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MANAGEMENT AND CLASSIFICATION OF CONSTRUCTION AND DEMOLITION WASTE IN INDIA

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ABSTRACT. *Construction and Demolition (C&D) waste have a huge potential to replace virgin materials. However, due to lack of management, its utilization has not been optimized. Issues like sharing of responsibilities among various stakeholders and classification of C&D waste are some of bottleneck on the part of effective implementation of C&D waste management in India. This paper illustrates quantity and quality of C&D waste generation in India, regulatory framework, policy interventions and R&D work carried out to classify C&D waste aggregate for production of concrete. Experimental studies were carried out using two different sources of recycled concrete aggregates; one batch of aggregates are obtained from Burari Plant located in New Delhi and another batch of aggregates were created in laboratory by crushing concrete cubes of 20- 30MPa. Thereafter, recycled concrete aggregates were classified on basis of specific gravity and water absorption and their performance in concrete have been evaluated in terms of fresh properties like workability, air content, bleed water percentage and mechanical properties like compressive and flexural strength. Study indicates that air content in concrete mixes prepared from recycled coarse aggregate (RCA) is 5-20 % more than corresponding control mix whereas admixture requirement for concrete mixes with RCA was found to be slightly higher in comparison to that of control. Experimental study indicates that compressive and flexural strength of concrete mixes prepared with recycled concrete aggregate has been reduced drastically in comparison to control mixes without recycled coarse aggregate.*

Keywords; Regulatory framework, policy interventions, classification of recycled concrete aggregates

1. INTRODUCTION

In India, environmental guidelines on Construction and Demolition (C&D) waste management dates back to 2016 [1]. The guideline also envisages duties of various stakeholders such as Government of India, State government, urban local bodies for the resolution of problems occurring during the implementation of C&D waste management rule. In India, production of C&D waste is about 30 million tonnes per year which is about 25% of Municipal solid waste (MSW) [2]. Activities like large scale construction, infrastructure projects and re-developmental works are under execution across country that contributes immensely towards C&D waste. Besides these activities, repairs & renovation works also contributes towards surge in C&D waste generation. Authorities have formulated adequate laws for utilization of C&D waste, however enforcement of such laws has encountered certain deadlocks. One such problem involves dumping of C&D waste in low lying areas, along with roadside or in public areas by private contractors for a certain price [3,4].

Segregation of C&D waste from Municipal solid waste is another issue related with management of C&D waste. Most of the individual dumps C&D waste along with organic waste making municipal waste heavy. Such action leads to degradation of C&D waste quality and makes segregation process a bit complicated. It was thought that activities such as collection, segregation, processing and re-use would have energized C&D waste management after issuance of C&D Waste Management Rules, 2016[1]. However, with limited number of C&D waste processing plant confining to certain metropolitan cities in India, it will be a hurricane task to obtain circularity in C&D waste management. Even in metropolitan cities, number of C&D waste plant are inadequate and supply of C&D waste to these plant is also irregular or not systematic [5].

The physical and chemical characteristics of the C&D waste based concrete aggregates as well as concrete produced from the same mainly depends upon the adhered mortar content around the natural aggregate. Mechanical properties of the concrete made with C&D waste based concrete aggregates such as compressive

strength, flexural strength and modulus of elastically are compromised due to higher water absorption value of the aggregates and variation in the mortar content (typically varied in the range of 25-75 %). Similarly, durability behaviour of the concrete made with C&D waste based concrete aggregates was not found to be at par with the concrete made with natural aggregates as reported in literatures [6-8]. Since, quantity as well as quality of adhered mortar is one of the main problem that limits the usage of C&D waste based aggregate for construction activities. This paper signifies importance of C&D waste management in India, policy interventions required in different areas and R&D work carried out to classify C&D waste aggregate so as to promote its utilization in structural and non-structural works.

2. GENERAL CLASSIFICATION OF C&D WASTE

Depending upon factors like population density, construction as well as demolition practices/ activities etc., the composition of C&D waste so generated and their qualities as well as quantities varies from city-to-city. In general, Construction and demolition waste generated from cities primarily composed of (a) aggregates (47%), (b) plaster and brick etc. (32%), (c) concrete (7%), (d) alloy (6%), (e) timber (3%), (f) others (5%) and this data is taken from Guidelines on Environmental Management of Construction & Demolition (C&D) Wastes, CPCB, Ministry of Environment, Forests & Climate Change, Government of India (2017) [1].

Materials such as tiles, wood, bricks and metals are sold for reuse as well as recycling purposes whereas remaining items are generally sent to landfills or dump along the roadsides creating environmental nuisance. Construction waste generated from construction industry comprises of building debris, rubble, earth, concrete, steel, timber, and mixed site clearance materials, generated from various types of construction activities including land excavation, building construction, demolition activities, road construction and building rehabilitation or repair. Normal construction wastes are wastage such timber from fabricated formwork, steel when steel bar cutting and so on. Even though prefabricated assemblies such as windows and doors, which are packaged in large quantities of cardboard, metal or plastic strapping and wood tend to produce a significant amount of construction waste. Construction waste can be classified in the form of solid, liquid, gas or combination of all these.

There are many challenges in C&D waste uses such as unstable source of C&D waste for recycling, absence of subsidies for recycling activities, insufficient attention paid towards waste minimisation, absence of regulations on on-site planning, unregulated landfill activities, a lack of coordination among different government departments, a lack of an effective waste tracking & disposal system. Compilation of C&D waste is creating harmful effects on the environment, ecological resources and human life. It contributes to various types of pollution like air pollution, water pollution, soil pollution and nose pollution. It is affecting the entire living world as along with human beings, plants and animals are also not untouched.

In India, C&D waste are classified as; a) Recycled Aggregates (RA) and b) Recycled Concrete Aggregates (RCA). RA generally composed of brick masonry waste, cement mortar waste, tiles waste etc. which is processed through wet process. Their contribution is about 90-92 % of the total C&D waste generation. RCA are generated from demolished concrete waste followed by screening through different filtering medium and in the end any contaminants if found available, the same is removed through dry processing. RCA generally consists of parent aggregates and aggregates with hydrated cement mortar that adheres to its surface [6]. Their contribution is about 8-10% of the total C&D waste.

3. C&D WASTE MANAGEMENT

In one of the Technology Information Forecasting and Assessment Council (TIFAC) study conducted in the year 2001, about 12-15 million tonnes per annum of C&D waste had been generated in our country which includes approximately 50 kg of C&D waste generated per m^2 of built-up area corresponding to new construction [7]. The estimate is 300–500 kg per sq. m of built-up area with respect to demolition. As of today, there is no official figure of C&D Waste generated by any urban local body (ULB.) At the national level, it is assumed that generation of C&D Waste varies in the range of 10-30% of the total MSW. Figure 1, indicates generation of C&D waste based upon different population categories of a city [2]. The value of C&D waste in different cities are the assumed or approximate values that was derived on the basis of existing population.

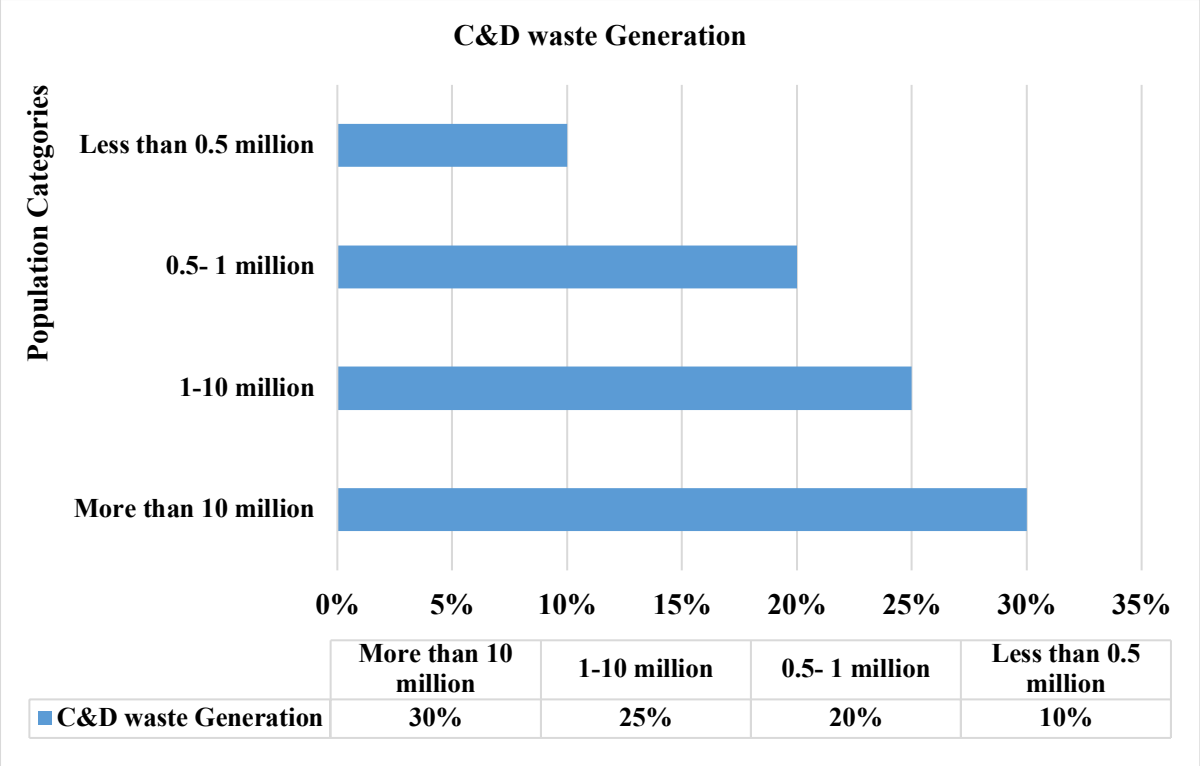

Fig-1: C&D waste generation Vs population level in India [2]

There are several factors that influences the quantity and quality of the C&D waste such as population, population density, urbanization rate and social economical status. Other important factors such as construction and demolition patterns as well as practices also impact the generation of C&D waste.

4. REGULATORY FRAMEWORK IN INDIA

There are numerous regulatory guidelines as well as provisions introduced by the government agencies like CPWD, MoUHA, MoEFCC for the management of C&D waste in India and few are given below [3,8,9]

4.1 Ministry of Environment, Forest & Climate Change (MoEFCC) guidelines on C&D waste management

- Solid Waste Management Rules (2016).
- Construction and Demolition Waste Management Rules (2016)
- National Environmental Policy (2006).

4.2 Ministry of Housing & Urban Affairs (MoUHA) guidelines on C&D waste management

- Municipal solid waste management-Manual (2000).
- Municipal solid waste management-TAG Report (2005).
- National mission on sustainable habitat (2010).
- Management manual on municipal solid waste (2016).

4.3 Central Public Works Department (CPWD) guidelines on C&D waste management

- Green building Norms (2012).
- CPWD manual for sustainable habitat (2014).

Aforementioned regulatory guidelines and framework for C&D waste has certain deficiencies related to its management at Government level, State level and urban local bodies (ULBs) levels. Therefore, following points have been suggested for the improving of C&D Waste Management. They are as follows:

- Strong lawful directives for the compliance of the regulatory framework
- Economic incentives along with strict Government supervision
- Clarity over responsibilities within all stakeholders through interaction
- Operational departments must have active coordination
- Ensure quality output as well as fulfillment of compliances through Digital monitoring setup/ Monitoring Committee

The guideline on C&D waste management for ULBs [1] primarily focusses upon its role in the overall implementation of provisions including institutional arrangement associated with the C&D waste management at local body levels. However, there are no specifications, codes, guidelines for C&D waste processing and recycling as well as the products manufactured from recycled waste. BIS is yet to bring out standard on these. However, IS: 383 revised in 2016 allows use of RCA & RA as a part replacement to natural aggregate [10].

5. C&D WASTE MANAGEMENT IN INDIA-CHALLENGES

Despite regulatory framework as well as guidelines available on C&D waste management in India, there persist some challenges such as (a) Operational challenges (b) Infrastructural challenges (c) Contractual challenges (d) Financial challenges that hinders the implementation of these framework (figure 2) [2].

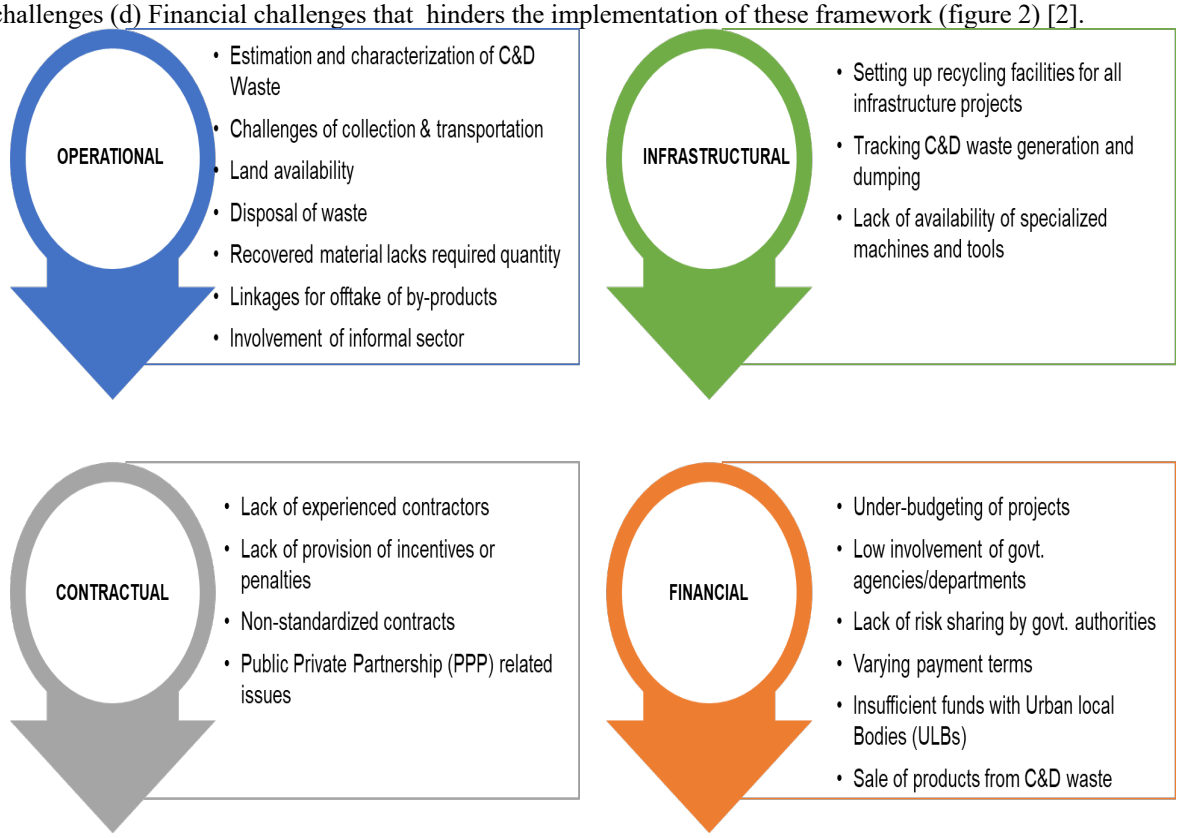

Fig-2: Challenges in C&D waste management [2]

6. POLICY INTERVENTIONS

For effective implementation of C&D waste management in India, a comprehensive action plan is required in the following areas [2];

i. C&D waste assessment
ii. Application of RCA, RA and derived products
iii. Small and large scale C&D waste collection system and its set up
iv. logistics to processing plant,
v. Encouraging C&D waste recycled products utilization at Govt. level , State level and Urban local bodies (ULBs) levels
vi. Policy mediations are also required from Government of India / State government / ULBs with respect to tax
vii. Standardization and Research needs

Policies should be formulated in the above areas in order to address the C&D waste management issues. Therefore, Demolition Plans as well as Segregation Plans for C&D waste management should be part of all civil engineering infrastructural projects. At the time of building plan approvals, these plans must be submitted to municipality or competent authority. In order to have accurate date on C&D waste generation, baseline concept like “Material passport” must be encourage. Therefore, all buildings should have a “material passport” which indicates the total carbon and a material footprint. Web-based portal system needs to be used for monitoring of the overall implementation of C&D waste management. Separation along with channelizing of the C&D waste will enhance the other waste utilization, such as organic waste /bio methanation, high calorific waste to energy

recovery etc. Concerned authority must notify that the waste producers must take economic burden for collection, transportation, processing, and disposal. Local Authority should look into appropriate management of C&D waste and segregation of C&D waste within its area / city including transportation to appropriate sites for processing and disposal. Concession agreements needs to be drafted at least after every 15 years. Corporations/ Urban local bodies (ULBs) should ensure buy-back of RCA from plants and should support them to save natural resources. At ULB/District, state and national level, the utilisation of C&D waste recycled materials should be encouraged by including such items in Schedule of Rates and Tender document(s). In India, presently, C&D management infrastructure is either not available or wherever it is available is found to be insufficient. There can be provisions envisaging Administrative, Financial, and other logistic support from the State Governments to the entrepreneurs in setting up the C&D plant, some of these are listed below

- Reduction in GST on C&D waste products from present applicable rate of 18% to 5%.
- Green tax exemption on empty vehicles while entering (returning) in the State having the C&D Waste processing plant in case of supplies of C&D Recycled Products are made outside the subject State.
- Electricity load charged at industrial rate in C&D waste plant should be reduced suitably.
- For setting, C&D waste plant, it is suggested to provide single window clearance w.r.t environmental norms and regulations.

7. RESEARCH WORK DONE FOR THE CLASSIFICATION OF C&D WASTE AS AN AGGREGATE IN CONCRETE

IS: 383 is the Indian specification on the utilization of coarse and fine aggregate in concrete. This standard was revised in the year 2016 and recommendations for the maximum utilization of C&D waste as part replacement to natural aggregate in the following categories has been made [10]:

- As a coarse aggregate, recycled concrete aggregate (RCA) up to 25 % has been permitted in Plain concrete, for Reinforced concrete (RC) work (≤M25 grade) up to 20 % has been permitted whereas in case of lean concrete, up to 100 % recycled concrete aggregate can be used. Recycled aggregate as a coarse aggregate is allowed only in lean concrete works with a maximum replacement level up to100 %.
- As a fine aggregate, recycled concrete aggregate up to 25 % has been permitted in Plain concrete, for RC work (≤M25 grade) up to 20 % has been permitted whereas in case of lean concrete, up to 100 % RCA can be used.

Aforementioned, IS 383 has restricted the use of RCA up to 20% in RCC for M25 grade of concrete and 25 % for non-structural application. However, various studies and International codes recommends higher value of RCA as a replacement of natural aggregate depending upon modal composition [12-16]. The use of RCA has been restricted because of the issues associated with Indian standard IS 383:2016 that requires immediate attention in the following areas

i. Classification of C&D waste based RCA- Presently, there is no classification with respect to quality of RCA
ii. Categorization of C&D waste based RCA – Presence of foreign materials such wood, metal, asphalt, bitumen etc. as has not been addressed.
iii. Presence of adhered mortar – Quality and Quantity is not defined in the specification

In order to maximize utilization of C&D waste based aggregate in civil engineering application, research work in the area of classification has been presented in this paper. The quality evaluation of C&D waste RCA was done on the basis of fresh and hardened properties of concrete mainly compressive and flexural strength and recommendations w.r.t classification of aggregate on the basis of adhere mortar content has been presented. The extensive studies were carried out on the usage of C&D waste based RCA as a replacement of natural aggregate in concrete using two different types of RCA. One lot of coarse aggregate (10 mm and 20 mm) sourced from IFLS Burari plant located in New Delhi and other lot of coarse aggregate (10 mm and 20 mm) obtained by crushing concrete cubes of compressive strength in the range of 20-30 MPa at laboratory. However, another two set of coarse aggregate (10 mm and 20 mm) were collected from IFLS Burari plant after a gap of two months each.

Property of RCA are chiefly influenced by the quantity and quality of adhered mortar presents around the natural aggregate. It affects the properties like density, water absorption and porosity to a greater extend in comparison to other properties like sieve gradation, flakiness and elongation [16,17]. In general, the density of RCA is 7-17 % lower in comparison to natural aggregate due to the presence of adhere mortar which is less dense [17] whereas water absorption ability of RCA is almost 3-5 times higher than that of natural aggregate. Adhered mortar on RCA has greater porosity than underlying rock which allows such type of aggregates to hold more water in its pores or to absorb more water than natural aggregates. This mainly includes eliminating the adhered mortar from the RCA surface using different methods such as acid treatment (pre-soaking method) and mechanical treatment. In case of acid treatment approach, use of highly concentrated acids namely HCl and H_2SO_4 not only increases the porosity of the RCA but also results into increase concentration of chlorides and sulphates in the

aggregates [19, 20]. It will lead to serious durability problems. Even handling and disposal of acids after testing is another challenge and may results into environmental problems. On the other hand, mechanical treatment is one of the most economical way of removing adhere mortar and same can be used for quantifying the adhere mortar content [20, 22]. Therefore, in the present study C&D waste based RCA were mechanically treated and results are discussed in section 7.1.

7.1 Physical Properties of Recycled concrete aggregates as received and mechanically treated

The preliminary investigation was carried out at 100 revolutions, 200 revolutions and 500 revolutions in Los Angeles abrasion testing machine and from the analysis of preliminary results, it was established that mechanical method with 500 revolutions in abrasion testing machine without any loading charge is the most suitable method. The comparison of test results of recycled concrete aggregates before and after mechanical treatment is listed in Table 1 and shown in figure 3.

20 mm RCA from Burari plant

10 mm RCA from Burari plant

20 mm RCA from lab

10mm RCA from lab

Fig-3: 20 mm and 10 mm RCA aggregate from Burari plant and lab crushed

From Table 1, it can be observed that the sieve gradation of as received 20 mm RCA is complying to the requirement of IS 383:2016 whereas 10 mm RCA sample1 and 10 mm RCA lab sample was found to be slightly coarser in nature. However, when mechanically treated in Los Angeles abrasion equipment for 500 revolutions without any charge an improvement in the gradation of 20 mm and 10 mm recycled concrete aggregate from Burari plant or lab sample obtained by crushing the concrete cube was seen. The total deleterious content in all the RCA samples were found to be less than 2 % i.e. within the permissible limit as defined in IS 383:2016. On the basis of test results, it can be seen that there is a significant improvement in the quality of RCA aggregate (both Burari plant as well as lab produced) after mechanical treatment.

Table-1: Comparison of Physical Properties of Recycled concrete aggregates as received and after mechanical treatment

S. No.	Test on aggregate		RCA Burari Plant – Sample 1 (as received)		RCA Burari Plant– Sample 1 (after treatment)		RCA Burari Plant – Sample 2 (as received)		RCA Burari Plant– Sample 2 (after treatment)		RCA Burari Plant – Sample 3 (as received)		RCA Burari Plant– Sample 3 (after treatment)		RCA lab (as crushed)		RCA lab (after treatment)	
			P1/20	P1/10	P1/20 /500R	P1/10 /500R	P2/20	P2/10	P2/20 /500R	P2/10 /500R	P3/20	P3/10	P3/20 /500R	P3/10 /500R	lab /20	lab /10	lab/20 /500R	lab/10 /500R
1	Sieve analysis	% Passing on	20 mm	10 mm	20 mm	10 mm	20 mm	10 mm	20 mm	10 mm	20 mm	10 mm	20 mm	10 mm	20 mm	10 mm	20 mm	10 mm
		40mm	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
		20mm	93	100	98	100	98	100	100	100	100	96	100	100	97	100	100	100
		10mm	2	74	15	85	3	90	15	95	13	85	20	90	6	77	24	100
		4.75mm	1	6	9	6	0	20	3	20	1	15	4	18	1	6	0.63	15
		2.36mm	0	0	-	2	0	5	0	4	0	8	0	10	-	-	-	5
2	Total Deleterious material (%)		0.1	0.1	0.1	0.1	-	-	-	-	-	-	-	-	0.05	0.05	-	-
3	Specific Gravity		2.39	2.37	2.48	2.44	2.33	2.32	2.42	2.40	2.52	2.42	2.55	2.44	2.37	2.35	2.40	2.37
4	Water absorption %		4.58	4.75	3.87	3.93	5.10	5.40	4.10	4.30	3.70	3.73	3.30	3.40	4.41	4.43	4.16	4.28
5	Aggregate Abrasion value %		24.0	22.0	25.0	25.0	35.0	-	-	-	23.0	22.0	-	-	24	23	20	24
6	Aggregate Crushing Value %		25.0	26.0	27.0	23.0	29.0	-	-	-	24.0	27.0	-	-	22	22	25	26
7	Aggregate Impact Value %		20.0	17.0	20.0	20.0	25.0	-	-	-	24.0	22.0	-	-	23	21	23	20
8	Combined flakiness and Elongation Index %		15.8	20	18.8	18.2	17.0	-	-	-	-	-	-	-	21.3	29.6	19.6	23.3

Note -"-" not tested

Properties of RCA such as specific gravity and water absorption value have been significantly refined after treatment when compared with non-treated aggregates. Mechanically treated aggregates have higher specific gravity and lower water absorption value which indicate that there has been removal of the adhere mortar during the testing in Los Angeles abrasion machine after 500 revolutions. An improvement in water absorption value in the range of 4.0% to 20.0% and specific gravity value in the range of 0.80 to 0.40 % have been observed in mechanically treated aggregate in comparison to non-treated aggregates. In terms of mechanical properties such as aggregate abrasion value, crushing value and impact value, test results of the RCA are found within the limit of 30% of IS 383:2016, as desired for the production of concrete for wearing surface. The combined elongation and flakiness index value is found to be in the range of 15 to 24 % for RCA which is less than the prescribed limit of 40 % in IS 383:2016. In general, overall quality of RCA aggregate in terms of mechanical properties is equivalent to that of natural aggregate as defined in IS 383: 2016. Depending upon results obtained, the main influencing properties of RCA are specific gravity and water absorption. Therefore, RCA should be classified on the basis of these properties.

7.2 Design mix

The mix designs were carried out at two different water cement ratios i.e. 0.45 & 0.65 at 100 % replacement level by volume (Table-2). Two types of recycled concrete coarse aggregate, one set of aggregates sourced from Burari Plant (as received, 3 No's) and another set prepared in laboratory by crushing concrete cubes were used. The concrete mixes were prepared with PPC cement conforming to IS 1489 Part1 [23], recycled concrete coarse aggregates and natural fine aggregate (Zone III, conforming to IS 383). Chemical admixture conforming to IS 9103 [24], superplasticizer (naphthalene base) was added to achieve workability in terms of slump value in the range of 75-100 mm. The mixes were evaluated for fresh properties like workability, air content and bleed percentage and mechanical properties. Details of the specimen cast is given in **Table 3.**

Table-2: Details of concrete Mix Proportions

Sl. No	**Sample ID**	**w/c**	**Mix Constituents**		**Recycled Coarse Aggregate as % of total aggregate (by Volume)**	**Remarks**
			Cement content (kg/m^3)	Water Content (kg/m^3)	(%)	
1	B1	0.65	280	180	60	Sample 1, Burari Plant, New Delhi
2	B2	0.65	280	180	60	Sample 2, Burari Plant, New Delhi
3	B3	0.65	280	180	60	Sample 3, Burari Plant, New Delhi
4	Lab1	0.65	280	180	60	Lab sample
5	CM1	0.65	280	180	60	Control mix, natural coarse aggregate
6	B4	0.45	378	170	65	Sample 1, Burari Plant, New Delhi
7	B5	0.45	378	170	65	Sample 2, Burari Plant, New Delhi
8	B6	0.45	378	170	65	Sample 3, Burari Plant, New Delhi
9	Lab2	0.45	378	170	65	Lab sample
10	CM2	0.45	378	170	65	Control mix, natural coarse aggregate

Table -3: Details of casting

Sl. No.	**Testing parameter**	**Type of specimen**	**Dimension of the specimen**	**Age of the testing**	**Test method**
1	Compressive strength	Cube	150mm x150mm x150 mm	7 and 28 days	IS 516 Part1 / Sec1
2	Flexural strength	Beam	100mm x100mm x500mm	7 and 28 days	IS 516 Part1 / Sec1

After 24 hours of casting, the concrete specimens were demoulded and water cured till the age of testing.

7.3 Test results of Fresh and Mechanical properties of concrete

Fresh properties: Concrete mixes were evaluated for the fresh properties like workability, air content and bleed water percentage as per relevant Indian standard. All the concrete mixes were designed for a slump range of 75-100 mm and accordingly dosage of admixture was adjusted and recorded in Table 4. In present study, it was observed that the use of recycled concrete aggregate affects the consistency of concrete mix due to higher water absorption of recycled concrete aggregate, less favorable grain shape and texture in comparison to natural aggregate as reported by other researcher also [16,25}. Using pre wet aggregates is preferable. On the perusal of the test results, it can be observed that air content in the concrete mixes prepared from RCA is 5-20 % higher than that of corresponding control mix whereas the admixture requirement for the RCA based concrete was slightly higher in comparison to that of control. This slight increase in air content and enhanced demand in admixture dosage were noted in RCA aggregate based concrete i.e. RCA/P1 and RCA /P2 whereas fresh properties of concrete made with RCA i.e. RCA/P3 and RAC/lab was similar to that of control mixes. Bleed test was also conducted as per the procedure given in IS 9103 on the concrete samples made with and without RCA, no bleed water has been observed in all the concrete mixes. Overall, fresh properties of RCA based concrete is similar to that of control mixes when RCA used in pre wet condition during the mix design.

Table-4: Fresh properties – workability, air content and bleed water percentage

Sl. No	Sample ID	w/c	Admixture dosage	Air content	Slump	Bleed water
			(% by weight of cement)	(%)	(mm)	(%)
1	B1	0.65	0.80	2.30	90	Nil
2	B2	0.65	0.80	2.30	90	Nil
3	B3	0.65	0.70	2.20	85	Nil
4	Lab1	0.65	0.70	2.00	95	Nil
5	Control 1	0.65	0.70	1.80	95	Nil
6	B4	0.45	1.1	1.90	95	Nil
7	B5	0.45	1.1	2.30	90	Nil
8	B6	0.45	1.0	2.20	90	Nil
9	Lab2	0.45	1.0	2.00	100	Nil
10	Control 2	0.45	1.0	1.80	95	Nil

Mechanical properties: Mechanical properties of hardened concrete mixes were assessed in terms of compressive and flexural Strength tested at 7 and 28 days. Hardened properties of concrete made with recycled concrete aggregate gets influenced by the characteristics of recycled aggregates and it is feasible to obtain better , comparable or lower strength compared to the concrete made with natural aggregate [6]. In fact, it is possible to produce concrete using recycled concrete aggregate whose compressive strength is higher than the targeted compressive strength of new concrete provided that quality of RCA is at par with conventional aggregate. However, in most of studies so far available indicates that concrete made RCA usually shows reduced compressive strength owing to high water absorption and weak residual mortar layer which creates concrete microstructure fragile [26, 27, 28, 35, 37,38].

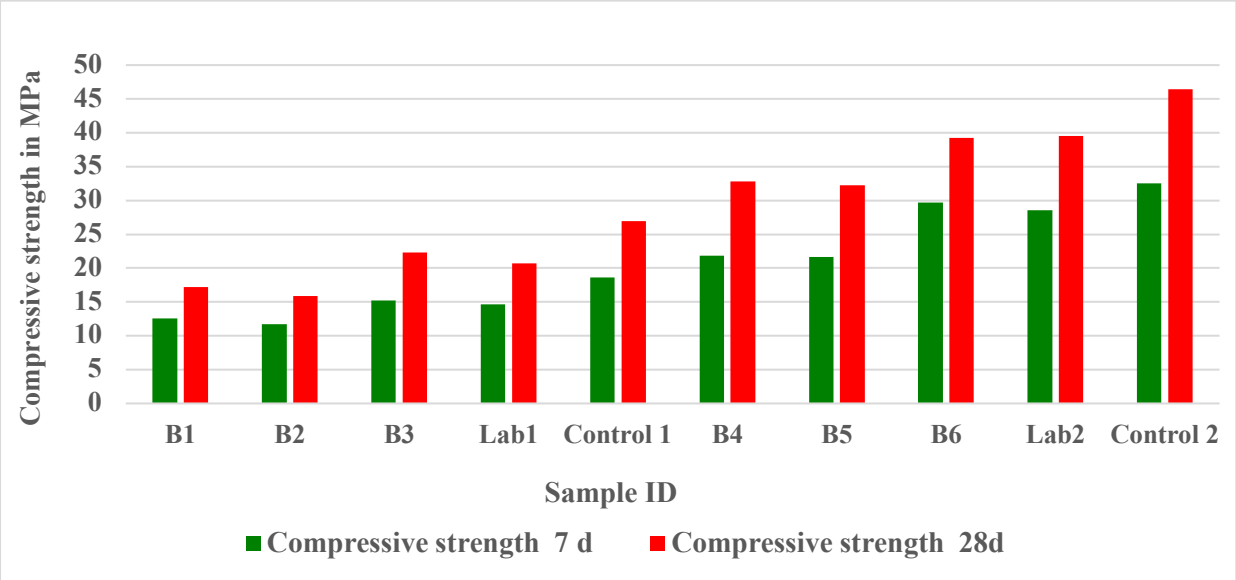

Fig-4: 7 and 28 days compressive strength of concrete

From figure 4 and 5, it is seen that concrete compressive and flexural strength prepared using recycled concrete aggregate has been reduced drastically in comparison to control mixes without RCA. The compressive strength of concrete made with RCA was found in the range of 10-40 % lower than that of control mix whereas in case of flexural strength, the reduction was found in the range of 10-30 % of control mix. These results are found in line with the available in the literature [17, 31, 39, 40, 41, 42, 43, 44).

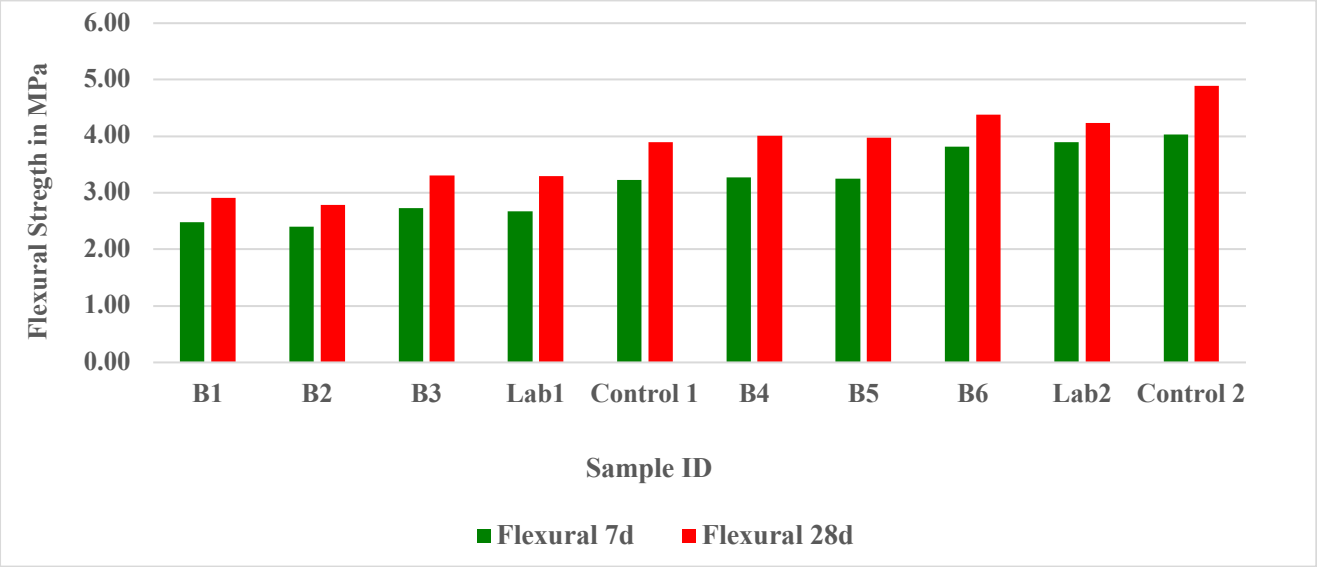

Fig-5: 7 and 28 days flexural strength of concrete

On further analysis of the test results, it has been observed that concrete made with RCA – B1 and B2, the reduction in strength characteristics is almost 30 % lower than that of control mixes whereas RCA- B3 based concrete and lab, the strength parameters i.e. compressive and flexural strength are 15 % lower than that of control mix. As already discussed above, it's the adhere mortar content that chiefly influences the strength characteristics. Therefore, these strength results indicate that mortar content in RCA – B1 and B2 is higher than that of RCA- B3 and lab i.e. strength in concrete mixes prepared with RCA – B1 and B2 is lower in comparison to concrete made with RCA- B3 and lab.

8. CONCLUSION

The management of Construction and Demolition (C&D) waste requires quantification of the C&D waste generated and concept like material passport of infrastructure project needs to be infused in urban local bodies. The monitoring of data through web based portal needs to be prioritized for effective tracking of C&D waste generation and consumption. Tax rebate and promotion of C&D waste based products by strengthening the codal provisions and government policies will act as catalyst in C&D waste utilisation.

To neutralize the variability effect in the quality of C&D waste based aggregate, there is necessity to have different classes of aggregate based upon their properties which can be based upon physical properties of aggregate like specific gravity and water absorption. The experimental result indicates that air content in the concrete mixes prepared from RCA is 5-20 % higher than that of corresponding control mix whereas the admixture requirement for the mixes prepared with RCA was found to be slightly higher in comparison to that of control.

The compressive strength of RCA based concrete was found in range of 10-40 % lower than control mix whereas in case of flexural strength, the reduction was found in the range of 10-30 % of control mix. This reduction in compressive strength and flexural strength is mainly due to formation of double interfacial transition zone (ITZ) which is responsible for reduced mechanical properties of C&D waste aggregate based concrete.

Mechanical treatment method involving 500 revolutions in LOS Angeles machine without any charge can be used as a technique for the quality improvement of the coarse recycled concrete aggregate. From the test results, it was observed that physical properties of the coarse recycled concrete aggregate such as specific gravity and water absorption improves significantly due to mechanical treatment. This is mainly due to removal of adhered mortar

Further scope of work: To investigate effect of different substitution level of classified recycled aggregate based concrete on fresh, hardened and durability performance in concrete and recommendations w.r.t to extent of utilization of these aggregates for structural and non-structural application need to be made. This work is under progress and in due time, results shall be made available in the public domain.

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