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Original Research Paper

Sustainable Development Through Recycling of Construction and Demolition Wastes in India

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ABSTRACT

Construction and demolition wastes constitute of uncontaminated solid waste resulting from construction, remodelling, repair and demolition of buildings, structures, roads, etc. This consist of bricks, concrete, other masonry materials, dust, wood, plumbing fixtures, roof coverings, glass, plastics, etc. When buildings are demolished large quantities of waste produces in a relatively shorter period of time. About 10-15% of municipal solid waste generates from C and D activities. Population explosion increases all sorts of needs and now a days we are facing scarcity, high rate, low quality materials in all the sectors including construction activity, which satisfies one of our basic need for shelter. To fulfil the needs of rapid industrialization and urbanization, large quarries are coming up and working extensively, which not only spoil the existing infrastructure while transporting but also creating great ecological and environmental problems. Instead of emptying earth crust by over-extraction of natural resources to satisfy our high demands, materials from construction and demolition activity can be reused or recycled. This not only becomes substitute to natural aggregates but also conserves rapidly diminishing natural resources, reduces the problem of C and D waste disposal, cut off the problems that might be encountered when C and D waste mixes with other waste or any environmental factor. In this article problems associated with C and D waste management and the options, which can overcome these problems are highlighted. To support and to encourage the use of recycled aggregate concrete, study was conducted on aggregates obtained from C and D waste. Various properties of conventional aggregate concrete and recycled aggregate, comparisons of strength and cost effectiveness of these two are briefly presented.

INTRODUCTION

Construction and Demolition (C & D) wastes contribute a major portion of total solid waste production. Rapid modernization and reconstruction leads the construction industry to draw enormous amount of natural resources and dispose large quantity of construction and demolition wastes in landfills. Considerably large volume of debris accumulates at demolition site, which is a serious threat to environment. It is not uncommon to see huge piles of such waste, which is heavy as well, stacked on roads especially in large projects, resulting in traffic congestion and disruption. Wastes from small generators like individual house construction and demolition, find its way into the nearby municipal storage bins making the municipal waste heavy and degrading its quality for further treatment like composting/energy recovery. Often it finds its way into surface drains, chocking them. C & D waste constitute about 10-15% of the municipal solid waste, hence appropriate management of this waste is required.

Apart from reconstruction, construction and demolition, debris also results from natural calamities. Depletion in the supply of quality aggregates has lead to the use of recycled aggregates. Prevention of the environment and conservation of rapidly diminishing natural resources should be the essence of sustainable development. There is critical shortage of natural aggregate for the production of new concrete but on the other hand enormous quantity of demolished concrete produced from deteriorated and obsolete structures, creates ecological and environmental problems (Akash Rao 2006). Recycling of aggregate materials from construction and demolition waste may reduce the demand-supply gap in both the sectors.

Recycling of construction and demolition waste as new aggregate for the production of concrete is not new. It is well known that, this was successfully used previously in various forms of construction during second world war. Europe utilized the recycled aggregates in its reconstruction on a large scale (Sanni 2004). Broken concrete and bricks, mostly from buildings can be used to give ‘Recycled Aggregate Concrete’ (RAC) and similarly broken pavement can be used to build reclaimed asphalt pavement. The rate of use of recycled aggregate is influenced by availability, engineering performance and by financial incentives.

Concrete and masonry waste can be recycled by sorting, crushing and sieving into recycled aggregate. This recycled aggregate can be used to make concrete for road construction or building material. According to study commissioned by Technology Information Forecasting and Assessment Council (TIFAC), New Delhi, about 70% of the construction industry is not aware of recycling techniques. The study recommends establishment of quality standards for recycled aggregate materials and recycled aggregate concrete. This would help in setting up a target product quality for producer and assure the user a minimum quality requirement, thus, encourage them to use it.

Components of C and D Waste

This category of waste is complex due to different types building materials being used, but, in general, may comprise of the following materials.

Major components: Cement concrete, bricks, cement plaster, steel (from RCC, door/window frames, roofing, railings of staircase, etc.), aggregates, stones (marbles, granite, sand, stone etc.), wood/timber, etc.

Minor components: Pipes (G.I., iron, plastic), electrical fixtures, panels, etc.

Effects on Environment

Disposal of C and D waste has become a major concern in recent years. Some building owners, waste haulers and demolition contractors are disposing this waste improperly and illegally in order to avoid transportation cost and tipping fee, at waste disposal facilities. Illegal disposal sites have discovered in gravel pits and groundwater recharging areas, on farm land and prime residential property as well as low lying areas. Land disposal of C and D waste presents a threat of groundwater contamination because of trace amount of hazardous constituents, which are sometimes encountered. Potential groundwater contamination results from small amount of hazardous materials such as organic compounds, heavy metals that may be present in the substances which have been applied to construction materials, or by improper disposal of residues or bulk chemicals in the waste stream. Degradation of groundwater quality may also result from larger amount of generally nontoxic chemicals such as chloride, sodium, sulphate and ammonia that may be present in leachate generated from C and D waste materials, when land filled. Therefore, we can say that, improper disposal of C and D waste does pose a threat to groundwater quality.

An illegal disposal site may also attract, illegal disposal of other types of waste including conventional municipal waste, industrial waste and hazardous waste. These would further impact the site and increase further cost for cleaning up an impacted or contaminated site. Open burning of demolition material is a major concern. Plastic material, insulation foam, painted wood will give toxic fumes when burnt. Leachate from ashes may impact the groundwater quality.

Management of C and D Waste

Management of C and D waste is a major concern for town planners due to the increasing quantum of demolition rubble, shortage of dumping sites, increase in transportation and disposal cost and growing concern about pollution and environmental deterioration.

Storage and segregation: C and D waste should be best stored at the point of generation without allowing that to scatter or thrown on the road. If not they not only cause obstruction to traffic but also add work load to the local body.

Segregation can be carried out at source during C and D activity or can be achieved by processing mixed materials to remove foreign materials. Before demolition, segregation is required to facilitate recycling or reusing of materials like wood, glass, cables, plastic, etc. In order to produce recycled aggregate that meets the specification, hazardous materials like lead based paints, glasses, etc. have to be removed from the structure prior to demolition and also to minimize special handling and disposal requirement of large quantity C and D waste. Segregation at source is most efficient in terms of energy utilization, economics and time.

Collection and transportation: Smaller quantity of C and D waste generated in case of repair and remodelling activities, can be dumped in low lying areas or can be removed on payment basis by local bodies.

Large scale C and D waste can be stored in dumper bins and then dumper bin lifter fitted with hydraulic hoist system can be used for efficient and prompt removal. If trailers are used tractors may remove these. Very large volume of C and D waste can be handled by front-end loaders in combination with sturdy tipper trucks, so that time taken for loading and unloading gets reduce.

Recycling and reuse: Recycling of demolition waste was first carried out after the II World War in Germany, to tackle the problem of disposing large amount of demolition waste caused by war and simultaneously generate raw material for reconstruction. C and D waste is bulky, heavy and mostly unsuitable for the disposal by incineration. Growing population and requirement of land for other uses has reduced the availability of land for waste disposal. Apart from mounting problem other reasons which support adoption of reuse, recycling strategy are reduced extraction of raw materials, reduced transportation cost, improved profits and reduced environmental impact. Fast depleting reserves of conventional natural aggregate have necessitated the use of recycling/reuse technology in order to conserve conventional natural aggregate for other important works.

Disposal: C and D waste is inert in nature and does not create chemical or biological pollution. Therefore, maximum effort should be made to reuse and recycle. C and D waste can be used for filling or levelling of low lying areas. In industrialized countries special landfills are, sometimes, created in abandoned mines and quarries.

C and D Waste Management: Indian Scenario

The idea of recycling concrete waste as coarse aggregates for new construction is gaining importance on the international scale. In India very few attempts have been made to use recycled aggregates on large scale. Central Pollution Control Board estimates current quantum of solid waste generation in India to be 48 million tones per annum, out of which the construction industry accounts for about 12-14.7 million tones (CPCB). At present management of waste from construction industry in India comprises the following elements.

1. Reuse of only selected materials salvaged in good condition during demolition.
2. Sending metallic items for recycling through scrap dealers.
3. Dumping remaining items to low lying sites and dumping areas.

Estimated waste generation during construction and renovation work is 40-60 and 40-50 kg/m^2 respectively. The highest contribution to waste generation is from demolition of buildings, which yields 300-500 kg/m^2 of waste (CPCB). Quantity of different constituents of waste that arise from construction industry in India is estimated as follows.

Constituent	Quantity generated in million tones/annum
Soil, Sand and Gravel	4.2-5.14
Bricks and Masonry	3.6-4.4
Concrete	2.4-3.67
Metals	0.6-0.73
Bitumen	0.25-0.3
Wood	0.25-0.3
Others	0.1-0.15

In India, concept of recycling is not so popular compared to other countries.

1. Acceptability of recycled materials is hampered due to a poor image associated with recycling activity in India.
2. Low dumping cost prevalent in India acts as a barrier for recycling activity. Imposition of charge on sanitary landfill can induce builders and owners to divert the waste for recycling.
3. Non awareness of recycling possibilities is one of the main barrier due to which waste is disposed only in landfills.
4. There is lack of government support and commitment towards development of recycling industry. Development of policy supported by proper regulatory framework is necessary.
5. Development of proper standards and specifications for recycled materials would provide producers a targets and users an assurance in quality of material.
6. Recycling technology for C and D waste has to be established on pilot scale in India. It is recommended that pilot scale plant for producing recycled aggregates in different construction activities is to be demonstrated. Central Road Research Institute or Central Building Research Institute may be involved to put up a pilot plant and to establish use of recycled aggregate in road and building construction.

MATERIALS AND METHODS

Method of mix design for M20 grade concrete proposed by IS: 10262-1982 was employed to design the Conventional Aggregate Concrete (CAC) mixes and finally Conventional Aggregates (CA) were fully replaced by Recycled Aggregates (RA) to obtain Recycled Aggregate Concrete (RAC) mixes (Rajkumar 2005, Akash Rao 2006). The mixture proportion by weight, used in the mixes CAC and RAC were fixed at 1 : 1.5 : 3.3 after several trials and with different water cement ratios (Shetty 1995). Materials used for the study were:

1. Cement: Ordinary Portland cement of 43 grade conforming to IS: 8112-1989
2. Fine Aggregate: Sand conforming to zone II of IS: 383-1999 having specific gravity of 2.68 and fineness modulus 2.5
3. Coarse aggregate: Crushed aggregate conforming to IS: 383-1999 as a CA. RA obtained from demolition waste of buildings of unknown strength at Mysore. Demolition waste aggregates contain demolished concrete 70%, demolished brick work 20%, mosaic tiles and other impurities 10%. These aggregates were separated by manually sieving into two sized fractions. Series-I, which passes through 40 mm IS sieve and retained on 20 mm

Table 1: Material properties of aggregates.

Sl. No.	Properties	CA	RA
1	Specific gravity	2.85	2.6
2	Water absorption, %	0.90	8.5
3	Impact value, %	21.00	32.0
4	Los Angeles Abrasion, %	23.50	42.5

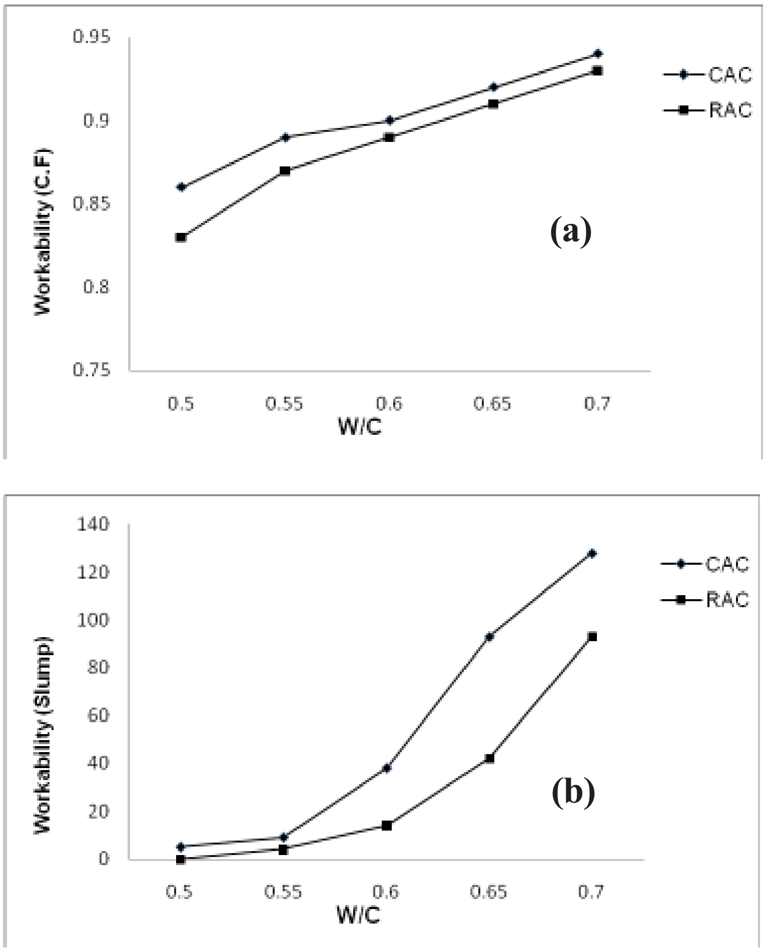

Fig (1): Comparison of (a) compaction factor (b) Slump.

IS sieve. Series-II passes through 20 mm IS sieve and retained on 4.75 mm IS sieve. Finally both were mixed proportionally to obtain similar grading of CA.

4. Water: Clean potable water was used for mixing. Tests were conducted on specimen of standard size as per IS: 516-1959. Table 1 shows physical and mechanical properties of both CA and RA. All the results of various tests conducted on concrete specimen cast are given in Tables 2 and 3.

RESULTS AND DISCISSION

The properties of RAC could vary widely depending upon source of the RA and age of concrete at the time of the demolition.

Physical and mechanical properties of aggregates: From the results it is observed that the recycled coarse aggregates were found to be weaker than corresponding virgin aggregate against mechanical action. Such behaviour is expected because of weak mortar component and weak mortar aggregate bond in RA. Same types of results were observed in the study conducted by Timothy (1998).

Properties of fresh and hardened concrete: Results show that workability of RAC mix is slightly lower than CAC mix, because the quantity of water required for desired workability was more due to residual mortar attached to recycled aggregate. Fig. 1(a) shows variation of compaction factor and Fig. 1 (b) shows variation of slump for the two typical concretes.

Compressive strength of RAC is varying from 5 to 25% lower than CAC at any W/C ratio. Tensile strength variation of RAC in direct tension and flexure is observed in the range almost 15% lower those of CAC. This reduction in strength may be attributed to the relatively higher water requirement of RAC and the weaker bond between fresh mortar and old mortar adhering to recycled aggregate. Variation of strength with water cement ratio is shown in Fig. 2.

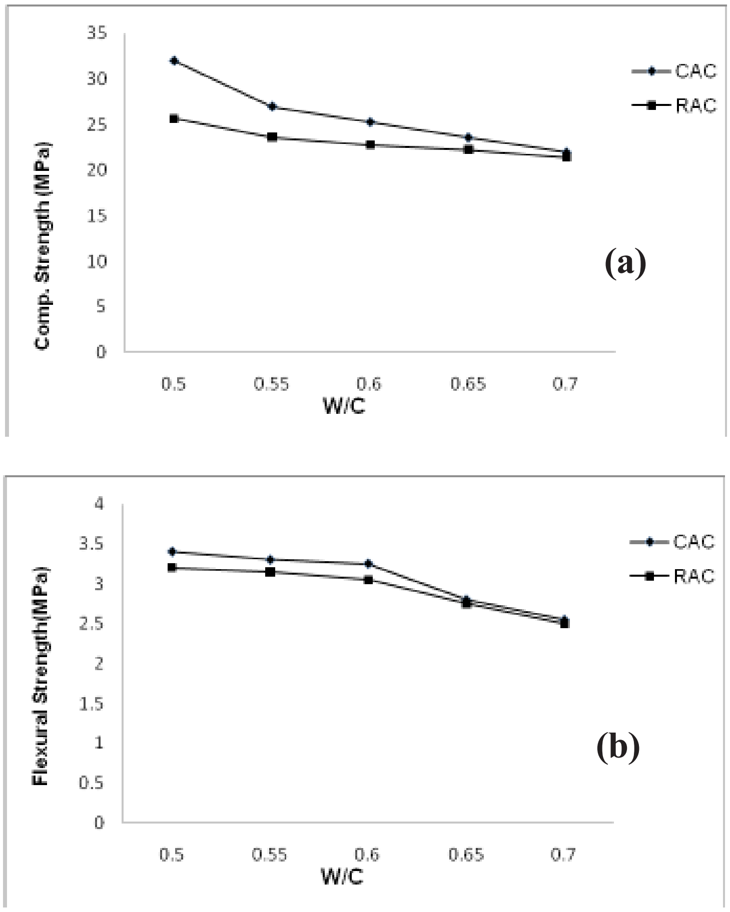

Fig (2): Comparison of (a) Compressive strength (b) Flexural strength.

Table 2: Test results for CAC.

Mix	W/C	C.F	Slum pmm	Compressive Strength N/mm^2 (28 days)	Flexural Strength N/mm^2 (28 days)	Split Tensile Strength N/mm^2 (28 days)
1:1.5:3.3	0.50	0.86	05	32.00	3.4	2.60
	0.55	0.89	09	27.00	3.3	2.50
	0.60	0.90	38	25.30	3.25	2.35
	0.65	0.92	93	23.60	2.80	2.20
	0.70	0.94	128	22.00	2.55	1.95

Table 3: Test results for RAC.

Mix	W/C	C.F	Slum pmm	Compressive Strength N/mm^2 (28 days)	Flexural Strength N/mm^2 (28 days)	Split Tensile Strength N/mm^2 (28 days)
1:1.5:3.3	0.50	0.83	00	25.65	3.20	2.50
	0.55	0.87	04	23.60	3.15	2.30
	0.60	0.89	14	22.75	3.05	2.25
	0.65	0.91	42	22.25	2.75	2.05
	0.70	0.93	93	21.40	2.50	1.90

Cost-benefit analysis: Costs of materials at Mysore are as follows:

1. Cement : Rs. 300 per bag
2. Sand : Rs. 900 per m^3
3. CA : Rs. 800 per m^3
4. Cost of labour and other miscellaneous expenses

   : Rs. 300 per m^3
5. Construction and demolition waste available free of cost. Labour cost to break the big pieces of waste into desired sizes : Rs. 150 per m^3

Cost comparison for unit volume of both CAC and RAC of given mix taken for the present study is as follows:

Mix : 1: 1.5 : 3.3
CAC : Rs. 2300
RAC : Rs. 1650

The above observations state that the cost of RAC is less than CAC. Transportation cost of C and D waste is not included, as it can be maintained by either tipping charge or on site production or some incentives. Even this cost can become competitive as the local aggregate sources diminish, leading to higher transportation cost for procuring from distant source.

CONCLUSION

Urban local bodies should make a plan for gainful use of construction and demolition waste. There should be a proper institutional mechanism to take care of collection, transportation, intermediate storage if any, utilization and disposal of C and D waste. In many ULBs like Mysore, health department is responsible for garbage management whereas the engineering department is responsible for C and D waste management. Under such circumstances, it is extremely important that either the solid waste management department is made responsible for collection of C and D waste or these two departments should work in close co-ordination. It is essential that proper accountability should be fixed and official information should be readily available regarding day to day situation.

Use of recycled aggregate concrete is technically, economically and environmentally feasible. Economical and environmental pressure justifies consideration of alternative material sources in places, where the available source of conventional aggregate is inaccessible. However, more research studies on RAC are necessary for practical application. The use of RAC should pose no problem at lower level applications such as plain concrete and pavement sub-base concrete, etc.

Lack of awareness is the main reason noted in using recycled products derived out of C and D waste. Hence, there is great need of all ULB’s, R and D institutions and construction industries to come together and work for promoting RAC.

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