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# LABORATORY INVESTIGATION OF THE USE OF CRUSHED OYSTER SHELL AND CRUSHED PALM-KERNEL SHELL IN BITUMINOUS MIX DESIGN

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**Abstract:** The potentials use of crushed oyster shell (COS) and crushed palm kernel shell (CPKS) as partial replacement of fine aggregates in bituminous surfacing were investigated. Fine aggregate was partially replaced with COS and CPKS in proportions of 0%, 10%, 20%, 30%, 40% and 50% by weight of varying bitumen content from 3% to 9.5%. Marshall Stability tests were carried out in accordance with American Standard for Materials and Testing (ASTM D 1559: 2004). 30% partial replacement was within the specifications for bituminous surfacing, having 6% optimum bitumen content. The Marshal Stability obtained with COS and CPKS was 2.70 kN and 2.31 kN respectively; the corresponding flow value was 4.10 mm, and 4.15 mm. Thus, partial replacement of fine aggregate with 30% COS and CPKS in bituminous mix is suitable for light traffic and can be used as alternative material in bituminous mix to reduce the cost of construction.

**Key words:** *Road binder, oyster shell, palm kernel shell, Marshall stability, flow*

## 1.0 Introduction

The popularity for concrete in construction by utilizing coarse aggregate, and fine aggregate (granite) drastically reduces the natural stone and sand deposits; this has damaged the environment thereby leading to ecological imbalance (Alengaram *et al*., 2008). The construction industry relies heavily on conventional materials such as cement, granite and sand for the production of concrete. The high and increasing cost of these materials has greatly hindered the development of shelter and other infrastructural facilities in developing countries. There arises the need for engineering consideration to explore suitable replacement local materials to substitute the natural fine and coarse aggregates; which could be used in the production of light weight concrete and asphaltic concrete and does lead to an overall reduction in construction cost for sustainable development.

In developed countries, the construction industries have identified many artificial and natural light-weight aggregates. This has brought immense change in the development of high rise structures using light-weight aggregates. However, the Nigerian government has been clamouring for the use of local materials in the construction industry to limit costs of construction.

Asphaltic concrete is derived from a mixture of coarse and fine aggregates, stone dust, mineral fillers and binder (bitumen). Asphaltic concrete surfaces are fairly easy to construct and repair (Neville, 1995). The construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment while reliable performance of the in-service highway is achieved. Two things are of major considerations in flexible pavement construction viz-a viz pavement design and the mix design. A good design of asphaltic mix is expected to result in a mix which is adequately strong, durable, resistive to fatigue and permanent deformation, environment friendly and economical among others. A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions and finalizes with the best one.

Increasing cost of construction, environmental degradation and depletion of conventional materials to make construction sustainable, has necessitated research into the use of alternative materials which can replace conventional ones in both concrete production and asphalt mixture. The use of such replacement materials contribute not only to construction cost reduction but reduce impact on the environment. The study will investigate the use of CPKS and COS as partial replacement for conventional aggregates in asphalt and recommend the optimum value of CPKS and COS that could be used as partial replacement in asphaltic mixture.

## 2.0 Literature Review

The road construction industry depends majorly on conventional materials such as; asphalt cement, granite, sand and filler for the production of asphalt concrete. The high and increasing cost of these materials have greatly hindered the development of road pavement facilities in developing countries. The need for engineering consideration of the use of cheaper and locally available materials to reduce the construction cost for sustainable development cannot be overemphasized. In recent years, natural resources have been considerably reduced due to growth of mining industries and increase in the usage of mined materials. Aggregate is a mined material which is being used in civil structures such as buildings, dams, bridges, and pavements. The amount of aggregate in asphalt paving mixtures is generally 90 to 95 percent by weight or 75 to 85 percent by volume and almost 12,500 tons of aggregates are being consumed for each kilometre of flexible pavements (Zoorob and Suparma, 2000). These amounts of aggregates are largely obtained from natural resources which are detrimental to the environment as a result of mining activities. Researchers in material science and engineering are committed to having local materials to partially or fully replace these costly conventional materials (Nwaobakata and Agunwamba, 2014).

Some of these wastes include sawdust, pulverized fuel ash, slag and fly ash which are produced from milling stations, thermal power stations, and waste treatment plants (Fermandez, 2014). In addition, other materials explored in partial replacement for aggregates include cow bone ash, palm kernel shells, fly-ash, rice husk, and rice straw as pozzolanic materials. The use of coconut husk ash, corn cob ash and peanut shell ash as cement replacement have also been investigated (Kandahl, 1992). However, the use of waste products such as furnace slag, steel slag, fly ash, palm kernel shell etc. as partial or total replacement of aggregate and filler in the production of asphalt concrete mixes in surface bound layers should be considered as alternative which is now coming up as a new development for economical sustainable infrastructure like road construction. This creates a demand for evaluation of the performance of those waste products in the asphalt mixtures; using agricultural waste materials as a partial replacement of asphalt aggregate mixture is one of the vital areas of research. According to Mohammed *et al*. (2014), about 1.5 million tons of palm kernel shells are produced per annum in Nigeria. This huge amount of waste creates significant amount of problems with respect to handling and storage, which are important both from the economical as well as environmental point of view.

Attempts have been made by various researchers to reduce the cost of asphaltic concrete constituents and hence total construction cost by investigating and ascertaining the usefulness of materials which could be classified as agricultural or industrial waste. Ndoke (2006) investigated the potentials of palm kernel shells (PKS) as coarse aggregates in road binder course with emphasis on strength of the asphalt concrete as given by the Marshal Stability and flow values. He observed that Palm Kernel Shells could be used as partial replacement for coarse aggregate up to 10% for heavily trafficked roads and 50% for light trafficked roads. Mohammed *et al.* (2014) presented a paper on the preliminary assessment of some properties of asphaltic concrete, with partial replacement of fine aggregate (sand) with crushed palm kernel shell. The preliminary investigation showed that replacement of some proportions of fine aggregate (sand) with crushed palm kernel shells is capable of imparting positively on some properties of asphaltic concrete. In addition, the study was able to establish the 10% and 50 % by weight replacement of fine aggregate with crushed palm kernel, satisfactorily supported the requirements for asphaltic concrete.

Yusuf and Jimoh (2011) worked on the appropriateness of the various nominal mixes of the ‘palm kernel shell concrete’ as rigid pavement. They evaluated the mixes accordingly at both fresh and matured ages with corresponding costs. They reported that the Nigerian PKS satisfies the density criterion for normal concrete and lightweight concrete in all respects while the palm kernel shell concrete at nominal mixes of 1:1½:3

and 1:1:2 satisfied the specifications for rigid pavement. Daniel and Emmanuel (2012) investigated on the effects of replacing crushed granite with palm kernel shells on the strength, density and workability of structural concrete with cost implications. Also, Oyedepo *et al* (2015) investigated the use of palm kernel shell (PKS) as a partial replacement for fine and coarse aggregates in asphalt. They affirmed that 20% of crushed palm kernel shell (CPKS) can be used as fine aggregates in heavy traffic road and 60% in medium traffic roads.

### *2.1 Overview of Oyster Shell*

Oyster shells are usually oval or pear-shaped, they are generally whitish-gray in outer shell colour, and their inside shell is usually a porcelain white. Oysters feed by extracting algae and other food particles from the water; they reproduce when the water warms by broadcast spawning. Oyster farming in south western Nigeria has become a major income source of the local fishermen and provides a steady supply source to meet the domestic oyster demand. Large quantity of oyster shells (OS), which is an industrial waste, are found in the vicinity of an oyster station because the shells are discarded after processing. Most OS are not reused but are illegally discarded in the surrounding area. Thus, an attempt is made to use crushed oyster shell as a replacement for fine aggregate.

### *2.2 Overview of Palm Kernel Shell*

Palm kernel shells are derived from the oil palm tree (Elaeisguineensis), an economically valuable tree, and native to western Africa and widespread throughout the tropics. In Nigeria, the oil palm tree generally grows in the rain forest region close to the coastal areas and adjacent to some inland waterways. Omange (2001) affirm that palm kernel shells are used mostly as a source of fuel for domestic cooking in most areas where they occur. He further stated that the shells are often dumped as waste products of the oil palm industry. Okoye *et al.* (2009) stated that the two predominant varieties of palm fruits namely *tenera* and *dura*; produce about 1.5 million tonnes of palm kernel shells per annum in Nigeria. Palm kernel shells have been used as aggregates in light and dense concretes for structural and non-structural purposes.

The use of waste materials (recovering) in the construction of pavements has benefits in not only decreasing the quantity of waste materials requiring disposal but can provide construction materials with significant savings over new materials. The use of these materials can actually provide value to what was once a costly disposal problem. Falade (1992) investigated the suitability of palm kernel shells as aggregates in light and dense concrete for structural and non-structural purposes. Other similar efforts in the direction of waste management strategies include structural performance of concrete using oil palm shell (OPS) as lightweight aggregate. Agricultural wastes have advantages over conventional materials in low cost construction. The use of waste materials in construction contributes to conservation of natural resources and the protection of the environment. (Ramezanianpour *et al.*, 2009). Thus, the overall relevance of asphalt concrete in virtually all highway engineering practice and civil construction works cannot be overemphasized; while the use of palm kernel shell will reduce the cost of construction.

## 3.0 Materials and Methods

### *3.1 Materials*

The 70/80 penetration grade bitumen was obtained from ASCASapelle in Delta State; the coarse aggregate (crushed rock) and filler passing through sieve no 200 (75 micron) was obtained from F.M quarry Irese in Akure, Ondo state. Also, the fine aggregate that is free from deleterious materials is finely selected river sand from Akure environs in Ondo State. However, a carefully selected PKS and Oyster shell were also source from Akure environs and Diobu, Port Harcourt, Rivers State respectively. The materials used for this research work were carefully selected to meet with standard requirements of materials used in asphaltic concrete.

### *3.2 Method*

Specified proportions of each material such as 6% filler of size 0.075 mm, 66% fine sand of maximum size 5 mm and 28% crushed stone of size 5-16 mm with 3 to 9.5% bitumen of penetration grade 70/80 were mixed together at 163˚C. The mixture was compacted with 50 blows both at the top and bottom to obtain cylindrical samples for the Marshall Stability tests. COS and CPKS were partially replaced at 0%, 10%, 20%, 30%, 40% and 50% by weight of total coarse aggregate in the mixture. Three samples each were prepared for each percentage replacement of fine aggregate with COS and CPKS. Several tests were performed in accordance to the standard specifications as follows:

i. Aggregate Impact Value (AIV) Test (BS 812-112:1990).
ii. Aggregate Crushing Value (ACV) Test (BS 812-112:1990).
iii. Specific Gravity Test (ASTM C127 - 12, 2012 and ASTM C128 - 12, 2015) for coarse and fine aggregates respectively.
iv. Bitumen Penetration Test (BS 2000-487, 2009).
v. Marshall Stability Test (ASTM D 1559, 2004).

## 4.0 Results and Discussion

Table 1 present the summary of result of various tests carried out on the materials. The result of AIV test obtained shows that palm kernel shell has the highest AIV value of 5.08% which is rated “exceptionally strong”; oyster shell has AIV value of 11.13% which falls within the “very tough” rating and coarse aggregates has AIV value of 21.70% which is termed “good for pavement surface course”. In all, all of them are satisfactory for road surfacing/wearing course. Also, the result of ACV test obtained shows that all of the aggregates tested have their ACV values less than 30% which is in conformity with the requirement of “Not more than 30% for Surface or wearing course”. The result of this test showed that the moisture in the bitumen is 3.9% which is less than the maxim permitted limit of 5%. The flash and fire point designated values are 280 - 300$^0$C and 300 – 320$^o$C respectively. However, an average value of 286$^o$C and 319$^o$C obtained for flash point and fire point respectively falls within the specified value; thus it indicates that the bitumen could be used in the production of Hot Mix Asphalt.

Table 1: Summary of Test Results

| S/N | Properties | Results Obtained | Recommended Standard | | Remarks |
|---|---|---|---|---|---|
| 1 | Moisture Content On Fine Aggregate | 2.14% | | | Satisfactory |
| 2 | Aggregate Impact Value Test | | **Specified Limit (%)** | **Toughness Properties** | |
| | | CA=21.7%<br>OS=11.13%<br>PKS=5.08% | < 10<br>10-20<br>20-30<br>>35 | Exceptionally tough / Strong<br>Very tough / Strong<br>Good for pavement surface course<br>Weal for pavement surface course | Satisfactory for road surfacing/wearing course |
| 3 | Aggregate Crushing Value Test | | **Specified Limit (%)** | | |
| | | CA=22.92%<br>OS=24.14%<br>PKS=5.07% | Not more than 30% for Surface or wearing course | | Satisfactory |
| 4 | Water In Bitumen Test | 3.9% | Max. Permissible is 5% | | Satisfactory |
| 5 | Flash Point Test<br><br>Fire Point Test | 286<br><br>319 | 280 - 300$^0$C<br><br>300 – 320$^o$C | | Satisfactory<br><br>Satisfactory |

*4.1 Bituminous Mix Design*

Design of bituminous mixes is basically selecting and proportioning aggregates and bitumen to obtain desired proportions in the constructed road. The desired properties of the mix are durability, flexibility, stability, tensile strength, imperviousness, resistance to skidding, fracturing and workability during construction. In designing of bituminous mixes, Marshall Stability test is used to determine the two important properties of strength and flexibility. Strength is measured through “Marshall Stability” of the mix and flexibility is measured in term of “Flow value”. Figures 1 to 6 are the graph of stability against the bitumen content, while Figures 7 to 12 are the graph of flow against the bitumen content for varying percentage replacement of CPKS and COS.

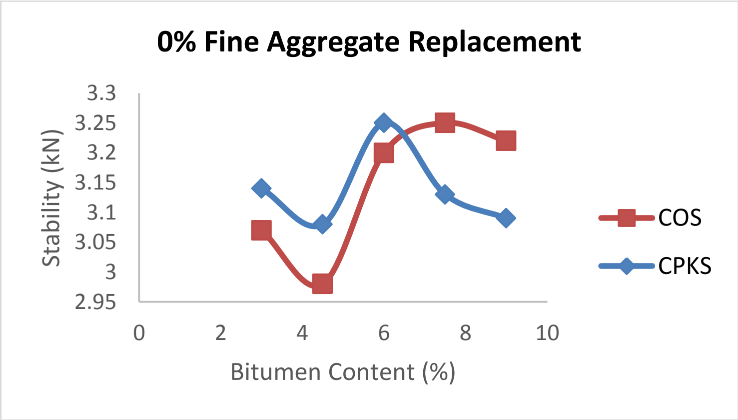


Figure 1: Relationship between Stability and Binder Content at 0% Partial Replacement

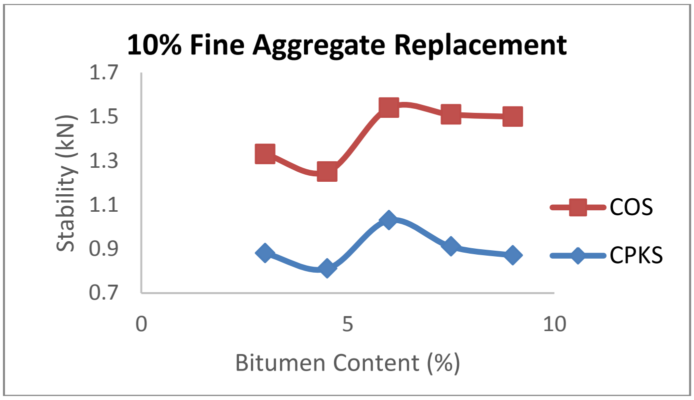


Figure 2: Relationship between Stability and Binder Content at 10% Partial Replacement

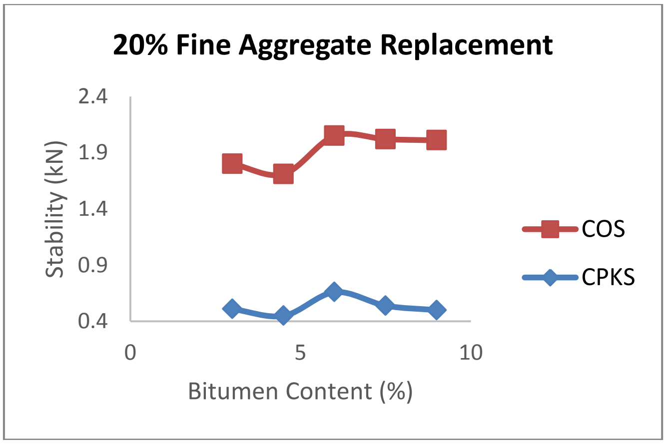


Figure 3: Relationship between Stability and Binder Content at 20% Partial Replacement

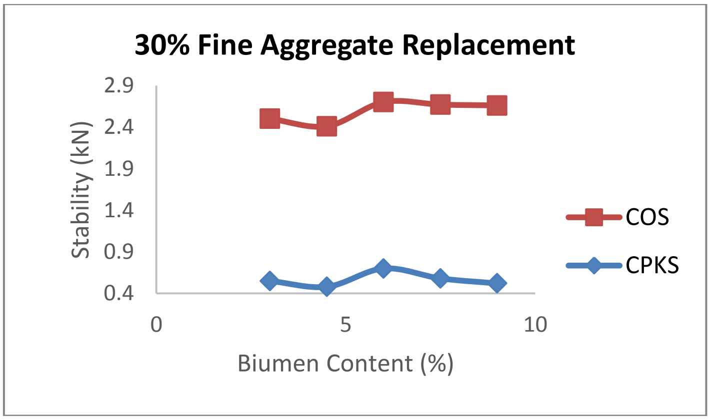


Figure 4: Relationship between Stability and Binder Content at 30% Partial Replacement

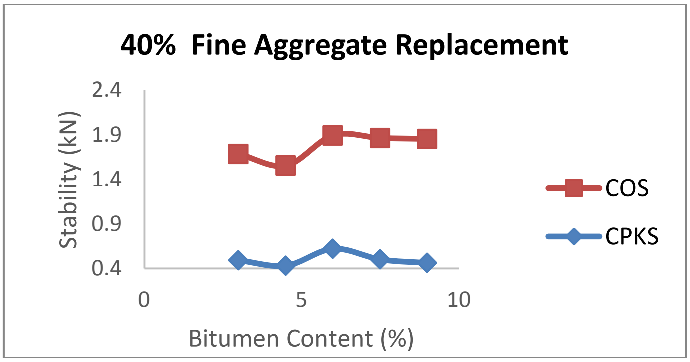


Figure 5: Relationship between Stability and Binder Content at 40% Partial Replacement

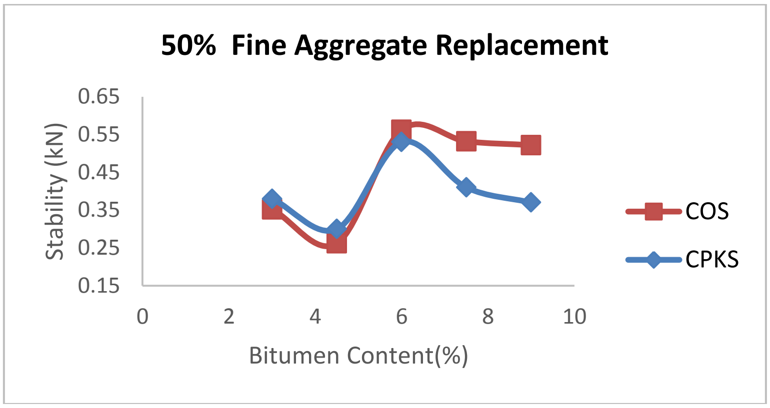


Figure 6: Relationship between Stability and Binder Content at 50% Partial Replacement

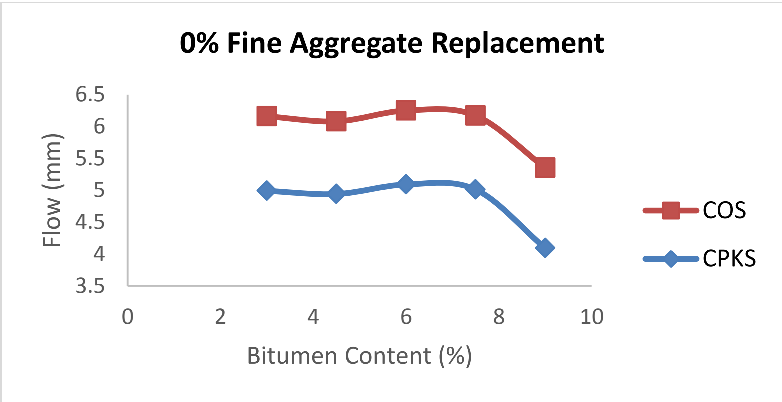


Figure 7: Relationship between Flow and Binder Content at 0% Partial Replacement

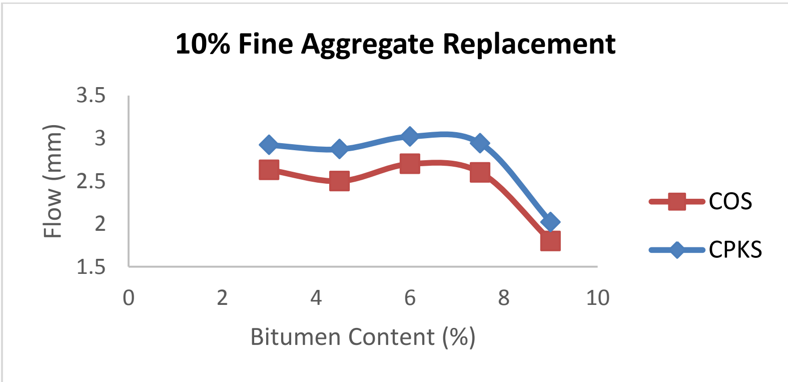


Figure 8: Relationship between Flow and Binder Content at 10% Partial Replacement

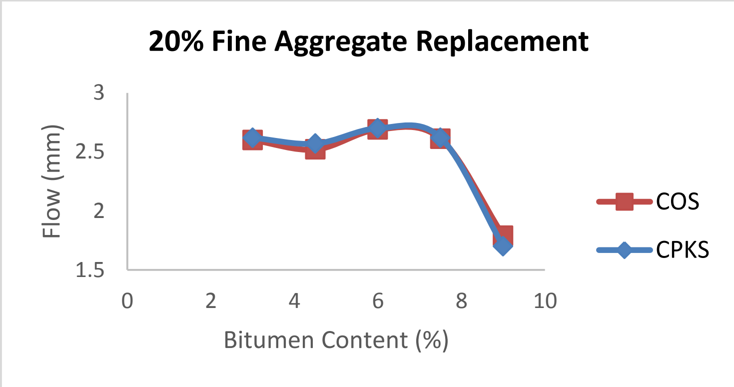


Figure 9: Relationship between Flow and Binder Content at 20% Partial Replacement

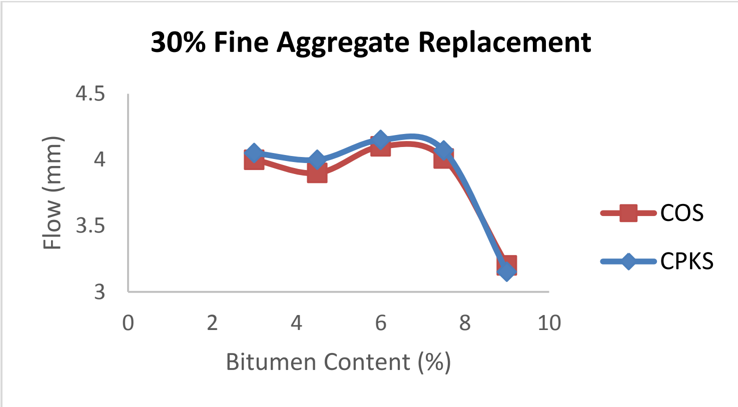


Figure 10: Relationship between Flow and Binder Content at 30% Partial Replacement

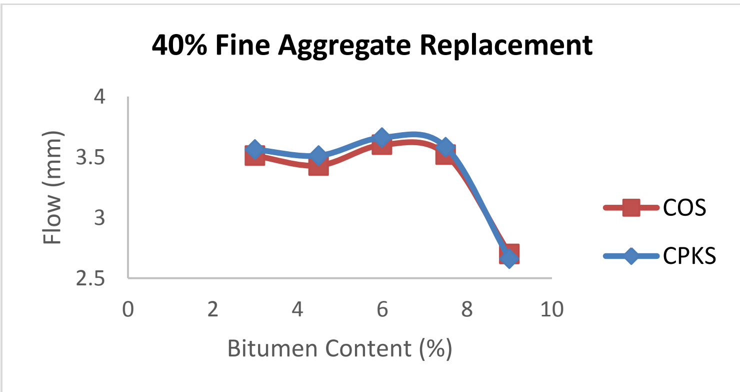


Figure 11: Relationship between Flow and Binder Content at 40% Partial Replacement

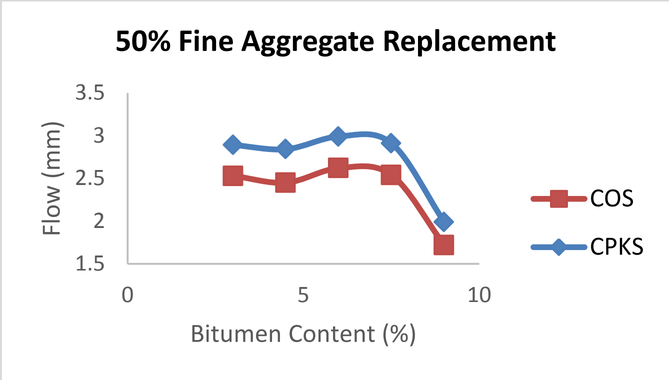


Figure 12: Relationship between Flow and Binder Content at 50% Partial Replacement

## 5.0 Concluding Remark

The Marshall Design Criteria for Stability provided by the Asphalt Institute requires minimum values for different traffic classifications as:

- 2.223 kN for Light Traffic.
- 3.336 kN for Medium Traffic.
- 6.672 kN for Heavy Traffic.

The 30% partial replacement with COS and CPKS has 2.7 kN and 2.31kN respectively which is more than the value stated for light traffic. The Marshall Design Criteria for flow at 0.25 mm provided by the Asphalt Institute for different traffic classifications are:

- 2 – 4 mm for Light Traffic.

The results show that at 30% partial replacement with COS and CPKS, the flow value obtained are 4.1 mm and 4.15 mm respectively; the flow value obtained is within the tolerance limit. In this study, COS and CPKS produces good bituminous mix with a reasonable Marshall Stability value which make it suitable for light traffic road. With the increase in the cost of construction materials and fast depletion of conventional materials, COS and CPKS provides a cheap source of pavement construction material at a reduced cost especially at riverine areas where it is available in large quantities and does reduces environmental pollution from depositing the shell indiscriminately.

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