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The Characteristics and Potential Use of Recycled Concrete Aggregate

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Abstract: This study present describes an investigation carried out to study the characteristics and potential use of recycled concrete aggregate in the manufacture of new concrete. Up to now, recyclable materials produced from road demolition have mainly been re-used in low quality applications in road construction. Two types of recycled aggregate namely recycled concrete and debris were taken from demolition waste and tested for characterization of aggregate and also for the mix-designs of concrete to achieve better mechanical strength. The results obtained with the use of the selected type of recycled aggregate shows a real possibility of making concrete from demolition waste which will lead to optimization in concrete production.

Key words: Recycled, concrete aggregate, demolition waste, debris, optimization, mechanical strength

INTRODUCTION

It is being made increasingly aware of the consequences of using primary aggregates for construction in Nigeria. In recent years, Nigerian waste management initiatives have aimed to reduce the dumping of inert construction and demolition waste at landfill sites and instead promoted its recycling and reuse in new build. The re-use of material derived from the demolition of buildings and other activities in the building industry is restricted because of lack of scientific data. There is not yet sufficient information available to show that recycled materials meet standard technical criteria for use or match the performance of natural materials. In additions, there are no rules clearly setting out the methods for using these derivatives, these shortcomings are particularly applicable to the recycled aggregate, which if they are to replace natural aggregates, they must invariably have to meet stringent structural and safety requirements (Cristofoletti, 1994).

In some European countries such as Germany, the difficulty and expense of obtaining aggregate from quarries has meant that the use of building and demolition waste has become increasingly widespread, as a result, both the recycling processes designed to produce high quality secondary raw materials and the technique for using recycle aggregate in the various construction sectors are quite advanced (Cairns, 1985) yet this achievement cant be simply transposed to the Nigeria situation because the technical norms that apply to all European countries are still to be standardized with respect to both requisites and performance criteria, more importantly, there is still no universally recognized quality control procedure to ensure adequate qualitative standards.

In Nigeria today, 5 million tones of demolition waste are produced each year and forecast suggest that by the middle of next century, annual production in terms of volume will reach 25 million cubic meters, with an ever increasing awareness of the consequences of waste disposal on the environment, the Nigerian solution is indeed pragmatic, there are infact no norms concerning neither the specification for recycled aggregate for use in building industry nor the types of building it can be used, with the exception to natural aggregate in the manufacture of concrete.

Anyone wishing to use recycled aggregate in Nigeria today, in the believe that such use will eventually become widespread and appropriately regulated, can refer to research carried out in other developed countries where the use of recycled aggregate is recognized even in the production of concrete, however a frequent limit of the research, in common with similar studies in Nigeria, is that it is based on 'laboratory produced aggregate', an aggregate produced by crushing material whose properties are well known, which is not the case for aggregates produced from the output of recycling plants, were the provenance of materials cannot be strictly controlled (Merlet and Pimiento, 1994).

Objectives of the study:

- Optimize the use of cement in concrete production.
- Determine the characteristics of the various types of aggregate according to the kind of waste material used.
- Examine the procedure of using the demolition waste in concrete manufacturing.

MATERIALS AND METHODS

As seen, there is yet no standardization of quality control for recycled aggregate and the methodologies used are those applied to natural aggregate, adapted occasionally to meet the special characteristics of recycled material or to facilitate the reading of results in relation to previous studies or the normative parameters of other countries referred to. The same goes for the equipments, which is the standard apparatus used in testing natural aggregates and normal concrete.

The recycled aggregate used in the tests came from R.O.S.E (Homogenized Recovery Demolition Waste) recycling plants, which have been operating Emilia Romagna for several years (Yanagi, 1991). The material was supplied in the form in which it is usually commercialized, sorted by grain size and transported in sack whose weight is easily verified. The aggregate tested was of four types:

- Concrete Rubble (CR), from the crushing of exclusively concrete waste, coming mainly from the demolition of reinforced concrete structures and cement manufacturers waste. It is possible, however, that this secondary raw material is also supplied to some collection points by factories producing precast elements in precompressed concrete or reinforced concrete with the problem of getting rid of production residue.
- Various Rubble (VR), from the crushing of general building waste, containing not only concrete but also the most common materials found in demolition waste (bricks and tiles).
- Quarry (Q), a normal aggregate of inert gravel from quarrying. In particular, the aggregate used comprised a combination of crushed limestone and river bed gravel.

For the tests, cubic moulds were made measuring 100×100×100 and 160×160×160 mm for compression. The mechanical resistance was tested in a controlled load-bearing hydraulic press (Lyne, 1998).

Screening of recycled aggregate: First the aggregate from the recycling plant was tested to establish its composition and performance parameters, which are fundamental for its subsequent use in the manufacture of concrete conglomerates. The volumetric mass and absorption value were measured by means of two different tests for large and small grain input, taking 5mm as the discriminating parameter. In accordance with Germans norms, both the apparent and real volumetric mass were measured for each of the four types of material; a significant reduction was found in the recycled aggregate compared to natural counterparts and this represents an advantage in concrete manufacture, given the compatibility of other characteristics (Table 1). Another important factor is the increase in absorption values. The presence of cement mortar round the stone particles in the recycled aggregate increase the materials porosity and hence gives significantly higher values for the absorption of water(Dillman, 2000).

Table 1: Characteristics of recycled aggregates

Characteristics	Concrete rubble	Various rubble	Tufa rubble	Quarry
volumetric mass, Large (Kg m^{-3})	2125	2112	2010	2708
Volumetric mass, Small (Kg m^{-3})	2208	2195	1862	2861
Volumetric mass, Total (Kg m^{-3})	2530	2515	2393	2880
Absorption, large (% by weight)	7.1	5	9.7	1
Absorption, small (% by weight)	11.8	13	18.9	3
Absorption, total (% by weight)	9	10.28	14.4	1.7

The large grain material was subjected to visual inspection to identify the different types of material present in the mixture. The same grain material was subjected to a colour matching test to detect the presence of organic substances.

Then the grain size distribution was measured for each type of recycled material.

Considering the overall characteristics of each type of aggregate, we can say that the inert type called concrete rubble meets all the parameters of a normal concrete aggregate and is thus suitable for the identical uses, the same is not true for various rubble, for here the values are significantly different from those of natural aggregate, thus the use of these materials must be regulated by specific norms and restrictions which take into account their characteristics as secondary materials and the processes involved in the recycling treatment (Ogbeide and Adejuyigbe, 2007).

Identification of mix design and tests on different concretes

This part of the study had 3 phases:

- Different concrete were made up according to the mix design used for natural aggregate and resistance values were measured using the recycled aggregates as supplied from plants; the parameters chosen were a maximum particle diameter of 30 mm, concrete type CEM II and a level of workability compatible with normal site requirements.

Table 2: Compressive strength of concrete with concrete aggregates

	Q	CR	CR+Q	CR+A	CR IPS 1	CR IPS 2	CR IPS 3
Compressive strength ($N\ mm^{-2}$)	33.9	23.2	25.1	28.9	29.7	32.7	32.3
Water/ Cement	0.51	0.34	0.36	0.37	0.36	0.57	0.35

- Methods were identified for improving the mechanical strength of concrete made from recycled aggregate, making it possible to reduce the quantity of water in the mixture: Replacement of part of the fine aggregate with natural aggregate (+Q), addition of fluidifiers (+A) and use of aggregate with Irregular Particle Size (IPS) to obtain higher absorption levels for fine fraction;
- Identification of the best dosing with irregular particle size and verification of data with a series of mixtures based on the concrete rubble type of aggregate.

RESULTS AND DISCUSSION

The result of the tests are significant both for the use of recycled aggregate according to current building practice and for further experimentation, first of all there is no doubt that concrete rubble always out-perform the various rubble. The result obtained shown that, even before introducing any modifications, this material stands comparison with natural aggregate and is suitable for the identical uses. The other types were found to require specific norms and restrictions.

In general the result justify expectation concerning the use of concrete manufacturer with recycled aggregate to replace, either totally or in part, traditional concrete, deciding on the degree to which it is use on the basis of the performance required and the corresponding characteristics. In term of compression strength (Table 2), the conglomerates containing concrete rubble showed an increase ranging from 7% for admixtures with quarry aggregate to 17% with fluidifiers and 22% with irregular particle size.

In brief, we can say that the different concrete with irregular particle size gave the best overall results. They offer the advantage of leaving unaltered the environment impact of the new type of concrete, while their only shortcoming is inferior workability, which can overcome by using adequate constipation techniques.

CONCLUSION

As the experimental data concerning concrete manufactured with aggregates from the recycling of building and demolition waste have shown, the use of such aggregate in place of quarried material is not only desirable but possible. Of course a distinction must be made between material based on Concrete Rubble and various rubble. The former aggregate performed well even when made up in the mixtures normally used for traditional concrete, providing conglomerates suitable for use as lean concrete as a substitution of quarry material, which is superior to such a use. When this recycled concrete is used with specially designed methodologies and procedures, it performs like normal concrete and is suitable for all uses except situations requiring particularly high resistance values.

The various rubble, on the other hand, can not be used in the manufacture of conglomerates according to traditional mix designs, they can replace quarry materials for infilling and road foundations, thereby reducing the environmental impact of these activities by no means the least reason for promoting the use of recycled aggregate is the economic one; when compared with their natural counterpart they represent a saving, at current market prices, ranging from about 25% for concrete rubbles for 45% for various rubble.

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