X-Ray Analysis of Igbokoda Sand, Southwestern Nigeria and its Application in Manufacturing and Construction Industries

Damilola Akinniyi
The Hong Kong University of Science and Technology

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Ola S.A., Akinniyi, B.D., Agbede, O.A., Oluokun, G.O. and Akanbi, O.T.

Abstract— **Soils that appear whitish in colour is generally believed to contain mineral called quartz. Quartz is a metamorphic rock which is beneficial to manufacturing and construction industries. This quartz has been discovered in Igbokoda area of Ondo state, south western Nigeria. This study confirmed and examined the nature and abundance of quartz found in the study area for the purpose of recommendation to manufacturing and construction industries. Soil samples were collected within the area and examined. Geotechnical and x-ray analyses were conducted on the sample. A Phillip 71011 Goniometer at 55MA and 40KV was used to X-ray the sample at 2º/2θ/min/cm. The radiation and filter used were Copper and Nickel respectively. The specific gravity obtained classified the sample as sandy soil; the grain size distribution result according to AASHTO classified the sample as fine sand. The X-ray result confirmed that Quartz is the most abundant mineral in the sample with peak value of wavelength at 4.33Aº, 3.56Aº, 3.43Aº, 2.43Aº, 2.28Aº, 2.25Aº, 2.10Aº, 1.97Aº. Also, Kaolinite and Vermiculite traces appeared at 6.81Aº and 11.05Aº respectively. It was established that Igbokoda sand is dominated with quartz. It is therefore recommended that industries like fabricating industries can be located around the area to tap the mineral as raw material. The soil in the area is also suitable as sub base material in road construction.**

Index Terms— Goniometer, Igbokoda, Soil, Quartz, X-ray.

I. INTRODUCTION

Generally, minerals play a vital role in improving the engineering and geotechnical properties of soils [1]. It increases the efficiency and suitability of soils in different facet of engineering productions. And as the engineering field widens its scope due to increase in the need for infrastructural development all over the world, more research work are now being carried out to discover undiscovered minerals present in engineering material like soils and rocks to improve the efficiency of all engineering productions that depends on them. Sand is one of the three principal types of soil, the other two being clay and loam. Sandy soil like others is an essential element in the engineering world, as it is used in diverse ways to enhance and make production. It also contains many desirable minerals which quartz is most predominant of them all. Quartz is the second most abundant mineral in the Earth's continental crust, after feldspar [1]. Pure quartz, traditionally called rock crystal (sometimes called clear quartz), is colourless and transparent (clear) or translucent, and has often been used for hardstone carvings. Quartz is abundant in soils because of its hard and tough nature; it doesn't break up nor crumble into smaller pieces easily and it's more resistant to water and weathering than most other minerals you'll find at the surface of the Earth. Pure quartzite is usually white to grey, though quartzite often occur in various shades of pink and red due to varying amounts of iron oxide (Fe_2O_3). Other colors, such as yellow and orange, are due to other mineral impurities [2].

Quartz minerals in soil or sediment are found in a coarse fraction [3]. It may be noted that 95 percent of the minerals are light minerals and the heavy minerals constitute a small fraction of quartz, feldspar and micas minerals. Quartz is usually an important mineral because of the formation of soil from highly siliceous material which may be accumulated in the eluvisl horizens. On the other hand quartz may be absent in the clay fraction of the highly weathered oxisols [4].

Quartz is made up of a continuous framework of silicon–oxygentetrahedra (SiO_4), with each oxygen being shared between two tetrahedra, giving an overall formula SiO_2. There are many different varieties of quartz, several of which are semi-precious gemstones [1].Quartz is an essential constituent of granite and other felsicigneous rocks. This is very common in sedimentary rocks such as sandstone and shale and is also present in variable amounts as an accessory mineral in most carbonate rocks. It is also a common constituent of schist, gneiss, quartzite and other metamorphic rocks. Because of its resistance to weathering it is very common in stream sediments and in residual soils. Quartz, therefore, occupies the lowest potential to weather in the Goldich dissolution series.

Unfortunately, the identification of the minerals present in clay soils has been a major challenge to Engineers and recently this problem is receiving solution on daily basis through the innovation of equipment which identifies and quantifies the minerals present in soils [5]. The name of this equipment is energy-dispersive x-ray analysis (EDXA) spectrometry. It is also referred to as energy-dispersive x-ray microanalysis, x-ray microanalysis, electron microscopic

Ola S.A. *Civil Engineering Department, Federal University Technology Akure, Ondo State, Nigeria*.
Agbede, O.A. *Civil Engineering Department, University of Ibadan, Oyo State, Nigeria*. ***Mobile No:*** *+234-80-3384-7722.*
Akinniyi, B.D. *Civil Engineering Department, University of Ibadan, Oyo State, Nigeria*. ***Mobile No:*** *+234-80-3801-9431.*
Oluokun, G.O. *Civil Engineering Department, Adeleke University, Ede, Osun State, Nigeria*. ***Mobile No:*** *+234-81-3116-1719.*
Akanbi, O.T. *Civil Engineering Department, Adeleke University, Ede, Osun State, Nigeria*. ***Mobile No:*** *+234-07-3087-8044.*

microanalysis, and energy-dispersive x-ray spectrometry. Its operation is based on electron diffraction to permit the rapid identification of individual mineral present in a soil [5]. This approach is used in this study to establish the presence and abundance of quartz minerals in Igbokoda sand.

1.1X-ray Diffraction

There are diverse analytical techniques that soil samples are generally subjected to, these include atomic absorption spectroscopy (AAS), x-ray diffraction (XRD), infra-red spectral (IR) analysis, energy dispersive analysis of x-ray (EDAX), differential thermal analysis (DTA) and thermogravimetric analysis (TGA). The focus of each type of analysis is different; an XRD study identifies the minerals that are predominant in soil deposits and also identifies the minerals in trace amounts. EDAX, DTA, AR or IR can be used for approximate quantification of the mineral identified in the soil. In the past, chemical methods based on differences in resistance of various clay minerals to chemical attack, the so-called "rational methods of analysis," were used. This method is not as accurate as x-ray diffraction method.

Generally, there are two techniques used in carrying out x-ray analysis of soils and these include x-ray powder diffraction analysis and energy-dispersive x-ray analysis. X-ray powder diffraction analysis is the basic technique for clay mineral analysis [6]. After preliminary removal of sand, clay is separated from silt by centrifugation or sedimentation from suspensions. X-ray diffraction patterns are obtained and compared with standards for identification of minerals [7,8,9]. Comparisons are complicated, however, by variations in diffraction patterns arising from differences in amounts of absorbed water, by the presence of imperfections in the crystal lattice structure of the minerals, and by mixed-layer structures formed by interstratification of minerals within a single particle [7]. Approximate quantification of mineral abundance in samples containing several minerals is possible, although subject to a variety of complications and errors [11,12]

Transmission electron microscopy is valuable for identifying aluminosilicates with a distinctive morphology [9]. Particles dispersed on a plastic film can be observed directly by transmission microscopy or shadowed to increase contrast by evaporating a heavy metal onto specimens prior to examination. Many aluminosilicates (e.g., montmorillonite, which occurs as broad mosaic sheets decomposing into minute flakes) lack a distinctive morphology and cannot be identified by this technique.

Energy-dispersive x-ray analysis (EDXA) requires a scanning or transmission electron microscope equipped with an energy-dispersive x-ray spectrometer and appropriate mathematical tools for analysing the resulting spectra. EDXA identifies and quantifies elements above atomic number [10]. Since the basic classification of clay minerals is based on structural formula and the atomic composition is similar for different clay minerals, EDXA cannot provide secure identification except by comparison with standards previously identified by other means. Application of EDXA without appropriate standards is likely to generate significant errors [13]. In practice, EDXA is ordinarily combined with conventional transmission electron microscopy to first visualize a particle. Probe size is then adjusted downward so that only the selected particle is analysed. The best results are obtained by operating the microanalysis in scanning transmission mode.

[4] investigates the sediments of the Tapti River using XRD and SEM techniques to detect minerals present in the sediments and the minerals found include Quartz, Kaolinites, Calcite, Vermiculite, Polygorskite, Micas and Gibbsite. [14] also used XRD technique in the characterization of a Brazillian Smectite and the technique was able to establish the presence of Quartz and other minerals in the soil. [15, 16] and other have used X-ray diffraction techniques to quantify quartz in a soil and found very effective.

This study therefore employs x-ray diffraction to analyse Igbokoda soil in order to determine its mineral constituent and consequently produce judgement on its economic importance in engineering construction and manufacturing industries.

II. MATERIALS AND METHOD

Soil sample was obtained at Igbokoda area of Ondo State (Plate 1.0).The sample was collected at about 0.3m depth at two different locations within the same axis.

Plate 1.0: Igbokoda Sand, Ondo State, Nigeria.

The sample was subjected to geotechnical and x-ray analyses. The geotechnical tests carried out according BS 1377 include moisture content (oven drying method), specific gravity and grain size distribution.

X-ray analysis was carried out according to Robert V. Ruhe and Carolyn G. Olson (Estimate of Clay mineral content, Water Resources Research Centre and Department of Geology, Indiana University, Bloomington, Indiana); the following standard procedures were used for x-ray powder diffraction analysis:

- ❖ Oriented glass slides was prepared from the <2-µm fraction of the standard, then the soil sample was added.
- ❖ The sample was x-rayed following heating at 600ºC.
- ❖ A Phillips-Norelco XRG-2500 machine was used with Ni-filtered Cuk α radiation with a scanning rate per minute.
- ❖ Diffractograms readings were taken and recorded for each sample. Interpretation was done by comparing the peaks obtained with those of standard minerals established by [8] and [12]. The diffractometer used for this analysis is a Phillip 71011 Goniometer (55MA and 40KV). The sample was x-rayed at 2º/2θ/min/cm. The radiation and filter used were Copper and Nickel respectively. Therefore, the wavelength (λ) was 1.5418Aº (this depends on the type of radiation used). The diffraction "d" was obtained using Bragg's law equation;

$$n\lambda = 2d\sin\theta$$

III. RESULTS AND DISCUSSION

Accuracy is an important concern in engineering analysis, design and construction. This therefore necessitate an accurate quantitative mineral analysis of engineering materials like rocks and soils found on the earth for better application of them in engineering and industrial sectors. This study hence investigates Igbokoda sand to confirm the abundance of quartz mineral in the soil. There is already speculation that the soil has the mineral by local people. The analysis was done using x-ray diffraction which has proved very effective in the quantitative analysis of minerals in soil [4].

According to geotechnical test carried out on the soil samples collected the specific gravity obtained is 2.69 (Table 1.0) which falls within the range of specific gravity of quartzite [4]. According to AASHTO, the grain size analysis classified the sample as an A-3 soil (Table 1.0, Figure 1.0). This established that the soil is dominated with sandy soil [17,18].

Table 1.0: Classification test result

Test	Data
Specific Gravity	2.69
% Sand	85.12
% Clay	14.88
Classification	Sandy Soil

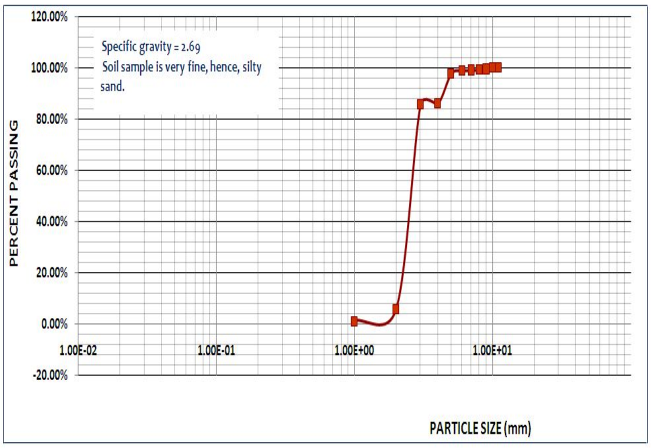

Fig 1.0: Particle Size Distribution Curve

Minerals in the clay fraction were identified from the oriented and powder diffraction pattern following the procedures highlighted in methodology above. Figure 2.0 shows the XRD patterns of sample analysed.
The result confirmed that quartz is the most abundant mineral in the sample as its peak appears at 4.33A°, 3.56A°, 3.43A°, 2.43A°, 2.28A°, 2.25A°, 2.10A°, 1.97A° [14]. This is in support of [4] result of the analysis of Tapti river sediment. X-ray diffractogram (peak) at 2θ =26.60° correspond to the quarts minerals at a spacing 3.338A°. Kaolinite and Vermiculite traces also appeared at 6.81A° and 11.05A°respectively (Figure 2.0).

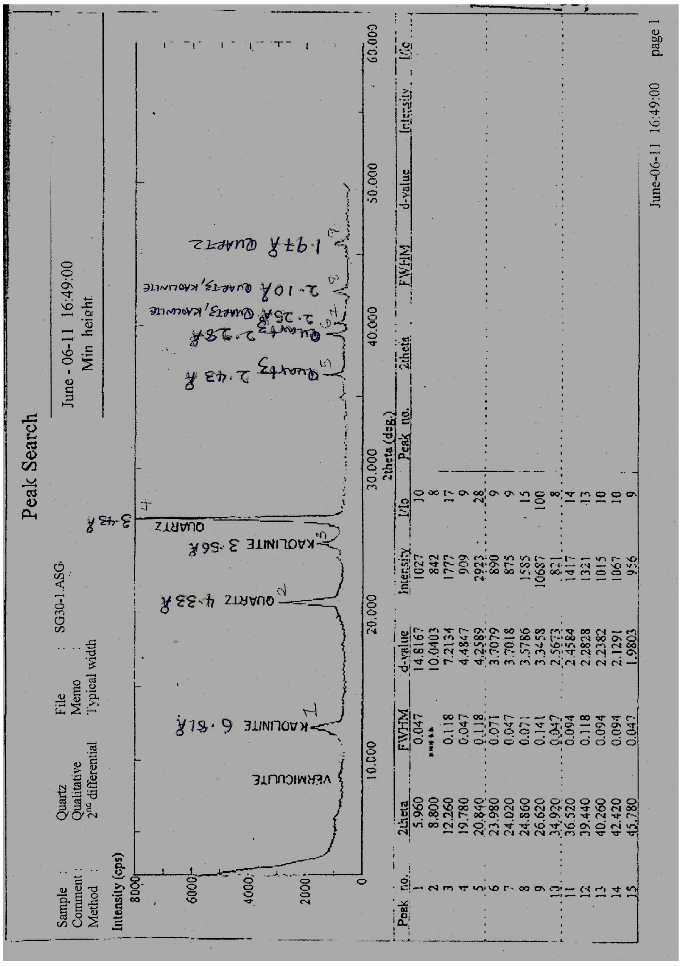

Figure 2.0: Identification of minerals in Igbokoda Sand using x-ray analysis result

IV. CONCLUSION AND RECOMMENDATION

The result of the various geotechnical tests conducted on the soil sample revealed that the soil sample collected is sandy soil and according to AASHTO using grain size analysis result the soil can also be described as a fine sand (A-3 soil) and hence a good sub-grade material.

This investigation established that the following minerals; vermiculite and kaolinite and quartz are found in Igbokoda soil with quartz dominating the soil sample collected. This seems to be naturally deposited in the area.

Considering the economic importance of quartz, it is recommended that industries like fabricating industry should be situated in Igbokoda area as this soil provides raw material which is an economic factor to consider in locating an industry. It is also usable in plastic industries. Furthermore, in construction, granite (coarse aggregate) and hardcore (which contains quartz) are very important material. Therefore, the town will be a good source of these materials for stone-pitching and control of erosion due to quartz's hardness and high resistance to weathering.

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