Review on Recycled Concrete Aggregates

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Abstract- *The use of recycled concrete aggregate (RCA) in concrete as partial and full replacements of natural coarse aggregate (NCA) is growing interest in the construction industry, as it reduces the demand for virgin aggregate. In addition, the use of RCA leads to a possible solution to the environmental problem caused by concrete waste, and reduces the negative environmental impact of the aggregate extraction from natural resources. This paper presents a comprehensive review on the use of RCA concrete in Pavements based on the experimental data available in the published research. The most important physical, mechanical, and chemical properties of RCA are discussed in this paper. However, more emphasis has been given to discuss the effects of RCA on the fresh and hardened properties, and durability of concrete.*

I. INTRODUCTION

Demolition of old structures and construction of new ones are frequent phenomena due to change of purpose, structural deterioration, rearrangement of a city, expansion of traffic directions, and natural disasters. About 850 million tons of construction and demolition waste are generated in the European Union each year, which represents 31% of the total waste generation. Countries such as China, India, Indonesia, Malaysia, Thailand, Gulf States, Turkey, Russia, Brazil and Mexico have recorded some of the strongest increases in the demand for waste recycling. Hence, progressive depletion of natural resources and growing awareness of sustainable waste management by the developed and emerging economies, have given ever-increasing relevance to recycle and re-use C&D waste in civil engineering projects.

1.1 Generation and recovery of construction and demolition Waste.

C&D waste constitutes a major portion of total solid waste production in the world, some studies have estimated **[26]** that up to 90% of demolition waste going to the landfills can be recycled and reused. Construction Waste occurs on account of building constructions and building renovations. Demolition waste results from demolition of built structures, bridges, roads etc. their complete removal or renovation. It also includes demolition debris caused due to natural disasters. The particular, there is a re-use market for aggregates derived from C&D waste in roads, drainage and othe construction projects. Technologies for the separation and recovery of C&D waste are well established, readily accessible and in general inexpensive. Despite its potential, the level of recycling and material recovery varies greatly (between <10% and over 90%) in countries across the globe.

1.2 Processing of construction and demolition waste.

Significant potential remains for increasing the use of recycled aggregate in concrete. In some countries, notably Germany, Switzerland and Australia, concrete containing recycled aggregate is now being marketed. The most common method for recycling dry and hardened concrete involves crushing. Mobile sorters and crushers are often installed on construction sites to allow on-site processing. In other situations, specific processing sites are established, which are usually able to produce higher quality aggregate.

1.3 Pavements as civil engineering applications of recycled aggregate.

Roadway infrastructure-A pavement is a multi- layer system which directly supports traffic and transmits the vehicular load to the road base. It consists of a concrete slab or asphalt slab resting on the foundation system formed by several overlapping layers of finite thickness. Conventionally crushed virgin aggregate were used in the road base and sub-base, but research carried out in recent decades made it possible to utilise recycled aggregate from C&D debris in the sub- base and sub-grade levels of the road way. In this role, the absolute strength needed to support the intensity of loading, is less important, but the consumption of the recycled concrete aggregate will be high due to the volume of material required in lower layers.

Concrete pavement

The field performance of recycled aggregate concrete (RAC) in pavement construction subjected to heavy traffic loads under aggressive weather conditions. RCA show performance at par or even better than that of corresponding control concrete. Later age enhanced strength and durability attributes of RCA concrete suggest its suitability for use in concrete based infrastructure such as pavement construction.

1.3. Environmental and Economic Impact of CDW

The environmental and economic impact of various disposal methods of CDW were evaluated using dynamic model [44]. The study revealed that recycling was the best method. Theoretically, recycling20%ofCDWwouldreducethecostofL.E.112,636.8billion($16,161.35billion)overa20 year period. It concluded by reinforcing the facts that recycling helps to conserve raw materials and landfills space, reduce GHG emission and costs to mitigate pollution. Recycling of aggregates requires about 4.0 kg CO2 per tonne, which is 22 to 46% lower than the convention aggregate. The utilization of 50% RC during in road construction would reduce the embodied energy and GHG emission of material component by 23%. The use of RC helps to reduce GHG emission by 65% while saving 58% non-renewable energyconsumption.

II. LITERATUREREVIEW

In recent years, certain countries have considered the reutilization of waste materials as a new construction material as being one of the main objectives with respect to sustainable construction activities. The properties of recycled aggregates obtained by crushing M40 grade natural aggregate concrete and concluded that the grading curve of the recycled coarse aggregate as well as of the natural coarse aggregate do not differ appreciably except that former type of aggregate possess lower specific gravity, higher water absorption capacity and significantly low resistance to mechanical action such as impact and crushing. The global aggregate production of 40 billion tons is an indication of the vast development projects which are materializing around the world. As the land for landfill becomes scarce and the world demand of aggregate reaches to an enormous 40 billion tons annually, ways to use C&D waste is gaining importance due to legislation, it is cheaper and available.

In Germany, the Federal Quality Association for Recycled Building Materials was established in 1984 and had its headquarters in Berlin. The main function of the association was to unite the major recycling companies in Germany and in 2006 it also became the headquarters of the European Quality Association for Recycling, which is the umbrella organization of quality associations of the European Union. Since 1980's, there has been considerable progress in C&D waste management systems in the developed economies, particularly in Australia, Western Europe and North America.

The physical properties of RCA influence the mix proportion and properties of concrete. The basic characteristics such as shape and texture, specific gravity, bulk density, pore volume, and absorption of RCA are generally worse than those of NCA due to the presence of residual cement paste/mortar and impurities. The magnitude of the effects varies with the nature and quantity of reclaimed cement paste/mortar that is present in RCA.

RCA tends to be very angular and rough due to the crushing of old concrete, and because of the presence of hardened cement paste/mortar adhered to the surfaces of original coarse aggregate. Typically, RCA particles contain 30 to 60% old cement paste/mortar, depending on the aggregate size (ECCO 1999). A greater amount of old cement paste/mortar is attached to the smaller size fractions of coarse aggregate. RCA is similar to crushed rock in particle shape, but the type of crushing equipment influences the gradation and other characteristics of crushedconcrete.

The specific gravity of RCA is usually lower than that of NCA The lower specific gravity of RCA is due to the presence of old cement paste/mortar on the aggregate particles that makes it less dense than NCA because of greater porosity and entrained air structure. The typical values of specific gravity of RCA range from 2.1 to 2.5 in the saturated surface-dry condition that are 5 to 10% lower than that of NCA.

Basic physical propertiesofRCA

Physicalproperty	RCA
Shapeand texture	Angular with roughsurface
Specific gravity (saturated surface-drybased)	2.1−2.5
Bulkdensity(kg/m3)	1200−1425
Absorption (wt.%)	3−12

The mechanical properties of concrete depend on the mechanical properties of aggregate. it was found that the mechanical properties of RCA are inferior to those of NCA. The aggregate abrasion value (AAV) is a measure for the wear resistance of aggregate. A higher AAV is obtained when the loss of material due to wear becomes greater. The AAV of RCA is usually higher than that of NCA. The typical Los Angeles abrasion values of RCA range from 20 to 45%, which are higher than those of NCA However, the AAV of RCA is generally below the acceptable maximum limit (50% by weight) for structural applications, irrespective of its origin. The aggregate impact value (AIV) is a strength value of an aggregate subjected to impact. AIV shows the resistance of aggregate to dynamic load. It has been found from the previous studies that the AIV of RCA (20 to 25%) is greater than that of NCA (15 to 20%) The attached mortar and cement paste make RCA less strong, and therefore result in a greater AIV for RCA. RCA can influence the properties of fresh concrete due to their greater angularity, surface roughness, absorption, and porosity. The effects of RCA on the key fresh properties of concrete. The greater angularity and surface roughness of RCA particles decrease the workability of concrete and make it more difficult to finish properly The degree of decrease in workability increases with the increased percentage of RCA in the concrete mix. Therefore, additional water is required for RCA concrete to obtain the same workability of NCA concrete.

The effect of RCA on the hardened properties of concrete can be negligible or significant depending on its source, type, content, gradation, and physical properties. Generally, the hardened properties of RCA concrete decline with the replacement level of NCA by RCA. As a general principle, up to 30% (on weight basis) of NCA may be replaced by RCA without significantly affecting the hardened properties of concrete (ECCO 1999).The range of changes in the hardened properties of concrete due to RCA. The decline in the performance of RCA concrete is related to the water to cement ratio used in mix design. RCA concrete requires lower water to cement ratio and higher cement content as compared to the parent concrete of RCA to achieve a particular compressive strength. At a water to cement ratio of 0.29, the resistance of NCA concrete to freezing and thawing was extremely high but the same water to cement ratio failed to provide an acceptable freeze-thaw resistance for RCA concrete.

The compressive strength of RCA concrete is usually lower than that of NCA concrete Most commonly, the compressive strength of RCA concrete is 5 to 10% lower than that of NCA concrete. But it can also be decreased up to 25% depending upon the quality of RCA. RCA concrete may have the similar and sometimes higher compressive strength than NCA concrete if the RCA is derived from a source of old concrete, which was originally produced with a lower water to cement ratio than the new concrete. RCA produced no effect on the compressive strength of concrete up to the replacement level of 30% by weight; but the compressive strength decreased for the RCA content more than 30%. the compressive strength of concrete was much lower when RCA was used in the oven dry state. In the case of high-performance concrete, 20 to 30% reduction in compressive strength was found due to the use of RCA.

The flexural strength of RCA concrete is generally lower than that of NCA concrete. The flexural strength of RCA concrete is typically 0 to 10% lower than that of NCA. The 3-day flexural strength of RCA concrete was higher than that of NCA concrete; but the strength was lower at the age of 28 days. In their study, the NCA concrete gained strength gradually and had a higher flexural strength than RCA concrete at later age. RCA did not produce any significant negative impact on the flexural strength of concrete. Nevertheless, the RCA concrete with adequate flexural strength can be produced for different applications, sometimes even with 100% replacement of NCA.

Durability is the capacity of concrete to resist weathering action, chemical attack, abrasion, and other adverse service conditions. RCA concrete can be highly durable even when the RCA is produced from concrete with durability problems, provided that the mixture proportioning is done properly and good quality is maintained during construction.

The properties of RCA concrete are influenced by several key factors such as water to cement ratio, RCA content, the type and size of RCA, the physical characteristics of RCA, the quality of the parent concrete of RCA, the moisture condition of RCA, curing condition, cement content, and air entrainment. The fresh and hardened properties of concrete are greatly influenced by the RCA content used as a partial or full replacement of NCA. The concrete produced with RCA had lower compressive strength and elastic modulus than NCA concrete. Also, higher RCA content increases water absorption but decreases density, thus leading to increased porousness in concrete. The use of 50 to 100% coarse RCA increases the water absorption and decreases the density of concrete by about 0.15 to 0.37% and 2.12 to 3.40%, respectively. The compressive and tensile splitting strengths of concrete decreased whereas the resistance to chloride-ion penetration increased with an increase in fine RCA content. They also observed that the drying shrinkage of concrete increased with an increase in RCA content, but it can be controlled by using lower water to cement ratio. Limited investigations were conducted to observe the size effect of RCA on concrete properties. Three different aggregate sizes to assess the influence of RCA size on the properties of RCA concrete. The higher reduction in the modulus of elasticity was obtained for the concrete made with a smaller size of RCA. In contrast, they found that the strength increases with an increase in the maximum size of RCA. They also found that the water absorption of concrete decreases with an increase in the maximum size of RCA. This is due to the relatively low content of weaker mortar adhered to larger-sized aggregates. Additional research is necessitated to investigate the size effect of RCA on concrete properties.

The outer environmental curing conditions produce the more adverse effects on RCA concrete than on NCA concrete. difference in the splitting tensile strength between NCA and RCA concretes is high when they are cured in the outer environment.

Moreover, the depth of carbonation of water-cured RCA concrete is almost twice smaller than that of air-cured RCA concrete. The decrease in the depth of carbonation produced by water curing might be partially due to higher internal humidity of concrete. Further research is required to assessthe effect of different curing conditions on the performance of RCA concrete. Thermal treatment method to improve the quality of RCA, and they found that after thermal treatment at 8000C, the RCA was reasonably comparable to the conventionally used river-dredged aggregates. The strength of concrete was affected by the unwashed RCA used in the concrete mix. However, the use of washed RCA negated the strength reduction.

Adjustment of water to cement ratio for the concrete mix could improve the strength of RCA concrete. As stated earlier, recommended lower water to cement ratio and higher cement content for RCA concrete than those of the parent concrete of RCA to achieve identical compressive strength. Similarly, lowering the water to cement ratio to a certain level was highly beneficial for RCA concrete to develop the freezing and thawing resistance equal to that of NCA concrete.

Application of Recycled Aggregates:

- It helps to promote sustainable development in the protection of natural and reduces the disposal of demolition waste from old concrete.
- Recycled concrete can be also used in the 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, port land cement concrete mix, landscaping rock, drainage aggregates, and erosion control is also happening.

III. INFERENCE

- RCA is useful as a substitute for NCA to produce concrete with acceptable properties and durability. However, the main problem of using RCA in new concrete is its inconsistent quality, particularly when it is obtained through demolition of old concrete structures.
- RCA can be successfully used in new concrete by meeting the standard specifications for natural aggregate. However, new specifications and guidelines are needed for RCA.
- The physical properties of RCA significantly influence the fresh and hardened properties of concrete. The aggregate abrasion, impact, and crushing values of RCA affect the strength properties of concrete.
- The use of 100% RCA is possible to produce concrete with acceptable quality. The concrete produced with RCA has generally 80 to 90% of the strength of a comparable NCA concrete.
- The reduction in the strength of RCA concrete is caused by the adverse physical properties of RCA and inadequately dense transition zone between RCA and bulk cement paste.
- RCA can be used in high-quality concretes such as high-strength, high-performance, and self-consolidating concretes by appropriate materials selection and mix design.

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