A Review Study on the Effect of Fresh & Sea Water on Recycled Coarse Aggregate Cement Concrete

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Abstract— The use of construction and demolition waste in concrete mixtures cured with the sea water leads to the production of a very sustainable concrete. The potential risk of steel reinforcement corrosion (due to chloride in the seawater) in such mixtures may be eliminated when considering plain concrete or noncorrosive reinforcement (e.g., fibre-reinforced polymer). This study enhance the performance of the fresh and hardened properties of a proposed green concrete mixed using construction and demolition waste as a recycled aggregate curing with fresh and sea water. Fresh and hardened properties of the concretes, including workability, strength gain, drying shrinkage, permeability, and microstructure, were characterized and studied. The study reveals that the use of seawater and RCA together has substantial effects on concrete performance. These strategies, however, somewhat reduce the green aspect of the proposed seawater-mixed concrete with RCA.

Keywords: Concrete, Recycled Coarse Aggregate, Construction & Demolition Waste, Sea Water, Compressive Strength, Tensile Strength, Flexural Strength

I. Introduction

Concrete is the most widely used man made construction material in the world. Concrete is a composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregate. 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 are 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.

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.

The construction industry in India is booming. Already at 10 per cent of the GDP, it has been growing at an annual rate of 10 per cent over the last 10 years as against the world average of 5.5 per cent per annum. This immense surge will have fallouts. Buildings are at the core of all our demands, namely water, energy and material — but they also create waste. This waste, generated in the construction, maintenance and disposal phases of a building, is called construction and demolition (C&D) waste. This includes waste from demolished structures, renovations in the real estate sector and construction and repair of roads, flyovers, bridges, etc. But C&D waste can be an invaluable source of building material. In fact, the recent controversy in India over sand mining has put the spotlight on the need to recycle, reuse and substitute naturally sourced building material.

The total C&D waste generated in India just by buildings in one year amounts to 530 MT, 44 times higher than the official estimate. Imagine the scenario if the waste generated by infrastructure projects such as roads and dams is added. Not surprisingly, in India, if C&D waste is quantified, it will be more than all the other types of solid wastes put together. Where is all this C&D waste going? A lot of it is being used by land sharks to illegally fill up water bodies and wetlands around urban centres for real estate development. The rest is just being dumped into rivers and open spaces.

II. Problem Formulation

This work was undertaken with various issues related to recyclable aggregate. This also enhances the improvement in properties of concrete mix which provides the solution for disposal in a useful way. Simultaneously with requirement of construction materials increasing day by day, more amount of construction and demolished waste can be managed. It also helps in finding its utility in concrete mixes for various construction works. Laboratory performance studies were conducted on concrete mixes. This study also manages to sustain the use of natural aggregates & conserve them for future need.

III. Literature Review

According to a 2010 "Report of the committee to Evolve Road Map on Management of Wastes in India" by the MoEF, it is estimated that the construction industry in India generates about 10-12 million tonnes of waste annually. Moreover, about 50 percent of the Construction and

Demolition Waste (C&D) is not currently recycled in India. Considering that construction and demolition waste comprises almost 1/3rd of Municipal Solid Waste (MSW) in India, it is important for all stakeholders to address the issue, its management and its solutions.

Construction agencies like CPWD say that Indian laws permit the use of only naturally sourced building material. The IS: 323-1990 Indian standard specification related to aggregates for concrete, laid down by the Bureau of Indian Standards (BIS), stipulates that concrete can be made only with naturally accessed materials. Construction agencies cite this rule to avoid using recycled C&D waste. C&D waste finds a brief mention in Schedule III of the rule for separate collection, in the Municipal Solid Waste (Management and Handling) (MSWM) Rules, 2000. Additionally, the Union ministry of urban development (MoUD) has a 2000 publication titled the Manual on Municipal Solid Waste Management that includes a chapter on C&D waste; the chapter provides some basic guidelines on its handling, but these are not binding.

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

Technically and legally, therefore, there does not seem to be any roadblocks in using recycled C&D waste as building material. The BIS has already set a precedent: it has introduced exception clauses for flyash usage in the manufacturing of building materials. There are other avenues as well. The Building Material and Technology Promotion council (BMTPC), an apex body that promotes development and use of innovative building materials and technologies, has a scheme called Performance Appraisal Certification Scheme (PACS). New products manufactured by using recycled waste in fact, any new product, system or technique not covered so far by the BIS can be certified under this scheme after evaluation. It has been used to certify new construction material (such as bamboo).

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. In 2012, the Supreme Court had asked state governments to amend the rules to regulate mining of minor minerals and ensure environmental management. On August 5, 2013, the National Green Tribunal (NGT) declared sand mining without environmental clearance as illegal. However, the concern for a deteriorating environment is being seen in the context of a growing shortage of these materials. The Union ministry of housing and urban poverty alleviation had told the Rajya Sabha in 2012 about the shortage of building material, especially for aggregates and concrete owing to mining bans/restrictions on environmental grounds. The shortage has been so severe that several civic projects in India are facing delays. This is aggravating the housing crisis and affecting the construction of roads, bridges, canals, etc. If sand mining and other naturally sourced materials have to be restricted and regulated, other strategies must be put in place to reduce demand.

A. Research on Construction Demolished Waste:

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.

Limbachiya et al., (2004) examined the performance of Portland-cement concrete produced with coarse recycled and natural aggregates. Effects of up to 100% coarse recycled concrete aggregates in concrete production were assessed for suitability for use in a series of designated application. Recycled coarse aggregates were sourced from laboratory cast concrete, airport pavement, rejected structural precast element, and demolished concrete. The recycled coarse aggregates (RCA) samples were produced in a single size fraction (20-5 mm) using commercial plant for the production of crushed-rock aggregate, comprising primary jaw and secondary cone crushers and screens. Natural gravel (max. of 20 mm size) and natural sand was used as fine aggregates. Their results showed that up to 30% coarse RCA can be used without any modification in the mix design, in concrete construction with performance similar to natural aggregate concrete. This suggests that a method of mix proportion used by Limbachiya et al., (2004) takes into account the effect of RCA content on concrete strength and can be integrated into existed concrete mix design procedures and production techniques. However, the proposed methodology will give initial proportions for trial mix purpose only. So, particular adjustments for individual material characteristics and proportions will have to be established through trial mix.

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.

Cement Concrete & Aggregates Australia (CCAA, 2013) made a review on the various types of aggregates in Australia. The purpose was to review the various sources of aggregate and examine their potential use in concrete and/or road construction. The aggregates were classified into four major types: natural, manufactured, recycled and by-product aggregates. These were described in terms of sources and production process, physical and mechanical characteristics, the benefit and limitations of their use in concrete and/or road construction. According to CCAA (2013), the recycled concrete aggregates (RCA) is proven to be practical for non-structural concretes such as pavement, road-base and sub-base, and to a limited extent for some structural-grade concrete. Any successful strategy must be based on both cost and performance.

B. *Creative Steps in India for C & D Waste Utilization*

Even though legal reform is taking a long time in India, several architects have already taken steps to reuse waste in their buildings. There is the example of a school building in Rajkot designed by Ahmedabad based architect Surya Kakani that has been built from the debris of Bhuj earthquake. The Institute of Rural Research and Development (IRRAD) building in Gurgaon has innovatively recycled and utilised its own construction waste in the building itself. But these are limited steps and they will have to be encouraged with policy and fiscal support. This is particularly relevant for the infrastructure necessary for development such as roads, flyovers, pavements, etc. In fact, the attempt to use recycled material from the Burari centre in New Delhi (see box: Delhi initiative) during the Commonwealth Games faced opposition as these materials are not backed by standards as yet. This mind set will have to change urgently. Globally, the strength of these materials has been proven; they are being used extensively. There is no reason why India cannot follow suit. India needs urgent intervention to protect its land, water, public space and environment from the construction expected to explode with the urban boom.

- Fast track formation of BIS code on recycled material: There is a need to have a code for recycled material. The precedent has already been set by induction of exception clauses for fly ash use into the manufacturing of building materials. There is a lot of research going on in this area; this research should be leveraged quickly to formulate standards and hasten the process.
- Revise CPWD SOR to include products made out of recycled C&D waste: Using publicly available scientific studies done by institutes like the National Council for Cement and Building Material, the CPWD should revise its SOR to allow use of products like paver blocks and flooring tiles made out of recycled C&D waste. This will ensure market development for the recycled products making them economically viable for recyclers and reduce subsidy burden on civic bodies.
- Promote efficient construction management practices to minimise waste: National regulations and municipal rules need to push for optimal use of building space and materials, waste prevention, use of recycled content, on-site segregation, and collection and disposal system.
- Promote use of alternative material in other infrastructure: Experiments by the Central Road Research Institute, Delhi have shown that it is possible to use C&D waste for building road, embankments and pavements. This must be included in the roadmap of all infrastructure construction agencies.

Seawater, or salt water, is water from a sea or ocean. On average, seawater in the world's oceans has a salinity of about 3.5%. This means that every kilogram (roughly one litre by volume) of seawater has approximately 35 grams (1.2 oz) of dissolved salts (predominantly sodium (Na+) and chloride (Cl−) ions). Average density at the surface is 1.025 kg/l. Seawater is denser than both fresh water and pure water (density 1.0 kg/l at 4 °C (39 °F)) because the dissolved salts increase the mass by a larger proportion than the volume. The freezing point of seawater decreases as salt concentration increases. At typical salinity, it freezes at about −2 °C (28 °F).[1] The coldest seawater ever recorded (in a liquid state) was in 2010, in a stream under an Antarctic glacier, and measured −2.6 °C (27.3 °F).[2] Seawater pH is typically limited to a range between 7.5 and 8.4.[3] However, there is no universally accepted reference pH-scale for seawater and the difference between measurements based on different reference scales may be up to 0.14 units.

C. Researches on Concrete with Sea Water

E.M. Mbadikea and A.U. Elinwa (2011), concluded that the strength development in the concrete produced increases with the increase in the hydration period. The higher the setting time, the lower the strength of concrete produced. The use of salt water in concrete production will reduce the strength of concrete produced to approximately 8%. Curing is very necessary in concrete in order to ensure the complete hydration of cement. The strength development in concrete depends on the percentage chemical composition of cement. The presence of chlorides and sulphates in salt water reduces strength of concrete.

Gracemodupeolaamusan1 & Festusadeyemiolutoge (2014) studied the effect of seawater on shrinkage properties of concrete. The analysis revealed that shrinkage was interdependent on concrete composition and the result exhibited a higher shrinkage value for concrete with higher cement content and with higher slump value. However, reduced shrinkage values were noticed with higher aggregate sizes. It was also observed that concrete mixed or cured with seawater has higher shrinkage value than the control batches with dry shrinkage analysis value of 83.5% increase for concrete mixed with seawater (CSW) when compared to the shrinkage value of the control batches.

Olutoge et al. (2014) studied the use of salt water for casting and curing of concrete during construction, most especially in coastal environment. It was concluded that water/cement ratio that will give the minimum value of slump with adequate workability as well as minimum cement content should be used with maximum aggregate size in order to minimize the shrinkage cracking.

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.

IV. CONCLUSION

This study gives an idea about the properties of recyclable aggregates. 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 also helps to study the effect of sea water on the strength of concrete mixes. Although it also helps to save natural aggregates for future needs.

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