

# Performance of Reclaimed Asphalt Pavement (RAP) as a Replacement of Fine Aggregate in Concrete

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**Abstract:** Road pavement failure is a challenging phenomenon for road maintenance agencies due to increase vehicular traffic. In developing countries, some pavements fail even before the completion and handing over site. During maintenance, the material removed from failed portions is regarded as waste and are disposed-off along road sides or in dumps. This paper investigates the possibility of recycling the material removed known as Reclaimed Asphalt Pavement (RAP) in concrete specimens as partial replacement of aggregate. RAP was used to replace the fine aggregates from 0-100% at 20% intervals. Water absorption, density and compressive strength tests were carried out. Increased workability, less water absorption and compressive strength of 75%, 25% and 28.4 MPa were achieved at 100% replacement, 20% and 40% replacement levels respectively

**Keywords:** compressive strength, density, fine aggregate, Reclaimed Asphalt Pavement, workability

## 1. Introduction

Asphaltic concrete is a black sticky bituminous material used in surfacing road pavements. In most part of the world, this material has been widely used in various configurations and has been more acceptable than the cement concrete pavement. In America alone, over 93% of the hard surface roads are made of asphaltic concrete [1]. In Nigeria, over 61,000 km of roads has been constructed/rehabilitated between 1986 to date [2].

During the service life of road pavement, failure may occur due to stripping, sub-base failure or erosion. As soon as stripping begins, displacement, detachment and pore pressure weakens the pavement causing pot holes, cracking and segregation of the aggregates from the bitumen [3]. These failed sections of pavement refer to as pot holes are usually removed and replaced and in some cases, the removal involves the sub-base material to achieve better results. Most of the materials removed during rehabilitation are discarded on landfills or road side causing environmental hazards.

Recycling of used material has been identified as a means to an end toward sustainable development. The recycling process known as Reclaimed Asphalt Pavement (RAP) refers to those recycled pavement materials that are removed or reprocessed during rehabilitation of existing flexible pavement which contains both degraded bituminous materials and aggregates particles [4]. The utilization of RAP materials in new pavement construction has been an advantage by reducing the quantity of waste debris disposed of in landfills and reducing the depletion rate of available natural resources. Taha [5] reported that RAP has become a sustainable route in road maintenance and rehabilitation by preserving environment, resources, and retaining the existing natural land forms. Sayed [6] reported that U.S

Environmental Protection Agency in 1993 estimated that over 73 million tons of asphalt material is recycled each year which is about 80% of total asphalt pavement removed each year.

Most of the recycling of pavement material is reused in road pavement construction and rehabilitation. Researches are also scarce in the area of RAP use in concrete production and maintenance. Concrete being the most used construction material all over the world have aggregate content of over 70% of its volume. If research of the possibility of utilizing RAP in concrete rather than using new mineral aggregates can be established, most of our landfills will be lowered, environment would be protected and natural land forms would be sustained and protected.

This paper attempts to investigate the possibility of utilizing RAP as fine aggregate in concrete. Concrete area dominant material in construction industry and its strength and durability being the key parameter was investigated. Utilization of RAP in concrete could serve as an alternative to disposal towards sustainable development.

## 2. Materials

The RAP material was sourced from the Federal Road Maintenance Agency (FERMA) road repairs construction site along Gombe-Bauchi highway in Nigeria. The material was prepared by milling which was crushed manually and sieved using 5mm sieve to [7]. RAP specific gravity of 2.45 was obtained. The sample passing the sieve was used as the replacement for the fine aggregate.

Fine aggregate mainly of natural river sand was used in this investigation which conformed to the requirement of BS [8] in zone 2 aggregate classification and specific gravity of

2.72 while the coarse aggregate from crushed mineral rock was used all obtained in Nigeria.

Ordinary Portland cement was used throughout the course of this research in conformity to ASTM [9] and portable drinking water from running tap was used which was clean and clear while undertaking the research work.

**Mix design**

Mix design of 1:2.07:3.11 for cement, fine and coarse aggregate respectively and water cement ratio of 0.5 was used throughout the research program. RAP replacement of fine aggregate at 0, 20, 40, 60, 80 and 100% was used. Table 1 shows the composition of the constituent materials used.

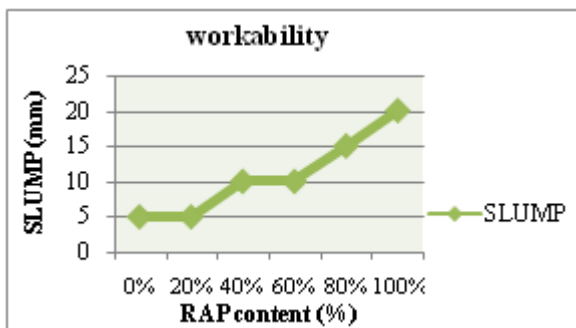
**Table 1: Mix Proportion**

RAP (%)	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	RAP (kg)	Water content (kg)
0	21.90	45.30	67.95	0.00	10.95
20	21.90	36.24	67.95	9.06	10.95
40	21.90	27.18	67.95	18.12	10.95
60	21.90	18.12	67.95	27.18	10.95
80	21.90	9.06	67.95	36.24	10.95
100	21.90	0.00	67.95	45.30	10.95

**3. Experimental Program**

**Workability**

Workability test in accordance with BS EN [10] was carried out. The use of RAP as a replacement of fine aggregate showed greater effect on the workability of the concrete. Fig.2 shows the result of the slump test carried out in concrete with a replacement of fine aggregate with RAP. Between 0-20 and 40-60% Rap replacements of fine aggregate, no noticeable change in workability was observed. 100% increment was observed at Rap content of 40% while above 60% RAP content, 50% increase in workability was recorded as shown in Fig.1. The increment in workability recorded is due to the bitumen content in the concrete matrix which does not absorb water. The excess water not absorbed by the particles cause the fluidity leading to higher workability. The reason for the constant workability at 0-20 and 40-60% could not be substantiated.

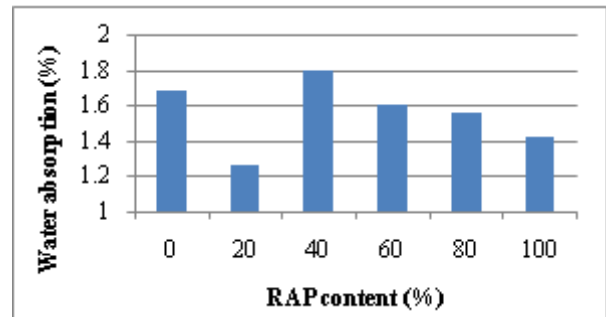


**Figure 1:** Workability of concrete containing RAP as fine aggregate

**Water Absorption**

Water absorption test in conformity with BS [11]: method for determination of water absorption of concrete. RAP content of 20% showed the best result with an absorption

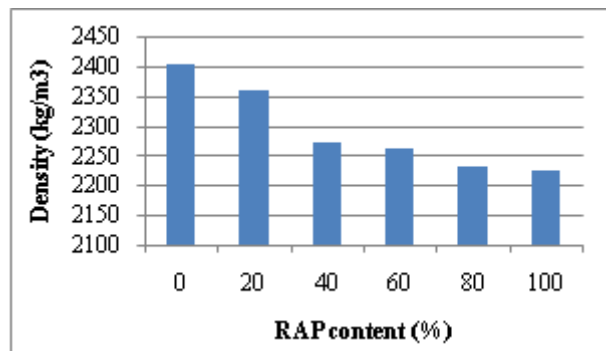
value of 25% less than the control specimen. The specimen with 40% RAP content showed the highest absorption value of 6.5% higher than the control. Fig. 2 shows the result of water absorption of RAP concrete from 0-100% fine aggregate substitution. Replacement of RAP in excess of 40% revealed continuous decrease in water absorption value less than that of the control. The reduction in water absorption of concrete containing RAP is due to the air voids created in the matrix preventing water getting access. More so, the replacement of fine aggregates RAP which may fill up voids within the specimen with bituminous tiny particles could also contribute to the water resistance of the specimens.



**Figure 2:** Water absorption of concrete containing RAP as fine aggregate

**Density of concrete**

The experiment was carried out in accordance with BS EN [12]: Standard Test Method for Hardened concrete Density. Specimen 18 numbers were used for the determination of density test. The densities of all the samples containing RAP were found to be lower than that of the control specimen as shown in Fig. 3. The density decreases with increase in fine aggregate replacement with RAP. Although, all concrete samples containing 20-100% RAP aggregate weigh more than 2000 kg/m<sup>3</sup> which outside the category of lightweight concrete specified by Neville [13].



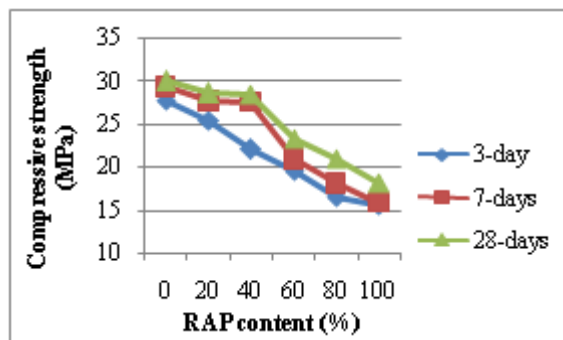
**Figure 3:** Density of Hardened concrete containing RAP as fine aggregate

**Compressive strength**

Compressive strength test was conducted in accordance with the provisions of BS EN [14]: Standard Testing Method for Making and curing specimens for strength tests using sample size 150 x 150 x 150 mm cube. A total of 54 specimens were produced and tested for 3, 7 and 28 days respectively. The curing was carried out in clean water pond

for the aforementioned period until testing days and the result is shown in Fig. 4.

It was observed that the compressive strength decreases with increase in RAP content for all the curing days. Replacement of RAP up to 40% did not show significant reduction in the compressive strength of the concrete specimens. A reduction in compressive strength of 4.7 and 5.2 MPa was observed for 20 and 40% RAP replacements respectively at 28-day. Compressive strength 7-day also showed similar trend with 28-days strength test which is about 3% less. The 3-days strength revealed a continuous linear reduction in strength with a gradient of about 0.15%. The reduction in strength is due to the ductility of bituminous particles in the RAP which allows compression of the specimen during loading. More so, the ductile behaviour of the RAP particles could also affect the hydration of the cement-aggregate gel thereby reducing its strength.



**Figure 4:** Compressive strength of concrete containing RAP as fine aggregate

#### 4. Conclusions

Reclaimed Asphalt Pavement (RAP) was used to replace fine aggregate in concrete at 0, 20, 40, 60, 80 and 100%. Workability, density and compressive strength were carried out on the specimens in line with specific standards. Based on the results obtained, RAP content of up to 40% was observed to be viable for both density reduction and compressive strength behavior. More research works are required to ascertain the true behavior of RAP concrete such as reducing the water cement ratio with increase in RAP replacement. Also, researches on ductility, impact value and other properties should be carried out.

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