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USE OF WASTE ASPHALT PAVEMENT IN CONCRETE: ANOTHER INSTANCE OF CONVERTING WASTE TO WEALTH

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ABSTRACT

Conversion of waste to wealth in every sector of the economy is becoming increasingly important. This study is an investigation into the suitability of waste asphalt pavement as replacement for coarse aggregates in concrete. After batching, 1:2:4 mix of concrete was produced by using granite as coarse aggregates and also by entirely replacing the granite (coarse aggregates) with waste asphalt pavement (WAP) at the water-cement ratios of 0.50, 0.55 and 0.60. The two blends of concrete so produced have low workability at these water-cement ratios. The compressive strength value ranges from 18.60 N/mm^2 to 18.91 N/mm^2 for the conventional concrete at the water-cement ratios while that of the WAP concrete ranges from 11.80 N/mm^2 to 12.67 N/mm^2. Though the statistical model establishes that the concrete produced with water-cement ratio ranging between 0.5 and 0.6 has approximately the same compressive strength values, but the conventional concrete differs in compressive strength from the WAP concrete; with the conventional concrete having a higher strength.

1. INTRODUCTION

It has been reported by World Bank (2012) that approximately 1.3 billion tonnes of wastes are being generated per year and this level is expected to increase to approximately 2.2 billion tonnes per year by 2025. However, it is the intention of scientists and researchers, as well as people in authority, to explore waste material recycling for environmental and economic advantages (Pourtahmasb and Karim, 2014). The asphalt industry has been investing in sustainable development and recycling for several years now. In many cases the industry has already reached the international environmental requirement to decrease their CO_2 emissions by 20% during 1990 –2020. Various infrastructure developments as well as maintenance in urban streets and roads have always necessitated the opening up of the paving. The excavated asphalt is collected and transported to the nearest asphalt plant or other appropriate location. At the plant, the asphalt is crushed and the crushed asphalt granules are used for new asphalt. This asphalt granule as well as the collected old asphalt is generally called reclaimed asphalt pavement (RAP). The asphalt industry is one of the forerunners of recycling and reuse. Asphalt is 100% recyclable, meaning practically that all of the RAP is either reused or recycled (Nordic Road Forum, 2012). In fact, according to the National Asphalt Pavement Association (NAPA) since most reclaimed asphalt is reused or recycled, asphalt pavement is recycled more than any other material and its use is growing. The amount of RAP in asphalt mixtures was 66.7 million tons in 2011 and 68.3 million tons in 2012 (Donaghy, 2014). Likewise, the Federal Highway Administration (FHWA) supports and promotes the use of recycled highway materials in pavement construction in an effort to preserve the natural environment, reduce waste, and provide a cost effective material for constructing highways (Federal Highway Administration, 2017). The so-called "Construction and Demolition Waste", is a potentially re-usable/recyclable product, and therefore should not automatically be defined as a waste, where doing so would restrict or prevent its subsequent use as a secondary material (European Asphalt Pavement Association, 2015). Energy and Environmental Affairs (2017) even suggests that asphalt pavement, brick and concrete (ABC) rubble, such as the rubble generated by the demolition of buildings, bridges or roadways, must be handled in accordance with the solid waste regulations which will allow and encourage the recycling/reuse of the ABC rubble. Recycled/Waste Asphalt Pavement is gradually establishing its importance in concrete work, Okafor (2010) concluded in his study that RAP aggregate has lower specific gravity and water absorption than the natural aggregate. He also affirmed that it is apparent that recycling of waste asphalt pavement for concrete aggregate is feasible and may become a viable and routine process for the generation of aggregate for middle and low strength concrete. Similarly, Gill and Berwal (2016) observed that concrete made up of RAP aggregate will naturally be economical as the mixing of RAP reduces the rate of gain of compressive strength as compared to fresh aggregate. In terms of leaching, according to Erdem and Blankson (2014), the environmental behaviour of the recycled aggregate concrete is similar to that of the natural aggregate concrete while Herrador, Pérez, Garach and Ordóñez (2012) submitted that the load-bearing capacity of the recycled artificial Construction and Demolition Waste aggregate was satisfactory. The thrust of this study is to evaluate the suitability of waste asphalt pavement in the production of concrete.

2. MATERIALS AND METHODS

2.1 Materials and Equipment Used for the Study

Materials used for the study include Ordinary Portland Cement (OPC) conforming to BS 12, fine aggregates (with 75% of the aggregates passing sieve size 2 mm) conforming to BS 882, coarse aggregates (of hard, durable granite of size 12.5 mm), Waste asphalt pavement (WAP) (obtained from the waste dump of a road rehabilitation/construction site along Sekona-Ife road in Osun State Nigeria) and potable water free of impurities. The old asphalt pavement was fine-graded, hot mix asphalt concrete. The waste asphalt pavement rubbles (shown in Figure 1) were mechanically crushed, sieved, graded to size similar to that of natural granite (shown in Figure 2). Thus, the WAP coarse aggregate consists of "asphalt mortar" (asphalt binder sand filler matrix). The apparatus and equipment used in the study include metal moulds (with internal dimension of 150 mm X 150 mm X 150 mm), set of BS sieves and mechanical sieve shaker, tamping rod, weighing balance, hand shovel, slump cone, compaction factor machine and compression testing machine.

Figure 1: Ungraded WAP

Figure 2: Graded WAP

2.2 Experimental Procedure

Batching and Mixing

The required proportions of cement, fine aggregates (sand) and coarse aggregate (granite) were batched manually by weight (for the 1:2:4 mix). The materials were thoroughly and uniformly mixed together using shovel and 0.5, 0.55 and 0.60 water-cement ratios were adopted. The same procedure was repeated by replacing granite (coarse aggregates) with WAP at the same water-cement ratios.

Sampling

The fresh concrete was now placed in the mould (150 mm X 150 mm X 150 mm in dimension) already coated with engine oil and this was done in three layers as a standard practice prescribed by BS 1881 (1970a). One third of the mould was first filled with the fresh concrete and then compaction was done using a compaction rod for about twenty-five blows and this was repeated in three layers in order to reduce the void ratio. The surface of the concrete cubes formed was then smoothened using a hand trowel.

Curing

After 24 hours of casting, the concrete cubes were demoulded and weighed. The concrete cubes were then cured in water so that the hydration process of cement used in preparing the concrete could continue.

Determination of workability of concrete

The workability of the conventional concrete and WAP concrete was determined through slump test performed in accordance with BS 1881 (1970b).

Determination of compressive strength of concrete

The concrete cubes (after being cured in water for 7, 14, 21 and 28 days) were placed in the compressive strength test machine and the failure load was determined. Three concrete cubes each were crushed for the different concrete blends at 7, 14, 21 and 28 days of curing and the average compressive strength determined.

3. RESULTS AND DISCUSSION

Specific gravity of the coarse aggregates

The specific gravity test conducted on the two aggregates (granite and WAP) revealed that WAP has a lower specific gravity of 2.28 compared to that of granite which is 2.70.

Workability of the concrete

Figure 3 shows the results of slump test. The results show that both the conventional and WAP concrete have a low workability at the three water - cement ratios chosen. Though, the slump value increases with increase in the water-cement ratio for the two types of concrete, the conventional concrete has a higher workability than the WAP concrete.

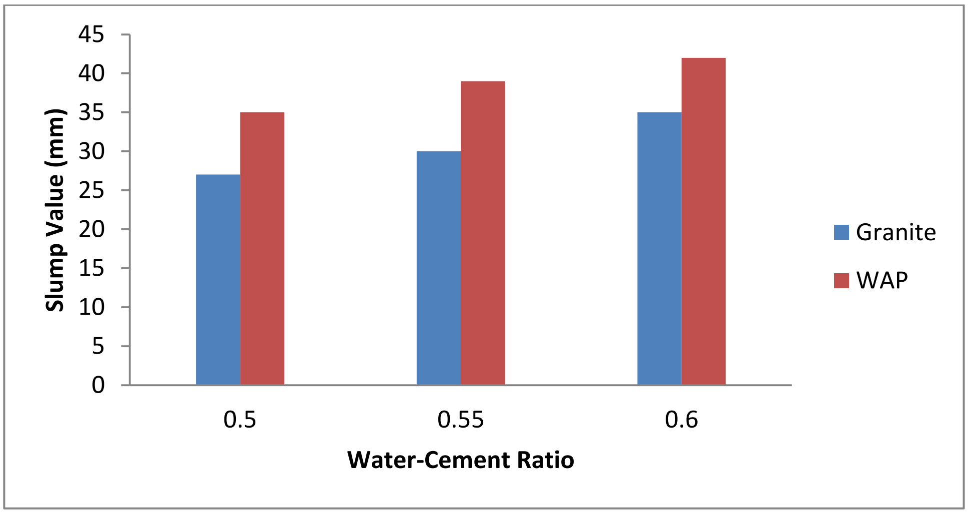

Figure 3: Slump Value – Water Cement Ratio Characteristics for the Granite and WAP Concrete

Compressive strength of the concrete

The compressive strength values of both types of concrete are presented in Table 1 and Figure 4. The compressive strength value increases as the water-cement ratio increases. The compressive strength ranges from 18.60 N/mm^2 to 18.91 N/mm^2 for the conventional concrete at the chosen water-cement ratios while that of the WAP concrete ranges from 11.80 N/mm^2 to 12.67 N/mm^2. The strength of both types of concrete fall in the strength class of normal/conventional concrete as prescribed by Portland Cement Association (1994), though the conventional (granite) concrete is stronger in compression than the WAP concrete.

Table 1: Average Compressive Strength Values at 7, 14, 21 and 28 days

Age of Curing (Days)	Compressive Strength (N/mm^2) for Conventional Concrete			Compressive Strength (N/mm^2) for WAP Concrete		
	0.50 W/C	**0.55 W/C**	**0.60 W/C**	**0.50 W/C**	**0.55 W/C**	**0.60 W/C**
7	10.17	11.80	13.47	6.35	6.76	7.45
14	16.98	17.12	17.25	8.20	8.55	8.80
21	18.00	18.28	18.49	9.67	10.20	10.74
28	18.60	18.74	18.91	11.80	12.32	12.67

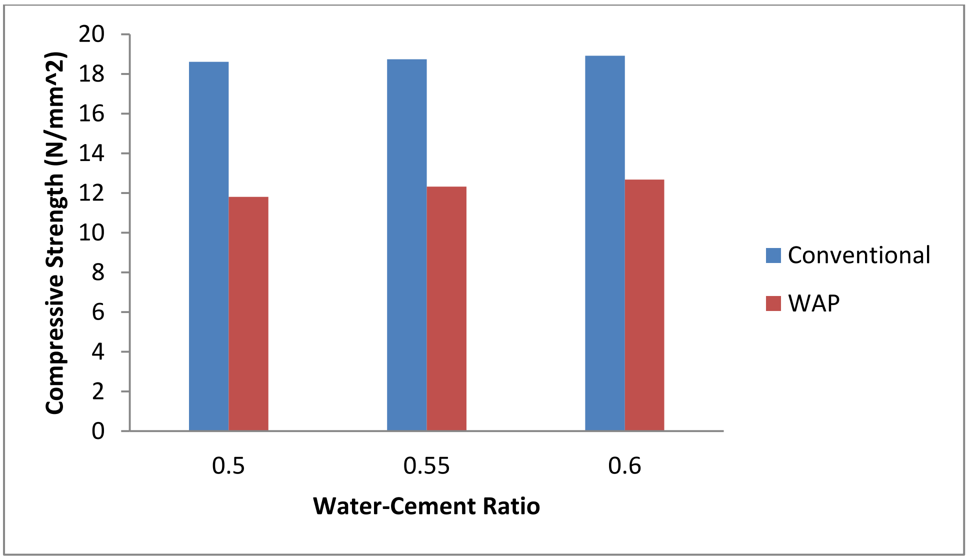

Figure 4: Compressive Strength Value – Water Cement Ratio Characteristics for the Granite and WAP Concrete

Statistical Analysis (Analysis of Variance)

Possibility of significant differences between the compressive strength values of the concrete cubes was determined through Analysis of Variance, the compressive strength values of the cubes at 28 days for the conventional and WAP concrete at the three water-cement ratios were used for this purpose as Table 2 shows the computations at 28 days. Table 3 rounds off the computation of two F values as the ratio of mean square between treatments to mean square between residual variations and the ratio of mean square between blocks to mean square between residual variations.

Table 2: Analysis of Variance in Compressive Strength at 28 days

	Conventional Concrete	Waste Asphalt Concrete	Row Total	Row Mean
A (0.50 W/C)	18.60	11.80	30.40	15.20
B (0.55 W/C)	18.74	12.32	31.06	15.53
C (0.60 W/C)	18.91	12.67	31.58	15.79
Column Total	56.25	36.79	**GRAND TOTAL = 93.04**	
Column Mean	18.75	12.263	**GRAND MEAN = 15.507**	

$V_R = b\sum(\text{Row Mean-Grand Mean})^2$

$V_R = 2[(15.20\text{-}15.507)^2 + (15.53\text{-}15.507)^2 + (15.79\text{-}15.507)^2] = \mathbf{0.3498}$

$V_C = a\sum(\text{Column Mean-Grand Mean})^2$

$V_C = 3[(18.75\text{-}15.507)^2 + (12.263\text{-}15.507)^2] = \mathbf{63.1218}$

$V = \sum(X - \text{Grand Mean})^2$

$V = [(18.60\text{-}15.507)^2 + (11.80\text{-}15.507)^2 + (18.74\text{-}15.507)^2 + (12.32\text{-}15.507)^2 + (18.91\text{-}15.507)^2 + (12.67\text{-}15.507)^2] = \mathbf{63.547}$

$V_E = V - V_R – V_C$

$V_E = 63.547 – 0.3498 – 63.1218 = \mathbf{0.0754}$

Table 3: Analysis of Variance in Compressive Strength (F Computation)

Variation	Degrees of Freedom	Mean Square	F
Between Treatments **V_R = 0.3498**	a-1=2	$S_R^2 = \frac{VR}{a-1}$=0.1749	F=$\frac{SR\hat{}2}{SE\hat{}2}$=4.6516
Between Blocks **V_C = 63.1218**	b-1=1	$S_C^2 = \frac{VC}{b-1}$=63.1218	F=$\frac{SC\hat{}2}{SE\hat{}2}$=1678.7713
Residual or Random **V_E= 0.0754**	(a-1)(b-1)=2	$S_E^2 = \frac{VE}{(a-1)(b-1)}$=0.0376	
Total V = 63.547	ab-1=5		

$F_{0.95}$=19 and $F_{0.99}$=99 at degrees of freedom of 2 and 2.

$F_{0.95}$=18.5 and $F_{0.99}$=98.5 at degrees of freedom of 1 and 2.

In the first instance, the values of F at 5% and 1% confidence levels are greater than the computed value, hence the null hypothesis is hereby accepted, and there are no significant differences between the compressive strength values of the concrete produced due to the change in water-cement ratio (rows). Moreover, the values of F at 5% and 1% confidence levels are less than the computed value, hence the null hypothesis is hereby rejected that is, there are significant differences between the compressive strength values of the concrete produced due to change in materials (columns). The statistical model establishes that the concrete produced with water-cement ratio ranging between 0.5 and 0.6 have approximately the same compressive strength values. However, the conventional concrete differs in compressive strength from the WAP concrete.

4. CONCLUSION

The specific gravity of WAP is lower than that of granite and the conventional (granite) concrete is more workable than the WAP concrete. The conventional (granite) concrete is stronger in compression than the WAP concrete, but considering the strength class of the WAP concrete, WAP can suitably replace granite in concrete production. There are no significant differences between the compressive strength values of concrete produced with water-cement ratio ranging between 0.5 and 0.6. It is important to posit that the use of waste asphalt pavement in concrete production is no doubt another instance of converting waste to wealth.

5. ACKNOWLEDGEMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

BS 1881 (1970a). *Testing Concrete: Method of sampling fresh concrete on site*. BS 1881 Part 1. London: British Standards Institution.

BS 1881 (1970b). *Testing Concrete: Slump Test.* BS 1881 Part 2. London: British Standards Institution.

Donaghy, S. 14th December 2014. *Reuse, Recycle, Reclaim*. Accessed 20th May 2018. Available: https://www.forconstructionpros.com/home/article/12028936/how-to-reuse-recycle-reclaim-asphalt

Energy and Environmental Affairs (2017). *Using or Processing Asphalt Pavement, Brick & Concrete Rubble.* Retrieved from http://www.mass.gov/eea/agencies/massdep/recycle/reduce/using-or-processing-asphalt-pavement-brick-and-concrete-.html

Erdem, S. and Blankson, M.A. (2014). Environmental performance and mechanical analysis of concrete containing recycled asphalt pavement (RAP) and waste precast concrete as aggregate. *Journal of Hazard Materials*. DOI: 10.1016/j.jhazmat.2013.11.040

European Asphalt Pavement Association (2015). *Recycling of Asphalt Mixes and Use of Waste.* Retrieved from http://www.eapa.org/publications.php?c=42

Federal Highway Administration. 27th June 2017. Asphalt Pavement Recycling with Reclaimed Asphalt Pavement (RAP). Accessed 20th May 2018. Available: https://www.fhwa.dot.gov/publications/research/infrastructure/structures/97148/rap134.cfm

Gill, V. and Berwal, P. (2016). Study on Bituminous Pavement Wastes Used As Replacement Material in Cement Concrete.

International Journal for Research in Applied Science & EngineeringTechnology, 4 (12): 324-326.

Herrador, R. Pérez, P., Garach, L. and Ordóñez, J. (2012) Use of Recycled Construction and Demolition Waste Aggregate for Road Course Surfacing. *Journal of Transportation Engineering, 138* (2):

Nordic Road Forum (2012). *Sustainable Asphalt Reuse*. Retrieved from http://www.eapa.org/userfiles/2/Publications/NVF_en.pdf

Okafor, F.O. (2010). Performance of Recycled Asphalt Pavement as Coarse Aggregate in Concrete. *Leonardo Electronic Journal of Practices and Technologies,* (17): 47-58.

Portland Cement Association (1994). High Strength Concrete. *Concrete Technology Today, 15* (1): 1-8.

Pourtahmasb, M.S. and Karim, M.R. (2014). Utilization of Recycled Concrete Aggregates in Stone Mastic Asphalt Mixtures. *Advances in Materials Science and Engineering, 2014*: 1-9.

World Bank (2012). Waste Generation. Retrieved from http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/Chap3.pdf