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A Review Study on the partial use of Recycled Coarse Aggregate in Concrete

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Abstract— RCA is made up of both aggregate and cement mortar from its original application. Its make-up results in absorption capacities, which are higher than NA. Its high absorption capacity indicates that RCA can retain a relatively large proportion of water. Internal curing of concrete is the practice of intentionally entraining reservoirs of water within concrete. This water is drawn into the cement at a beneficial point in the cement hydration process. This water allows for a more complete hydration reaction, less desiccation, a less permeable concrete pore system, and less susceptibility to the negative effects of poor curing. The potential for RCA to act as an internal curing agent was evaluated in this research. The study reveals that the use of RCA has substantial effects on concrete performance. These strategies, however, somewhat reduce the green aspect of the proposed mixed concrete with RCA.

Keywords: Concrete, Recycled Coarse Aggregate (RCA), Construction & Demolition Waste, Natural Aggregates (NA), Strength Parameters

I. INTRODUCTION

The consumption of concrete is increasing day by day. As a result of this, natural aggregates are depleted at a fast rate; to serve the growing demand the rocks are crushed and river beds are mined at a rapid rate for the supply. Moreover natural or river sand were weathered and worn out particles of rocks and are of various grades or sizes depending upon the amount of wearing. Now-a-days, good sand is not readily available; it is transported from a long distance. Those resources are also exhausting very rapidly. So it is a need of the time to find some substitute to natural river sand.

On the other hand, due to rapid industrialization and development, many non-biodegradable wastes are generated. Problem arises in treating them and if left or land filled, can cause serious environmental issues. The alternate way is to use this industrial waste in concrete construction as per its suitability which will serve dual benefits; saving from pollution and exploitation of natural resources

At the same time, scope exists for the development of new or improved technologies for construction using alternate materials. The mineral aggregates, associated binders and modifiers used in the industry at present, occur in sufficient quantities to satisfy the current demands. Alternative materials are unlikely to be found in sufficient quantities for building construction to replace existing materials and the objective of these new or improved technologies should therefore, be focused on utilizing the currently available materials in a more efficient and cost-effective manner. In addition, consideration of the environment through sustainable development of buildings is of paramount importance. This is applicable to both new construction and rehabilitation works, with the latter placing emphasis on recycling as focal point in future technologies.

II. PROBLEM FORMULATION

This effort was undertaken with different issues related to recyclable aggregate. This also enhances the improvement in properties of concrete mix which provides the way out for discarding in a functional way. Simultaneously with requirement of construction materials increasing day by day, extra amounts of construction and demolished waste can be managed. It also helps in finding its utility in concrete mixes for various construction works. Experimental studies were conducted on concrete mixes. This study also manages to sustain the use of natural aggregates & preserve them for upcoming need.

III. LITERATURE REVIEW

Piles of waste from large C&D projects are a common site on city roads across India. These causes not only traffic congestion but also make municipal waste loads heavier, thereby reducing their quality for composting or energy recovery. Indiscriminate mining of sand and other minor minerals has caused extensive damage to the environment, scarred rivers, made many areas susceptible to floods, and destroyed the crucial recharge zones.

Though a number of innovative cost-effective recycled building materials, components and construction techniques have been developed and are available, housing and building agencies have not adopted them in their construction practices. Lack of standardisation, not listing these techniques and materials in the nation Standard Codes and/or the Schedule of Rates (SOR), poor policy push and lack of awareness are the key barriers. Various researches based on these factors have been discussed below:

D.V. Prasada Rao and P.L. Sindhu Desai (2014) stated that the Recycled Concrete Aggregate (RCA) has compressive strength comparable to the Natural Concrete Aggregate (NCA) compressive strength for all grades (M20, M25, and M30) of concrete. This can be attributed to the cement mortar coat of RCA participates in hydration process and contribute additional strength. They were suggesting to go for 100% replacement of RCA in Structural Concreting [1].

Prakash Somani, Brahmtosh Dubey et.al (2016) states that the compressive strength of Demolished Aggregate Concrete (DAC) is relatively lower up to 15% than Natural Aggregate Concrete (NAC). Their suggestion is to use this concrete as a base material for roadways to reduce the pollution involved in trucking material [8].

B.Kavitha and M. Lenin Sundar (2017) suggested that when 15% of Cement and 25% of Coarse Aggregate was replaced with Glass Powder and Tile Waste, the compressive strength is found to be maximum of 36.44 N/mm2 for M30 Mix.

Vikas Srivastava, Mohd Monish et.al (2015) narrated as M25 grade mix of recycled concrete can be replaced upto 10% of cement with waste powder; 20% of fine aggregate with waste fine aggregate; 30% of coarse aggregate with waste coarse aggregate, in a single mix [9].

Poon et al., (2002) developed a technique for producing concrete bricks and paving blocks using recycled aggregates obtained from construction and demolition waste. The study was based on laboratory trials to investigate the possibility of using recycled aggregates as replacement of both coarse and fine natural aggregates in moulded bricks and blocks. A total of three series of mixtures were prepared in the laboratory series and the mix proportions prepared and laboratory. Their findings showed that for masonry bricks, all mixes satisfied requirements of BS 6073 for compressive strength of greater than 7 N/mm^2 in Hong Kong. However, the testing was inverted (turned) the bricks into by 90 degree angle from normal testing procedures (i.e., 1800) which, recommended in many standards like Tanzanian standards: such that TZS 283:2002(E) and European standard (i.e., NEN-EN 772-1:2000). Since testing method was different, such outcomes cannot be directly transferred to another country, which have different testing procedures, quality specifications as well as economic and technology.

Soutsos et al., (2004) investigated the potential for using construction and demolition waste as aggregates to manufacture precast concrete blocks at Liverpool, UK. They carried out a market research study to determine the economic viability of using C&D waste derived aggregates in the production of concrete building blocks. Concrete and masonry derived aggregates that were obtained from DSM Demolition limited (ltd) and then crushed by W F Doyle ltd were used in block production. Cement used was Rapid Hardening Portland cement. Other materials used included pulverized fuel ash (pfa) and ground granulated blast-furnace slag (ggbs) as cement replacements in order to maximize the use of recycled waste products. The manufacturing process used in factories for large-scale production involves a ‘vibrocompaction’ casting procedure which was replicated in laboratory scale. A dry concrete mix with a low cement content (about 100 kg/m^3) used. Soutsos et al., (2004) found that the coarse fraction of the aggregate can be replaced not more than 20% with masonry-derived aggregates without significantly affecting the desired compressive strength of 7 N/mm^2 (a targeted one). Furthermore, results showed that in order to maintain the strength at 7 N/mm^2 when coarse quarried aggregates are replaced by masonry aggregates, the excess amount of cement up to 70% is required, which consequently, not only adds to the cost of the block production but also imposes threats to the ecosystem (environment).

Kartam et al., (2004) reported that the generation of C&D waste will continue because no country neither live in a waste free condition nor construction activities reach a zero waste status. In addition, Kartam et al., (2004) reported in Kuwait that the recycled aggregates used for reinforced concrete work is approximately 5%, 50% for plain concrete, and 100% for road works and backfilling. These results show that a large amounts of recycled aggregates are used for road construction followed by plain concrete works and lastly reinforced concrete works. However, they did not mention the use of plain concrete works which should be for casting beams, slabs, concrete blocks, panel walls etc. Based on Kartam et al., (2004) study, it was assumed that the plain concrete represents concrete blocks production. For this case, it was assumed 50% of recycled aggregates were used for concrete blocks production in Kuwait. Also 50% represent the recycled aggregates portion to the total amount of aggregates used in concrete mix. However, it is not yet known how much recycled aggregates can be used for concrete blocks production; this work addresses this issue in Tanzania. Kartam et al., (2004) reported also that in a market economy, the choice between recycled and natural materials depends upon costs and quality. On the other hand, many standards and guidelines regard recycled materials as inferior in quality when compared to virgin materials (Lave et al., 1994), taking Tanzania as a case study, there are no standards for recycled products. So, this research adopted available standards which were developed for material extracted from natural sources e.g., TZS 283:2002(E) to be used for the recycled products in Tanzania.

Poon and Chan (2006) investigated the feasibility of blending of recycled concrete aggregate and crushed clay brick as coarse and fine aggregates in production of paving bocks in order to provide a viable option for the use of crushed clay brick derived from C&D waste in Hong Kong. Materials used were including cementitious materials (Ordinary Portland cement and fly ash), recycled concrete aggregate (RCA), recycled clay bricks (CB) and water. In paving block production, a portion of recycled concrete aggregate was replaced by crushed clay brick by 0%, 25%, 50% and 75%. Two series of mixture were prepared. Their results indicated that the incorporation of crushed clay brick reduced the density, compressive strength and tensile strength of the paving blocks. Water absorption of the resulting paving blocks were higher than that of the paving blocks that did not incorporate crushed clay brick. Although it was found that crushed clay brick impaired the quality of the resulting paving blocks to a certain extent, the paving blocks using 50% crushed clay brick met the minimum requirements specified by AS/NZS 4455 and ETWB of Hong Kong (Grade B) for pedestrian areas and 25% crushed clay brick satisfied the compressive strength requirement for paving blocks (Grade B) prescribed by ETWB of Hong Kong for trafficked area.

Evangelista and Brito (2007) conducted the study on the use fine recycled concrete aggregates as partial or global replacements of natural fine aggregates in the production of structural concrete. The experiment was carried out to monitor the mechanical behavior of such concrete. The fine recycled concrete aggregates were obtained from an original concrete of standard composition and properties and was made in laboratory conditions. After, 35th day, the concrete was crushed by jaw crusher and then the mechanical sieving was used to separate the aggregates fractions and only the fractions between 0.075 mm and 1.19 mm were used. The natural fine (sand) aggregates had the same sizes (i.e. 0.075-1.19 mm). Different mix compositions were designed with a common target slump of 80±10 mm.

The mix design was primarily conceived for the reference concrete, made only of natural aggregates. It was then adapted for the remaining mixes, taking into account the different water/cement ratios, expected to increase along with the recycled aggregates replacement ratio. It was expected that the replacement of fine natural aggregates (FNA) with the correspondent fine recycled aggregates would cause a large increase in the w/c ratio. In order to keep it at an acceptable level (below 0.45 since for a 100% replacement ratio, existing literature predicted a huge increase in the water content necessary to keep the workability of the mix constant), a modified carboxylate based superplasticizer (1.3% by weight of cement) was used. Other materials used were CEM I 42.5R Portland cement (380 kg/m^3) and crushed limestone coarse aggregates. Evangelista and Brito concluded that it is viable to produce concrete made with fine recycled concrete aggregates suitable for structural concrete, considering that the compressive strength does not seem to be affected by the fine aggregate replacement ratio, at least for up to 30% replacement.

Tang et al., (2008) investigated the potential of using recycled demolition aggregate in manufacture of concrete paving blocks and flags. According to Tang et al., (2008), the industrial processes for concrete paving blocks and flags were replicated in the laboratory by using vibro-compaction process. The vibration applied was uniform to the entire mould while concrete compacted by a pneumatic hammer. They found that the recycled demolition aggregate does not cause a significant reduction in the compressive and tensile strength of concrete blocks, if the replacement levels are kept low (i.e., not more than 25% replacement).

Poon and Lam (2008) study aimed to quantify the effects of aggregate to cement (A/C) ratio and aggregate properties on the properties of the blocks prepared with recycled materials such as recycled crushed aggregate (RCA) and recycled crushed glass (RCG). The study was divided into two parts: a) to determine the effects of A/C ratios on the properties of blocks prepared with different types of aggregates, b) to evaluate the influences of combinations of aggregates on properties of blocks. Materials used in the study were OPC, natural crushed aggregate (NCA), RCA, RCG and water. The maximum size of all the aggregates was less than 5 mm. It appears that Poon and Lam (2008) study used only fine aggregates to produce what they called concrete blocks.

Tam (2009) carried out research to compare the implementation of concrete recycling in Australian and Japanese construction industries. It was found that the C&D waste constitute 42% of all solid waste generated in Australia; out of that, concrete (cementitious) waste constitutes 81% of the total volume. To minimize the concrete waste generated from construction activities, recycling was considered to be of the methods to improve the environment. Recycling offers three major benefits: i) reduce the demand upon new resources; ii) cut-down transport and production energy costs; iii) uses waste which would otherwise be transferred to landfill site. Questionnaire survey and structured interview approaches were used to carry out the investigation on concrete recycling situation in Australian and Japanese construction industry. Tam (2009) found that 82% of metal is recycled while, 54% of concrete waste was recycled in Australia compared to 98% of concrete recycling in Japan. Further findings showed that the recycled waste was used in road construction as road-base materials, drainage and backfill materials in Australia and Japan, while in Japan, some of recycled concrete was even used for structural applications. The reason pointed out on why Australia was not using recycled material for structural material products like concrete was lack of knowledge, experience and lack of political will. It was found that many local councils in Australia do not allow the use of recycled aggregate for concrete applications. Other limitations in Australia included: i) absence of a uniform national approach to waste minimization; ii) lack of information on the extent, and sources of waste; iii) landfill levies are too low to be an incentive to reduce waste generation and waste deposition; iv) insufficient education in the private sectors in investing on waste management technologies; v) poor quality of recycled products. Tam (2009) reported that Japan unlike Australia, uses advanced technologies which can improve quality of recycled aggregates. Based on the Tam (2009) findings, it can be concluded that in order that recycling of C&D waste into building materials to be feasible and applicable, quality of recycled products must be given a high attention.

Gupta 2015 discusses that normally coarse aggregate is the fractured stone obtained from rocks in hills or pebbles from river bed, and because of depletion of good conventional aggregate in certain regions, the need for development of Recycled Aggregate technology should be taken up commercially. It is similar to fly ash, which is available from electrostatic precipitators of various super thermal power stations which is an industrial waste material. It is chemically reactive when, mixed with cement for use in concrete. This is also useful as partial replacement of cement, as it gives concrete having better impermeability. Thus, it has a wider use in construction industry. He also notifies large scale recycling of demolished waste will offer, not only the solution of growing waste disposal problem and energy requirement, but will also help construction industry in getting aggregates locally. Such demolition waste can be crushed to required size, depending upon the place of its application and crushed material is screened in order to produce recycled aggregate of appropriate sizes. An aggregate produced by demolished buildings will be called Recycled Aggregates [25].

Sankarnarayanan et al 2015 find out the scenario in India presence of Construction & Demolition waste and other inert material (e.g. drain silt, dust and grit from road sweeping) and observes the following:

1) The potential to save natural resources (stone, river sand, soil etc.) and energy, exists in these wastes.
2) Its occupying significant space at landfill sites.
3) Its presence spoils processing of bio-degradable as well recyclable waste, Construction & Demolition waste has potential use after processing and grading, Utilization of Construction & Demolition waste is quite common in industrialized countries but in India so far no organized effort has been made.

Tiwari et al. (2014) concluded that there is no reduction in the strength if we use salt water casting and curing the concrete. There is some increase in the strength if salt water is used for casting and curing. This concrete can be used for mass concreting without any decrease in strength properties. However, steel embedded in concrete is more prone to corrosion in sea water as studied by a no of researchers.

Mirza and Saif 2014 have studied the effect of silica fume on recycled aggregate concrete characteristics. The percentages of recycled aggregate replacements of natural aggregate used by weight were 0, 50, and 100%, whereas the percentages of silica fume replacements of cement used by weight were 5, 10, and 15%. The results show that the compressive and tensile strengths values of the recycled concrete aggregate increase as the recycled aggregate and the silica fume contents increase. The study also indicates that in order to accommodate 50% of recycled aggregate in structural concrete, the mix needs to incorporate 5% of silica fume [21].

Parekh, Modhera (2011) discuss the issues relating to sustainability and limited natural resources. They also suggest use of recycled and secondary aggregates (RSA), for example crushed concrete and asphalt and industrial by products such as fly ash and blast furnace slag. Then products now reused in different material production. There are many studies that prove that concrete made with this type of coarse aggregates can have mechanical properties similar to those of conventional concretes and even high-strength concrete is nowadays a possible goal for this environmentally sound practice [25].

IV. Conclusion

This study gives an idea about the use of recyclable aggregates in a concrete mix. The physical properties of the C & D waste aggregates in combination with the natural aggregates show the suitability of these aggregates for construction and maintenance purposes. This study suggest to assess the performance of concrete mixes with the partial replacement of natural aggregates with recyclable coarse aggregates. Although it also helps to save natural aggregates for future needs.

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