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EFFECTIVE UTILIZATION OF BITUMINOUS ASPHALTS WASTE AS AGGREGATES IN CONCRETE

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ABSTRACT

The present trend of indiscriminate dumping of waste bituminous asphalts on the highways in Nigeria calls for urgent attention. The trend all over the world now is the conservation of natural resources and reduction of waste being generated as a result of different human activities. This paper has looked at how the used bituminous asphalts material can be effectively utilized for other construction purposes. Different types of test like: slump, flow table, fire resistance and compressive strength tests were carried out on the bituminous asphalt waste that was mixed with sand and cement to make concrete, and the result was compared with concrete made from granite of size 20mm, gravel of size 15mm and bush gravel of size less than 8mm. The flow table tests conducted showed that both granite and bituminous concrete mixes have low flow rate, while coarse and bush gravels have medium flow rate. The bituminous concrete has the highest cube strength of 25 N/mm^2 after 28 days. In conclusion, bituminous asphalts could be a very good substitute as aggregate in concrete for some marine structures that are not exposed to fire.

Key words: Aggregate, Bituminous asphalts, Concrete, Highways, Structures.

INTRODUCTION

Concrete is a homogeneous mixture of cement, sand, aggregate and water. The strength of the concrete depends on it mix ratio and some other sundry properties like water/cement ratio, etc. Olanipekun *et al.*, (2006) carried out studies on the use of coconut and palm kernel shells as alternative aggregate in concrete, they concluded that coconut shells were more suitable than palm kernel shells when used as substitute for conventional aggregates in concrete production if economy is considered. Adesanya and Raheem (2009) used Corn cob ash as a partial substitute for cement in concrete; it was concluded in the work that only up to 8% Corn cob ash substitution is adequate where blended cement is to be used for structural concrete. Slag was also used in thin ferrocement concrete by Memon *et al* (2007); periwinkle shell, sawdust, slates, etc. have been previously used as alternative aggregates in concrete.

Reith (1982) mentioned the use of crushed limestone of 8 mm sizes as aggregate with natural sand for the concrete dome of the church of the holy sepulcher in Jerusalem, and his report showed that the crushing strength was 25 N/mm^2 at 28days. Pacheco-Torgal *et al* (2002) also carried out test on different granites, calcareous and gabbroic materials as aggregate in concrete and were able to compare the concrete made from this different materials, the conclusion reached was that there is not much difference on concrete durability parameters when produced either with granite, gabbro or calcareous coarse aggregate.

Natural pozzolana was used as an aggregate component in lightweight concrete by Mouli and Khelafi (2007). They were able to conclude that lightweight concrete with pozzolana, as a coarse aggregate has sufficient strength and adequate density to be accepted as structural lightweight concrete. Also Blaga and Beaudoin (1985) concluded that materials which contain organic resins (commercial polymer) in conjunction with Portland cement could be used in concrete. Lawal (2002) also concluded that a small proportion of polymer (Rubber) from used tyres in the rubber-cement ratio less than 0.10 is a very good supplement in concrete.

In Nigeria, the Federal Government established a body known as the Federal Road Maintenance Agency (FERMA). The role of this body is to maintain all Federal roads in the country. This body has been doing a good job since its establishment in the year 2000, but most of the waste materials (bituminous asphalts) that were scraped of the road surface are left beside the roads, and these have been serving as nuisance to most road users. Sometimes accidents have occurred as a result of the waste left behind after repairs were completed. These are some times left to block drains, which has led to flooding. It is the believe in this paper that all these waste can be reused or recycled, especially as coarse aggregate in concrete.

In recent years, there has been an increase in the awareness of the need to conserve natural resources and recycle or reclaim those materials which are in short supply. It is generally believed that the conservation of existing sources of construction materials is a major priority for future generation. In Nigeria, the demand for raw aggregate especially for construction purposes has continued to grow over the last decade.

Given correct conditions, efficient recycling of waste materials could reduce the demand on natural aggregates. In view of the increasing pressure on the supplies of natural aggregate, more recyclable materials like the used bituminous asphalt should be encouraged. Therefore the objective of this work is to determine the use of bituminous asphalts waste as aggregate in concrete.

MATERIALS AND METHODS

Materials

The ordinary Portland cement was used as the main binder in the concrete having an average 28-day compressive strength of 25 N/mm^2. Coarse aggregates were produced from crushed bituminous asphalt obtained from the waste product from repaired roads (scraped surface). This is a material used for road surfacing. It is made from the mixture of aggregates and binders. Bituminous materials for road surfacing are manufactured at a bituminous plant by drying and heating aggregates and mixing them with binder in carefully controlled proportions under carefully controlled temperature conditions. The more commonly used bituminous plant is the "Batch plant". In the batch plant, the aggregate are fed from stockpiles into several storage bins or hoppers, each of which might contain up to 20 tons of a particular single size aggregate or a mixture of size. When the plant is in operation, aggregate are taken from these storage bins in controlled amounts.

These batches were then carried by the conveyor belts into oil/gas fired rotating dryer where they are dried by cascading through the flame provided by the burner. The aggregates emerged from the burner at a temperature somewhat higher than that which is required i.e. to allow for cooling during further processing and are carried to a set of screens (usually placed at the highest point in the plant) where they are again separated into different sized fractions and deposited in to as many six hot storage bins. As materials are required, a batch of perhaps 2 tons or more is drawn off into a weigh hopper. This batch is made up of the exact proportions of the various sizes of aggregate and filler required mix design. The aggregate-filler mixture is discharged into a twin- shaft paddle or pug mill mixer, where the required amount of that binder is added through a spray bar mounted in line with the paddle shafts and a thorough mixing is carried out. The mixed materials is then discharged into a truck for direct transfer to the site, or transferred to heated insulated storage bins for later usage.

Bituminous materials can be laid by hand or by a large variety of machines. The compaction is the act of applying mechanical effort by means of rollers or other equipment to increase the density of a bituminous material. The objective is to reduce the void contents and thereby enable the mechanical properties of the material to be fully realized (O'Flaherty, 1986).

The fine aggregate was local, natural and non-reactive sharp sand of an average safe bearing pressure of 25 kN/m^2 (Medium Sand).

Experimental procedure

Four different types of aggregates that are commonly used in different sites all over Nigeria were tested. These aggregates consist of coarse gravels of sizes that range between 10 mm and 15 mm, depending on the location where it is found. Another gravel called 'Bush' gravel with grain size properties that are less than 8 mm but not below 2 mm, granite of 20mm size and the bituminous asphalt that has been crushed to size 40mm and below.

Concrete was made from each of these four different aggregates at a mix ratio 1:2:4, and the concrete obtained from this different aggregate were tested both at the laboratory and in the field. Short term test of between 1 day and 28 days were carried out.

Slump test, fire resistance test and compressive strength test were carried out. The purpose of these three tests was to determine workability (stiffness), fire resistance and concrete strength respectively.

Slump test

This test is used extensively in site work all over the world. The mould for the slump test is a frustum of a cone, 300 mm high, 200 mm base and 100 mm top diameter. Both the top and base are open. Concrete was filled in to the mould in three layers with each layer tamped 25 times. Immediately after filling, the cone was slowly lifted and the unsupported concrete slumped. The decrease in the height of the center of the slump is called slump and measured to the nearest 5mm.

The slump test is very useful for checking the variation of materials being fed into the concrete mixer. An increase in slump may be an indication that the moisture content in the concrete has unexpectedly increased or a change in the grading of aggregate, such as deficiency of sand. This test helps in determining consistency in concrete (Neville and Brook, 1987).

Fire resistance test

The concrete were exposed directly to fire for about 2 hours. This experiment involved the arrangement of dry woods together in a row, the concrete cubes were then arranged on this wood and other sets of woods were arranged on the concrete. The concrete cubes were than sandwiched in between the woods. The woods were set on fire and the concrete was then observed at every 15 minute interval, it was observed that the bitumen started melting before the first 15 minutes.

Flow table test

Basically, this test was to assist in determining the degree of workability according to BS 1881: part 105 (1983) and also to determine segregation by measuring the spread of a pile of concrete subjected to jolting.

The apparatus consists essentially of a wooden board covered by a steel plate. This board is hinged along one side to a base board. Each board being 700mm^2 in area. The upper board can be lifted up to a step so that the free edge raises 40mm. Appropriate markings indicate the location of the concrete lightly tamped by a wooden tamper in a prescribed manner, placed using a mould 200mm bottom diameter and 100mm top diameter. Before lifting the mould, excess concrete is removed, the surrounding table top is cleaned and after an interval of 30 seconds, the mould is slowly removed. The tabletop is jolted 15 times in 15 seconds. In consequence, the concrete spreads and the maximum spread parallel to the two edges of the table is measured. The average of these two values given to the nearest millimeter represents the flow. A value of 400 indicates a medium workability and 500 a high workability, while any value below 400 indicate a low workability.

The flow rate can be obtained by finding the percentage of initial diameter over the final diameter; a value from 0 to 150% can be obtained. The jolting applied during the test encourages segregation. If the mix is not cohesive, the larger particles of aggregate will separate out and move toward the edge of the table.

Compressive strength test

The test employs a 150 mm cube. The standard method describe in B 1881: part 116 requires that the test specimen should be cured in water at 20±2^{0}C for 28 days and crushed, by loading in a compressive strength testing machine at a constant rate of stress increase of between 12 and 24 Nmm^{-2} immediately after it has been removed from the curing tank. The stress is increased until rupture occurs in the concrete. Usually, loading is completed within 2 or 3 minutes.

Figure 1. shows the 7 and 28 days test results for all the samples.

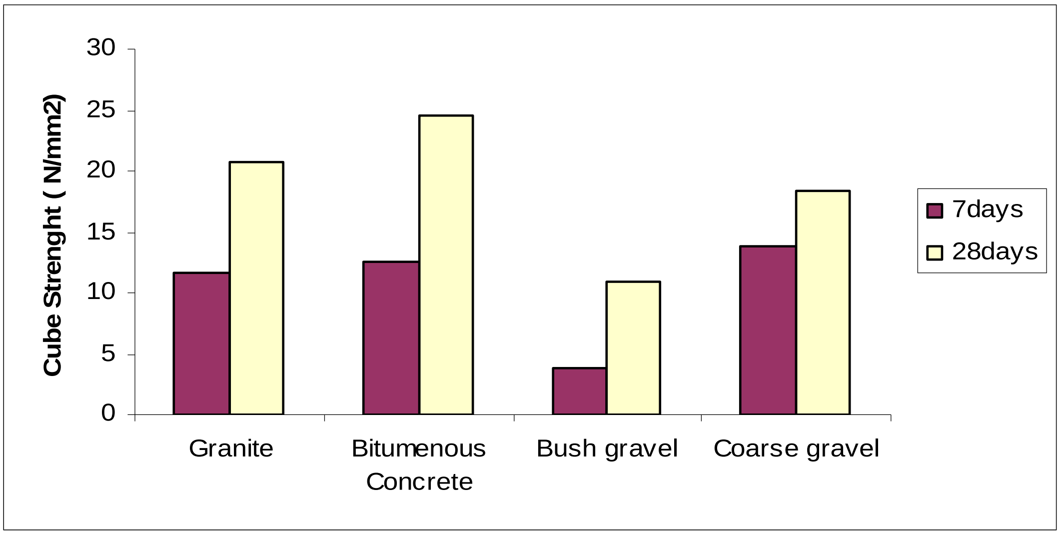

Figure 1: Variation in 7 and 28 days cube Strength for tested concrete

RESULTS AND DISCUSSION

The slump test results in Table 1 showed that the bituminous concrete has the lowest slump and this implies that it has a good workability, while coarse gravel concrete gave the highest slump results hence it has a very poor workability. The fire resistance test results are summarized in Table 2.

From the results of the flow table test (Table 3). It was observed that both granite and bituminous concrete mixes have low flow rate, while coarse gravel and bush gravel have medium flow rate. The workability of granite and bituminous concrete are low, if compared to that of bush gravel and coarse gravel with both having a medium workability. During the experiment, it was observed that the segregation in bituminous concrete is very high because some of the large sized aggregate rolled away from the concrete mix during jolting, this must have been as a result of the insolubility of bitumen in water, hence; the bitumen coated aggregate can not withstand the jolting since there is no cohesion in the mix as a results of the bitumen present. Also, the cement paste of bush and coarse gravels were observed to flow away from the mixture leaving a hand full of coarse aggregate in the middle. This reaction is as a result of too many fine aggregates that easily mix with cements in the mixture. The performance of granite was good in this particular test..

Table 1: Results of Slump Tests

Name of Samples	Maximum size of aggregate (mm)	Slump (mm)
Bituminous Concrete	40	10.00
Granite(Crushed rock)	20	25.00
Coarse gravel	15	175.00
Bush gravel	< 8	130.00

Table 2: Results of fire resistance test

Samples	Observations	Inference
Bituminous Concrete	Bitumen in concrete melts within first 15 minute, cracks were observed on the samples after the fire was extinguished	Can not withstand fire
Granite(Crushed rock)	Colour changes from grayish to dirty browns, no cracks observed after fire was extinguished.	Fire resistance is very good
Coarse gravel	Colour changes from brownish grey to deep brown, cracks were observed on the samples after the fire was extinguished	Fire resistance is fair
Bush gravel	Colour changes from dirty brown to deep brown, cracks were observed on the samples after the fire was extinguished	Fire resistance is fair

Table 3: Flow rate results

Name of samples	Initial concrete diameter (mm)	Final concrete diameter (mm)	Flow rate %
Bituminous concrete	200	360	80
Granite(Crushed rock)	200	370	85
Coarse gravel	200	420	110
Bush gravel	200	395	100

Based on the laboratory results obtained, the Department of Environment's (DOE) design of normal concrete mixes method as reported by Kong and Evans (1993), was adopted in analysing the water content (equation 1), cement content (equation 2), fine aggregate and coarse aggregate content presents in each sample of the four concrete specimens (equation 3). The mix ratio used in this work was 1:2:4, in mass and the water cement ratio used was 0.5 for all the samples (Table 4).

Table 4: Concrete Mix Design Analysis Results

Specimens / Properties	Granite	Bituminous Concrete	Coarse gravel	Bush gravel
28 days compressive strength(N/mm2)	21	25	11	18
Cement (kg)	320	250	370	415
Fine aggregate (kg)	660	480	920	1095
Coarse aggregate (kg)	1400	1610	815	590
Water/cement ratio	0.59	0.62	0.61	0.54
Density of concrete (kg/m3)	25.7	24.93	23.25	23.35
Mix ratio	1:2:4	1:2:6	1: 2.5 :2	1:3:1

$$W = \frac{2}{3}W_f + \frac{1}{3}W_c \qquad \text{……..1}$$

$$C = \frac{W}{w/c} \qquad \text{……….2}$$

$$V_a = 1 - \frac{C}{\gamma_c} - \frac{W}{\gamma_w} \qquad \text{………..3}$$

where, W is water content, W_f is water content appropriate of the type of fine aggregate, W_c is water content appropriate for the type of coarse aggregate, C is cement content, w/c is water cement ration, V_a is the aggregate content, γ_c is the density of cement, while γ_w is the density of water. The water cement ratio obtained for each sample in Table 4 was the results from the analysis.

From Table 4, it can be observed that the bituminous concrete has the highest strength after 28 days, and its analysed mix ratio was 1:2:6. This shows that it has a lot of coarse aggregate within it; the high strength must be as a result of the large coarse aggregate present in it. Apart from its limitation in resisting fire, as a result of the bitumen present, this material is good for concrete.

The granite concrete was next and it was within the expected 28 days average cube strength (20 N/mm^2). It maintains the mix ratio of 1:2:4 after analysis, this is a good result because it falls within the expected out put.

The coarse gravel also gave a 28 days strength of 18 N/mm^2, although it is just a little below the expected results, and the analysed mix ratio obtained was 1: 2.5:2, this shows that it has some little fine aggregate within it above the expected results, and the coarse aggregate present is lower than the expected amount, this is not a bad results at all. But efforts should be made not to add fine aggregates to this type of concrete during mixing, the mixing should be gravel and cement only, this will encourage good compressive strength and adequate workability.

The results of the bush gravel has shown that this material is weak for use as a concrete aggregate, because, it gave 11 N/mm^2 strength after 28 days, and the analysed mix ratio was1:3:1. This shows that it contains over 60% of fine aggregate, which must have contributed to it low strength. This is not good for concrete and it must be discouraged from been used as aggregate in concrete.

CONCLUSION

The use of bituminous asphalt waste as aggregate in concrete should be encouraged because it gave a good result of 25 N/mm^2 from the compressive strength test over other aggregates. Apart from its low fire resistance, which can reduce it functions in the construction of fire friendly strictures like Chimney, and Cooling towers, it can be effectively used for marine structures like Harbors, Jetties, Bridges, Dams etc. Care should be taken during casting of the concrete especially during compaction, in order to reduce honey comb as a results of segregation. It can also be reused to fill potholes on the highways when mix with cement, fine aggregate and water in the right proportions, also in the construction of rigid pavements for motor parks. This result has also showed that the bituminous aggregate can be worked upon as a partial replacement for granite in the structures mentioned above that are not exposed to fire, instead of the current trend of dumping the materials indiscriminately on the highways.

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