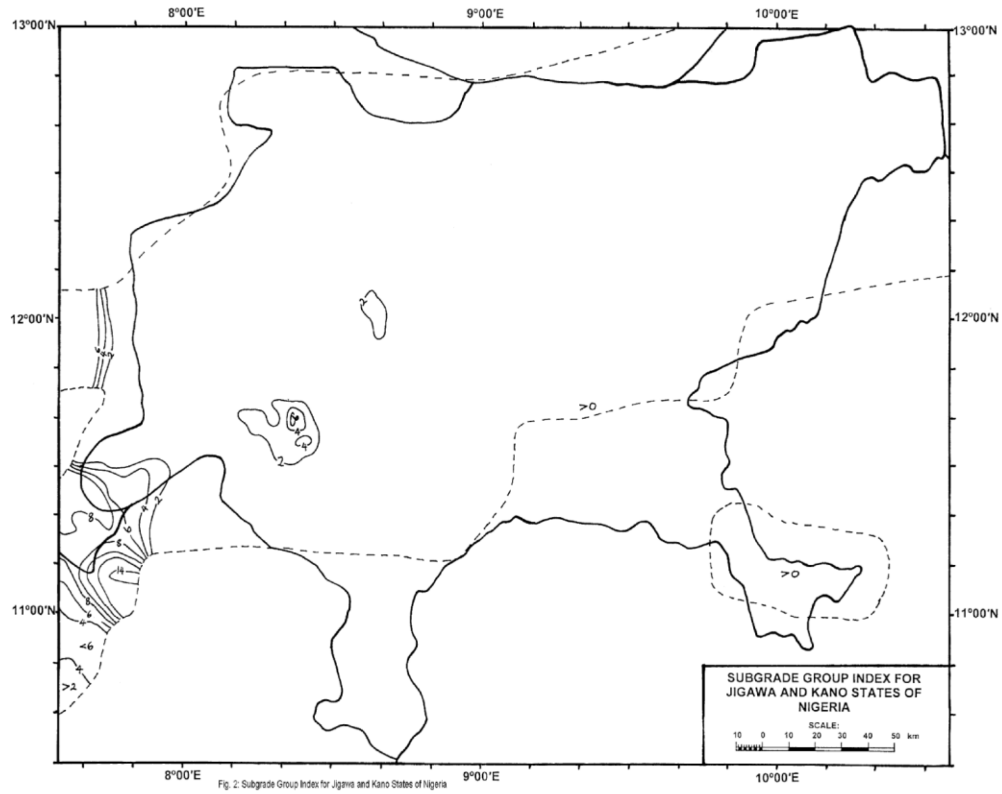

Figure 2: Subgrade group index for Jigawa and Kano states of Nigeria

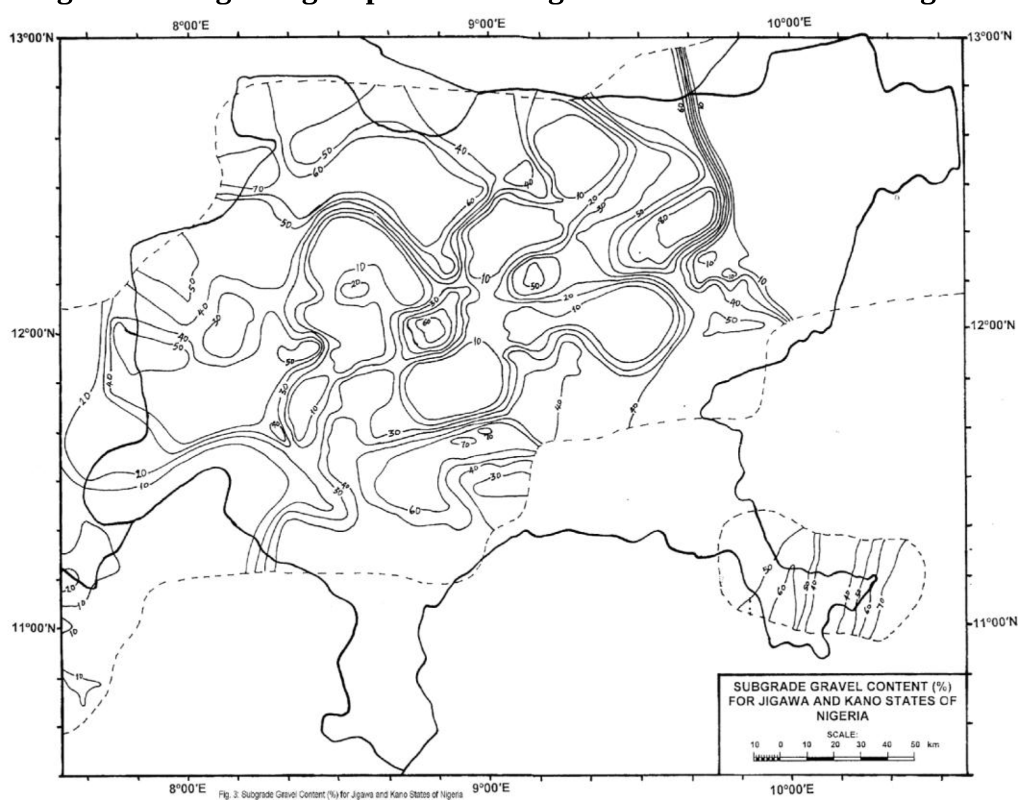

Figure 3: Subgrade gravel content (%) for Jigawa and Kano states of Nigeria

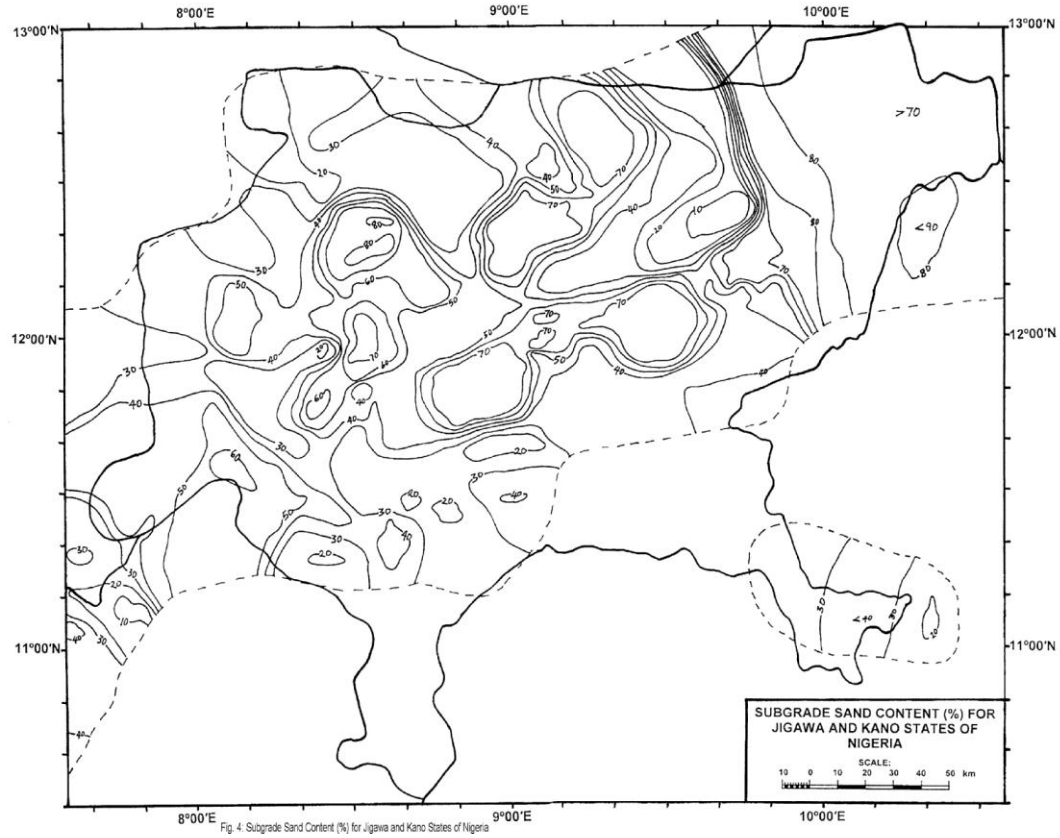

Figure 4: Subgrade sand content (%) for Jigawa and Kano states of Nigeria

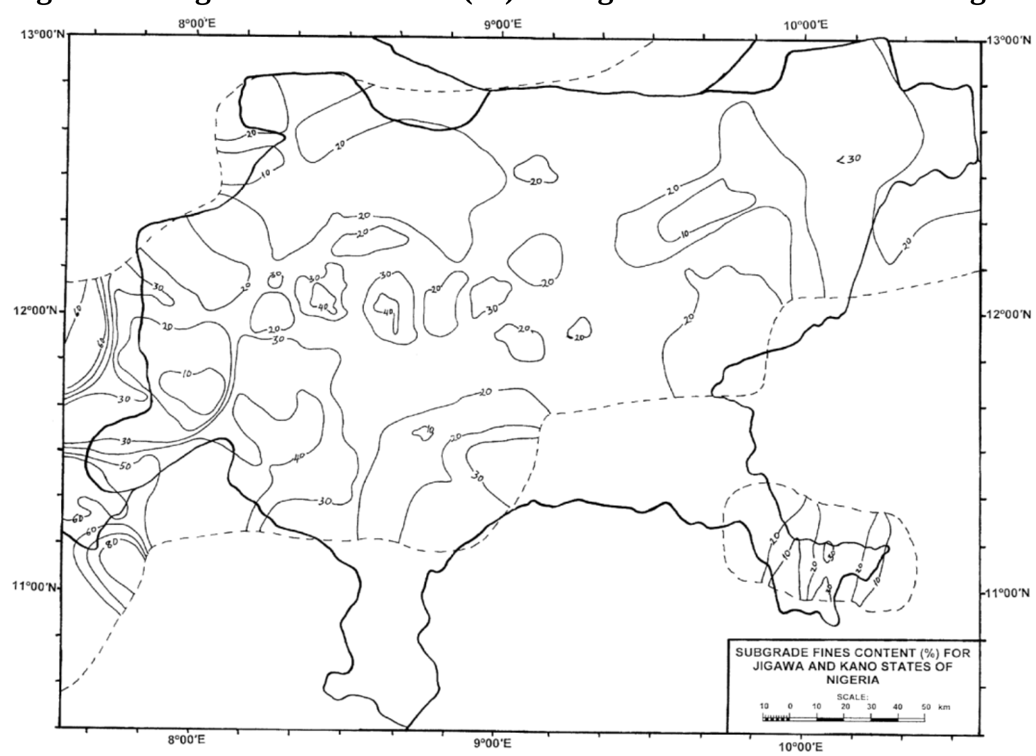

Figure 5: Subgrade fines content (%) for Jigawa and Kano states of Nigeria

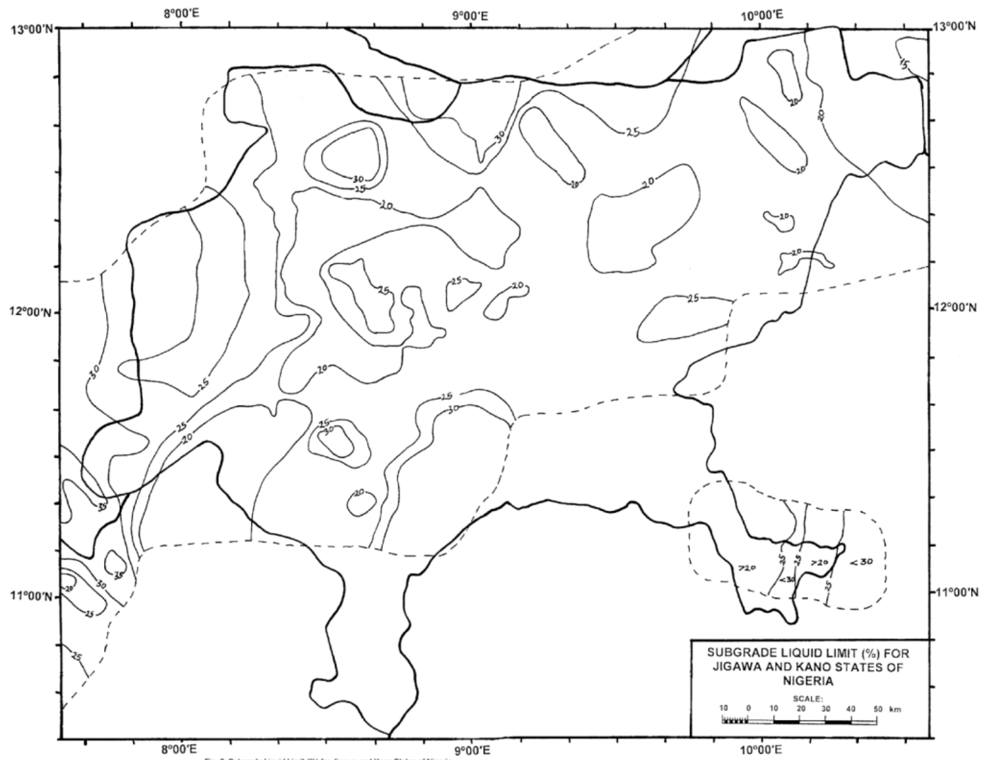

Figure 6: Subgrade liquid limit (%) for Jigawa and Kano states of Nigeria

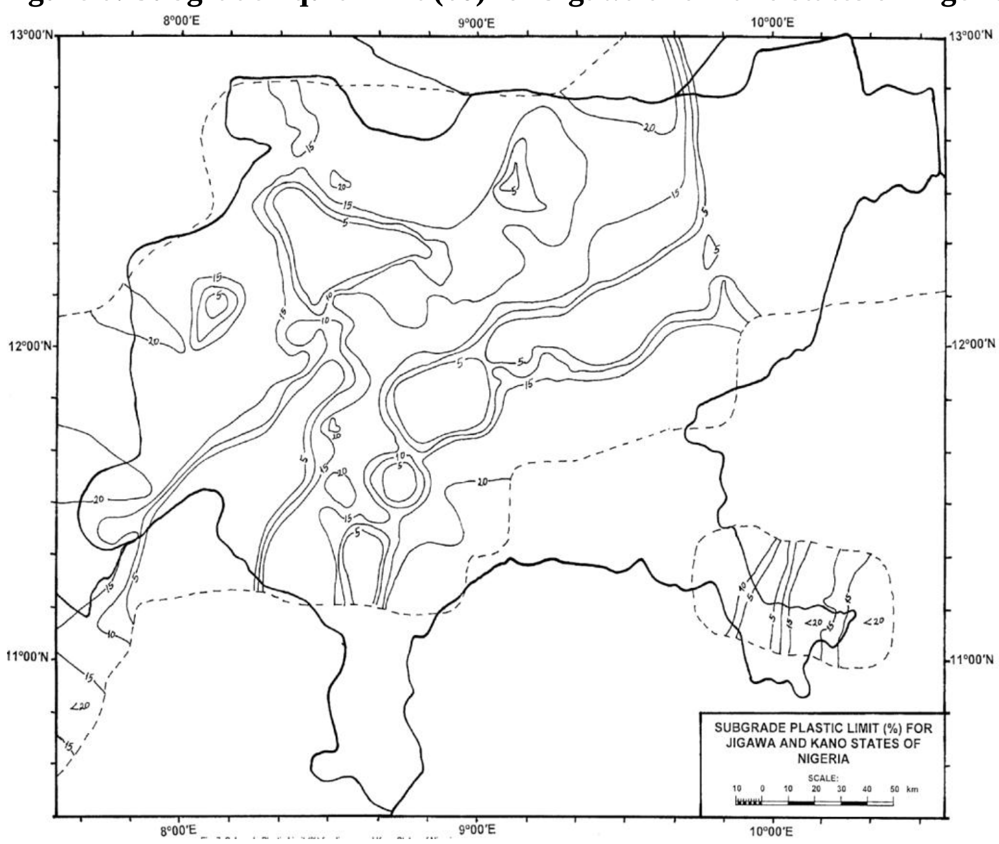

Figure 7: Subgrade plastic limit (%) for Jigawa and Kano states of Nigeria

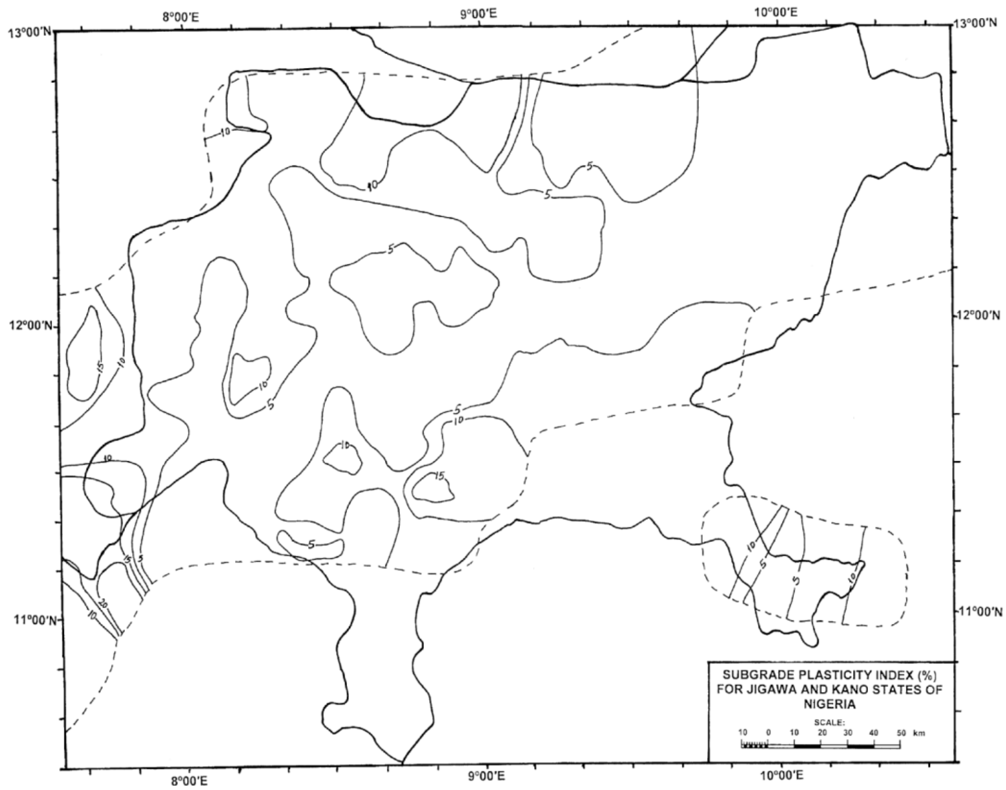

Figure 8: Subgrade plasticity index (%) for Jigawa and Kano states of Nigeria

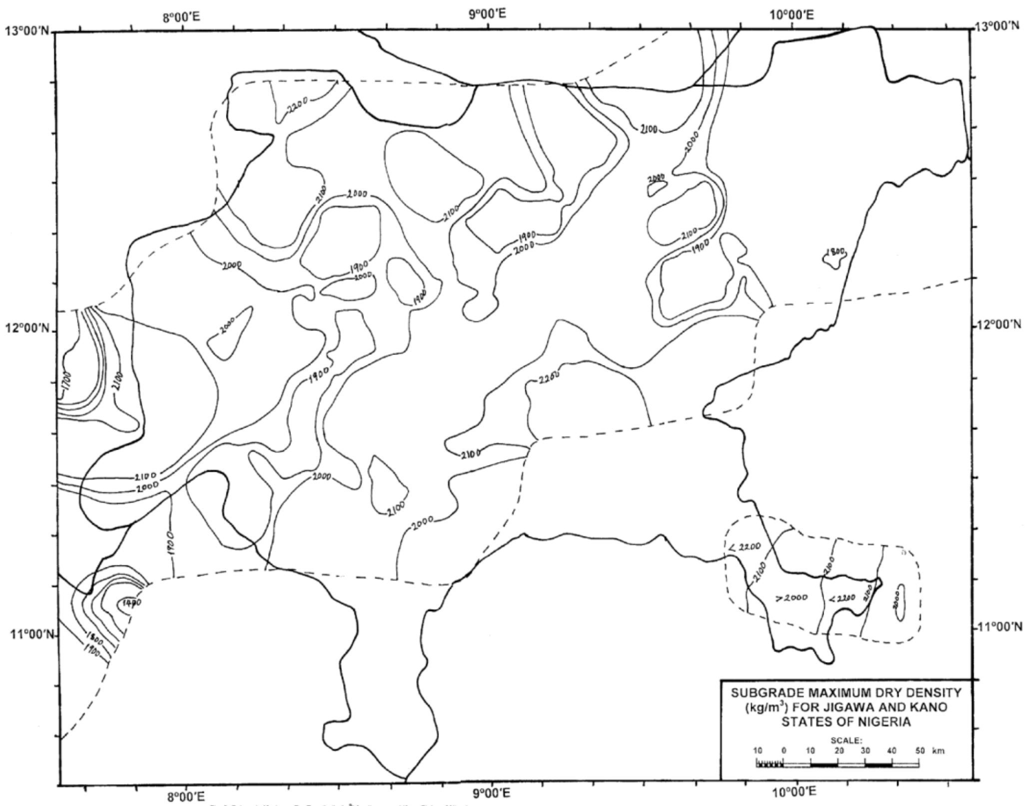

Figure 9: Subgrade maximum dry density (kg/m^3) for Jigawa and Kano states of Nigeria

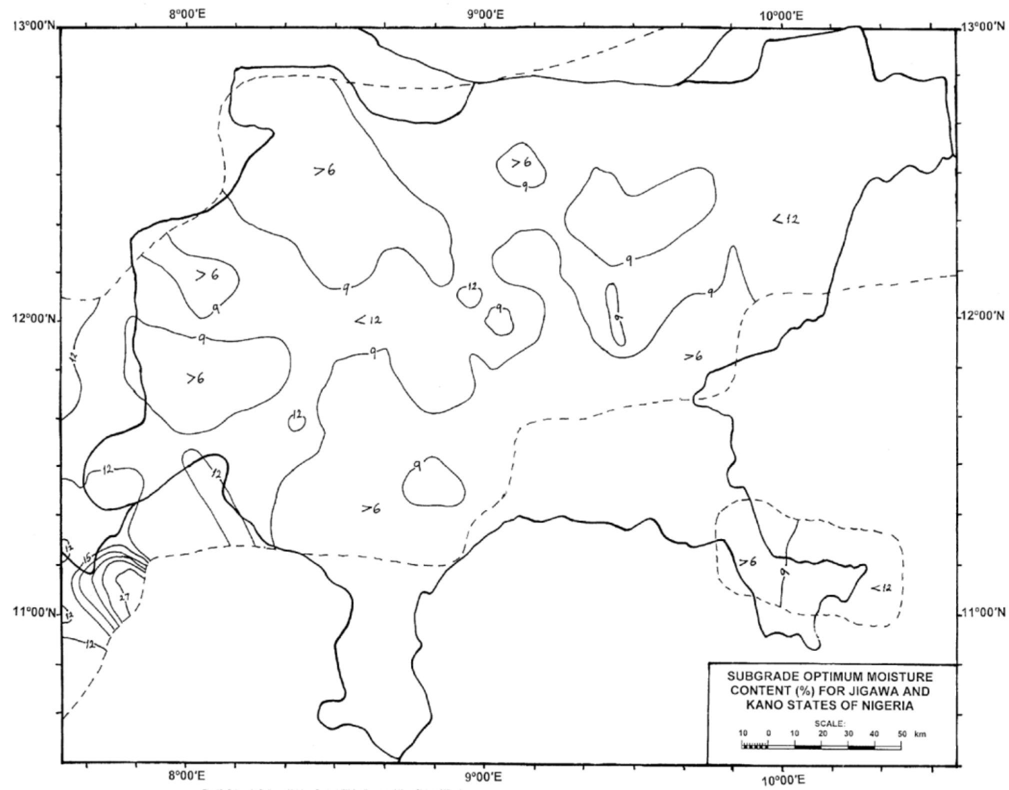

Figure 10: Subgrade optimum moisture content for Jigawa and Kano states of Nigeria

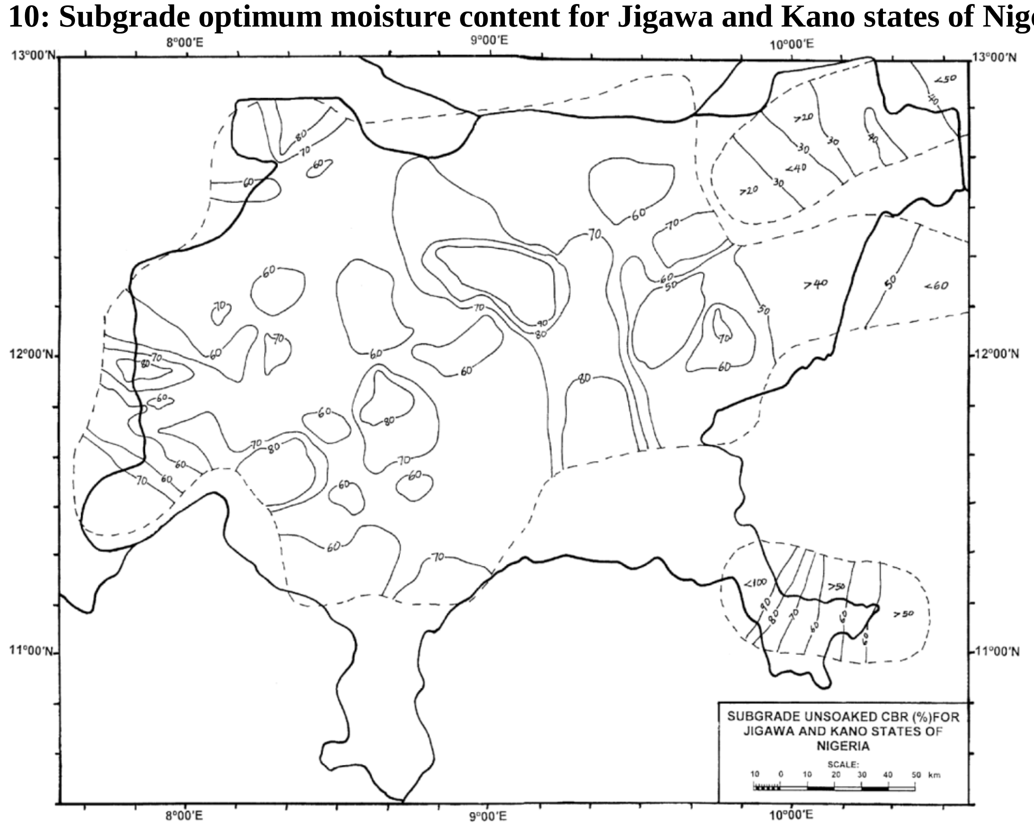

Figure 11: Subgrade unsoaked CBR (%) for Jigawa and Kano states of Nigeria

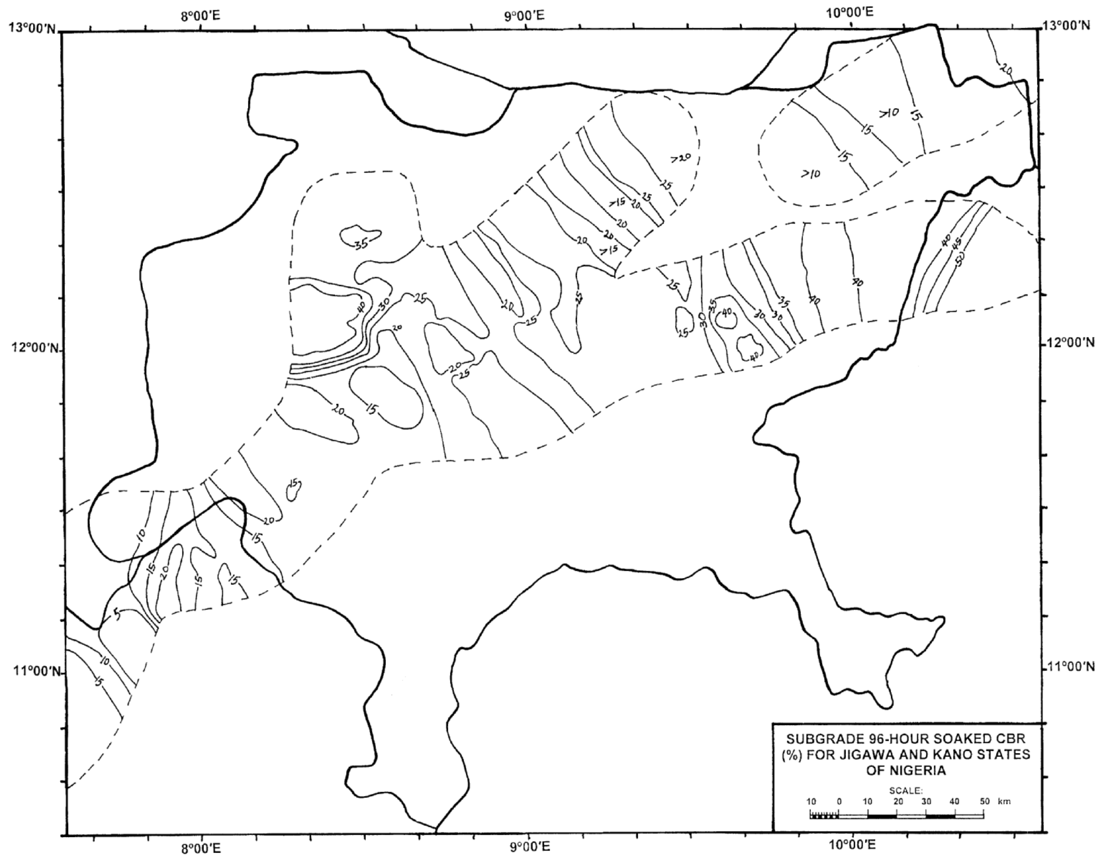

Figure 12: Subgrade 96-hour unsoaked CBR (%) for Jigawa and Kano states of Nigeria

The main strategy employed was the utilization of the results of past soils and materials investigations. For the purpose of this study therefore, data was collected from reports of past soils and materials surveys carried out by various consulting firms for the federal and various state governments along various road axes over various periods of time, from reports of soil research conducted by research institutes and laboratories of tertiary educational institutions, as well as from journals and conference proceedings on Nigerian soils. A major percentage of the information collected was from the Federal Ministry of Works, the Nigerian Building and Road Research Institute (NBRRI), Highway, Geotechnical and Civil Engineering Firms; and the Ministries of Works of some states, as acknowledged in Okunade (1998).

5. Interpolation and contouring methods

The maps were produced by automated procedures to eliminate the defects of manual and other procedures of subjective nature. The values of the soil properties for the engineering subgrade maps were interpolated using Shepard's algorithm (Shepard, 1968), a weighted-average technique which has been found to consistently produce desirable results. The AASHTO soil grouping is a property without a numerical value which could be interpolated. An algorithm for producing proximal maps was therefore employed for the AASHTO soil grouping map. In a proximal map, the "interpolated" value at any point is the value of the variable at the nearest data point location. The final contouring was done using raster techniques, after which the contours were traced by hand and superimposed on the base maps consisting of the geographical boundaries of the study area.

6. Discussion of results

In line with the geological, morphological, climatic and vegetation pattern of the study area, it is observed that the AASHTO soil grouping of the soil in the area is mainly A-2-4 and A-4, with some A-1-a, A-1-b, and A-2-6. The group indices are generally low (less than 2). Over the whole area, the grain sizes are predominantly gravelly and sandy with a moderate proportion of fines (generally less than 30%). The liquid limits are very low (below 30%) and the plastic limits much lower (below 20%). The resulting plasticity indices are generally low (less than 10%). The maximum dry densities are fairly uniformly high over the whole area (between 1,900 and 2,100 kg/m3). The optimum moisture contents are between 6 and 12%. The unsoaked CBR values are generally high (from 30 to 90%), but the 96-hour soaked CBR values are much lower (from 10 to 40%) though values up to 50% are obtained in a locality. From the study, it can be inferred that the subgrade soils in the study area are very suitable for road pavement construction purposes.

With these information, an atlas of isopleths of subgrade soil properties was therefore compiled and database formed. This atlas will be a source of primary information and reference for the use of consulting and practicing engineers, researchers, lecturers, students, as well as foreign consultants wanting to conduct investigations in the study area. The atlas will also be an invaluable aid to road planners, designers, highway engineers, contractors, etc., not only in road route location and land resource evaluation but also in the preparation for further detailed field work in the area of interest.

7. Conclusion

An “atlas” comprising the engineering (AASHTO) classification map and isopleths of subgrade soil properties of Jigawa and Kano States of Nigeria was compiled. The atlas will be a source of primary information and reference for the use of consulting and practicing engineering firms as well as institutions of higher learning and research in the study area. It will be expedient and cost effective in that it will eliminate the cost and drudgery of a preliminary investigation but may not preclude the site investigations necessary before the final location of the road project and/or during its actual execution.

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