Experimental Assessment of Properties of Earth Soil Used in Concrete Production

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Abstract. Soil as an aggregate material is one of the major ingredients for concrete production. One of the soils used as a fine aggregate material for general construction most especially concrete production is the earth soil without resorting to its properties and mechanical analysis. It is based on this that the study assessed the physical properties of the earth soil and mechanical properties of concrete produced through it. In assessing the physical properties' quality of the earth soil sampled analysis such as grain size distribution, percentage of silt content, water absorption, loose and rodding bulk density, specific gravity, and percentage of void were carried out. Also, mechanical properties of concrete produced with the earth soil were carried out using the compressive strength testing machine. The finding of the study showed that the result of the property analyses carried out on the earth soil does not meet the expected result as stipulated in ASTM C29 / C29M-17a. Also, the result of the mechanical properties of the concrete produced showed that the strength of the concrete decrease as the age of the concrete progresses from 11.23\% (7 days), 6.87\% (14 days) to 13.12\% (28 days). The study suggested that the earth soil is not a standalone aggregate material suitable for construction work most especially concrete production. The study concluded that to boost the property quality of the earth soil, a certain percentage of the aggregate should be stabilized using a well graded fine aggregate material such as river sand in order to boost its suitability for general construction work most especially concrete production.

Keywords: Earth soil, Silt content, Water absorption, Bulk density, Specific gravity.

1. Introduction

According to Awofeso [1], a high percentage of low-income earners in developing countries cannot afford decent housing even with 100\% of their income saved for between 7-10 years. Because of this, most homeowners in developing countries would prefer the use of locally sourced materials to build their houses [2]. As noted by World Bank [3], Ogunbayo [4] & Ogunbayo [5] high cost and scarcity of
building materials have led to most homeowners relying on locally sourced construction material including aggregates. This is because most citizens are looking beyond the government housing schemes that have not effectively addressed their housing needs [6]. However, Ogundipe [7], Afolabi [8] & Nduka [9] postulated that in using a locally sourced material for construction work or construction products including concrete production the material should meet with relevant standards. Afolabi [8] & Ogunbayo [10] posited that the use of locally sourced construction materials should be encouraged because of its availability as against the use of imported materials that is scarred and susceptible to releasing harmful materials through it preservatives on users. As noted by Khyomesh [11] & Ojerinde [12] they stated that of the total cost of building construction material accounts for 60-70% of the total amount. Hence, the use of available, cheaper, and suitable local sourced construction materials such as earth material could contribute to building construction sustainability [12], [13], [14]. Additionally, Kulkarni [15] & Ogunbayo [16] opined that toward this end in building construction earth material might be found useful. Karkush [18] described earth soil as colluvial soil formed by the movement of soil from its original place by gravity through action such as weathering process, landslide, and chemical alteration of rocks to form soil at or near earth’s surface. However, Ojerinde [12], Ogunbayo [13] & Kulkami [15] postulated that the use of earth soil is not new in the construction of building most especially in the developing economy. They asserted that it is of importance to improve the quality, durability, and strength of such earth material if envisioned for construction of buildings meant for dwelling purpose. To this end, the investigation to understand the physical and mechanical properties of the earth material for usage in construction work most especially concrete production have been the focus of many researchers in developing countries [12], [18], [19], [20], [21]. For instance, Awoyera [20] reported that there was high strength value for a higher percentage of earth soil in the mortars tested in the mechanical strength of earth soil and ceramic waste experimented. Also, other researchers that concluded researches on physical and mechanical properties on earth soil include [22], [23]. Other researchers such as Olofinlade [21] investigates pulverized fired clay brick wasted gotten from earth soil as a partial replacement for Portland cement combined with waste glass powder in the production of mortar. Also, Subbarao [25] produced concrete pavement and sandcrete blocks from mixing red earth soil with measure cement. To reduce building production cost, Ojerinde et al [12] considered potentials of earth soil combined with rice husk ashes in the production of compressed earth block (CEB). Although, Akinymi [18] posited that the earth soil would provide a better alternative to river sand which is a major constituent of concrete production within most developing nations. However, Ojerinde [12] affirm that there is little or no reported strength parameter of earth soil used for concrete production. From the review, it can be deduced that there is seemed to be several studies on the usage of earth soil as replacement aggregate material in the production of components of building such as concrete, sandcrete block among others. However, there exists a dearth of study on the assessment of physical and mechanical properties of earth soil used for concrete production and as a replacement material.

2. Material and Method

For this study, earth soil was obtained from site in Awela-Arepo area of Ijoko, Ogun State, Nigeria in accordance with [25]. In having a good basis in assessing the physical properties’ quality of the earth soil, analysis such as grain size distribution, percentage of silt content, water absorption, loose and rodding bulk density, specific gravity, and percentage of void were carried out on the aggregate sampled in accordance with [25], [26], [27] & [28]. In the production of concrete, type-1 of currently supply contamination-free ordinary Portland cement (BUA brand) of 42.5R grade was obtained and used for the production of the concrete in accordance with [29]. Concrete produced with the earth soil
and crushed granite was mixed base on M15 concrete grade with a mix design of 1:2:4 using clean water devoid of impurities and good for consumption in accordance with [30]. The mechanical properties of the concrete produced after curing were determined through the compressive strength test of the concrete cube for 7 days, 14 days and 28 days as postulated in [30] & [31]. In assessing earth soil sampled the following equipment were used for both physical and mechanical properties which include digital weighing balance, tamping rod (25mm size), straight edge, cylindrical metal measure (3litre), thermostatically oven, scoops, shovel, hand trowel concrete steel cube, wheelbarrow among others. The compression testing machine Model YES-2000, Max.Capacity:2000KN Production No: W1010, Production Date: July 2010 was used to determine the strength parameters of the concrete produced. Additionally, the dimension tolerance was measured when the experiment was carried out as reported by [19] & [21]. Also, the safety procedure for the study was strictly in line with the recommendation of [7].

3. Result and discussion

3.1 Grain size distribution

In accordance to BS EN [25] the grain size property analysis of the earth soil (fine aggregate) and granite (coarse aggregate) used for the concrete specimen was carried out. The result of the analysis based on Figure 1, 2 and Table 1 indicated that the aggregate sampled have a coefficient of uniformity (Cu) of 5.33 (earth soil) and 4.50 (granite), as well as co-efficient of curvature (Cc) of 2.52 (earth soil) and 1.07 (granite) respectively. As shown in Table 1, the earth soil according to the unified soil classification system (USCS) as postulated by [26], is not uniformly graded and can be classified as a poorly graded sand (SP) since Cu < 6 and/or Cc < 1 or Cc >3. It is of significance to note that a poorly graded fine aggregate cannot be well compacted like a well-graded fine aggregate [26]. Additionally, based on the USCS ASTMD [28], the granite could be adjudged as well and uniformly grade gravel since Cu ≥ 4 and 1 ≤ Cc ≤ 3. As shown in Table 1, the earth soil samples do not satisfy the particle size requirements for general construction work including concrete production.

![Grain size distribution of earth soil sampled (fine aggregate)](image-url)

Figure 1. Grain size distribution of earth soil sampled (fine aggregate)
Figure 2. Grain size distribution of granite sampled (coarse aggregate)

Table 1. Physical properties of earth soil sampled

| Specimens    | \(D_{10}\) | \(D_{30}\) | \(D_{60}\) | \(C_u\) | \(C_c\) | USCS (Grp. symbol) |
|--------------|------------|------------|------------|--------|--------|-------------------|
| Earth soil   | 1.50       | 5.50       | 8.00       | 5.33   | 2.52   | SP                |
| Coarse aggregate | 3.00       | 6.59       | 13.50      | 4.50   | 1.07   | GW                |

Formulations: \(C_u = D_{60}/D_{10}\), while \(C_c = (D_{30})^2/D_{10} \times D_{60}\)

3.2 Percentage of silt content of earth soil sampled

The result from Table 2, revealed that the earth soil as an average percentage of 6.88% of silt, this specified that the silt content of the sampled aggregate increased by 14.67% as against the minimum of 6% silt content for fine aggregate as postulated in [27]. The result showed that the percentage of silt content in the aggregate sampled is very high. This might be due to the presence of a high percentage of silty soil materials (clay and loam) in the earth soil within the study area sampled. The result revealed that the earth soil sample will require high amount of paste to coat its surface in order to left more paste for lubrication during concrete production.
Table 2. % of Silt content of earth soil sampled

| Specimens       | Sample tag | ES1  | ES2  | ES3  |
|-----------------|------------|------|------|------|
| Earth soil      | Vol. of soil | 5.50 | 8.00 | 5.33 |
| % of silt present | 6.59       | 13.50| 4.50 |
| Average % of silt (%) | 6.88       |      |      |      |

Formulation: (volume of silt/volume of soil *100%).

3.3 Water Absorption value of earth soil sampled

The result as shown in Table 3, shows an average water absorption value of 6.3 % for the earth soil sampled. As indicated in Table 3, the average water absorption value for the earth soil sample is > 3% and this does not satisfy absorption values of < 3% expected for fine aggregate as specified by postulated by [28]. The finding of the study revealed that the earth soil does not satisfy the water absorption rate expected for fine aggregate require for construction work including concrete production. The high rate of water absorption of the sampled aggregate could be attributed to high silt contained in the earth soil whereas, silt tends to retain more than well graded-fine aggregates.

Table 3. Water absorption value of earth soil sampled

| Soil Specimens | Analysis Description                  | Sample 1 | Sample 2 | Sample 3 |
|----------------|--------------------------------------|----------|----------|----------|
| Wet (W₁)       | Weight of vessel+ Soil + Water (g)    | 300      | 300      | 300      |
| Dry (W₂)       | Weight of vessel+ Soil + Water (g)    | 284.5    | 281.5    | 280.8    |
|                | Water absorption value %              | 5.49     | 6.57     | 6.84     |
|                | Average Water absorption value %      |          |          | 6.3      |

Formulations: (W₁-W₂ / W₂ * 100%)

3.4 Loose and Rodded bulk density of earth soil sampled

The result in Table 4, showed that earth soil sampled as an average loose bulk density of 1.561 kg/ltr, and an average rodded bulk density of 1.766kg/ltr. The result indicated the loose bulk density for the sampled earth soil does not meet with a value of between 1520-1680 kg/ltr expected for fine aggregate used for construction work include concrete production as stipulated in [28]. Nevertheless, after the sample was rodded by applying 25 evenly distributed strokes of tapping rode to each layer surface, the bulk density of the aggregate increased to 1.766kg/ltr kg/ltr. This showed that the bulk density value for the sampled earth soil increases by 6.25% as against 1520 -1680 kg/ltr as stipulated by [28].
Table 4. Loose and Rodded Bulk density of earth soil sampled

| Description                  | Vol. of meas. metal (ltr) | Empty weight of meas. Metal (kg) | Weight of meas. metal + aggr. (kg) | Net weight of aggr. (kg) | Density of aggr. (kg/ltr) | Av. bulk density of aggr. (kg/ltr) |
|------------------------------|---------------------------|----------------------------------|-----------------------------------|--------------------------|--------------------------|---------------------------------|
| Loose bulk density (R)       | 3                         | 6.875                            | 4.189                             | 1.590                    | 1.561                    |
| Rodded bulk density          | 3                         | 6.879                            | 4.193                             | 1.561                    |

Note: The condition of the aggregate sampled was dry when carrying out the loose and Rodded bulk density analysis

3.5 Specific gravity and percentage of void in the earth soil sampled

The result in Table 5 showed values for the specific gravity (Gs), loose bulk density (R), and percentage of void present in the earth soil sampled. The revealed that the earth soil has a Gs value of (2.42), R-value of (1.561), and percentage of void (55.02%). The finding of the study indicated that the Gs value does not fall within the recommended value of between 2.50-3.00 for normal weight well-graded fine aggregate as specified in [27]. Also, the finding revealed that the percentage of the void in the earth soil sampled increases by (10%) as against expected void of 45% - 50% for normal weight well-grade aggregate as stipulated by [28].

Table 5. Specific gravity and percentage of void in earth soil sampled

| Aggregate properties       | Unit | Earth soil |
|----------------------------|------|------------|
| Sample size                | mm   | 4.75       |
| Specific gravity values    | Gs   | 2.42       |
| Loose bulk density         | R    | 1.561      |
| Void in aggregate          | %    | 55.02      |

Formulation for void %: (Gs-R/R*100%); where Gs = specific gravity of aggregate while R=Loose bulk density of aggregate sampled

3.6 Mechanical analysis of concrete strength

The result in table 6 showed that the concrete cube produced with the earth soil has a bulk density of 2133kg/mm³ (7days), 2222 kg/mm³ (14days), 2256 kg/mm³ (28 days). Also, the result revealed the average strength of 8.99 N/mm³ (7 days), 13.10 N/mm³ (14 days), and 13.26 N/mm² (28 days) for tested mechanical properties of concrete cubes produced with sampled earth soil and other adhesive concrete materials. The finding of the study indicated that as at 28 days the bulk density of the concrete produced reduced by (6.38%) as against expected bulk density of 2400 kg/mm³ maximum
expected for concrete as postulated by [28], [31]. Additionally, the finding of the study reveal that in accordance with ASTM [30] strength grade for M15 concrete with mixed ratio of 1:2:4, the strength of the concrete produced reduces by 11.23% (7 days), 6.87% (14 days), and 13.12% (28 days). The implication of this result is that as the age of concrete progresses there is a decrease in the strength of concrete produced with the earth soil.

Table 6. Concrete density and Mechanical properties of concrete produced

| Age (days) | Cube weight (kg) | Cube volume (mm³) | Cube Density (kg/mm³) | Cube 1 (N/mm²) | Cube 2 (N/mm²) | Cube 3 (N/mm²) | Average strength (N/mm²) | ASTM M15 grade conc. Str. (N/mm²) |
|------------|------------------|-------------------|-----------------------|---------------|---------------|---------------|-------------------------|----------------------------------|
| 7          | 7.2              | 0.003375          | 2133                  | 8.92          | 9.01          | 9.05          | 8.99                    | 10 (65%)                         |
| 14         | 7.5              | 0.003375          | 2222                  | 13.05         | 13.25         | 12.99         | 13.10                   | 14 (90%)                         |
| 28         | 7.6              | 0.003375          | 2256                  | 13.42         | 13.15         | 13.26         | 13.26                   | 15 (99%)                         |

150mm size concrete cubes were used for the experiment

4.0 Conclusion

The study assessed the physical properties of earth soil and the mechanical properties of concrete produced through it. The result of the physical properties shows that earth soil sampled was not uniformly graded and can be classified as a poorly graded sand and does not satisfy the particle size requirements for general construction work including concrete production. The result also shows that the percentage of silt content (6.88%) in the earth soil is very high as against the minimum of 6% silt content for fine aggregate required for concrete production. This might be due to the presence of a high percentage of silty soil materials (clay and loam) in the earth soil. The study further shows an average water absorption value of 6.3% for the earth soil sampled, this indicated that water absorption value for the earth soil sample is > 3% and it does not satisfy absorption values of < 3% expected for fine aggregate require for construction work including concrete production. The result also shows that earth soil sampled as an average loose bulk density of 1.397kg/ltr, and average rodded bulk density of 1.581kg/ltr. The result indicated that the loose bulk density for the sampled earth soil does not meet with a value between 1520-1680kg/ltr expected for fine aggregate used for construction work include concrete. The study also revealed that the earth soil sampled has a Gs value of (2.42) and percentage of void of (55.02%). This result indicated that the Gs does not fall within the recommended value of between 2.50 to 3.00 for uniformly graded fine aggregate. It also shows that the percentage of void in the earth soil sampled is far above the void of 45% - 50% expected in a well-graded fine aggregate. Additionally, the result of the mechanical properties of the concrete produced with earth soil sampled together with other adhesive material showed an average compressive strength of 8.99 N/mm² (7 days), 13.10 N/mm² (14 days) and 13.26 N/mm² (28 days). The indication of this result is that the strength of the concrete produced reduces by 11.23% (7 days), 6.87% (14 days), and 13.12% (28 days), this shows clearly that as the age of the concrete progresses there is a gradual decrease in the strength of concrete produced with the earth soil. The result shows that the strength of the concrete produced is
not in conformity with the strength of concrete produced with M15 grade. The result of the findings of the study showed clearly that the earth soil is not a standalone aggregate material suitable for construction work most especially concrete production and other related concrete product such as sandcrete block moulding. The study therefore, concluded that to boost the property quality of the earth soil, a certain percentage of the aggregate should be stabilized using a well graded fine aggregate material such as river sand in order to increase it suitability for general construction work most especially concrete production. The study suggested that further study should be carried out on the suitable replacement aggregate materials and its impact on the physical properties and mechanical properties of the earth soil.

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