International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:14, No:12, 2020

An Overview of Construction and Demolition Waste as Coarse Aggregate in Concrete

S. R. Shamili, J. Karthikeyan

***Abstract*—**Fast development of the total populace and far and wide urbanization has surprisingly expanded the advancement of the construction industry. As a result of these activities, old structures are being demolished to make new buildings. Due to these large-scale demolitions, a huge amount of debris is generated all over the world, which results in a landfill. The use of construction and demolition waste as landfill causes groundwater contamination, which is hazardous. Using construction and demolition waste as aggregate can reduce the use of natural aggregates and the problem of mining. The objective of this study is to provide a detailed overview on how the construction and demolition waste material has been used as aggregate in structural concrete. In this study, the preparation, classification, and composition of construction and demolition wastes are also discussed.

***Keywords*—**Aggregate, construction and demolition waste, landfill, large scale demolition.

I. Introduction

DUE to the large-scale demolitions of buildings, a huge amount of debris is generated all over the world, which causes serious environmental pollutions including a disposal problem. As of late, it was accounted for that around 850 million tons of construction and demolition waste (CDW) was produced in the EU every year, which represents to 31% of the general waste [24]. Huge volumes of waste concrete can also be derived from construction demolition and rehabilitation projects, concrete testing laboratories, and construction damaged or collapsed as a result of human-induced actions or natural disasters, such as earthquakes. Aggregates derived from the demolition of concrete members and structures generally referred to as Recycled Aggregates (RAs). These, hardened cement can be crushed and reused as coarse aggregate of new concrete, prompting a specific sort of "green concrete" in which normal coarse aggregates are partially or completely replaced by Recycled Concrete Aggregates (RCAs), while simultaneously decreasing the purported CDW. Utilizing CDW as a total can lower the utilization of natural aggregates and the issue of mining.

Although, in contrast with natural aggregate (NA) the nature of CDW total is poor, which limits its utilization in assortments of construction applications.

There are two types of CDW aggregates. The aggregate containing a minimum of 95% crushed concrete is called RCA and 100% crushed masonry-based aggregate is called RA. Several studies highlight that RCAs are more porous than NAs [1]-[3]. This higher porosity is attributed to the presence of capillary pores, micro-cracks which is accessible to water.

S.R.Shamili, Research scholar, is with the National Institute of Technology, Tiruchirapalli, India- 620015 (phone: +91 861 079 2647; e-mail: shamili.sr@gmail.com).

J.Karthikeyan, Associate Professor, is with the Department of Civil Engineering, National Institute of Technology, Tiruchirapalli, India- 620015.

In Europe, the commitment of each industrial sector to the age of waste is very much depicted by EEA (European Environment Agency), thinking about information from the States of the European Union. The rates of waste production vary impressively among various divisions and waste categories. In Fig 1, it is noted that the largest percentage (48%) corresponds to CDW, whereas municipal waste, which probably better represents the idea of waste in the common way of thinking, is only about 12% [9].

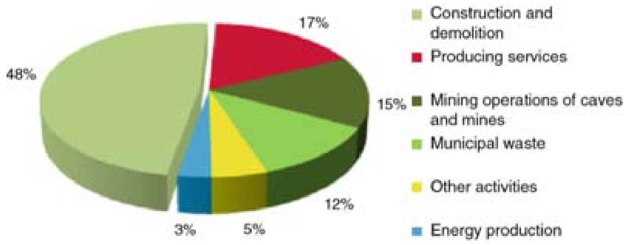

Fig. 1 Total waste generation per sector in UE 15 (EEA2007) [9]

As CDW can be used in construction like NA, this type of aggregate is characterized using methods similar to those used for NA characterization. In any case, CDW contains a few contaminants, for example, wood, plastics, and gypsum these defiling materials ought to be taken out before the use of CDW as a total in concrete. Therefore a substitute is required with

- Similar grain size
- Similar mechanical properties
- Workable
- Cost-effective
- No effect on cement chemistry.

A. Sources of Construction Waste Material

Construction waste materials are possibly generated by various sources:

- Design source
- Procurement source
- Handling of material source
- Operation source
- Residential source
- Other sources

II. Past Studies

Yu-chang et al. [5] concluded that the 100% replacements of natural coarse aggregates with recycled coarse aggregate give 41.4 MPa at 28 days which can be used for structural applications. Surface pretreatments can improve the properties of fresh and hardened concrete where it seals the pores the workability is enhanced

Ahmed [4] stated that the workability of RA concrete is decreased with an increase in RA. RA concrete containing 25% of RCA gives improved compressive, tensile, and flexural strength of concrete. Water absorption increases with an increase in RA. Besides, 40% of fly ash reduced the water absorption of RCA and compressive strength is increased for 56 and 91 days.

Purushothaman et al. [3] concluded that the Presoaking RA in H_2SO_4 is more efficient than HCl in removing the attached mortar of RA. Hence, the properties of RA as well as the RA concrete are improved. Among the mechanical treatment methods, the heating and scrubbing technique improves the quality of RA and hence the property of RA concrete.

Somna et al. [2] concluded that the ground fly ash can slightly improve the compressive strength of RA concrete. Then the reduction of W/B, the water permeability coefficient was reduced effectively with the utilization of ground fly ash debris in RA concrete.

Matias et al. [1] concluded that greater RA molecule density results about higher concrete's specific density. The utilization of superplasticizers brought about a diminishing pattern of concrete workability, suggesting that superplasticizers lose efficiency with increasing the RA proportion. In general, incorporation of RA reduces the compressive strength, however for making up the vast majority of the strength misfortune; the superplasticizers can be added to improve the mix compactness.

III. Processing Procedure of Construction Waste Material

Fig. 3 shows a view of the demolition of buildings. Fig. 4 shows the view of the electromagnetic separation process. Fig. 5 shows the recycled coarse aggregates.

IV. Classification of CDW

A. Building Materials

Construction, destruction, reclamation, and renovating ventures all produce a great deal of building material waste. This waste may include insulation, nails, electrical wiring, rebar, wood, plaster, scrap metal, hardened cement, and bricks. These materials might be harmed or unused, yet can be reused or reused in different structures. Hardened cement, bricks, and plaster can be crushed and reused in other construction or building projects.

B. Dredging Materials

These are materials or items that are uprooted during the construction or destruction of a site. These materials may incorporate trees, tree stumps, rubble, earth, and shakes. These materials can be reused or reused.

Selective demolition to reduce individual fragments of broken concrete

⇓

Separate storage of concrete, brick, rubble, and mixed demolition debris which is heavily contaminated with wood, plastics, and gypsum

⇓

Manual or mechanical pre-separation – (removal of large pieces of woods, paper, plastics, etc.)

⇓

Primary screening – (removal of soil, gypsum)

⇓

Primary crushing

⇓

Magnetic separation – (removal of remaining ferrous matter)

⇓

Secondary screening

⇓

Manual or mechanically removal of remaining contaminants – removal of lightweight matter such as plastics, paper, wood)

⇓

Secondary crushing

⇓

Washing, screening – (removal of remaining contaminants such as plastics, paper, wood, and gypsum)

⇓

The fraction of concrete demolition waste and brick rubble <40mm

⇓

Finish screening into size fractions according to customer's wishes

Fig. 2 Processes of construction waste materials

Fig. 3 Demolition of buildings [10]

Fig. 4 Electromagnetic separation process [11]

Fig. 5 Recycled Coarse Aggregates

C. Hazardous Materials

Hazardous waste may incorporate lead, asbestos, plasterboard, paint, thinners, strippers, and solvents, mercury, bright light bulbs, and airborne jars.

V. Types of Construction Material And Recycling Strategies

A. Bricks

Because of destruction of the buildings, brick wastes are generated which might be contaminated with mortar, plaster and sometimes blend with other materials like timber and concrete. At present, bricks are recycled by crushing and using as filling materials [16].

B. Concrete

Demolition of existing structures and testing of concrete samples in the laboratory leads to concrete wastes etc. In general, recycling measures of concrete wastes are used as aggregates. The crushed concrete aggregate can be used as a replacement to NA in the new concrete and also can be used in the construction of road base and trenches [16].

C. Ferrous Metal

The material that can be recycled completely with highly profitable are the wastes of ferrous metal [16]. Fig. 6 shows the ferrous metals.

Fig. 6 Ferrous metals [13]

D. Masonry

Masonry wastes are generated by destruction of masonry structures, where it is crushed and recycled as masonry wastes. It can be used as thermal insulating concrete and as an aggregate in traditional clay bricks [21].

E. Non- Ferrous Metal

Aluminum, copper, lead, and zinc are the non-ferrous metals which are generated at construction sites where most of these materials could be recycled [21].

F. Paper and Paper Board

These are another type of waste material which is estimated to comprise one-third of construction waste by volume. These wastes are recycled to produce new paper products [21]. Fig. 7 shows paper and cardboard wastes.

Fig. 7 Paper and cardboard wastes [12]

G. Plastics

The plastic waste is best possible for recycling if the materials were collected separately and cleaned. Recycling becomes difficult if plastic waste was mixed with other plastics and other contaminants. The recycled plastics can be used as street furniture, roof, and floor, PVC widow noise barrier, cable ducting, panel [21]. Fig. 8 shows a view of plastic waste.

H. Timber

All over the world, timber waste from construction and demolition work is produced in huge amount. Other construction processes like cleaning, de-nailing, and sizing are done initially and then easily utilized [21]. Fig. 9 shows a view of timber waste.

Fig. 8 Plastic wastes [15]

Fig. 9 Timber waste [14]

VI. Composition of CDW

According to the European List of Waste [27], CDW covers a very broad range of materials. Excluding non-hazardous waste, the most common categories of identified are:

- concrete, bricks, tiles, and ceramics
- wood, glass, and plastic
- bituminous mixtures, coal tar, and tarred products
- metals
- soil (including excavated soil from contaminated sites).

Elchalakani and Elgaali [24] estimated the percentage of CDW materials shown in Fig. 10.

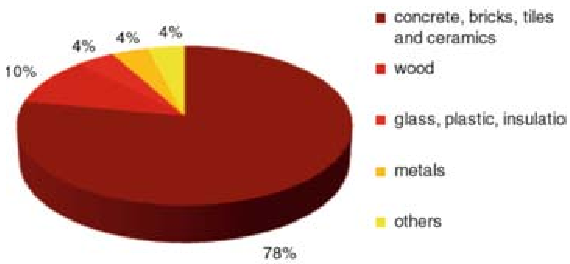

Fig. 10 CDW waste materials [8]

Coarse CDW aggregate having a particle size of 4–16 mm is reported by [7]; its compositions are presented in Table I. Distributions of materials in a few construction demolition wastes reported in various published works and summarized by [6] are presented in Table II.

VII. Properties of Aggregates

Aggregate occupies more than 75% volume of concrete mix [26] and therefore the characterization of properties of a new material to be used as aggregate should be evaluated properly, namely because it is produced from different types of materials. The properties of aggregates are:

- Physical properties
- Workability properties
- Strength properties

TABLE I
COMPOSITION OF COARSE CDW AGGREGATES (PARTICLE FRACTION: 4–16 MM) [7]

Constituents	proportions in % (mm)		
	CDWA 1	CDWA 2	CDWA 3
Concrete	92.4	92.1	85.5
Masonry	1.9	1.6	5.3
Asphalt	4.9	1.4	3.3
Lightweight materials	0.0	0.6	0.5
Fines	0.2	3.4	4.4
Miscellaneous materials	0.5	0.9	1.0

TABLE II
DISTRIBUTIONS OF MATERIALS IN CONSTRUCTION DEMOLITION WASTES [6]

Materials	Pereira [28]	de Brito and Saikia [29]	de Brito and Saikia [29]	Wang [30]
	Amount in %			
Concrete, ceramics	58.3	84.3	85.0	24.0
Metals	8.3	0.08	1.8	2.0
Wood	8.3	0	11.2	42.0
Plastics	0.83	0	0.20	32.0
Bituminous concrete	10.0	6.9	0	0
Other waste	14.2	8.8	1.8	0
Total	100	100	100	100

A. Physical Properties

1. Density

Density is one of the fundamental criteria of aggregate and is critical to design concrete mixes and control a few properties of the resultant concrete. The density of CDW total is lower than that of normal aggregate. This is because of the presence of permeable and less dense concrete paste in the CDW aggregate.

2. Water Absorption

The water absorption limit of CDW aggregate is higher than that of typical aggregate as CDW aggregate is made out of concrete paste, which is permeable ordinarily and subsequently, the water absorption limit of different sorts of CDW aggregates varies. The variation of water absorption limit is because of the variation of concrete paste content in this aggregate just as the content of different components, for example, crushed clay brick and tiles, which have exceptionally high water retention capacity.

3. Porosity

As the CDW aggregate has a higher water absorption capacity than the normal aggregate, therefore it has higher water accessible porosity than the normal aggregate.

4. Los Angeles Abrasion Tests

According to ASTM C-33, "Standard specification for concrete aggregates," [28] the Los Angeles abrasion value should be less than 50% for aggregate used to produce concrete and should be less than 40% for aggregate used to make roads. In general, CDW aggregate has a lower abrasion value than NA because of the presence of adhered mortar, which disintegrates during abrasion along with some parts of NA. Table III shows the test results for the physical properties of CDW.

TABLE III
PHYSICAL PROPERTIES OF CONSTRUCTION DEMOLITION WASTES [21]

S.No	Physical property	Test results
1	Maximum size	20mm
2	Fineness modulus	7.4
3	Specific gravity	2.64
4	Bulk density (kg/m^3)	1356-1510
5	Water absorption (%)	0.55
6	Aggregate crushing value (%)	29.58
7	Aggregate impact value (5%)	18.36
8	Moisture content (%)	4.2

B. Workability Properties

1. Slump Cone Test

Slump Cone Test, Table IV, shows the slump value in mm with different percentages of CDW. According to [22], results indicate that there is a decreasing trend of workability with the increase in CDW. Table IV shows the test results for the workability properties of CDW.

TABLE IV
WORKABILITY PROPERTIES OF CONSTRUCTION DEMOLITION WASTES

% CDW waste	Slump (mm)
0%	135
25%	128
50%	90
75%	60
100%	50

C. Strength Properties

Compressive strength Test, Table IV, shows the value in Mpa with different percentages of CDW. According to [22], results indicate that there is a decreasing trend of strength with the increase in CDW. Table V shows the test results for the strength properties of CDW.

TABLE V
STRENGTH PROPERTIES OF CONSTRUCTION DEMOLITION WASTES

% CDW waste	7th day (Mpa)	14th day (Mpa)	28th day (Mpa)
0%	34.4	38.6	56.6
25%	29.9	37.5	44.2
50%	27.1	36.3	43.2
75%	23.2	31.3	32.1
100%	21.8	30.2	38.1

VIII. DISPOSAL OF CDW

Before demolition debris is removed, contamination from lead, asbestos, or distinctive dangerous materials must be resolved [17]. Hazardous materials must be discarded independently, as indicated by government regulation [17]. Landfills CDW or municipal solid waste could be used in disposing demolition or destruction debris [18]. Alternatively, debris may likewise be sorted and recycled. Arranging may occur as deconstruction on the destruction site, off-site at a sorting area, or a construction and demolition recycling center [18]. Once arranged, materials are overseen independently and reused likewise.

Landfilling

The natural removal route for construction debris is to send it to landfill destinations. Sending the debris straightforwardly to a landfill causes numerous issues [23]:

- Increases construction cost, explicitly the transportation cycle [19]
- Occupies a large area of land
- Reduces soil quality
- Causes water pollution
- Causes air pollution
- Produces security risks [20] etc.

IX. SUMMARY AND INFERENCES

From the results of the literature review, it is evident that RCA can be used in concrete as aggregate both fine and coarse. It is concluded that,

- CDW aggregates may contain only NAs with adhered mortar or several types of contaminants such as bitumen mixtures, plastics, bricks, and tiles in minor amounts along with NA and adhered mortar contents
- The density of CDW aggregate is lower than those of NAs, due to the existence of porous and less dense cement paste/mortar in the CDW aggregates
- Additional water is necessary to compensate due to the extra absorption of the CDW aggregates during the preparation of the concrete mix.
- Compared to NA, the surface of CDW aggregate is rough and porous due to the presence of mortar adhered.
- A progressive reduction in compressive and tensile strength by increasing the percentage of RAs in the mix

Hence this paper has discussed the classification, composition, manufacturing process, and properties of RAs.

REFERENCES

[1] Daniel Matias, Jorge de Brito, Alexandra Rosa and Diogo Pedro (2014), Durability of Concrete with Recycled Coarse Aggregates: Influence of Superplasticizers, journals of materials in civil engineering 26(7).
[2] Rattapon Somna, Chai Jaturapitakkul, A.M.ASCE, Wichian Chaleeand Pokpong Rattanachu, (2012), Effect of the Water to Binder Ratio and Ground Fly Ash on Properties of Recycled Aggregate Concrete, journals of materials in civil engineering 24(1)
[3] Revathi Purushothaman, Ramesh Ruthirapathy Amirthavalli and Lavanya Karan (2015), Influence of Treatment Methods on the Strength and Performance Characteristics of Recycled Aggregate Concrete, journals of materials in civil engineering 27(5).
[4] S. F. U. Ahmed (2013), Properties of Concrete Containing Construction and Demolition Wastes and Fly Ash, journals of materials in civil engineering 25(12), 1864-1870.
[5] Yu-chang Liang, Zheng-mao Ye, Franck Vernerey and Yunping Xi (2015), Development of Processing Methods to Improve Strength of Concrete with 100% Recycled Coarse Aggregate, journals of materials in civil engineering 27(5).
[6] Coelho and de Brito (2011), Distribution of materials in construction and demolition waste in Portugal, waste management, and research: the

journal for sustainable circular economy 29(8).
[7] Mukesh Limbachiya, Elana morracchino, Angelos Kouloris (2007), Chemical-mineralogical characterization of coarse recycled concrete aggregate, Waste Management 27(2).
[8] https://lh3.googleusercontent.com/cuYoSt04_1cWlwSvPS37Yhr4K9xKHlnElvINzog55wohaf4uQ-3VpD7d5oyQze21i1tK=s170
[9] https://lh3.googleusercontent.com/GF6hS0hy8s23CwHVD5cHD7FCgVYqj3fqk7lTcIThNu8VQKggcONYVyH4eUpSSosNr7T_=s170
[10] Demolition of buildings , Excavator on building demolition site, Date taken: 21 March 2012Location: Howbridge Hall Rd, Witham CM8 3HY, UK
[11] Electromagnetic separation process Date taken: 29 April 2019
[12] Paper and cardboard wastes More information: Recycling plant, waste paper, cardboard boxes, Germany Date taken: 29 June 2017
[13] Ferrous metals Date taken: 17 jan 2014
[14] Stockpile of waste timber, timber recycling, Krefeld-Uerdingen, North Rhine-Westphalia, Germany, Europe Date taken: 5 July 2008
[15] Plastic wastes Date taken: June 15 2018
[16] https://theconstructor.org/concrete/construction-waste-recycling/1088/
[17] US EPA,REG. "Harmful Materials and Residential Demolition - US EPA". US EPA. Retrieved 19 April 2018.
[18] Management, Ohio EPA Division of Materials and Waste. "Construction and Demolition Debris (C&DD)". epa.ohio.gov. Retrieved 19 April 2018.
[19] "Recycling Construction and Demolition Wastes: A Guide for Architects and Contractors" (PDF). April 2005.
[20] "Construction Waste Management | WBDG Whole Building Design Guide". www.wbdg.org. Retrieved 2017-05-06
[21] Manish Kumar Singh and Dilip Kumar (2014) "Physical Properties of Construction & Demolished Waste Concrete" IJSRD - International Journal for Scientific Research & Development| Vol. 2, Issue 08, | ISSN (online): 2321-0613
[22] Suraya Hani Adnan, Lee Yee Loon, Ismail Abdul Rahman, Hamidah Mohd Saman, Mia Wimala Soejoso Fakulti Kejuruteraan Awam dan Alam Sekitar (2016) "Compressive strength of recycled aggregate concrete with various percentage of recycled aggregate" https://www.researchgate.net/publication/301680302_Compressive_strength_of_recycled_aggregate_concrete_with_various_percentage_of_recycled_aggregate?enrichId=rgreq-1512948d256211460dbfdfa17da3bbcb-XXX&enrichSource=Y292ZXJQYWdlOzMwMTY4MDMwMjtBUzozNjg0MTU3NDQyNDk4NTZAMTQ2NDg0ODU2NjgyNA%3D%3D&el=1_x_2&_esc=publicationCoverPdf
[23] Mohamed Elchalakani and Elgaali (2010) Sustainable Concrete made of Construction and Demolition Wastes using recycled Wastewater in the UAE, Journal of advanced concrete technology, volume 10 pp.110-125
[24] R. V. Silva1, J. de Brito and R. K. Dhir (2014) Properties and Composition of Recycled Aggregates from Construction and Demolition Waste Suitable for Concrete Production, Construction and Building Materials, 65:201–217 https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1016%2Fj.conbuildmat.2014.04.117
[25] https://www.cement.org/cement-concrete-applications/concrete-materials/aggregates
[26] EU Construction & Demolition Waste Management Protocol September 2016
[27] ASTM C-33, "Standard specification for concrete aggregates"
[28] L Pereira - Diss. Mestrado, Minho Univ., Portugal, 2002
Construction and demolition waste recycling: the case of the Portuguese northern region
[29] Jorge de Brito and Nabajyoti Saikia 2012 "Construction and Demolition Waste Aggregates" doi.org/10.1007/978-1-4471-4540-0_3
[30] Y.Wang, AliTouran, ChristoforosChristoforou, HatimFadlalla
A systems analysis tool for construction and demolition wastes management, Waste Management Volume 24, Issue 10, 2004, Pages 989-997

S. R. Shamili was born on June 14- 1992 in Namakkal, Tamil Nadu. Graduated her Under grbuation (2013) from Oxford Engineering College, Tiruchirapalli, Tamil Nadu under Anna University, Chennai, Tamil Nadu. Graduated her Post graduation (2015) degree from B. S. Abdur Rahman University, Chennai. Currently pursuing a Ph.D. in the National Institute of Technology, Tiruchirapalli, Tamil Nadu. The major field of study in Structural Engineering. She was working as Assistant Professor at Periyar Maniammai University, vallam, Thanjavur, Tamil Nadu for one year. Research area includes "Construction and demolition waste and E-Waste in concrete".

J. Karthikeyan holds a Ph.D. in Structural Engineering from IIT Rourke. He is an Associate Professor of the Civil Engineering Department at the National Institute of Technology, Tiruchirapalli, Tamil Nadu. His research interests include Prestressed concrete bridges, Long span bridges, and advancements in concrete technology and materials.