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Original Research Article

Evaluation of Concrete Performances Based Recycled Aggregates of Road and Build Demolition for a Formal Using in the Republic of Congo

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Abstract

The reuse of recycled aggregates in the composition of concrete is a major challenge today in response to the high cost of construction and the environmental impact of waste This work evaluates the the physic-mechanical properties of concrete using recycled building demolition aggregates and bituminous concrete of pavements in the Republic of Congo. The idea was to check whether these recycled aggregates can have the same performance as when they were first used in concrete. From the results obtained, the recycled building aggregates have good mechanical strength according to the Los Angeles (32.5%) and Micro-Deval (29.3%) tests. Concrete made from building demolition aggregates (CRA1#) has a 28-day compressive strength of (28.8MPa), which is very close to that of the CNA# control concrete (31.11MPa). Concrete incorporating a mixture of asphalt concrete and building demolition aggregates (CRA3#) has a compressive strength of 20.32MPa. In terms of compressive strength, only CRA1# and CRA3# can be used as class C25 concrete for CRA1# and C20 for CRA3#.

Keywords: Recycled aggregates, Recycled concrete, Compressive strength, Water absorption of concrete.

INTRODUCTION

The construction industry contributes to a country's social and economic development. The expansion of buildings and the rebuilding of infrastructures lead to an enormous consumption of natural resources (i.e., aggregates) and the production of various types of waste throughout the world. Whether for buildings or roads, the use of large quantities of aggregates extracted from quarries has a significant impact on the environment (fauna, flora) and generates high construction costs [1, 2]. The dumping of demolition waste in the open often hampers the functionality of drainage works, roadways and green spaces, particularly in developing countries, such as the Republic of Congo. For example, the transport of building demolition waste following heavy rains has recently had a considerable impact on the drainage of rainwater through ditches and on the comfort of roadways in some towns in the Republic of Congo. The reuse of aggregates from demolition or waste in construction is at the forefront of concrete construction today [2].

It is an interesting alternative with a number of advantages [3, 4], including the elimination of waste in towns and cities, the reduction of construction costs, the development of the circular economy through labor-intensive practices, and so on. Recent studies have shown that concretes made from recycled aggregates can perform quite similarly to concretes made with the natural aggregates. This performance depends on the proportion of recycled aggregates used [4- 8]. Al-Azzawi [3], showed that substituting 25% recycled aggregates in the concrete composition makes it possible to obtain acceptable physical-mechanical properties. Loureiro *et al.*, [8], found that concrete made from recycled aggregates had better flexural strength but lower compressive strength than natural aggregate concrete. However, while in some countries the use of recycled aggregates is preceded by studies, in Republic of Congo this is not yet the case.

In fact, many recycled aggregates from a variety of uses, including aggregates from the demolition of concrete from buildings and pavements, construction waste and masonry rubble, etc., are currently being used in the informal construction sector in the Congo without any prior technical studies. In each context, the reuse of recycled aggregates can face various technical and scientific difficulties [9]. For example, in the Republic of Congo, the difficulties identified are as; (a) granular heterogeneity from one demolition site to another or from one waste site to another, (b) he varied origin of aggregates, (c) the lack of studies on the geotechnical characteristics of recycled aggregates, (d) the limited processing methods for each mod of producing recycled aggregates, (e) the lack of information on the actual exploitation time of natural aggregates in their first use. The use of recycled aggregates in concrete construction in the Congo today requires appropriate studies to meet the safety and durability requirements of structures, such as compressive strength, concrete porosity, density, etc. The aim of this work is to characterize the properties of concrete incorporating recycled aggregates from the demolition of concrete buildings and asphalt pavements in the Republic of Congo. It is also a question of verifying the physical and mechanical characteristics of these recycled aggregates compared with their first use, in order to have an idea of their effect in the new concrete composition.

MATERIALS METHOD

A. Materials

The sand used is fine sand from the Djoué river (fineness modulus < 2). The recycled aggregates used came from the demolition of concrete buildings, concrete asphalt roadways and others concrete structures in Brazzaville. The selected samples were subjected to a fragmentation operation before manual sorting of the grains according to their diameter, color and origin. The cement used was CMEII 32.5R, produced by FORSPAK society in Congo.

Figure 1: Recycled aggregates, (A, B) road demolition, (C) build demolition, (D) prepared sample

B. Method

B.1 Identification of raw materials

The grain size and distribution of all the aggregates (sand, gravel) were determined by the Grain Size Analysis test in accordance with standard NF P94-056. Fig.2 shows the grading curves for white sand, natural aggregates and recycled aggregates.

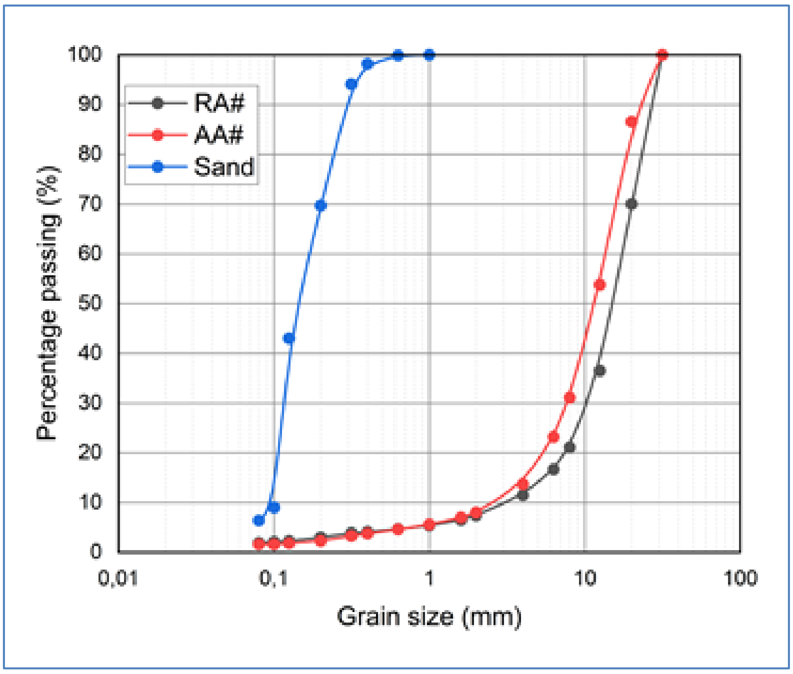

Figure 2: Sizing curves for sand, natural and recycled aggregates, RA# - recycled aggregate, AA# - recycled asphalt aggregate

The grain size distribution of recycled aggregates from demolition of concrete structure is spread out (Fig.2), according to the values of the coefficients, Cu (6.26 > 2) and Cc (1.85). That of aggregates from recycled asphalt pavement is also spread out, Cu (5.02) and Cc (1.55).

The percentage of sand passing through the 80µm sieve is 3.8%; the values of the coefficients Cu= 1.92 < 2 and Cc =1.05 indicated a uniform and well graded distribution of the grains of this sand. The percentage of recycled asphalt aggregate passing the 80µm sieve is 1.6% and Cu=5.04>2; Cc= 1.55; the grain size distribution is well spread out. These two curves have a similar appearance, but merge in the fine part.

The cleanliness of the aggregates was measured by the Sand Equivalent (SE) test on a fraction of particles < 2 mm in accordance with standard NF EN 933-8. The S.E. value (in %) is the ratio of the quantity of flocculate (in cm) and the particles of sedimented material (in cm).

The absolute density of recycled and natural aggregates was determined by pycnometer method in accordance with standard (EN 1097-1). The water absorption coefficient of the aggregates (WA) was measured using the pycnometer method (standard NF EN 1097-6), in order to determine the water retention capacity of the material. The principle of the method is to immerse the sample in water for 24 hours, measuring its saturated masses.

The mechanical resistance of recycled and natural aggregates, notably the fragmentation by impact and wear by reciprocal friction of the particles, was determined by the Los Angeles (LA) and Micro-Deval (MDE) tests (NF EN 1097-1, 2). Table 1 shows data on the identification of raw materials. Recycled aggregates from the demolition of building concrete have good mechanical strengths based on Los Angeles (LA = 32.5< 40%) and Micro-Deval values, which verify the (LA + MDE ≤ 50) relationship. Recycled aggregates from the demolition of building concrete absorb a significant amount of water WA (7.3%) compared to natural aggregates WA (1.6%), which can be explained by the presence of cement mortar in their composition [10]. The sand used is very clean SE (97.86%), which means a high cement content.

Table 1: Geotechnical characteristics of raw materials

Material characteristics	Sand	Recycled concrete aggregate	Recycled asphalt aggregate	Natural aggregate
Sand Equivalent (S. E%)	97,86	/	/	/
Apparent density (ρd, g/cm3)	1,61	1,40	1,24	1,39
Absolute density (ρs, g/cm3)	2.5	2.22	2.33	2,68
Absorption coefficient (WA %)	/	7,3	0	1,6
Los Angeles (L.A %)	/	32,5	/	31,1
Micro-Deval (MDE %)	/	29,30	/	21,82

B.2 Experimental Characterization of Concrete

The Dreux-Gorisse method was used to determine the quantities of materials required for the composition of the concrete [11]. Cylindrical specimens were made from four concrete mixes (Table 2).

For a cement dosage C (360 kg/m3), a slump at the Abrams cone estimated at 8 cm and a target compressive strength at 28 days of 30MPa (C30), the dosage adopted for 1m3 of concrete per sample is given in Table 2.

Table 2: Dosages of materials used in concrete

Material	Concrete mixture (kg/m^3)				
	1m^3	CNA#	CRA1#	CRA2#	CRA3#
Cement	360	10,044	11,844	13,824	13,824
Sand	500	13,950	16,450	19,200	19,200
Aggregate	758	21,148	24,938	24,938	29,107
Water	165	4,604	5,429	8,000	9,104
Total	1783	49,746	58,661	65,962	71,235

CNA# - ordinary concrete, i.e., the control sample, composed of sand and natural aggregate,
RA1# - concrete made from recycled aggregates from building demolition (5/25 aggregate) and sand,
CRA2# - concrete made from recycled aggregates from the demolition of recycled bituminous concrete and sand,
CRA3# - concrete made from recycled aggregates, building demolition, recycled bituminous concrete and sand.

B. 3 Tests Specisms Concrete

The slump of concrete (Slump test) was measured using the Abrahams Cone method (standard NF P18-451), to assess the consistency of milled concrete under the effect of its own weight, and to determine the conditions for use in formwork (Fig.3).

Figure 3: Slump test on concrete study

Water absorption by total immersion (Abs) is an indicator of a concrete's durability, and is correlated with the porosity and dry specific mass of the material. It is determined in according the standard NF EN 1097-6.

Compressive strength characterizes the mechanical aptitude of hardened concrete; it is measured using standardized specimens of hardened concrete at a given age in accordance with standard EN 12390-4. For this study, nine cylindrical specimens for each concrete sample were measured at 7, 14 and 28 days of age.

RESULTS AND DISCUSSION

A. Physical properties of concrete

The average at cone slump for all recycled aggregate concretes is 9 cm, while that for natural aggregate concrete is 8.5 cm. The values for dry density and absorption coefficient after water immersion are given in table 3. It can be seen that the density of recycled aggregate concrete is lower than that of natural aggregate concrete, which is due to the loss of mass through friction of the recycled aggregate grains when they are first used. The mass of water absorbed by recycled aggregate concrete is less than that of natural aggregate concrete, which can be explained by the increase in fines, which occupy a high proportion of voids in the granular skeleton of recycled aggregates.

Table 3: Density and absorption of hardened concrete

Physical characteristic	Concrete sample			
	CNA#	CRA1#	CRA2#	CRA3#
Concrete density (g/cm3)	2,45	2,25	2,23	2,26
Concrete absorption coefficient Abs (%)	3,31	2,65	2,21	1,96

B. Mechanical Properties of Concrete

Figure 4 present the compressive strength of concrete at 7, 14 and 28days.

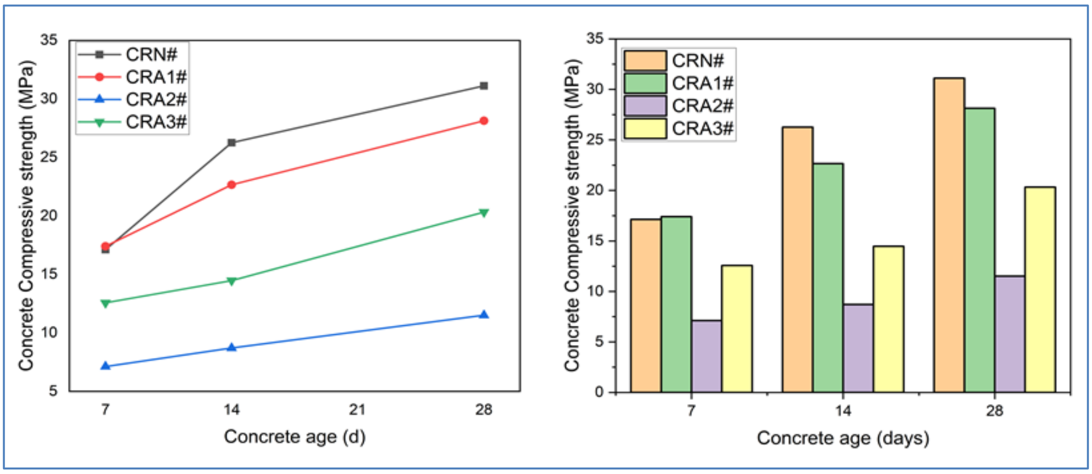

Figure 4: Compressive strength of concrete by type of gravel as a function of curing time

Figure 4 shows a normal progressive evolution of the compressive strength of the control concrete CNA#, the characteristic strength obtained at 28 days is Cs (31.11MPa). CRA1# concrete has an acceptable compressive strength that develops progressively from 7 to 28 days, Cs (28 MPa), although this value is lower than that of the control concrete. The compressive strength at 28 days of CRA2# concrete is (11.51MPa), lower than that of the control concrete. The reduction in this strength can be explained by the poor adhesion between the recycled asphalt concrete aggregates and their loss of mechanical strength due to the repeated action of road traffic, in addition to the excessively low density of bitumen. CRA3# concrete has a 28-day compressive strength of 20.32 MPa, which increases progressively from 7 to 28 days.

This slow development can be explained by the fact that the proportion of recycled bitumen aggregate residues is lower, which does not encourage rapid development of concrete strength. The compressive strength obtained from the CRA1# and CRA3# concrete samples is higher than that obtained in certain works on cylindrical specimens.

To regard the compressive strength values (Fig.4), concrete using recycled aggregates from the demolition of concrete structures, and concrete mixtures based on aggregates from the demolition of asphalt and concrete structures, can be used for concreting structural elements in accordance the standard ACI 318/2014 [12]. In [3], the compressive strength found on a concrete with 100% recycled aggregate was 17.15MPa, it was recommended as structural concrete. Indeed, the difference between the compressive strengths in our work and past research's may also be due to the fatigue effect depending on how long the aggregates have been used in the old concrete. The presence of the old cement slurry on the recycled gravel weakens the structure of the mixture, and the presence of pores makes it easier to break the bonds between solid grains in the mixture [13].

DISCUSSION

The durability of concrete is governed by certain intrinsic characteristics such as compressive strength, density and porosity [14]. Figure 5 shows the evolution of the compressive strength as a function of the absorption rate after immersion of the concrete.

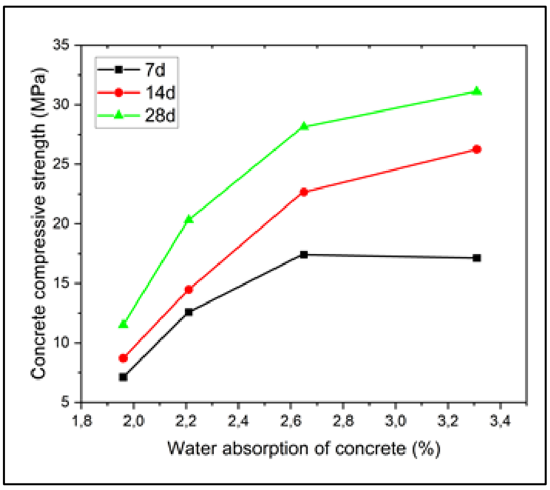

Figure 5: Correlation between compressive strength and water absorption of concrete

This graph (Fig.5) shows that for each concrete sample tested, the compressive strength evolves in correlation with the water absorption, whatever the curing time of the concrete.

While the compressive strength of concrete is highly dependent on the type of cement (Crentsil *et al*.,) [15], it can also be seen that, depending on the type of aggregate used, the amount of water absorbed by the pores of the concrete reduces its characteristic compressive strength. Thus, from right to left, at 7, 14 and 28 days of hardening: (i) with a water absorption rate of 3.31% in the concrete based on natural aggregate, a fairly rapid change in compressive strength is observed at 7, 14 and 28 days of hardening (17.12-26.26-31.11MPa); (ii) for the water absorption rate of 2.65% in concrete based on recycled aggregates from building demolition, the compressive strength evolves normally from 7, 14 and 28 days of hardening, but it decreases compared to the reference concrete (17.40-22.60-28.13MPa); (iii) for the water absorption rate of 2.21% in the concrete with recycled aggregate from the demolition of concrete structures and recycled asphalt aggregate, the compressive strength evolves in a slightly disparate manner at 7, 14 and 28 days of age, and is lower than in the two previous samples; (iv) the concrete based on recycled asphalt aggregate, which has absorbed 1.96% water, shows a remarkable decrease in compressive strength (7.12-8.12-11.51 MPa). Fig.6 present the correlation of concrete density as a function of water absorption coefficient.

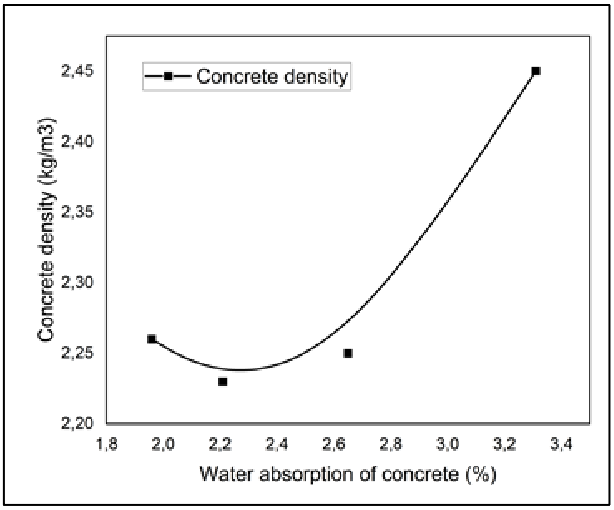

Figure 6: Correlation between concrete density and water absorption of concrete

The density of concrete evolves in correlation with its water absorption, which may justify the influence of porosity and compactness on the durability of concrete. This evolution is similar to that in figure 5, which proves the importance of controlling water absorption in concrete before it is use.

CONCLUSIONS

The characterization of raw materials enabled us to quantify the quality of recycled aggregates from the demolition of buildings and pavements in the Congo, and then to assess their influence on the physical-mechanical properties of hydraulic concrete.

The Los Angeles and Micro-Deval values show that recycled aggregates from the demolition of structures in Congo have satisfactory mechanical strength compared with natural aggregate. For the two types of aggregate used (building demolition aggregate and bituminous concrete aggregate), the particle size analysis showed that their size distribution is spread out and continuous, which is recommended for making concrete. The absorption coefficient of concrete made from recycled aggregates is low compared with that of natural aggregates. Of the three concrete samples, only concrete samples CRA1# and CRA2# show interesting compressive strengths, although they are below the target value. Nevertheless, the use of these concretes may be recommended for routine work. The use of concrete based on recycled aggregate from the demolition of bituminous concrete should be avoided. In addition, studies should be carried out to analyze the effect of incorporating substitution rates of recycled aggregate from the demolition of concrete structures in the Congo on the durability of new concretes. Consideration will also be given to assessing the effect of incorporating recycled aggregates with other wastes on the properties of concrete. It will also be important to carry out a survey on the duration of existing buildings, the cost of building with palm nut shell waste as a stabilizer for clay soils, etc.

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