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RECYCLING AND REUSE OF CONSTRUCTION AND DEMOLITION WASTE: SUSTAINABLE APPROACH

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Abstract: Urbanisation is putting huge pressure for the efficient utilisation of the existing land. Old structures are being demolished for proving the way to new and modern structures. Land has become a scarce commodity in the urban cities and with increase in Floor Area Ratio (FAR) to accommodate more population causing demolition of existing structures for reconstruction. Sometimes these existing structures has not yet completed their design life yet they are demolished for new one. The debris that is produced in demolition of these structures are in huge amount and disposal of this Construction and Demolition (C&D) waste in sustainable manner is the biggest challenge today. Recycling and reuse of such a large waste is need of an hour. This paper focuses on current trend in this field by elaborating various ways to use these waste both from the laboratory research scale as well as commercially available technologies around the globe.

Use of these C&D waste save huge amount of natural resources, reduce CO^2 footprint, Reduce environmental impact, Create space in urban areas by its reuse, reduction of large space required for dumping sites and creation of job and business opportunities across the globe. This paper provide detail of recycling facility in Delhi, India along with technology used in other countries like Japan, Korea etc. This paper also elaborate on recycling potential of these C&D waste, challenges in processing and using C&D waste and finally guidelines for sustainable use of these waste.

Keywords: C&D Waste, Recycling, Sustainable environment, Demolition Waste, solid waste management;

1. Introduction

DyeLand is most scare commodity in urban cities across the globe. Burgeoning population is creating pressure for better utilization of land in existing cities. To cater the need of housing and commercial requirement new construction is being done by demolishing the old structures and construction on vacant land. The improvement in economic conditions in the developing countries has caused the large scale growth in construction industry. This construction activity is generating huge amount of Construction and Demolition (C&D) Waste. Every year around 3000 MMT(Million Metric tons) of waste is produces in European Union, out of which 30% of total waste i.e. around 900 MMT is generated by construction industry alone in the form of C&D waste ([1]Bravo et. al. 2015, [2]Torgal 2013). In United States estimate production of C&D waste is reported around 140 MMT per year ([2]Torgal 2013). In developing countries like India and china there is a substantial rise in this C&D waste as reported around 14 MMT is generated in Shanghai, China alone in 2012 ([3]Ding and Xiao 2014) Out of the total waste around 80 % consists of concrete, bricks and blocks.

The illegal dumping and unplanned disposal of this C&D waste is causing the severe ecological and environmental problems. Hence the reuse and recycling of C&D waste is paramount important. It 's planned use not only reduces the exploitation of virgin raw material but also solves the problem of waste disposal. Its also leads to more availability of land by preventing the dumping sites. Environmental impact such as deforestation, illegal mining of river beds for aggregates, air and water pollution, consumption of fossil fuels for transportation, top soil loss etc. is also reduced.

Introduction of green building concept has somehow helped in utilizing the waste produces during construction but great awareness is required across the globe in reuse and recycling of Demolition waste. Especially in developing countries where construction is happening on massive scale.

As per EU waste framework directive 2008/98/EC minimum recycling percentage of C&D waste should be minimum 70% by 2020 ([4]Ledesma et. al 2015) which is a great step forward in targeting the problem of C&D waste. As per 2013 estimate average recycling of this C&D waste in EU-27 is only 47%. ([2]Torgal 2013) This shows that increasing this percentage to 70% is enormous task which not only need detailed research at laboratory scale but advance technologies which are cost effective to achieve this target.

The C&D waste mainly consists of concrete, brick, ceramic and mortar together constitution around 80%, whereas wood and metal around 10%. Wood and metal are generally recycled easily however concrete, brick, ceramic and mortar are generally available in mixed form and need processing before being put to use. Although use of Recycled Aggregates (RA) are being studied since last 50 years but not being used in new structures due to lack of consistency in their properties and non-availability of regulatory framework for their use. Various experimental results has shown that the use of these recycled aggregate lead to poor concrete performance mainly in durability aspect. Reason reported are higher porosity in these aggregates and high water absorption lead to poor water to cement (w/c) ratio. Also during demolition process lot of micro-cracks develops in these aggregate leading to higher penetration and high permeability. ([5]Soares et. al 2014). Lot of processed recycled Aggregates are still used in nonstructural components like paver blocks, Plain Cement Concrete, Sub-base below road pavement, Concrete pipes, asphalt mix and fire insulation blocks. ([4]Ledesma et. al. 2015, [6] Meijide and perez2014, [7] Ozalp et. al. 2016, [8] Melicevik et. al. 2015, [9]Medina et. al 2015, [10] Leiva et. al. 2013, [11]Ossa et. al. 2016,[12] Rodriguez et. al 2016)

2. Composition

In India as per (TIFAC, 2000) total quantum of C&D waste generated is around 15MMT however it is not a very accurate estimate since most of the C&D waste is dumped illegally which is not accounted for in the reports. The masonry, concrete and mortar together constitute over 65% of this C&D waste.([13]Thomas and wilson 2013). Typical composition of C&D waste produced in India is shown in fig 1

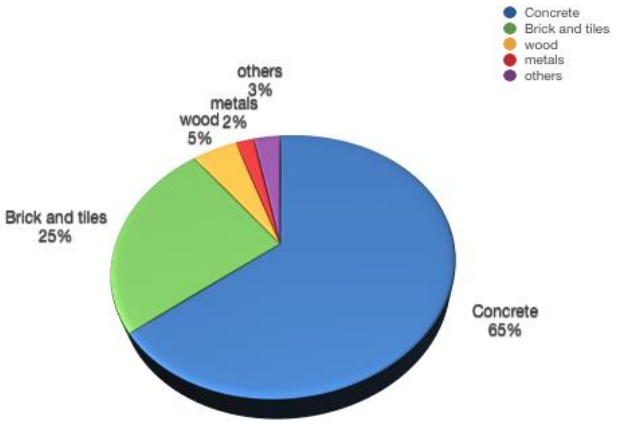

Fig 1- C&D waste composition in India ([14]Bhattacharya et. al 2013)

3. Environmental Impact

Improper disposal and illegal dumping of these C&D waste is causing a environmental degradation. This environmental impact is becoming the major issue in cities and across various municipality in managing their solid waste management. Huge heaps of C&D waste causes rise in flood levels of the rivers, scouring of the banks, depletion of resources, leaching out of hazardous material in the water causing impact on marine life. Illegal dumping around the roads causes traffic congestion, chocking the surface drain causing flooding on the pavement etc. C&D waste from small house demolition generally find its way into municipal bin causing the problem in treatment of solid municipal waste. ([13]Thomas & Wilson 2013). These waste are sometimes buried in the site itself

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Fig 2- Recycling process of C&D waste into aggregate ([9]Median et. al. 2015)

causing the formation of impervious layer which doesn't allow the growth of vegetation and prevent infiltration of rain water inside the ground.

4. Reuse of C&D waste

There is an urgent need to understand the reuse and recycle potential of these C&D waste which on one hand will generate potential business opportunity, employment generation and above all environmental sustainability. Useful products like reinforcement, Mild Steel, doors and windows, Structural steel, Bricks and other metal items can be taken out easily and again put to reuse without much processing ([15]Winkler 2010). Not only building material but also asphalt toppings can be used as the base for new asphalt pavement. As it is well said that reuse is the most beneficial form of recycling the waste products. In developing countries like India and China where there is poverty and massive requirement of low cost housing these products can be consumed easily and also reduce cost of construction of affordable houses. Once the reusable item is taken out rest of the C&D waste can be processed for recycling

4.1 Recycling of C&D waste

Once the reusable material is taken out the rest of the material is mainly consists of C&D Waste aggregate. As per BS 8500 (2002) this C&D waste aggregate are classified into two category one recycled concrete aggregates (RCA) and other crushed masonry based aggregate known as recycled aggregate (RA) ([16]Brito and Saikia 2013). However small amount of contaminants like wood particles, gypsum, paper, cardboard, glass and plastics has to be removed to get usable aggregates. Various techniques such as eddy current magnetic separation, Air shifting, dry density separation and spirals are few of the techniques applicable today to automatically separate the contaminants as mentioned above (fig2) ([17]Coelho and Brito 2013).

Composition of C&D waste aggregate depends on the original construction and demolition waste, on the demolition technique used and the collection procedure from the site. Typically RCA contain around 70% of coarse and fine aggregate and 30 % of cement paste ([16]Brito and Saikia 2013).

The quality of C&D aggregate depends on the amount of mortar on that aggregate. Also more the waste is treated better the quality of aggregate produced. However higher processing increases the cost of aggregate and thus making it economically unviable in places where natural aggregate is cheaply obtained.

5. Laboratory/ research scale work.

Various experiments and tests are done on these C&D Waste aggregate to determine its properties and potential uses. Most of the work show good performance in mechanical property however the durability properties are major concern that need to be focused.

5.1 Mechanical properties

Almost all of the research works had concluded that the compressive strength value of concrete prepared with C&D Waste aggregate declined with increasing the replacement ratio with natural aggregate. The main governing factor is poor Interfacial Transition Zone (ITZ) between the aggregate component and the paste for the recycled Aggregates. ([9]Medina et. al 2015, [8]Milicevic et. al 2015, [7] Ozalp et. al 2016, [4]Ledesma et. al 2015)

In an experiment by [8]Milicevic et. al 2015 about 62 samples of concrete were produced using crushed brick and roof tiles as aggregate with different replacement level and it was found that with reference to concrete mixture with natural aggregate the density and modulus of elasticity of C&D concrete were 30% lower. It was further reported that comparable compressive strength were achieved at low replacement levels.

The water absorption capacity of RCA and RA are very high as compared to natural aggregate. As reported in RA adhere mortar is around 16-17% and for RCA it is around 1-13 % with average of 5.6% ([16]Brito and Saikia 2013). This high water absorption lead to low workability for same water/cement (w/c) ratio as compared to normal concrete. To mitigate this problem high dosages of additives are needed to make up for the loss of the workability while using RCA in concrete. This lead to poor mechanical performance due to formation of weaker ITZ.

In other experiment by [4]Ledesma et. al 2015 natural fine sand were replaced by recycled sand from C&D waste and used for M10 concrete production with different replacement level from 0 to 100 % and it was concluded that compressive strength were found above 10Mpa for replacement up to 50 % however drying shrinkage and water absorption increased substantially. The author recommended use of recycled sand for indoor environment for nonstructural concrete for replacement up to 50 %.

5.2 Durability properties

It has been seen that the concrete made with C&D waste aggregates show very poor durability performance as compared to concrete with natural aggregate.

In in experiment by ([1]Bravo et. al 2015) C&D waste from five different recycling plant in Portugal were obtained. The influence of RA in durability performance of concrete were tested both for the coarse and fine aggregate replacement Fig 3- crushing ofC&D waste dry process in Burari, New Delhi
([19]Majumdar 2014)

with RA. It was concluded that carbonation depth increased up to 180% with reference to natural aggregate concrete. It was also found that chloride diffusion coefficient increased up to 130% w.r.t reference concrete. However these result were for 100%

Fig 3- crushing of C&D waste dry process in Burari, New Delhi ([19]Majumdar 2014)

replacement of natural fine aggregate with recycled fine aggregate. Various other researchers have also found the high chloride conductivity in range of 40% to 87% higher when recycled aggregates were used as compared to natural aggregate concrete ([16]Brito and Saikia 2013).

With respect to shrinkage it was reported in a review paper by [18]Silva et. al 2015 that 100 % coarse RCA in concrete can increase shrinkage by up to 80% when compared with normal aggregate concrete. Similar results were obtained by number of authors between 60-90 % higher shrinkage when 100% replacement is done for natural aggregates with Recycled aggregates ([16]Brito and Saikia 2013). This high shrinkage characteristic lead to poor performance of concrete due to greater extent of cracking, hence poor durability to aggressive environments.

6. Case study Delhi

In collaboration with Municipal Corporation of Delhi (MCD), Infrastructure Leasing & Financial Services Limited (IL&FS) set up India's first Construction & Demolition (C&D) waste recycling

Facility in Burari, New Delhi in 2009 with operating capacity of 500 tons per day (TPD). The plant has been successfully processing C&D waste into recycled aggregates which can be used for brick making and building roads. This pilot project was set up on Public Private Partnership (PPP) basis to demonstrate the potential benefit of use of C&D waste in urban city Delhi. Around 7 acre of land was given by MCD for a period of 10 year and the plant was commissioned in 2009.

This plant is a fixed type recycling plant. Following processes are involved in recycling of C&D waste

First segregation is done for undesirable items like plastic, metal, FRP sheet, rags etc with mechanical and Manual means then remaining waste is segregated into three parts a) Whole bricks b) Big concrete pieces c) Mixed C&D waste. Whole Bricks are sold separately, large concrete blocks are broken into smaller pieces (200-400 mm size) using

rock breaker and mechanical hammer. These are then processed and broken into smaller aggregate suitable for making concrete. This concrete is used for making nonstructural materials like kerb stone, paving blocks and tiles.

As shown in fig 4 brick mortar were also used by the same plant as road sub-base material in the test strip which is working fine as on date.

Fig 4- Test road strip using C&D waste in Delhi ([19]Majumdar 2014)

6.1 Case study Japan and Korea

Various objective were laid down in Korea's 2nd C&D Waste management plan (2012-2016) which mainly emphasis on improvement in waste management information system which emphasis on online record of C&D waste by both contractor and treatment companies, substantial reduction in the amount of mixed waste and implementation of life – cycle inventory data on C&D waste.

In Japan high emphasis is given on environmental impact hence while determining the price or quality of product the environmental conservation costs are added. Japan defines concrete class based on properties of recycled aggregates. Class H concrete for strength upto 45Mpa which utilises good quality C&D aggregate, Class M concrete which are not exposed to severe environmental condition and finally class L concrete utilising low quality C&D aggregate having high water absorption and used only for backfill and levelling concrete ([20]Bansal et. al 2014,[16] Brito and Saikia 2013)

7. Future technology and Development

In a study by [10] Leiva et. al. 2013 it has been found that there is a improvement in fire insulation characteristic of blocks containing C&D waste. Concrete blocks were prepared using recycled aggregate from 20 to 100% replacement of natural aggregate. These blocks were tested and found to have improved properties w.r.t reference concrete for fire resistance, heat insulation and acoustic insulation. The reason for this improved properties was low density of blocks and more voids in these blocks thus making them suitable for nonstructural use such as blocks and prefabricated concrete panels.

In an another study in Mexico by [11]Ossa et. al 2016 the use of recycled aggregate upto replacement of 20% were recommended in hot asphalt mix for paving urban roads. Similar result were obtained by [21]Gomes and Perez et. al 2014 for use of C&D waste aggregate in cold asphalt mix.

As we have seen the use of RA as Subbase has a huge potential for road construction. These recycled material are not effected by weathering, abrasion, physical and chemical change hence very much suitable for sub-base layer in pavement construction. ([22]Jimenez 2013)

8. Guidelines

It has been found that there is no consensus on standardisation process for recycle and reuse of C&D waste. Each country has its own technology and standard due to vast variation in the properties of C&D waste across the locations. However there is great awareness across the nations regarding proper utilisation of this waste to conserve mother earth. Following guidelines are recommended for sustainable use of these waste.

a) One should follow strategy of Use-Reuse-Recycle-Landfill. First we should utilise the natural resources to its maximum potential by minimising the waste. Then the waste must be reused as much as possible if not in

the same project than in the other project. After reuse the waste should be recycled using environmental friendly techniques for its maximum utilisation in various products. Finally Landfill will be done in planned and designated locations only.

b) In developing countries like India where natural aggregate is available at cheap prices incentive should be given by the government for utilising C&D waste aggregate along with subsidy to companies recycling these C&D waste by providing them land free of cost, interest free loan on purchase of plant and machinery and making it compulsory for government project to utilise products from C&D waste.

c) More recycling plant should be proposed on PPP basis as the case of Delhi based on the detail survey about viability of these plants. Learning from the best practices around the globe can help in forming guidelines for using these waste.

d) Strict regulation and vigilance to prevent illegal dumping by imposing high fines will prevent environmental degradation. Also giving incentive for transportation of C&D waste to nearest recycling facility based on quality of waste will enhance proper disposal.

e) Selective demolition practices consisting of systematic removal of various reusable components like door and windows, structural steel, metallic components etc. Thereafter proper segregation and sorting at site itself before sending to recycling plant.

9. Conclusions

After studying different technologies, various research work on utilisation of C&D waste it is concluded that the C&D waste reuse and recycling has a great business potential. Its success depends on the incentive by the government and formation of standards, strict compliance of regulations and better state of an art technology for recycling of these wastes.

a) It has generally seen that the use of C&D waste is restricted for use in green buildings only which require certification.

b) In developing countries lack of regulation lead to illegal dumping causing environmental degradation.

c) It is seen that there is very high diversification in properties of C&D waste available across the location. Hence problem in classification and standardisation.

d) Lot of mixed C&D waste has large amount of clay based material in it which makes is non suitable for recycling as cost of processing shoots up. Due to unsuitability, this type of C&D waste goes for landfill only.

e) With new and latest research it is being concluded that the problem of C&D waste utilisation can be managed easily provided all section of society come forward to take pledge for protection of environment and healthy future for coming generation

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