

Review article

Review Of The Use Of Construction And Demolition Waste In Concrete.

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Abstract.

Many countries in Europe, America and Asia are now relaxing their infrastructural laws to allow the use of construction and demolition waste, otherwise known as recycled aggregate, in concrete.

This paper reports the basic properties of recycled fine and coarse aggregates in comparison with natural aggregates. The effects of changes in all aggregate properties on concrete are discussed. Basic concrete properties like compressive strength, flexural strength, workability etc are discussed with respect to different combination of recycled aggregate with natural aggregate. Codal guidelines of recycled aggregate in various countries are discussed together with present status of recycled aggregate in Nigeria. **Copyright © IJEATR, all rights reserved.**

Keywords: Recycled aggregate, Natural aggregate, Sustainability, Compressive strength, Flexural strength, Workability.

Introduction.

Fredona (2007) has shown that the global demand for construction aggregates may exceed 26 billion tones by 2011 China (25%), Eu (12%), and in USA (10%). As a result of recent development particularly in the Port Harcourt area, significant increase in the use of aggregates in Nigeria is expected. In Nigeria, over 15 MT of solid wastes are generated annually from construction industries, which include wasted sand, gravel, bitumen, bricks and masonry concrete. Globally, some quantity of such waste is being recycled and utilized in building materials (Asolekar 2004). Therefore, concrete recycling is very important for sustainable development in our times (Oikonomou 2005).

Concrete rubble usually constitute the largest proportion of construction and demolition waste (C&D). Crushed concrete rubble, after separation from other concrete and demolition waste and sieved, can be used as a substitute for natural coarse aggregates in concrete or as a sub-base or a base layer in pavements (Hansen 1992; Collins 1994; Mehta and Monteiro 1993 and Sherwood 1995). This type of recycled material is known as recycled aggregates (Poon et al 2002).

Aggregate In Concrete.

The cementing medium in concrete fills voids between aggregate particles providing lubrication of the fresh concrete and give strength to the hardened concrete; whereas, the aggregate in concrete provide a relatively cheap filler for the cementing material, provide a mass of particles which are suitable for resisting loads, abrasion and weather; and also reduce the volume changes resulting from the setting and hardening process.

70 to 80% of the volume of concrete is made up of aggregates, a granular material derived from natural rock or natural sands and gravels. In selecting aggregate for use in concrete, care must be taken to select good aggregate, not reactive silica which leads to deterioration of the concrete, not weak friable aggregate and not highly porous aggregate. Some of the aggregate properties are directly dependent upon the parent rock and some are not. Properties that are dependent on parent rock are chemical and mineralogical descriptions, petrographic description, specific gravity, strength, hardness, and colour, and properties that are independent of parent rock are surface texture size and shape.

The characterization of aggregate is commonly on the basis of the specific gravity, (i) normal weight (ii) light weight and (iii) heavy weight, and further by grading, shape, inclusion, bulk density, chemical composition, drying shrinkage and water absorption.

The Need For Recycled Concrete Aggregate (RCA).

In view of sustainability and limited natural resources, USA, Japan and parts of western regulations have considered use of recycled and secondary aggregates (RSA), such as crushed concrete, asphalt and industrial byproducts and have sufficiently put in place that use of RSA exceeds 10% of the total use of aggregate. Recycled materials may not necessarily mean greater sustainability as they require energy to produce. So, instead the appropriate use of materials for both performance and function may have to be considered (Dhir et al 2006).

In Nigeria, the main reason for increase of the volume of demolition concrete waste is development of new infrastructural such as building of new roads; and all buildings on the right of the way demolished. Such demolition is going on daily, particularly in the Port Harcourt area of Nigeria. Such waste has been proved to be an excellent source of aggregates for new concrete production; and the concrete proven to have mechanical properties similar to those of conventional concretes and even high strength concrete is nowadays a possible goal for this environmentally sound practice (Ajdukiewicz and Kliszczewicz 2002; Khatib 2005 and Leite 2001). No thorough prove of similar properties for the fine fraction of these recycled aggregates, as their greater water absorption can jeopardize the final results. The existing codes concerning recycled aggregates for concrete production strongly limits the use of these products (PCA 2002; Kasai 1993 Task force of the standing committee of concrete 2004).

Existing Knowledge On Use of RCA.

The knowledge and tests of RCA should include:

- (i) Historical data of old concrete, masonry and old structure.
- (ii) Mechanical data of resistance to abrasion/degradation.
- (iii) Physical data of water absorption, specific gravity, amount of chlorides and sulphates etc.

(iv) Environmental data, especially in cases where RCA seem to create "leachates".

Since 2002, RCA reflected the highest and most consistent quality of all recycled aggregates available. Although mobile crushers have the advantage of avoiding transportation of construction and demolition (C&D) waste away from site (fig 2), they are rarely sophisticated enough to remove all impurities. Instead, recycled aggregates from central recycling facilities undergo a number of processes to ensure higher quality, and take great care to control the type of C&D waste that is allowed to be stockpiled. Soil, silt and clay can be particular problems and care is usually taken to avoid them.

In Japan, attempts have been made to further improve the quality of recycled aggregate by several methods such as heat and rubbing, eccentric-shaft rotor method and straight forward mechanical grinding. Only a few cases are reported of use of recycled aggregates in structural concrete, and the amount of recycled aggregate used has always been small compared to the total coarse aggregate weight; such as the case in an office building in the UK in 1999 (Desmyster and Vyncke 2000). Recycled aggregates are weaker, more porous and have higher values of water absorption than normal aggregate. However, when recycled aggregates from crushed concrete are used to replace up to 20% by weight of the coarse natural aggregate in concrete, little effect on the properties of concrete is noticed (Handicks and Pieterston 1998).



Figure 1: Pictures of demolition waste along Trans-Amadi, Port Harcourt, Nigeria.



Figure 2: Pictures showing transportation of demolition waste from site at Trans-Amadi, Port Harcourt, Nigeria.

Mix Proportions.

Compressive strength decreased with increase in a/c ratio and is directly proportional to strength of the blended aggregate (Poon and Lam 2008). The extent to which the properties of concrete are affected by the use of recycled aggregate depends on the water absorption, crushing value and soundness of the recycled aggregates (Kikuchi et al 1998).

Stress-Strain Behaviour.

Concrete strength decreased when recycled concrete was used (Barra de Oliveira and Vasquez 1996); and the strength reduction could be as low as 40% (katz 2003; Chen et al 2003). No decrease in strength for concrete containing up to 20% fine or 30% coarse recycled aggregates, but beyond which there was a systematic decrease in strength as the content of recycled aggregates increased (Dhir et al 1999). Quality of recycled aggregate did not affect strength at high water/cement (w/c) ratio but at low w/c ratio (Ryu 2002; Padmini et al 2002). A conservative value for replacement of aggregate is 20% by mass, which was adopted in BS 8500-2 (2002). The code virtually does not permit use of fine RCA in concrete as it causes instability of the mix and the strength of the resulting concrete (Dhir et al 1999; BS 8500-2 (2002); but the flexural strength and modules of elasticity of RCA are proportional to the compressive strength (Dhir and Paine 2010). RCA has higher levels of drying shrinkage than natural aggregate for the same compressive strength and creep is also higher in recycled aggregate concrete than equivalent natural aggregate concrete (Fraaiji et al 2002).

Durability.

Recycled aggregate concrete has better resistance to carbonation than natural aggregate concrete (Dhir and Paine 2007) because recycled aggregate concretes have higher cement content to achieve a given strength. Abrasion resistance of recycled aggregate concrete has been assessed using an accelerated abrasion method (Dhir et al 1999). Up to 30% by mass of recycled aggregate as coarse aggregate, there is only a small difference in abrasion resistance (approximately 0.2mm), and which is within test repeatability but below 30%, the difference is as much as 1mm. With the replacement of fine natural and fine recycled concrete aggregate, the abrasion resistance seems to increase.

Standards In Place At The Moment For Recycled Aggregate.

A. European Practice.

European standard, BS EN 12620, defines natural manufactured and recycled aggregate as: (i) Natural aggregates, being from mineral sources and subject to nothing more than mechanical processing.
(ii) Mechanical aggregates being of mineral origin resulting from industrial process involving thermal or other modification and
(iii) Recycled aggregate, result from the processing of inorganic material previously used in construction.

Besides these, a number of categories for coarse recycled aggregate were introduced. BS 8500-2 defines the constituent materials that may be used in concrete in recycled and manufactured aggregates (BS 8500-2:2002). RCA is obtained from crushing demolished concrete structures, discarded precast elements and unused hardened concrete, and by definition (BS 8500-2) it must be predominantly composed of concrete (at least 83.5% by mass) with not more than 5% masonry.

B. Japanese Practice.

Japanese standards (JIS A 5021) recognizing that composition of recycled aggregate does not necessarily reflect performance capability, are introducing specifications for three standards of recycled aggregate for concrete. (i) low quality recycled aggregate for backfilling, filling and leveling concrete. (ii) Use of RCA with blended cements as a measure against alkaline-silica reactivity (iii) Provision of requirements for "normal" recycled aggregates.

International Experience On RCA.

There is general guidance supporting of RCA and grouping aggregates into three classes:

- (i) Class A: RCA for use in a whole lot of concrete including marine environments.
- (ii) Class B: Covering most natural and RCA and suitable for most 'moderate' exposure conditions.
- (iii) Class C: RCA suitable for only the 'mildest' exposure conditions.

Use of RCA for new concrete has also led to the production of concrete of high strength performance (Limbachiya et al 2002). Use of RCA upto 30% is usually recommended with addition of super plasticizer for achieving the required workability of new concrete (Zankler 1999; Rilem 1994; BRE 1998). Three types of RCA are specified by Rilem (Rilem 1994):

- (i) Types i - which consists primarily from masonry rubble.
- (ii) Types ii - which consists primarily from concrete rubble.
- (iii) Types iii - which consists of a blend of RCA (max 20%) and natural aggregates (min 80%).

Alternative way of classifying RCA is by density and Rilem 1994 specifies the following classes.

RCA (i) Origin: brickwork, brick content (by weight): 0-100%.

RCA (ii) Origin: concrete, brick content (by weight): 0-10% .

RCA (iii) Origin: concrete and brickwork, brick content (by weight): 0-50%.

On Economic Use Of Aggregates.

Natural aggregate is the main alternative to using recycled aggregates; but cost of processing to recycle aggregates in the UK is becoming less than that of disposing of the demolition waste and purchasing new aggregates, due to increases in landfill tax and the newly introduced aggregates levy. If RCA have to be transported a significant distance from the place of production to the place of use, as shown in fig 2, then both the cost and environmental benefits may become more questionable (Shakdar and Tanaka 2004; Sengupta 2002; Bhattacharyya et al 2004).

As seen in fig 1 and 2, up to 15- 20% of solid wastes is being recycled in various building components as a result of incremental increase in the cost of construction materials in Nigeria.

Conclusion.

This paper has demonstrated the significant potential for growth of RCA as an appropriate solution to the anticipated increased world-wide construction activity. There are few (if any) applications issues related to use of RCA. New standards are easing its use in higher value applications. Nonetheless, this is very much limited to few countries and the message has to travel round the world to make a meaningful difference to the suitable use of RCA in concrete.

Practice has to catch up with the sound knowledge of use of RCA, which needs to be capable of being packaged in a manner that is easily workable and help to gain confidence on use of RCA.

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