

Management of Construction and Demolished Waste as an Aggregate Substitute in Cement Concrete

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

India is in the process of modernization in the construction sector by repairing, renovation, up-gradation. Presently concrete, the universal building materials whose main ingredient is coarse aggregate. The local natural resources like stone products and sand may exhaust and put the sector deficient of aggregates. The wise use is to reuse recycled concrete and demolition wastes generated from the construction sectors due to shift from horizontal to vertical growth of urban areas. The replacement of recycled coarse aggregate shall efficiently organize the waste management, moderate the environment degradation, and upsurge sustainability.

Use of recycling material in the construction industry as a recycled concrete is highly challenging. So our project deals about reusing of demolished concrete blocks from C & D wastes by form of Recycled coarse aggregate (RCA) are replacing the Natural coarse aggregate in concrete and use in the construction industry. The replacement of RCA in special concrete of 7 and 28 days of curing and the various physical and mechanical properties of materials and strength test of both concrete such as workability, compressive strength, split tensile strength and flexural strength. The test value are compared both in concrete.

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Our project investigates on recycling demolished waste materials in order to reduce construction cost and resolving housing problems faced by the low-income communities of the world. The crushed demolished concrete wastes is segregated by sieving to obtain required sizes of aggregate, several tests were conducted to determine the aggregate properties before recycling it into new concrete.

Keywords: C&D wastes; climate change; mechanical strength; recycling & reuse; sustainability.

ABBREVIATION

BMTPC : Building Materials & Technology Promotion Council
BMPC : Building Material Promotion Council
C&DW: Construction and demolition wastes
SBM : Swachh Bharat Mission
MoHUA : Ministry of Housing and Urban Affairs
IS : Indian standard
Gol : Government of India
SDG : Sustainable Development goals
PPP : Public Private Partnership
TPD : Tones/ day
NDMC : North Delhi Municipal corporation
RCA : Recycled coarse aggregate
SP. Gr. : Specific gravity

1. INTRODUCTION

The construction methodologies and the materials have altered from mud-built thatched house (Paleolithic period) to the present green buildings in smart cities during the anthropogenic epoch. Fast sprawl of urbans, industries with spurt in the fiscal activities are setting marvelous stress on housing and infrastructural activities. With passage of time man have changed their building materials from perishable goods (leaves, straws etc.) to natural materials (mud, stone, timber, or clay) and at present we have shifted to synthetic materials like tiles, plastics and paints etc. Toth, [1]. In the transition phase during shift from the post-Holocene construction to present Anthropocene buildings, there was involvement of huge amount of dense, bulky and non-biodegradable building demolished wastes.

Centre for Science, and Environment has reported that 5.75billion m² floor area has been generated in India during 2005 dumped as landfill or road side. TIFAC's (Tech. Information, Forecasting, and Assessment Council's) also have assessed C&D waste (new construction and old demolition) was 165 to 175MMT/year during 2005 to 2013 with 12 to 15MMT/Year (2001)/,<https://cdn.cseindia.org/userfiles/Construction-and%20demolition-waste.pdf>. They were

generated both in urban (more) and rural sectors whose efficient disposal has posed threat to the environment and the ecosystem. India generates about 165-175 MMT/Yr of C&D waste as estimated by BMTPC [2]. Out of which only 1% of the total construction and demolition wastes (C&DW) is recycled whereas rest are used in landfill, strewn across road side which causes both land, air and soil degradation as per the Building Material Promotion Council (BMPC), BMTPC [2], Napier, [3] , Down to Earth 31st. march 2016 and 25th Au. 2020.

The various bulky and huge demolished wastes are stones, bricks, old cement concrete, cement plasters, steel, and in small proportions are plastics, GI or iron pipes, asphalt, gypsum, electrical fixers, panels, glass panes and wooden or ply woods etc. The Swachh Bharat Mission (SBM), Ministry of Housing and Urban Affairs (MoHUA) of Government of India (Gol) has beset for recycle and reuse of total solid waste as well as C&D waste in cities and cosmopolis. By large or small, C&D Waste Management Rules, (March 29th, 2016) invokes that disposal of C&D wastes is the responsibility of the stakeholders but not the CPWD or BMTPC.

The C&D trash is massive but least attention paid for its disposal routes and methodologies. Roads are blocked or drains are jammed due to unauthorized disposal of the waste, **Fig 1 (a) and (b)**. The C&D waste generation and their management has become concern mostly in urban areas which is expanding at faster rate particularly old cities like Delhi, Calcutta, and Hyderabad etc. BMTPC, and Fly Ash Research and Management (C-FARM), has reported 2019. Delhi, Mumbai and Calcutta have generated about 5000MT/day, 3000MT/day and 2000MT/day respectively. The annual C&D waste generated in India was 45Kg/m², 400 Kg/m²and 50Kg/m² of new, demolished and renovated constructions respectively.

The shortages in horizontal growth due to land access have forced to grow urbans vertically in India to accommodate the population growth. Modern technology can provide easy livelihood

services to vertical high rise buildings. The innovative construction technology and materials in towns, smart cities, and cosmopolis have outdated old sturdy individual infrastructures which demanded to be demolished and are to be replaced high rise mansions Napier [3].

The Indian Green Building Council (IGBC) and the Leadership in Energy and Environmental Design LEED registered projects stressing upon new constructions by replacing old one shall also enhance the rate of generation of C&D wastes. The growth of the urban from challenged the generation of C&D waste disposal in major old cities of India. Measures to abate and re-handle the C&D waste by recycling or reusing if not done, may pose risk to the soil and environment as well as a barrier to the viable movement construction industry of India.

The C&D wastes can be transformed to recycled aggregate by crushing, grading and segregation of organic matter and further processed to concrete rubble for reuse in construction. Present research aims at to determine the strength characteristics of recycled C&D wastes and to compare the strength behaviour with natural coarse aggregate for use in structural concrete as coarse aggregate. As the national plan is based on reuse of C&D waste after recycling, the present investigation establishes a methodology to re-utilize the C&D waste as RCA.

2. THE METHODS AND METHODOLOGIES

The work stresses upon to study the basic properties of coarse aggregate like water absorption, specific gravity, mechanical properties, such as abrasion resistance, crushing value were also calculated. The mechanical strength properties like compressive, split tensile and flexural strength were investigated to have comparison with conventional concrete. The research involves recycling the C&D waste to coarse aggregate size, the mix designing M-25 grade of cement concrete (CC), mixing, placing and curing period of 7, 14 and 28 days. The properties of the orthodox ready mix concrete (RMC) using recycled coarse aggregate (RCA) at various blending strategies are also in estimated.

3. LITERATURE REVIEW

Etxeberría, et al. [4] have mentioned that there is 20 to 25% less in compressive strength was due to the mortar sticking to concrete and fit for reuse

in concrete having low to moderate compressive strength (20-45MPa)..The C&D waste generation in India was 10MMT to 15MMT

/yr by MoUD (2000), 10-12MMT/Yr (MoEF) 122010, and 12MMT/Yr. by CPCB http://cpcb.envis.nic.in/pdf/Comments_Env_Mgmt_07.03.17.pdf. Padmini et al. [5], Kou et al. [6] mentioned that the C&D wastes are coated with mortar that absorbs moisture which reduces the strength of concrete. The compressive strength found to be reduces by 0 to 30 % of recycled concrete aggregate (RCA) by around 5 N/mm² at lower w/c proportions. It may be due to high porosity, and permeability variable coarse aggregate gradation, and contamination in demolished concrete. Limbachiya et al. [7], Tabas et al. [8], Mac Neil et al. [9], Katz [10], Yehia et al. [11], Ahmad et al. [12]. The change in strength properties of recycled C&D wastes and fly ash was tried and of opinion that flow ability and resistance to chloride attack improved but strength reduced, Kim et al. [13]. The properties of recycled C&D waste concrete was tested under different 28 days curing settings and found by moist curing, and total replacement of coarse aggregates exhibited higher comp. strength, Baojian et al. [14], Shaban et al. [15].

TIFAC [16] has estimated, the C&D generation for new construction/demolition was 40 kg/m² to 50 kg/m² of floor area. Whereas for the same demolished floor area it was 300-500kg/m². Kolaventi et al. [17] have reported that the attitude disparity of the builder and the workforce going in a wrong way of C&D waste management and their proclivity of strategy planners must have to practice code of behavior by training of workforce for an efficient waste management. The massive amount of crude C&D waste are creating serious problems in construction hotspots like residential, industrial or institutional, commercial complexes Faruqi et al. [18].

The connectivity have been surged and demands demolition of old roads, underground lines, tunnels, and construct more lane pavements, which shall generate enormous C&D waste and shall threaten the sustainability of land, and air in future (Owasis, 2019[19], Owasis et al., 2021[20]). UN reports about 68% of population projected in the world shall have domicile in urban, by 2050. <https://www.un.org/development/desa/en/news/population/2018-revision>

India creates at an estimated 150MMT of C&D waste every year. According to Building

Material Promotion Council (BMPC), 53 cities in India were prepared to meet the challenges of recycle and reuse of C&D wastes in 2017. But the apocalyptic pandemic has killed the achievement of the target; only as in 2020 13 cities have recycled plants of C&D waste whereas management of Municipal waste has been invoked in almost all the cities and towns in India. The detailed investigation to the research gap needs extensive study.

3.1 Need for Study

The Swachh Bharat Mission under ministry of urban development imagines handling of 100% waste produced in urban communities by second October, 2019 as a key target, which

incorporates C&D waste MOEF&CC [21]. In India; C&D wastes is lost without reusing except recycling of 1% of waste generated. The abuses of C&D wastes are felt mainly in huge urban areas. As per C&D waste management rule 2016, specifies the management and treatment of C&D waste for productive utilization by reusing. There in it is mandated that the contractor or the Municipality has to procure and reuse 10 to 20% of C&D materials in corporation, municipality, and Government contracts. The risks involved in careless dumping that invite accidents, fatalities, trauma and environmental degradation. The land is scarce in urbans; landfill even cannot accommodate municipality waste. So recycling and reuse of this waste draws attention, (Fig. 1) Taffese et al. [22]



Fig. 1. The C&D wastes that have blocked the roads and choked the drains (India)

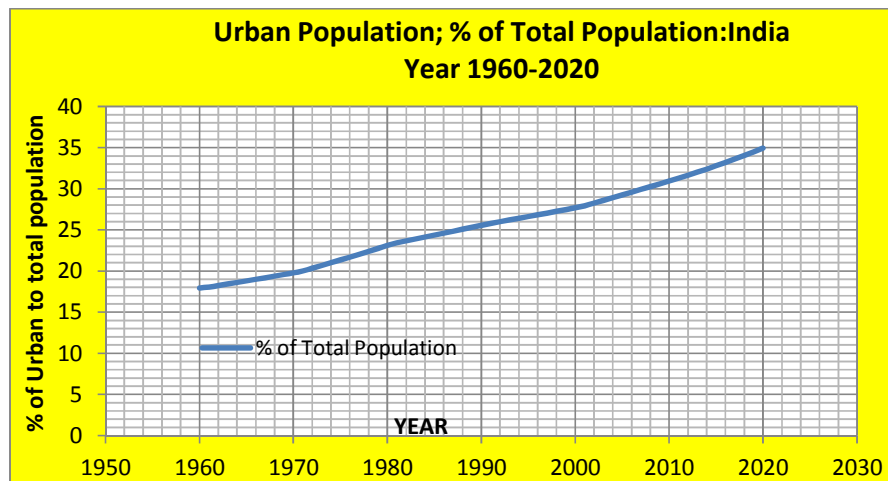


Fig. 2. Urban population growth rate (%) in India (Source: World Bank Data)

3.2 Economic Importance of Recycled C&D

Municipal wastes are distinct from C&D waste. International Market Analysis Research and Consulting (IMARC) Group have predicted the C&D wastes management market of the globe shall breed at @ 5.30% CAGR from 2021 to 2026.

<https://www.imarcgroup.com/construction-demolition-waste-management-market>. India's urban population was with a growth rate (2.3 FY 2020) and grown from 80.76million in year 1960 to 481.98million in year 2020 (World Bank data, <https://data.worldbank.org/indicator/SP.URB.TOT.L?>) (Fig 4)

The volume of C&D wastes are major solid waste in advanced nations all over the globe. This C&D waste cannot be properly recycled and reused due to paucity of land fill areas, left unattended on roadside or drains hindering traffic flow and free discharge. The C&D wastes are included under the Sustainable Development Goals (SDG-4). Limbachiya, [7], Safiuddin et al. [23], Macneil et al. [24], Bustilo et al. [25], have reported that by natural aggregate extraction involves huge energy consumption and CO₂ emission. Recycled coarse aggregate from C&D from sites is economic Fig. 3 (a,b).

The construction sectors have augmented in generating C&D waste to a tune of 10%/year.

As per the cost analysis in Project Report CYBC, (BMTPC Ready Reckoner, [26] the % of saving in cost by recycled construction waste from solid/Hollow blocks 25% to 30% and from paver blocks are 20 to 25%.

3.3 Disposal of C&D Waste: India

The C&D waste management in India can be cost effective as it involves collection, recycling, landfill or incineration. The artifact has been given importance from Waste Management Rule 2016, and CPCB's Guidelines on Environmental Management of C&D Waste from 2017, Ram et al. [27], CPCB guidelines, [28], BMTPC report [26].

The C&D Wastes comprise of new construction, renovations, demolitions, road digs and service or utility installations. They are city-specific or project-specific that varies with the extent of urbanization. Presently the C&D wastes are dumped at road sides, drains, low lying areas, river banks, sea shores and real estate developments. The Swachh Bharat Mission (MoUD) [29], C&D Waste Management Rules [21], Swachh Survekshan [29] has imposed strict adherence and formulate action plan for 100% solid waste management of C&D wastes of urban areas.

[http://jkspcb.nic.in/Content/Construction Demolition WasteManagement.aspx?](http://jkspcb.nic.in/Content/Construction%20Demolition%20WasteManagement.aspx)

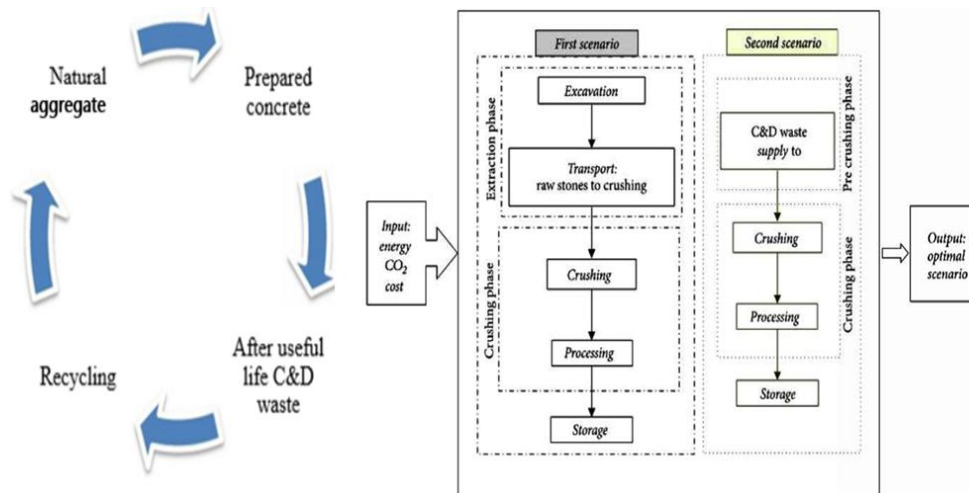


Fig. 3(a), (b). RCA and processes involved in processing C&D waste

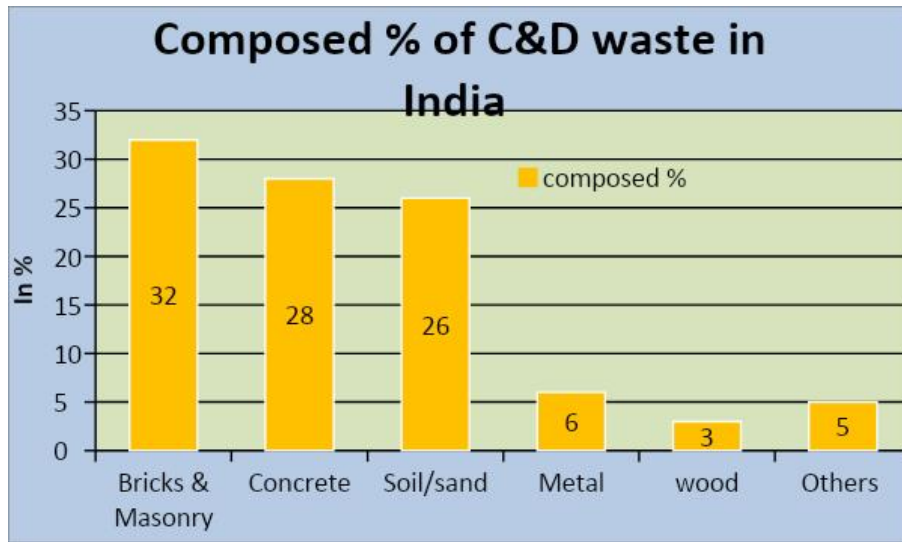


Fig. 4. % of various composition in Urban’s C&D waste in India (BMTPC [26])

Delhi has three recycling plants (Burari, Mundka and Shastri Park) working, and other three are under pipeline projects (Rani Khera, Bakkarwal, and north Delhi). About 168 sites have been designated for waste collection with highest in NDMC (North Delhi Municipal Corporation). The potential recycling of C&D waste in India are New Delhi (4150MMT.Year), Gurgaon (300MMT), Ahmadabad (1000MMT), Pune (125MMT), Mumbai (1200MMT), Bengaluru (750MMT), Chennai (1200MMT) and Hyderabad (300MMT). Mohan et al. [30], Somvansi, A., Down to Earth, Friday 05 July [31]. The distribution of various composition in Urban’s C&D waste in India BMTPC [26], Fig – 4.

reuse of the squander concrete. The recycled coarse aggregate (RCA) may have additives like metals, tiles, plastics, iron, aluminum, flotsam and jetsam as trash which may be discarded as heterogeneous. But homogenous demolished concrete blocks, brick bats, and waste concrete can be recycled and reused as RCA.

Rodríguez, et al. [32], Hoornweg et al. [33], Ding et al. [34], have reported that the recycling C & D waste which is fit for recycling are separated, stockpiled and loaded to the conveyor after stamping removal of scraps and trashes. Later crushed in crusher, graded screened, and washed for quality enhance and the final product is RCA, (Fig 4.). However the C&D wastes recovered from pavements, matured brick constructions may not selected for RCA generations and may be used for landfill as they generate huge CO₂ and, consume energy during recycling and profligate.

3.4 Recycled Aggregates production

The present problem is the search for climate compatible concrete which should be easily disposed in normal landfills, further recycled and

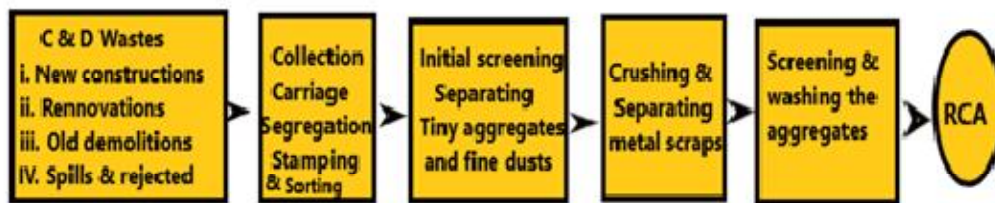


Fig. 5. The recycling processes involved in management of C&D waste in India

3.5 Methods of Sorting and Cleaning

Electromagnetic methods of separation are adopted to sort out steel scraps by magnetization processes which are the common odds available in RCC.

Dry separation methods are employed that eliminates the lighter particles or heavier dusts by blowing by blowers supported by air compressors. Similarly the low density pollutants are segregated by floating scrapers, water planes, or buoys fitted in sink tank. Hand picking of floating materials can also be employed to clean trash from RCA (**Fig 6(a)** and **Fig 6(b)**). The trash consists of different materials including, plastics, sharps, broken wooden logs, wrecked glasses, rusted metal, scrap ceramics *etc.* which generate menacing setting as they are disposed at unfenced road sides and fallow areas.

3.6 Physical Properties of Materials

The utilization of such reused materials tends to support reduction in energy use in handling natural building materials, making them fit for use. RCA has lower specific gravity and higher water absorption limit in contrast to natural aggregates due to presence of old mortar.

The properties of cement made with the generated RCA are turned weak due to exposure. Cement, the binder, might have lost its gel formation properties. So the physical properties of the RCA need to be assessed.

4. FINE AGGREGATES

The silica, mostly act as an inert filler material in concrete. They can be the crushed stone tiny particles or collected from natural rivers and drains of size 0.0625 mm down to 2mm. Ocean sand isn't suggested for its use in concrete due to its salinity and chemical

contaminations. Present test samples have used river sand from the nearby river Daya which is designated under type III of IS: 383 [35] (Reaffirmed) for all the experiments in the University lab.

4.1 Coarse Aggregate

Coarse aggregate, was used for the test samples where the RCA shall be a part substitute is machine crushed black hard granite chips of size 12mm to 20mm (screened and sorted). The Black HG chips available in the igneous rock quarry available within 10km from the laboratory.

4.2 Recycled Coarse Aggregate (RCA)

The recycled coarse aggregate (aggt.) are the processed materials recovered from demolished wastes of CC or RCC structures. They are generally more than 20years old and deteriorated by strength of chemically. These waste materials after reprocessing must be made ready for reuse. So before use the investigator should conduct aggregate tests and the results should adhere to IS:383-1970 [35].

Recycled coarse aggregate under investigation were collected the construction and demolished waste from the source of old fire station building from our nearest area which situated for 25 years. We collect only concrete rubble pieces for easy crushing in our lab for the testing purpose. For recycling aggregate test set up arranged at laboratory to process recycled aggregates that could be used for laboratory experiments. 1st the concrete rubble crushed manually by hammer then processing with jaw crusher. This laboratory tested cubes were part of the construction work. This was used as the one of the sources of Recycled Aggregate.



Fig. 5(b). Wet separation (AQUAMOTOR)



Fig. 6(a). Electromagnetic Separation Process

4.3 Working of Jaw Crusher

The Jaw Crusher designed for reducing the size of aggregate. It is based on reciprocating movement of movable jaw that compress and crushed the concrete rubbles in required size. A convenient hand wheel provides an easy means of adjusting the jaw opening without the use of a wrench. Smooth jaws insure a more uniform product and easy cleaning (Fig 7). The aggregate passing through 20mm sieve and retained on 10 mm sieve was used as recycled aggregate.

4.4 Properties of Natural and Recycled Coarse Aggregate

Raw materials for generation of the natural aggregate and recycled aggregate have varieties of aggregate properties depending upon source of Destination. The RCA includes natural aggregate covered with cement paste residue, piece of normal aggregate, or plane concrete paste and few polluting influences. So texturally they are disfigured, unpleasant, angular and elongated. RCA's in comparison to natural coarse aggregates are large in size, trash inclusive, source specific, light, higher water absorptivity, and lower strength. When made concrete have less workability properties.

Some of the comparison of the properties of ingredients of conventional concrete and RCA are in Fig. 8 and Table 1.

4.5 Concrete Mix Design

Considering the physical properties and locale grade of concrete use it was decided to test the effect of RCA concrete and conventional concrete of M-25 grade which includes and

water Mansa et al. [36]. To moderate some of the physical properties of RCA concrete, a variety of admixture may be added. The concreting process as elucidated in IS 456- [37] can be, proportioning ingredient as per mix design, batching the ingredients of concrete weight, mixing at batching plant, transporting by tipper or agitated concrete trucks, placing, compacting and curing.

Presently for the design mix for conventional or RCA concrete, the Indian standard code (IS:10262 [38]) has been considered. The absolute two designated concrete Normal aggregate concrete (NAC) and Recycled aggregate concrete (RAC) has been prepared and tested for it's mechanical strength (compressive, Split tensile, and flexural strength) properties of M25 grade of concrete. The test samples, cubes (150 x 150 x 150mm) for comp. strength, cylinders (150mm dia and height 300mm) for split tensile test, and for flexural strength, beams of size 100 x 100 x500mm) are prepared using Cement+ natural aggregate+ fine aggregate+ water (9 no. s of test samples) and Cement+ recycled aggregate+ fine aggregate+ water (9 no. s of samples)

The design volumetric mix proportion of grade of M25 grade (1: 1 :2) has been worked out and found to be Target Strength of mix proportioning is $f'_{ck} = f_{ck} + 1.65s = 25 + 1.65 \times 4 = 31.6 \text{ N/mm}^2$ with water cement ratio of 0.45, (IS: 456 -[37] & IS Code 10262 –[38]) with workability 75mm and exposure condition was mild. Where f_{ck} is the characteristic strength, σ is standard deviation. Later the concrete slump test results were found for NAC and RAC were given in Table 2.



Fig. 7. The laboratory jaw crusher used for producing coarse recycled aggregate



Fig. 8. Natural river sand; (b): machine crushed HG chips; (c): Recycled coarse aggt

Table 1. Comparison of physical properties of ingredients RCA concrete with OPC cement (IS:12269-1987)

Properties	RCA	Cement	River	BHG	IS code followed	Apparatus
Texture	Nasty	grey	Gold	Black	IS 2402 (1963)	Appearance
Consistency		35%		0.976		Vicat's appar.
Fineness	8.57		2.91	7.97	IS: 383-1970	Sieve
Sp. gr,	2.46	3.2	2.54	2.85	IS: 4031 (2)-2005	Sp. gr. bottle
Initial setting	-	45min	-	-	IS: 4031 (5)-1999	Vicat's appar.
Final setting time	-	522min	-	-	IS: 4031 (5)-1999	Vicat's appar.
Water absorption	3.04		0.95	0.95	IS 2386-3 (1963)	Lab test
Density(kg/m ³)	2315	1445	1553	1755	IS: 2386 (III) - 1963	Lab test
Impact value	10.6			8.04		
Nominal max.	20m		5mm	20m		Le-Chatelier's

Table 2. The concrete slump test results of NCA and RAC for M-25 grade concrete

SI. No.	W/C Ratio	Concrete mix	Height of mould	Height of subsidence	Slump
1	0.5	NAC	300	231	69
2	0.5	RAC	300	236	64



Fig. 9. Curing tank for curing the Concrete test specimens

After the test specimens were prepared, the concrete blocks were placed in the water filled tank. As per the requirement the specimen samples were collected (after 7 days, 14 days

and 28days) from the curing tank for conducting mechanical tests (Fig 9).

4.6 Mechanical Strength Properties

The hardened concrete undergoes strength tests like optimum compressive loading strength under compression, diameter wise splitting the test cylinder (Split tensile), and bending strength (Flexural) to assess the mechanical properties of either NAC or RCA concrete (Siddique et al.[39], Givi et al. [40], Ayub et al. [41], Yehia et al. [11], Dave et al. [42].

5. COMPRESIVE STRNGTH TEST

Comp. strength of concrete is vital property as concrete carry ≈ 90-95% compressive loadings. The strength of the concrete is estimated as per the standard practice (IS: 516 [43]. The machines used are in Fig. 10

The cubes made and cured are tested for this strength for 7days, 14 days and 28days strength. At hardened state the compressive strength of concrete was found by UTM, or the compressive test machines (CTM) and the test results are shown in Table 3. Fig 11.

6. SPILT TENSILE STRENGTH

The split tensile test sticks to IS: 5816 -1999 [44]. The test samples were submerged for 7 days,14 days and 28 days in curing tank. The test is done by setting the cylinder samples on a level plane between the stacking surfaces of a UTM. The heap will be applied with constant loading @ 140 kg/sq cm/min until the cylinder cracks.

The strength calculation (Ft) : $F_t = \frac{2P}{\pi DL}$

Where P = the maximum load applied to cylinder specimen; D- dia. of cylinder in mm, and L- length of cylinder in mm. The results of the split tensile strength are in Table 4. Fig 12.



Fig. 10. Compressive test Machine and Universal test machine for finding

Table 3. Values of compressive strength for NCA and RCA concrete tested by CTM

Concret	Curing	No. of cube	Peak load	Compressive	Average
NCA	7	1	375	16.65	16.48
		2	367	16.31	
	14	1	501	22.26	22.90
		2	530	23.55	
	28	3	706	31.37	30.39
			662	29.42	
RCA	7	1	335	14.88	14.87
		2	337	14.94	
	14	1	489	21.75	21.25
			467	20.75	
	28	1	573	25.46	25.73
			585	26.01	

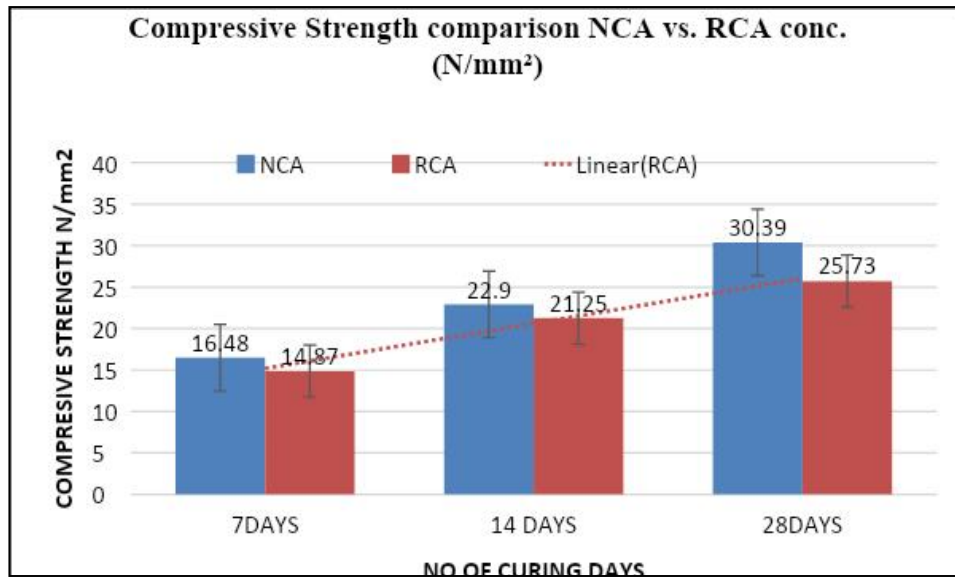


Fig. 11. The compressive strength of the NCA and RCA made concrete of grade M-25

Table 4. The split tensile strength results of NCA and RCA after 7, 14, and 28 days

Concrete Mix	No. of days curing	Peak load (N)	Tensile
NCA	7	172	2.43
	14	179	2.54
	28	210	2.97
RCA	7	149	2.1
	14	158	2.23
	28	169	2.39

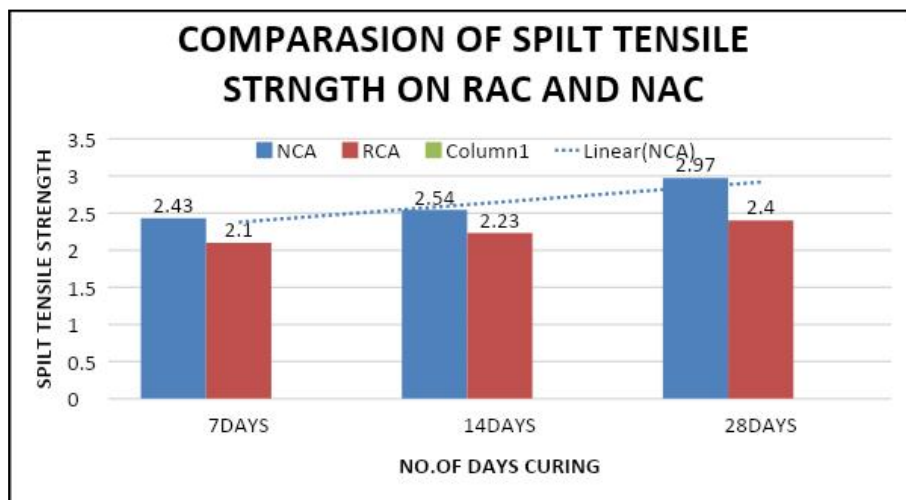


Fig. 12. The split tensile strength of NCA and RCA concrete after 7, 14, 28 days curing

7. FLEXURAL STRENGTH OF CONCRETE

The sample will be set in the machine in such a way that the load will be applied to the upper

surface of the form, along two lines separated 20.0 or 13.3 cm separated. The hub of the examples will be cautiously lined up with the pivot of the stacking gadget. The heap will be applied without stun and expanding

persistently at a pace of stacking of 400 kg/min for the 15.0 cm examples and at a pace of 180 kg/min for 10.0 cm examples. The heap will be expanded until the example fizzes, and the greatest burden applied to the example during the test will be recorded. The presence of the broke essences of concrete and any surprising highlights in the kind of disappointment will be noted. The Flexural strength test was directed on crystal test examples for concrete blends made with traditional totals and reused coarse totals The test was directed on test examples at the ages of 7, 14 and 28 days after curing restoring till the day of test. Also, flexural strength test was done on concrete blends. The Mould size of beam frexural- 100mm X 100mm X500mm

$$F_{cr} = PL / BD^2 \quad (a > 13.33)$$

Where P- Maximum load applied to beam in N; L- Length of specimen in mm; B- breath of specimen in mm, and D- Depth of specimen

From study of all the strength properties of the normal and recycled coarse aggregate concrete it is found that the compressive,

Flexural and split tensile properties of RCA samples are less than the NCA samples. Hence before common use of the RCA and ready mix concrete materials, the engineer should know the source of C&D waste and suitable place where it can be used **Table 5 & Fig-13.**

8. DISCUSSION

Reuse of the C&D wastes and saving the atmosphere from nexus gasses and deterioration, RCA's can substitute normal aggregates in concrete where low strength concrete are needed. The RCA can be subbase material, and as concrete can be used in low traffic and low volume roads. The recycled waste can have better use as making paver blocks, filling interstices of large rock blocks in sea walls, slope protection works, Spurs construction, and low landfills for high rise structures etc.. Considering the stress of management of C&D waste, the suitability of satisfying strength characteristics has been studied.

Table 5. Comparison of values of flexural strength NCA and RCA concrete beams

Concrete Mix	No. of days curing	Flexural Tensile
NCA	7	2.62
	14	3.43
	28	3.72
RCA	7	2.32
	14	3.03
	28	3.22

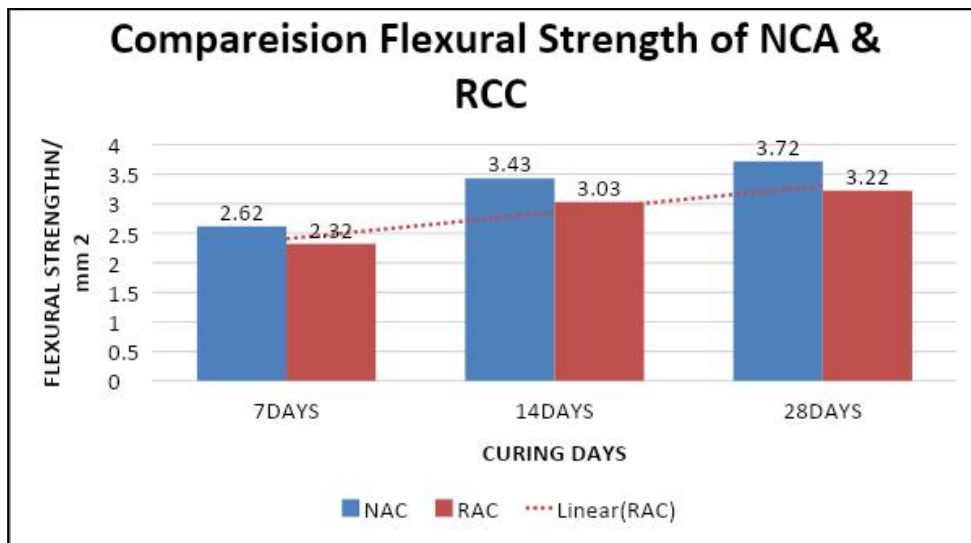


Fig. 13. Comparison of flexural strength in N/mm² of NCA and RCA concrete beams



Fig. 14. From C&D waste to usable products after recycling

From the literature and the laboratory studies it is inferred that the RCA concrete has wide market in India and can have application in less traffic pavements, drains, kerbs, land filling areas. The wise use can save project cost, produce less CO₂ from less squashing, and save environment from degradation. Apart from saving natural resources, maintain sustainable biome. Some of uses of C&D wastes are in.

However during use of RCA concrete one should born in mind that it is of poor mechanical strength lying less by 15% to 20%. The collection, milling and marketing of RCA, may deteriorate the local environment and the structures shall be moisten, creep, and have drying shrinkage due to higher water retention of RCA concrete. Adequate guidelines and more elaborative acts and laws must be made at government level for the persons mis-managing their C&D waste.

The Environment Minister highlighted that the local bodies will have to utilize 10-20% material from construction and demolition waste in municipal and government contracts. Cities with a population of more than one million will commission processing and disposal facility within 18 months from the date of final notification of these rules, while cities with a population of 0.5 to 1 million and those with a population of less than 0.5 million will have to

provide these facilities within two years and three years respectively. <https://earth5r.org/sustainable-construction-waste-management-india/>

The following questions are yet to be answered and partly answered. It is about global waste key factors, management scenario, the processes, and the market trend. The impact of the COVID -19 on this industry for last two years, and the stages of value chain of the global C&D waste must be searched.

9. CONCLUSION

Most of the old cities of India has become 1000years old and the massive structures are deteriorating with weather and climate change. Anthropogenic modernization, shift from horizontal to vertical growth of township, making of green houses in smart cities have compelled those cities to demolish all its structures. Particularly in 21st century annual generation and disposal of about 150MMT has become challenging. The six R's (Reduce, Reuse, Recycle, Recover, Redesign, and Remanufacture) for management of C&D waste must be adopted. By proper management of C&D waste the country can cultivate waste-to-energy expertise, recover materials from trashes, proper land use/land cover, maintain sustainability and green biome for our future generation.

Since the RCA is source and location specific, adequate record of the amount of C&D waste, the process of their disposal must as per the rules made by the government. The physical, chemical and the strength properties of these trash materials must well researched. It is to be thought that how to improve the workability; Sp. gr., reduce water absorption. Present C&D waste management system stresses on formulation of strict guidelines for optimized recycling,, reuse as higher grade concrete and decision making about selective demolition, reuse in renovated structures considering the cost viability to meet the present demand for the construction and demolition wastes Karanthi et al. [45].

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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