Methods for Optimization of Construction and Demolition Waste: A Review

[1]Shahab Ali Khan, [2]Anwar Ahmad
[1]M.Tech. Student, [2]Associate Professor
Civil Engineering Department
Integral University, Lucknow, U.P, India

Abstract: Construction and demolition waste is responsible for many environmental hazards in the construction industry. The aim of this study is to identify the issues related to construction and demolition waste at national and international level. It is estimated that the total quantum of such waste generated in India is 11.4 to 14.69 million tonnes per annum in 2004. An overview of construction and demolition waste and their reusability prospects are presented here for the promotion of 3 R's i.e. Reduce, Reuse and Recycle. This paper identifies the composition of construction and demolition waste and will also focus on two important constituents of this waste i.e. concrete and brick waste generated in the construction industry. Various researchers have worked on reuse of the waste generated from concrete and brick waste which is presented in this paper.

***Index Terms* - Life cycle, Environment, Sustainable, Optimization, Reuse, Recycle**

I. INTRODUCTION

The construction industry provides huge infrastructural facilities to the mankind but at the same time it generates extensive construction and demolition waste. This waste has enormous environmental impacts as it causes pollution from noise, dust and smoke, thus degrading the air, soil and water quality. The risk to environment created by such waste is life threatening can reach to an irreversible cycle.

(Thomas & Wilson, 2013) report that construction industry is largest economic expenditure in India. According to the information from eleventh five-year plan, it is the second largest economic activity after agriculture and hence the Indian construction industry has huge impacts on the environment. Construction industry consumes high volume of raw materials and products and it generates high employment opportunities as well. An analysis of the forward and backward linkages of construction shows that the effect in the construction on economy is estimated to be significant. A research by Gayakwad (2015) states that the environmental issues such as increase in the flood levels due to the illegal dumping of construction and demolition waste into the rivers, resource depletion, shortage of landfill and illegal dumping on hill slopes are evident in the metro cities.

Raju Ponnada (2015) found that waste from individual house construction or demolition find its way into nearby municipal bin/vat/waste storage depots, making the municipal waste heavy, degrade quality of municipal waste and makes it difficult for further treatment like composting and about 10-20 % finds its way into surface drains, choking them.

It is reported that the concrete, brick and masonry together constitute more than 50 percent of the total C&D waste. This emphasizes the importance of study of this component of waste because it can lead to enormous savings.

II. LITERATURE REVIEW

Iacoboaea et al. (2010) defined "construction and demolition waste" as waste resulting from building, renovating, rehabilitating, repairing, consolidating, demolition of civil and industrial constructions, city structures, transport infrastructure as well as the activity of dredging and clogging up. Another researcher Gayakwad (2015) has defined C & D waste as "waste which arises from construction, renovation and demolition activities". These also include the surplus and damaged products and materials arising in the course of construction work or used temporarily during the course of on-site activities.

Thomas & Wilson (2013) have reported the cost analysis of various modes of expenses in Indian construction industry and they found that the component of material cost comprises nearly 40-60% of the project cost. This information is important because any development should respond to the challenges of environmental sustainability, low carbon emission and minimal resource depletion, as we are facing crisis.

Raju Ponnada (2015) have mentioned that projections for building material requirement of the housing sector indicate a shortage of aggregates upto 55,000 million m3. Additional 750 million m^3 would be required for achieving the targets of the road sector. Recycling of aggregate material from construction and demolition waste may help reduce the demand-supply gap in both these sectors.

A study was conducted by Kucukvar, Egilmez, and Tatari (2016) for optimization of waste. The study was performed on ferrous and non-ferrous metals and the results show that recycling of these materials significantly contributed to reductions in the total carbon footprint of waste management. On the other hand, it is also mentioned that recycling of asphalt and concrete increased the overall carbon footprint due to high fuel consumption and emissions during the crushing process.

Elgizawy et al., (2016) report that there are a lot of environmental problems such as dust, noise, vibration and pollution of soil and groundwater at the construction sites. More over the biodegradation of wastes in the landfills causes a lot of health and environmental problems.

Stäubli & Kropf, (2004) conclude that dust and aerosols at construction sites, originating from spot or diffuse sources must be curtailed and adequate prevention should be taken at the source.

Some data states that concrete waste water that reaches watercourses, can kill aquatic plants and animals including frogs and fish, which is a huge loss. Dilution is not an option. ("FACT SHEET 8J - Preventing Pollution by Construction Contractors," 2014).

Omotayo & Akingbonmire, (2017) have recommended some practices such as; Whole Building Reuse, Selective Demolition and Deconstruction, and Reuse and Recycle of building materials, for optimization of C & D waste.

Chandrakanthi (2002) proposed a model to predict waste generation rates, as well as to determine the economic advantages of recycling at construction sites. The researcher proposed that a future advanced version of the model can be applied to any construction site to: determine the amount of daily waste generation, resource and time requirement for sorting and transporting of recyclables.

(Sachan, 2014) brought forward the benefits from recycling of C & D waste in terms of reduced costs, marketing opportunity, tax benefits, and reduced environmental impacts.

2.1 Overview of C & D waste in India

Gayakwad (2015) has mentioned in their paper that as per report prepared by the MoEF (Ministry of Environment and Forest) in 2008 it was estimated that 0.53 million tonnes/day of waste is generated in the country. But as per the world bank report Asian countries produce around about 1000kg per capita per year. This means that the figure stated by the MoEF is very less than the world bank report figure. This shows that India is underestimating the construction and demolition waste handling.

A report by TIFAC states that the construction industry is largest economic expenditure in India and according to eleventh five-year plan, it is the second largest economic activity after agriculture. The total quantum of C&D waste generated in India is estimated to 11.4 to 14.69 million tonnes per annum (TIFAC, 2000).

A report of Central Pollution Control Board 2017 (2017) mentioned that the quantum of generation of C & D waste estimates available from other sources are as follows:

a. 12 MT - 15 MT by TIFAC (2001);

b. 10 MT -12 MT by MoEF (2010)

c. 12 MT by CPCB d. 165-175 MT per annum between 2005-2013 (BMTC)

d. Forecast estimates: Upto 23.75 million tons annually and these figures are likely to double fold upto 2016. (Source: International Society of Waste Management, India).

2.2 Overview of C & D waste at Global level

Thomas & Wilson (2013) reported that presently, awareness of resource-efficient construction practices is lacking in most countries. The countries like U.K, U.S.A., France, Denmark, Germany and Japan have succeeded in developing economically feasible technologies for recycling up to 80-90% of C&D waste. However, least effort has been reported for the utilization of construction waste in India.

Mcdonald & Smithers (1998) mentioned that the construction industry in Australia contributes approximately 15% by volume of all solid waste disposed in landfills each year. It also stated that the Australian government, in common with many other countries, has legislation in place to reduce landfill requirements by 50% by the year 2000.

A study by Poon, Yu, Wong, & Cheung (2004) reports that waste management in the building industry in Hong Kong has become a major environmental issue in recent years. One of the major concern is increasing amount of C&D waste being dumped at landfill sites. A study was conducted on five public housing construction sites and it was observed that waste generation could be significantly reduced by the use of precasting and system formworks. The major causes of wastes were improper preparation and handling, misuse, and incorrect processing. In general, it was observed that little on-site waste sorting was carried out.

Yeheyis, Hewage, Alam et al. (2013) reported the C&D waste generated by the Canadian construction industry accounts for 27 % of the total municipal solid waste disposed in landfills. However, it is evident that over 75 % of construction industry waste could be recycled, salvaged and/or reused. They proposed a conceptual C&D waste management framework to maximise the 3R (reduce, reuse and recycle) and minimise the disposal of construction waste. This can be achieved by implementing sustainable and comprehensive strategy throughout the lifecycle of construction projects. They also developed a life cycle-based C&D waste sustainability index. This approach can be used to make decisions related to selection of material, sorting, recycle/reuse and treatment or disposal options for C&D waste.

2.3 Composition of C & D waste

Elgizawy, El-Haggar, and Nassar, (2016) mentioned in their paper that The Environmental Protection Agency (EPA) in the US defines C & D waste as "waste that is generated from the construction, renovation, repair, and demolition of structures such as residential and commercial buildings, roads, and bridges". C & D waste comprises mainly of concrete, asphalt, masonry and wood products as well as metals, plastics, insulation, and paper and cardboard.

Patel & Patel (2016) proposed a conceptual framework to organize the sources of construction waste into six categories. (1) Design: Blueprint error, Detail error, Design changes; (2) Procurement: Shipping error, Ordering error; (3) Handling of materials: Improper storage/deterioration, Improper handling (Off-site and on-site); (4) Operation: Human error (by craftsmen or other laborers), Equipment malfunction, Acts of God (catastrophes, accidents, and weather); (5) Residual: Leftover scrap, Irreclaimable non-consumables.

The contractors on construction site encounter polluting and hazardous materials every day and it is their job to make sure all proper procedures are followed and to immediately clean-up and report any spills or releases (Tech, 2006).

Cha, Kim, & Han (2009) reported the following factors were effectively identified as the most significant commitment of contractor's representative on site; Collecting packed materials back by suppliers, Minimizing rework in the construction phase, Design and construction using standardized materials, Appointment of laborers solely for waste disposal.

Hemalatha, Prasad, & Subramanya (2008) explained category of waste as major and minor components. Major components are: Cement concrete, bricks, cement plaster, steel, rubble, stone, wood. Minor components include: pipes, electrical fixtures, panels, tiles etc.

Ghosh, Haldar et al. (2016) mentioned of two categories of C &D waste. (1) Non-Recyclable materials– RCC, Bricks (Damaged), Plastering materials and lime concreting (Major), Mixed Earth (Minor) and (2) Recyclable Materials-Steel and Bricks (Major), wood, sanitary pipes, Glass (Minor).

2.4 Concrete and Brick Waste

The two most important constituents of C & D waste are identified as concrete and brick.

Thomas & Wilson (2013) reported that the concrete, brick and masonry together constitutes more than 50% of the total C&D waste.

Batayneh, Marie, & Asi, (2007) reported that ground plastics and glass were used to replace up to 20% of fine aggregates in concrete mixes, while crushed concrete was used to replace up to 20% of coarse aggregates. To evaluate these replacements on the properties of the OPC mixes, a number of laboratory tests were carried out like workability, unit weight, compressive strength, flexural strength, and indirect tensile strength (splitting). The main findings of this investigation revealed that the three types of waste materials could be reused successfully as partial substitutes for sand or coarse aggregates in concrete mixtures.

Biglarijoo et al. (2017) conducted a study on the effects of recycled concrete aggregate (RCA) and waste glass (WG) on the properties of concrete. The response surface methodology was used to optimise and model the results of tests for compressive strength, tensile strength, slump, water absorption, electrical resistivity and hardened unit weight. The effective variables of the experiment included RCA (0–65%) as coarse aggregate replacement and WG (0–40%) as fine aggregate replacement. The results obtained indicate that high volumes of waste materials could be used in concrete without a significant reduction in the mechanical and durability (namely water absorption and electrical resistivity) properties of the concrete. Moreover, when WG was substituted in the mixture, the water absorption, electrical resistivity and workability of the concrete improved and the use of RCA had a significant influence on the mechanical properties of the concrete. Based on these statistical analysis, all the proposed models were adequate, with coefficients of determination above 0·95. The optimum condition in which all response targets performed properly was found to be 17% of RCA and 35% of WG.

John, Mittal, & Dhapekar (2017) mentioned that approximate composition of C&D waste is: 40%-50% -Recycled Coarse Aggregates, 22%-25%-Fine Aggregates 15%-20- plastics, ceramics, glass materials etc. Optimizing utilization of these demolition waste (coarse and fine recycled aggregates) can reduce environmental impact and natural reserve can be saved.

Masood et. al (2002) performed tests where cement and similarly fine aggregate were partially replaced by demolished waste. Tests were performed for structural properties such as compressive strength, flexural strength and split tensile strength of recycled concrete. They studied recycled concrete and re- cycled aggregate concrete whose properties were compared with results for the conventional concrete.

Rosman, Abas, & Mydin, (2014) conducted study to investigate the use of concrete waste in concrete blocks with a special focus on the thermal and mechanical properties of the resulting products. They prepared three varieties of concrete mixtures, each contained different amounts of concrete waste of 0%, 5% and 15%, respectively. Cube specimens were prepared from these waste and analysis performed for data on their compressive strength, density and ultrasonic pulse. Thermal investigations were carried out on each admixture as well as on a control concrete block of model design. The thermal data results indicated that the 15% concrete waste mixture had the lowest temperature in comparison to the surrounding air.

Agarwal & Krishan (2017) presented a study that aims to develop C&D waste brick of size 225 mm × 115 mm × 75 mm for the two different compositions (F-type & C- type). Natural coarse and fine aggregates were replaced by Cement and fly ash as a binder along with C&D waste. Physical and mechanical testing (compressive strength and water absorption) was carried out as per Indian Standards for the desired composition.

Lin et. al (2010) investigated the pozzolic characteristics of pastes that contain waste brick from building C&D wastes. Experimental results reveal that waste brick has potential as a pozzolanic material in the partial replacement of cement.

Demir & Orhan (2003) conducted research to investigate the addition of waste-brick material in brick production. The effects of recycling of waste brick material on the durability and mechanical properties of the bricks were analysed. The results show that at a mass of 30% fine-waste material additive, fired at 900◦C, the test sample has an adequate strength. The reuse of this material in the industry would contribute to the protection of farmland and the environment.

III. CONCLUSION

Construction industry is found to be the most important because it consumes high volume of raw materials and products and generates high employment opportunity. The paper aimed at studying of the national and international scenario in terms of waste generated. Different organizations have estimated amounts of C & D waste in India. Countries like Australia, Hong Kong, Canada, and India are still struggling to optimize the C & D waste. The major and minor components of waste are: Cement concrete, bricks, cement plaster, steel, rubble, stone, wood, electrical fixtures, panels, tiles etc out of which concrete, brick and masonry together constitutes more than 50% share. Various researches have been conducted and they recommend waste reuse as recycled concrete, re-cycled aggregate concrete, brick from waste has potential as a pozzolanic material in the partial replacement of cement, use of waste-brick material in brick production etc.

The study concludes that these materials have a lot of scope for recycling and reuse, and there is a need to plan strategies for optimization of these as resources for future construction materials to save environment.

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