Index Properties of Aluminum Dross Modified Pavement Geo-material

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Abstract.
The recovering of aluminium from aluminium dross waste involves so much cost and energy. As a result, there is a need for its utilization as an engineering material. This research assessed the suitability of aluminium dross waste in improving the index properties of pavement geomaterial. Aluminum dross, a solid waste from aluminum industry was added at 4%, 8%, 12%, and 16% by weight of the lateritic soil sample. Sieve analysis, Atterberg limit, specific gravity test, Compaction test, and California bearing ratio (CBR) were carried out on the samples. The increased addition of aluminium dross to the sample reduced the plasticity index from 15% to 13.8%, which showed an improvement in the soil sample. Also, the CBR value increased from 51.22 to 64.32 with the addition of aluminum dross which signifies increased strength of the stabilized soil sample. The increase in strength of the aluminum dross stabilized soil is due to the good binder–matrix interaction of aluminum dross and the soil. The result of this experimental research showed that the utilization of aluminium dross in improving the strength properties of pavement interlayer proved to be a sustainable alternative.

Keywords: (Aluminum Dross, stabilization, Lateritic soil, Solid waste, Engineering test, Preliminary Test, Construction)

1. Introduction
Aluminum Dross is a by-product of aluminum production. Today much energy is consumed to recover aluminium from the dross; this energy could be saved if the dross is diverted and utilized as an engineering material [1]. The use of aluminum dross as a stabilizing agent has not been well utilized like other stabilizers. Research by [2] showed the usage of white/black dross in concrete and asphalt products and concluded that there is significant potential for its use as a filler (<700µm). The same author emphasized that utilization of this material as a filler in asphalt may improve stiffness and it is thought that it could also improve abrasion resistance and control micro-cracking. Although road construction has been the major area of application of stabilization techniques, they have also been applied to soil foundation strengthening [3].

Aluminum dross is one of the waste products obtained during aluminum refining. It consists of metal, salts oxides, and other non-metallic substances [2]. According to [4] aluminum dross is classified according to their metal content into white and black dross. White dross is of higher metal aluminum content and it is produced from primary and secondary aluminum smelters, whereas black dross has a lower metal content and is generated during aluminum recycling (secondary industry sector). Approximately, up to 4 million tonnes of white dross and more than a million tonnes of black dross are reported throughout the world each year, and around 95% of this material is landfilled [4-5]. Aluminum dross as a solid waste showed promising characteristics in improving the engineering properties of soils based on its chemical composition as seen in figure 1. Soil improvement in the form of soil stabilization is any treatment applied to a soil to improve its strength and reduce is vulnerability to water. This makes the treated soil to be able to withstand the stresses imposed on it by traffic under all weather conditions without deformation, and then it is generally regarded as stable. This definition applies irrespective of whether the treatment is applied to a soil in situ or after the soil has been removed and placed on a pavement or embankment [6]. This was further buttressed by [7] who defined soil stabilization as the process of improving the physical and engineering properties of a soil to obtain some predetermined...
engineer targets. Different types of stabilizing agents have been used in the past from organic to
inorganic. The inorganic types of stabilizing agents have been popularly applied to soil stabilization,
such as cement Bell, ([7], lime McKinley et al [8], Cai et al. [9], fly ash and their mixtures; Ouhadi and
Goodarzi, [10], Zhu and Liu, [11].
In a bid to have an eco-friendly environment, improve trash to treasure initiative in road construction
with the target of improving geometrical strength, the use of aluminium dross was adopted in this
research.
1.2 Motivation
The Use of aluminium dross waste has been used to make refractory materials such as brick or used in
concrete as filler. The utilization of this waste, improves stiffness, abrasion resistance, and control micro-
cracking of material [2]. According to the analysis of the author, the other elements with 27% comprises
of compounds common to pozollanic materials. Additionally, mechanical property evaluations revealed
the possibility for dross waste to be utilized as an active aggregate in concrete, resulting in up to 40%
higher flexural strength and 15% higher compressive strength compared to pure cement. This unique
strength properties of aluminium dross waste motivated this research so as to come up with a strong and
durable pavement.

2.0 METHODOLOGY

2.1 Materials
The materials used for this study were lateritic soil, water and Aluminum Dross (ALDS). The lateritic
soil was collected from a laterite borrow pit at kilometer 10, Idiroko road Ota, Ogun state, Nigeria
(Latitude 6°40’52" N and Longitude 3°9’11” E). The sample is reddish brown in colour (Plate 2). They
were all collected at depths representative of the soil stratum and not less than the 1.2m below the natural
ground level. The organic matters, small aggregates, broken wooden material, pieces of glasses are
removed carefully from a soil sample. Previous investigations conducted on the lateritic soil indicated
that oven drying significantly changes its plasticity and compaction properties [12]. Therefore, all mix
designs for this type of soil were prepared from air-dried soil. The Aluminum dross used in this study is
obtained from Aluminum Rolling Mills dump site Ota Ogun state, Nigeria. (Plate 1). The Aluminum
dross samples were crushed to reduce its particle size down to less than 0.425 mm. It was sun-dried to
eliminate natural water and sieve through sieve 425µm (Plate 1). Pipe borne water was from Covenant
University, Ota Ogun State, Nigeria.
2.2 Sample Preparation
The air-dried aluminum dross and lateritic soil were broken into smaller sizes and sieved through a 2mm sieve. The sieving was done to ensure that the soil was of uniform grade throughout the experiment as avowed by [13]. The required amount of water known as optimum water content (OMC) was determined for the natural soil. Aluminium dross was added to each of the soil samples in 4%, 8%, 12%, and 16% by weight of the soil sample. The preliminary test includes: Natural water content, Sieve analysis, Specific Gravity, Atterberg limit and CBR.

2.3 Methods
Disturbed samples of lateritic soil were collected and subjected to tests to determine index properties, particle size distribution, soil classification and compaction characteristics in accordance with the procedures described in [14].

The stabilization was done at 0%, 4%, 8%, 12% and 16% of ALDR by dry weight replacement of the soil sample. Atterberg limit test which includes the liquid limit and plastic limit were determined in accordance with [15] as specified by Head (1992). Strength index in the form unoaked CBR tests was carried out in accordance with the procedure outlined in [16]. The specification relating to the use of these parameters for highway design and construction in Nigeria are given in Nigerian General Specifications [17]. All the soil samples for tests were air dried for 1 day before testing in order to simulate field conditions.

3.0 RESULTS AND DISCUSSION
3.1 Summary of the Preliminary Analysis of Soil Samples
It was observed that the percentages passing 75μm sieve was less than 35%. According to the Liquid Limit (LL) and Plastic Index (PI), of 43 and 15 respectively, the soil was classified as A-2-6 based on AASHTO Soil Classification System (Table 1).

Table 1: Classification Test.

| Natural Moisture Content | 8.6 |
|--------------------------|-----|
| Liquid Limit             | 43  |
| Plastic Limit            | 28  |
| Plastic Index            | 15  |
| AASHTO Soil Classification System | A-2-6 |
| Max Dry Unit Weight (KN/m3) | 1.79 |
| Optimum Moisture Content (%) | 15.6 |

3.2 Index Properties
In this research, Plastic Index (PI) and Liquid Limit (LL) of the sample was 14.75 and 42.87 respectively. Hence the sample was within the range of intermediate plasticity. Plasticity index according to [18] has its own range too; plasticity index of 10 – 20 is an indication that the plasticity is medium.

![Plastic limit versus % Replacement](image-url)
The result showed that a positive relationship exists between the plastic limit and Aldr addition up till 16% (Figure 4). There exists an increment in the plastic limit from 28.02% to 40.8%. The almost flat curve of the liquid limit and plastic limit can be explained by the predominance of kaolinite, with its low cation exchange capacity in the laterite soil of Southwest Nigeria as reported by [19].

![Liquid limit](image1.png)

Figure 3: Liquid limit of the sample with ALDR

The addition of Aldr to the sample reduced the plasticity index from 15.1% to 13.8%. This showed an improvement in the soil sample (figure 3). The result showed that the addition of aldr from 8% reduced the plasticity index of the stabilized sample. This is an indication that the index property of the soil sample improved upon the addition of aldr. The soil sample improved from a subgrade material to a subbase material. This may be due to the presence of silicon oxide, aluminium oxide and calcium oxide, according to [20] these oxides are known to have pozollanic characteristics.

![Plasticity Index](image2.png)

Figure 4: Plasticity Index: of the sample with ALDR

3.3 Plasticity index of the sample with ALDR
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3.4 ENGINEERING TEST
3.4.1 Effect of Compaction on Strength Indices (Maximum Dry Density)
The result of compaction test carried out showed clearly the effect of aluminum dross residue on maximum dry density (MDD). Figure 5 showed that at every increase in aluminum dross residue content, the MDD obtained decreased in value, however the highest MDD was obtained at 8% addition of Aldr.
3.4.2 Optimum Moisture Content (OMC)

It can be deduced that more moisture was required to make the stabilized sample reach its maximum density, which is an indication of the effect of the stabilizing agent. This reduced the available pore spaces in the compacted samples, thereby making it relatively difficult for water to be absorbed by the stabilized sample as compared to the un-stabilized sample. The graph of optimum moisture content (OMC) against aluminum dross residue content in figure 6, presents the relationship between aluminum dross residue content and optimum moisture content which increased from 15% to 19%. There is an increment in the optimum moisture content. The increase in OMC is probably due to the additional water held within the flocculent soil structure due to excess water absorbed [21].

The relationship between Maximum Dry Density and Moisture Content and is as shown in figure 8.

3.4.3 California Bearing Ratio (CBR)

Upon the addition of Aldr to the soil sample, the load-bearing capacity of the soil increased which indicated an improvement in the soil strength index as seen in figure 8. This follows a similar trend with bagasse ash and corn cob ash by [19-20] respectively. Further increment in the percentage of aluminum dross increased the CBR from 51.22% to 62.41% (figure 6) although the increment is not as high as that of the conventional stabilizers according to research carried out by [20]. Thus, the increase in strength of the aluminum dross stabilized soil is due to good binder–matrix interactions. Also, the Agglomeration of particles of the aluminum dross may cause pockets of air between particles leading to increasing in density of a stabilized sample which may affect the strength index of the stabilized sample. The improvement of the strength properties of pavement interlayer is important for effective and efficient transportation [21-26] which is key to national growth.
Conclusion

This experimental research assessed the suitability of aluminum dross in improving the strength of lateritic soil for pavement construction. The soil sample and stabilized samples were subjected to atterberg limit and CBR test. The result of the research revealed that:

- The addition of Aldr to the sample reduced the plasticity index from 15.1% to 13.8% which signifies an improvement in the soil index properties.
- Aluminum dross residue content increased the optimum moisture content increased from 15% to 19%. The increase in OMC is probably due to the additional water held within the flocculent soil structure due to excess water absorbed.
- Further increment in the percentage of aluminum dross increased the CBR from 51.22% to 62.41%
- Thus, the increase in strength of the aluminum dross stabilized soil is due to good binder –matrix interactions.

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