© INTERNATIONAL JOURNAL FOR RESEARCH PUBLICATION & SEMINAR
ISSN: 2278-6848 | Volume: 08 Issue: 07 | July - September 2017
Paper is available at www.jrps.in | Email : info@jrps.in

APPLICATION OF RECYCLED AGGREGATE IN CONCRETE: A REVIEW

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ABSTRACT
This study presents an overview of the development and application of recycled aggregate in the production of concrete. Nowadays, in a large part of the world, demolition of old and deteriorated buildings and traffic infrastructure, and their replacement with new ones is a usual phenomenon. As a consequence, the volume of demolished concrete is increasing day by day, which generates a lot of waste and ultimately pollutes the environment. However, because of rapid industrialization, production and utilization of concrete is rapidly increasing, which results in increased consumption of natural aggregate as the largest concrete component. Hence, the preservation of natural aggregates sources is being threatened day by day. On the other hand, the protection of the environment has become one of the major issues of our present world. The reduction of raw material consumption and energy consumption is critical elements in this regard. Therefore, recycling of demolished concrete for new construction is essential to preserve the natural resources as well as to solve the disposal problems of demolished concrete.

Keywords: Demolished concrete; recycling; recycled coarse aggregate

INTRODUCTION
Nowadays, in a large part of the world, demolition of old and deteriorated buildings and traffic infrastructure, and their substitution with new ones is a usual phenomenon (Malešev et al., 2010). It is worth mentioning that the prime reasons behind these are a rearrangement of a city, expansion of traffic directions, changes of purpose, structural deterioration, & increasing traffic load, natural disasters, etc (Malešev et al., 2010; Kumar & Babu, 2015). As a consequence, the volume of demolished concrete is increasing day by day, which generates a lot of waste and ultimately pollutes the environment. Uddin (2007) stated that the global production of demolished concrete is estimated at 2–3 billion tons per year. Furthermore, Fisher & Werge (2009) reported that about 850 million tons of construction and demolition of waste are generated in the EU per year, which represent 31% of the total waste generation. Also, in the USA, the construction waste produced from building demolition alone is estimated to be 123 million tons per year (FHWA, 2004). Similar to many other countries also in Bangladesh, the volume of demolished concrete is increasing alarmingly due to the deterioration of concrete structures as well as the replacement of many low-rise buildings by relatively high-rise buildings due to the booming of real estate business (Uddin, 2007). The typicalway of managing this material has been through its disposal in landfills. Consequently, the human environment is getting polluted incessantly because of such disposal of huge amount of construction waste.

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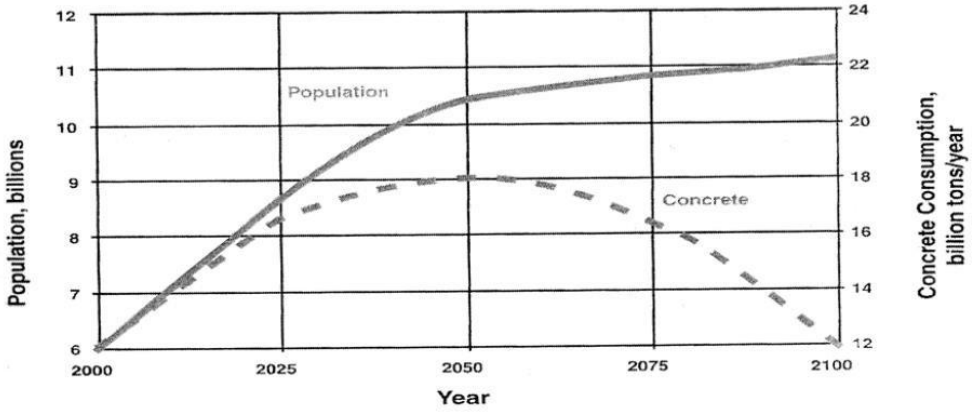

Fig. 1: Consumption of concrete and population in the world (Uddin et al., 2006)

However, because of rapid industrialization, production and utilization of concrete is rapidly increasing, which results in increased consumption of natural aggregate as the largest concrete component. For instance, two billion tons of aggregate are produced each year in the United States, is expected to raise to more than 2.5 billion tons per year by the year 2020 (FHWA, 2004). Crushing of concrete to produce coarse aggregate for the production of new concrete is one common means for achieving a more environmentally-friendly concrete. Hence, the preservation of natural aggregates sources is being threatened day by day. One of the ways to preserve natural aggregate is to utilize the recycled aggregate in the production of concrete (Uddin et al., 2006; Khalaf et al., 2004). Therefore, recycling of demolished concrete for new construction is essential to preserve the natural resources as well as to solve the disposal problems of demolished concrete. Recycling of demolished concrete will also provide other benefits, such as the creation of additional business opportunities, savingthe cost of disposal, saving money for local government and other purchaser, helping local government to meet the goal of reducing disposal, etc. Based on this perspective, it is realized that concrete industry can be made sustainable through recycling of the demolished concrete.

RECYCLED AGGREGATE

Recycling is the act of processing the used material for use in creating a new product. The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. Recycled aggregate is comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. Recycled aggregates are produced from the re-processing of mineral waste materials, with the largest source being construction and demolition waste. These wastes are normally composed of concrete rubble usually, constitutes the largest proportion of C&D waste. It has been shown that crushed concrete rubble, after separation from other C&D waste and sieved, can be used as a substitute for natural coarse aggregates in concrete or a sub-base or a base layer in pavements.

Recycling concrete wastes will lead to reductionin valuable landfill space and savings in natural resources. In addition to the environmental benefits in reducing the demand on land for disposing the waste, the recycling of construction and demolition wastes can also help to conserve natural materials and to reduce the cost of waste treatment prior to the disposal. If the technology and public acceptance of using recycled aggregate are developed, there will be no requirement for normal aggregate if 100% of demolished concrete is recycled for new construction (Malešev et al., 2010; Uddin et al., 2006).Therefore, the topic of recycling of the demolished concrete is getting considerable attention under sustainable development nowadays.

RECYCLED CONCRETE AGGREGATE

Generally, recycled concrete aggregate (RCA) is made by following two-stages, crushing of demolished

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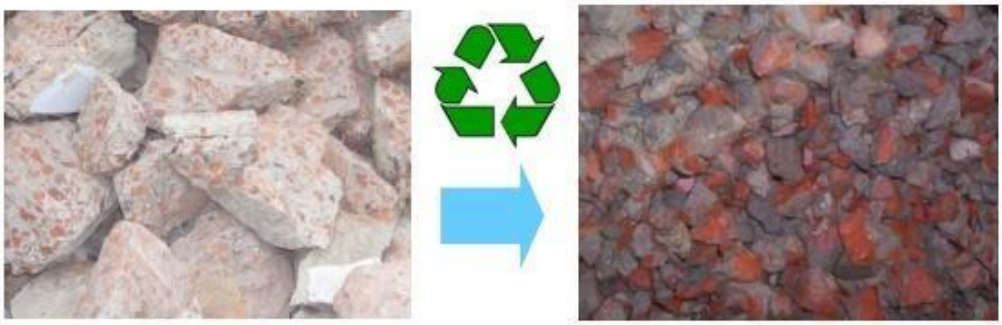
concrete and screening for the removal of contaminants such as reinforcement, paper, wood, plastics and gypsum (Malešev et al., 2010). A lot of research has been done with respect to the applicability of recycled concrete in the production of concrete. The researchers applied different techniques in order to examine the suitability of RCA to produce sustainable concrete. Based on the literature study, it has been found that of recycled aggregates are suitable mainly for non-structural concrete applications (Yong & Teo, 2009).



Demolished Concrete Blocks Recycled Coarse Aggregate (RCA)

Fig. 2: Demolished Concrete Block and Recycled Coarse Aggregate (Uddin et al., 2006)

Concrete made with such recycled concrete aggregate is called recycled aggregate concrete (RAC). The activities of renovation and demolition in the maintenance and modernization of buildings generate large amounts of solid waste and rubble, adding to the already vast and continuously increasing solid waste stream. Currently, there is a widespread move to adopt new operational strategies aimed at prevention and minimization of the waste generation as close as possible to the sources aiming for a responsible pursuit of environmentally sustainable developments. This development is primarily induced by aspects of economics such as rising tip charges, transport distances and fuel costs, which are forcing demolition contractors to find other less costly options to dispose of building and demolition waste than at waste management centers and landfill sites.

The use of recycled concrete aggregate (RCA) as an alternate for dense-graded aggregate base course (DGABC) applications over the recent years have been approximately 10% to 15%.Presently 60 to 70 percent of demolished concrete is using as sub-base course aggregate for road construction. Researchers are continuing investigations to utilize recycled aggregate in new construction effectively. Most of the contractors are left with the decision as to which material to be used where their usage of RCA is seemingly based on cost. The aggregate particles of recycled concrete compare well to conventional mineral aggregates in that they possess good particle shape, high absorption, and low specific gravity. Recycled concrete aggregate has also been shown to have no significant effect on the volume response of specimens to temperature and moisture effects.

PROPERTIES OF RECYCLED AGGREGATE

Based on the literature study, when demolished concrete is crushed, a certain amount of mortar and cement paste from the original concrete remains attached to stone particles in recycled aggregate. Certainly, this attached mortar is the main reason for the lower quality of RCA compared to natural aggregate (NA). Recycled aggregates typically are of poor quality compared with natural aggregates due to lower stiffness caused by crushing of waste concrete and higher water absorption capacity given by old cement paste attached to the surface of recycled aggregate. The properties of RCA in comparison to the Natural aggregate are listed below (Malešev et al., 2010):

- ✓ increased water absorption
- ✓ decreased bulk density
- ✓ decreased specific gravity
- ✓ increased abrasion loss
- ✓ increased crushability
- ✓ increased quantity of dust particles

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- ✓ increased quantity of organic impurities if concrete is mixed with earth during building demolition

APPLICATION OF RECYCLED AGGREGATE

Application of recycled concrete is important as it helps to promote sustainable development in the protection of natural and reduces the disposal of demolition waste from old concrete. After World War II, the applications of recycled aggregate in construction have started by demolished concrete pavement as recycled aggregate in stabilizing the base course for road construction (Olorusongo, 1999). Yong (Khalaf et al., 2004) reported thatrecycled concrete can be applied as many types of general bulk fills, bank protection, sub-basement, road construction, noise barriers and embankments. Furthermore, it can be applied to soil-cement pavement bases, lean-concrete bases, structural grade concrete and bituminous concrete (FHWA, 2004; Yong & Teo, 2009). Recycled concrete can be also used inthe production of concrete for pavements, shoulders, median barriers, sidewalks, curbs and gutters, building and bridge foundation. Growth in the use of recycled concrete for retaining wall backfill, portland cement concrete mix, landscaping rock, drainage aggregates, and erosion control is also happening (Uddin et al., 2006).

BENEFITS OF RECYCLED AGGREGATE

The advantages associated with the recycling of demolished concrete can be pointed as below (Kumar & Babu, 2015; Poon et al., 2002, Xiao & Falkner, 2007; Olorusongo, 1999):

- ✓ Saving of natural resources
- ✓ Creation of additional business opportunities
- ✓ Saving cost of disposal of demolished concrete
- ✓ Saving money for local governments and other purchasers
- ✓ Saving energy when recycling is done at site
- ✓ Helping local government to meet their goal of reducing disposal and
- ✓ Minimizing hazards to collect coarse aggregate from different natural resources

CONCLUSIONS

In this day and age, the world is concern as well as passionate about reducing, recycling and reusing. Earlier, the waste from non-biodegradable material like demolished concrete or this type of project would end up in a landfill, costing a huge amount of space. Auspiciously, the scenario is not the same any longer. In recent years, the researchers have found that it is possible to recycle the old concrete. Even though the word "recycled concrete" could be a little bit perplexing, this recycled concrete is extremely robust and reliable. Review of several studies suggested that the use of recycled materials has a positive impact on different aspects. This includes the benefits in enhancing the sustainability of the construction industry while reducing cost, providing solutions to environmental pollution and reducing the need for natural resources.

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