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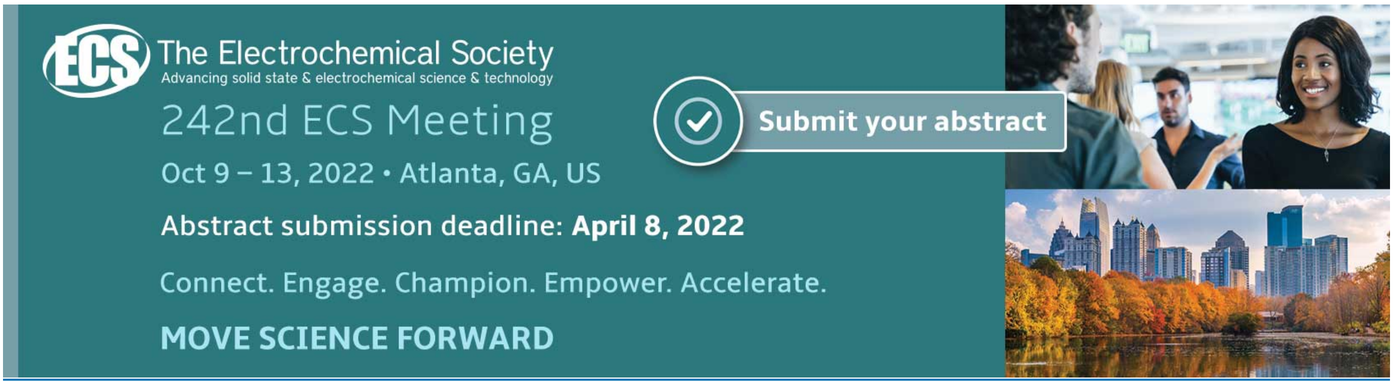

# Assessment of the Engineering Properties of Modified Asphalt Using Aluminium Dross as a Filler

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**Abstract.** Aluminum dross waste creates environmental burden for manufacturers and hence the need for its re-use. This experimental research assessed the engineering properties of modified asphalt using aluminium dross as a filer material. The aluminium dross used was obtained from a steel manufacturing industry. Elemental composition of the oxides was done using XRF equipment. Sieve analysis of the aluminium dross and the coarse aggregate was also assessed. Additionally, ductility, penetration, ball and ring and Marshall stability test were used in achieving the aim of this research. The outcome of the research revealed that 10-20% addition of the aluminium dross improved the stability of the modified asphalt. Physical observation revealed that the utilization of the waste stiffened the modified asphalt. The result showed that the addition of aluminium dross reduced the VMA. This will also increase the asphalt mix flushing. Additionally, at higher percentage addition of the waste the stiffness of the asphalt mix increases especially at a higher temperature. The use of this material will help in the reduction of solid waste and reduce the cost of management while reducing the cost of pavement construction in track with the trash to treasure drive.

**Keywords:** Asphalt; Aluminium Dross; Pavement; Bitumen; Flexible Pavement; Transportation

## 1. Introduction

### *1.1 Motivation*

The need for the effective disposal of aluminium dross waste is a great burden for most steel and aluminium producing companies globally. This is due to the myriad effect of the improper disposal of this waste to human and animal health. Additionally, it has serious environmental and health implications too such as Alzheimer's disease, silicosis and bronchitis as avowed by [1-15]. Though aluminium dross is not totally a waste, a lot of energy and money is involved in extraction aluminium from the solid waste. Based on the energy requirement and the cost involved in the extraction, this waste is usually landfilled. [16] Affirmed that about one million tonnes of black dross and about four million tonnes of white dross are being produced globally from steel and aluminium producing company.

According to the author, 95% of these materials are openly dumped with serious health and environmental effect. Hence this research attempts to use solid waste as a filler in the production of a sustainable, cost-effective asphalt.

### *1.2 Background*

The urge to provide sustainable material in road construction has birthed the need for the development of alternative materials in asphalt production, which include the use of wastes both processed and recycled. These wastes ranges from agricultural to industrial waste [17-22]. The use of aluminium dross in pavement construction was adopted in a bid to reduce solid waste from the steel production industry. Aluminium dross a light weight metal, ductile material having is the by-product of aluminium production [23]. Its abundance is due to the wide usage industries and homes [24]. Aluminum dross as defined by [25] is a by-product of the aluminium smelting process. It is an inevitable waste product from the primary and secondary aluminium processing company [26,27]. Aside from aluminium metal, dross may likewise contain other chemical compounds e.g. $MgF_2$, $SiO_2$ and MgO and so on.

This solid waste is divided into white and black dross based on the coloration and the content of the aluminum in it. However, the white dross is richer in aluminum than the black dross. Additionally, the white dross is known as the non-salt containing dross while the black dross is the salt containing dross [28-32]. Additionally, [29] affirmed that aluminium dross are classified according to their content.

Recent review revealed that the recovery of the aluminum from the dross is been processed in the rotary kilns, while the salt cake is usually land filled. Much energy is devoured to recuperate the aluminium from the dross; this energy can be spared if the dross could be redirected and used as a construction material. (Reddy et al., 20l4). Other application of aluminium dross as a construction material as avowed by [16, 33]. A lot of energy is consumed in the recovery process which can be conserved if the waste is re-used for other purposes and hence its utilization in pavement construction which is an important component of effective transportation [34-42]. This research assessed the engineering properties of aluminium dross as a filler in asphaltic concrete pavement.

## 2. Materials and Methods

### *2.1 Materials*

The aluminium dross waste used for this research was obtained from a steel rolling industry in Ota, Ogun State, Nigeria is the capital of the Ado-Odo/Ota local government area. Municipal waste generated in the state is quite high due to the large number of industries. One of such waste is aluminium dross. Based on this research, the effect of aluminium dross in asphaltic concrete is determined using 0%, l0%, 20% and 30% of aluminium dross as a filler in the modification of asphaltic concrete sample. The coarse and fine aggregate used was purchased from a quarry in Ota, Ogun State, Nigeria. Bitumen of grade 60/70 was purchased in Lagos, Nigeria and used all through the research.

### 2.2 Sample preparation

The aluminium dross was obtained and packed in air-tight polythene bags. It was air-dried for forty-eight (48) hours. The lump aluminium dross was crushed and sieved into 106µm and 184µm. Other wastes in the dross sample were removed before pulverization. The aluminium dross was used at 0,10,20,30% addition of the bitumen mixture. Fine aggregates passing through a 4.25 mm sieve, coarse aggregates retained on the sieve of mesh size 4.75 mm was used for the research.

### *2.3 Test and Methods*

*E*ngineering tests were carried out on the bitumen to determine the rheology. The softening point and viscosity test were done in accordance with ASTM standards [43]. The bitumen penetration test was done in accordance with AASHTO specification. To achieve the aim of the research, the bitumen was modified with aluminium dross as a filler at at 0, 10, 20 and 30%. The rheology of the modified bitumen was also subjected to the rheological test. Finally, marshal test was conducted to ascertain the stability of the modified asphalt using AASHTO specification.

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## 3. Results and Discussion

### *3.1 Preliminary test on the Aluminium Dross*

The chemical composition of the oxides in the aluminium dross waste was assessed using X-ray fluorescence which is a non-destructive analytical technique. The result of the experiment is as shown in Table 1, with $Al_2O_3$ having the highest percentage of oxides and SrO as the least oxide in the aluminium dross sample.

**Table 1**: Oxide Concentration Table

| ELEMENT | CONCENTRATION (Wt. %) |
|---|---|
| Magnesium Oxide | 0.93 |
| Aluminium Oxide | 77.17 |
| Silicon Oxide | 13.48 |
| Sulphur Oxide | 0.70 |
| Chlorine | 0.27 |
| Potassium Oxide | 0.16 |
| Calcium Oxide | 1.12 |
| Chromium Oxide | 0.07 |
| Manganese Oxide | 0.20 |
| Iron Oxide | 4.18 |
| Zinc Oxide | 0.23 |

The sieve analysis of the aggregates used in the modification of the asphalt is as shown in Figure 1. The result conformed with AASHTO specification for the design of asphaltic concrete for road construction.

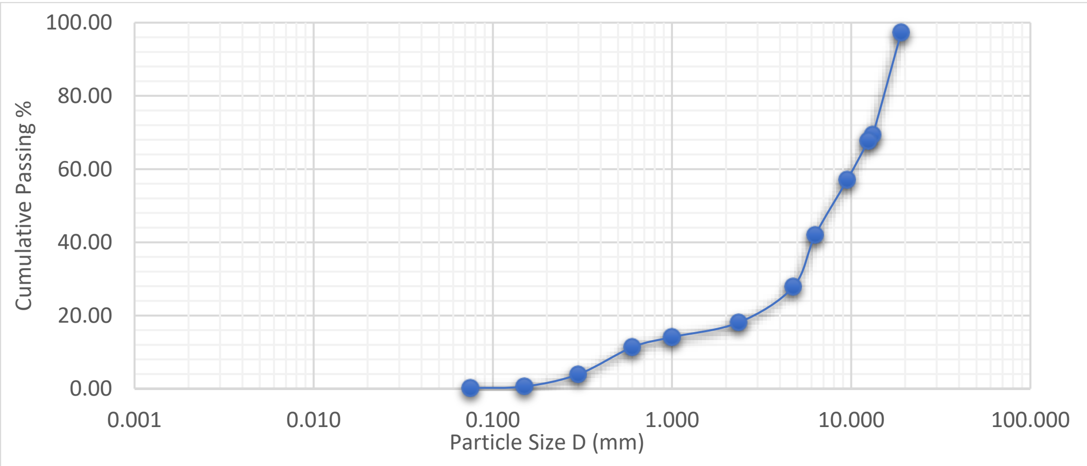


**Figure 1**: Sieve Analysis of the Coarse Aggregate

### 3.2 Bitumen Tests

The tests on the purchased bitumen are as shown in Table 2. The result showed the softening point test, penetration test, softening point test and ductility test.

Table 2: Preliminary test on the bitumen

| Tests | Sample 1 | Sample 2 | Sample 3 | Average |
|---|---|---|---|---|
| Penetration Test | 5.5 | 5.7 | 5.55 | 5.6 |
| Ductility Test | 49 | 47 | 52 | 49.3 |
| Softening Point Test | 43 | 44 | 43.5 | 43.5 |
| Ball and Ring Test | 5 | 5.3 | 5.7 | 5.3 |

3.3 Asphalt Test

Stability verifies the performance of the asphalt mixture under loading. The stability at 20% is the highest with 14.97kN see Table 4. As the percentage of the filler in the asphalt increases, the stability. With about a 6.7% decrease in the Marshall stability. However, a lower percentage addition of this waste gave a better result than 30% addition.

Table 3**:** Marshall and Volumetric Properties of Bitumen Content Mix

| **Tests** | **10%** | **20%** | **30%** |
|---|---|---|---|
| **Marshall Stability (kN)** | 14.07 | 14.97 | 13.96 |
| **Flow (mm)** | 3.15 | 3.24 | 4.18 |
| **Density (g/cm$^{3)}$** | 2.35 | 2.35 | 2.33 |

The various volumetric results are tabulated in Table 4. From the research, the higher the aluminium dross in the sample, the lower the volume of void. This indicates that at a higher percentage of the aluminium dross, the pavement became less crack sensitive due to the oxidization of the asphalt, which will fill the voids.

Additionally, the Voids in Mineral Aggregates (VMA) was also assessed, as shown in table 5. This was obtained by the addition of the air voids and the asphalt content. This parameter is a function of the aggregate size used in the asphalt mixture. This buttress the assertion of Haydar, (2011) that the addition of mineral filler will reduce the VMA. The result showed that the addition of aluminium dross would reduce the VMA. The implication of this that the addition of this waste may impede the absorption of bitumen by the aggregates, thereby reducing the durability of the asphalt and the pavement. This will also increase the asphalt mix flushing. It also implies that at higher percentage addition of the waste in the asphalt mix. This will invariably, increase the stiffness of the asphalt mixture, especially at a higher temperature. Hence the use of this material may not be encouraged in the temperate region because of the high temperature in this zone so to reduce the incidence of thermal cracks (Haydar, 2011).

Table 4: Asphalt Volumetric Analysis

| **Tests** | **10%** | **20%** | **30%** |
|---|---|---|---|
| **Vv (%)** | 4.52 | 4.05 | 3.87 |
| **VFB (%)** | 67.02 | 69.4 | 70.2 |
| **VMA (%)** | 13.7 | 13.2 | 12.97 |

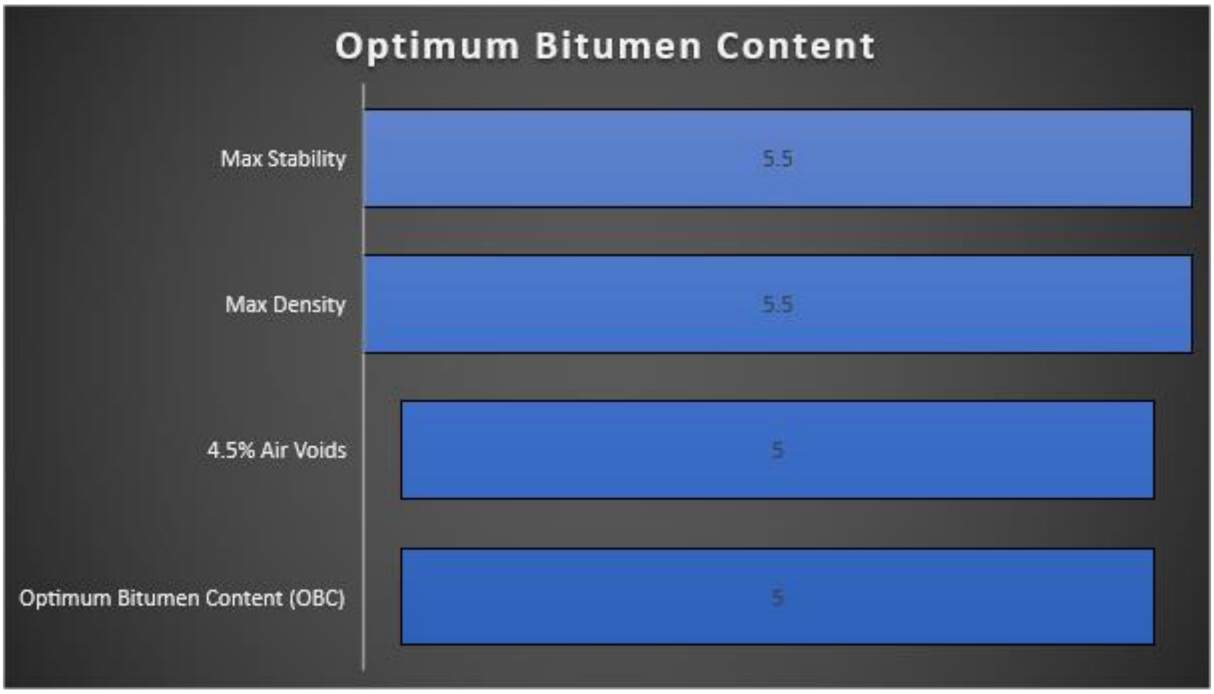


Figure 2**:** Determination of Optimum Bitumen Content

### 3.4 Marshall Stability

Marshal stability was conducted to assess the effect of the modified asphalt sample under loading. The result of the Marshall stability is as shown in figure 3. From the figure, the Marshall stability result obtained was higher than the control at 10 and 20% addition of the solid waste. The mix with 30% aluminium dross gave the lowest stability result. The increase in the stability may be attributed to the improved adhesion in the mixture (Sabina et al., 2009; Chen et al., 2009) because of the addition of the waste. Additionally, the dry method of mixing also aided the improved Marshall result, as the natural crystalline nature of the mixture was retained. The had a minimal change in the shape property.

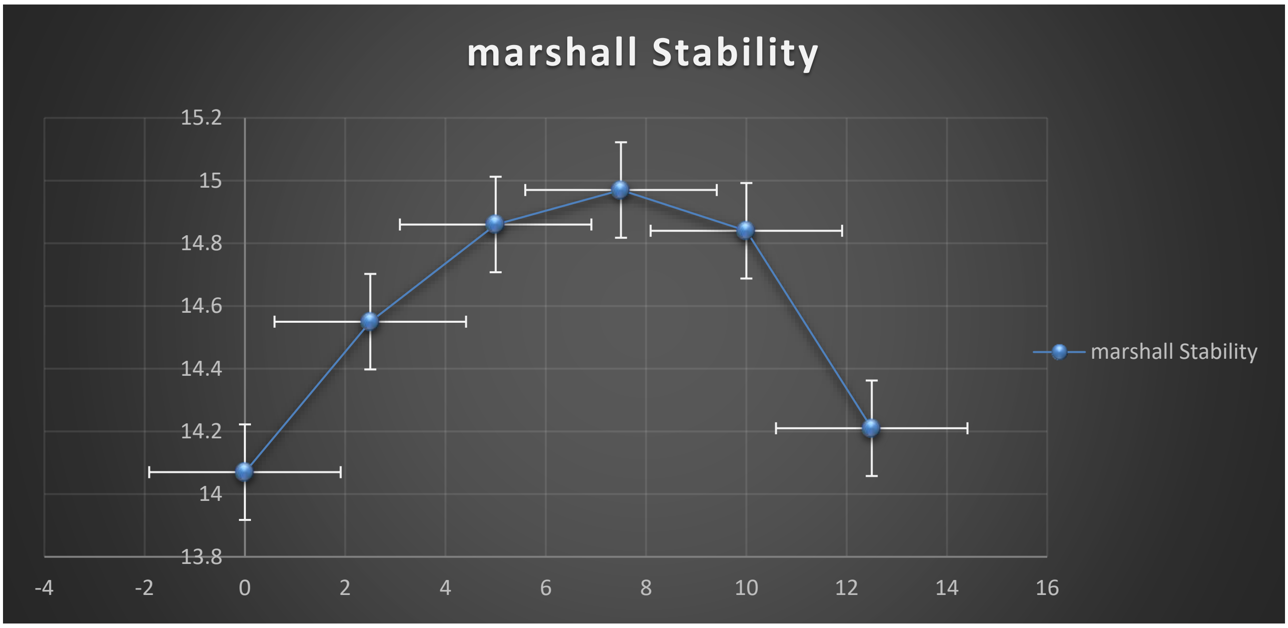

Figure 3: Marshall Stability Vs Bitumen Content

## 4. Conclusions

This experimental research assessed the utilization of aluminium dross as a filler in the modification of asphalt for the design and construction of a sustainable pavement. To this end, a preliminary test was carried out on the purchased bitumen sample before modification. Stability and volumetric analysis of the asphalt was also conducted. The findings of the research are as listed:

i. Physical observation revealed that the utilization of the waste stiffened the modified asphalt.
ii. The result of the Marshall stability is as shown in figure 4. From the figure, the Marshall stability result obtained was higher than the control at 10 and 20% addition of the solid waste.
iii. The increase in the stability may be attributed to the improved adhesion in the mixture.
iv. The result showed that the addition of aluminium dross would reduce the VMA.
v. The addition of this waste may impede the absorption of bitumen by the aggregates, thereby reducing the durability of the asphalt and the pavement.
vi. This will also increase the asphalt mix flushing. It also implies that at higher percentage addition of the waste in the asphalt mix.
vii. The use of the waste will increase the stiffness of the asphalt mixture especially at a higher temperature

Ultimately the use of aluminium dross is useful in wearing course construction in a bid to reduce solid waste and reduce the cost of road construction.

## Recommendation

Future research should investigate the effect of this using waste at a higher percentage on the stability of asphalt.

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