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Promoting the Reuse of C&D Wastes with Better Properties via Construction Made from Recycled Concrete Aggregates.

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Abstract: The demand of infrastructure has increased strikingly due to increasing populace and improved standard of living. Construction sector has witnessed record development due to change in its policies and India being a developing country is seeing ascent in the construction activities. The change is an unavoidable part for rapid urbanization and demolition and reconstruction are the basic necessities for redevelopment. Construction and Demolition (C&D) squanders become a crucial ecological difficulty because C&D squanders are non-biodegradable. In this paper an analytical study is engulfed which incorporates Recycled Concrete Aggregate (RCA) obtained from C&D squanders as a halfway replacement of fine aggregate in Self-Compacting Concrete (SCC) utilizing Two Stage Mixing Approach Method (TSMA) to acquire a concrete with durability properties better than Normal Mixing Approach (NMA). [1]–[4]

Keywords - Construction and Demolition; Recycled Concrete Aggregate; Self-Compacting Concrete; Two Stage Mixing Approach Method; Normal Mixing Approach.

INTRODUCTION

Natural resources are rapidly dwindling. One such resource is aggregate, which is rapidly depleting due to massive construction extraction. This industry uses a lot of natural resources every year. The overuse of natural resources is causing faster depletion of their sources, causing concern in the construction industry[5]. Extensive mining of gravel and sand threatens rivers, streams, and other natural resources. Reduce the amount of virgin aggregate mining to protect the natural ecosystem and resources.

Due to a sharp rise in construction activity around the world, a massive amount of Construction and Demolition (C&D)[6] waste was produced. A long series of environmental and social problems came into play due to C&D waste that was handled inadequately. A major way these C&D wastes are disposed of is through dumping[7]–[9]. Recycled Concrete Aggregate (RCA) can be made from recycled C&D waste, which helps to cut down on waste generation in that category. Reused aggregates are used to make recycled concrete aggregate (RCA). Even this makes a difference. Because of this, there is an increased likelihood of an environment-friendly concrete being developed. Work is currently being done on RCA worldwide, as the end product, concrete aggregate, has nearly identical properties to Virgin Concrete Aggregates (VCA)[10]. Recycled concrete appears to have structural value. Of the experimental results that have been evaluated, about half of them have proven to achieve the desired 2 strengths of RCA by using authentic mixing approaches alongside the inclusion of admixtures showing that SCC can also be produced using RCA.

CONSTRUCTION AND DEMOLITION (C&D) WASTES

United States (US), Environmental Protection Agency (EPA) defined C&D waste. As per EPA, waste materials comprising of the debris generated during the construction, renovation, and demolition of buildings, roads, and bridges is called as C&D waste.[11]

Building components such as concrete and mortar are commonly recovered from C&D waste. As we move towards a more sustainable development model, the generation and handling of C&D waste is unavoidable. Handling C&D waste should prioritise the 3R philosophy of Reduce, Reuse, and Recycle[12]. After World War II, Germany adopted the recycling concept. Concrete from demolished buildings was reused for construction. But many countries are unaware of the 3Rs' potential. So, they still find land filling to be the easiest option. Creating C&D waste is harmful to the environment, but it is unavoidable due to rapid urbanization. Redevelopment necessitates demolition and reconstruction.[8], [9]

Concrete makes up 30-40% of the world's construction waste. Generation C&D waste is a concern for developing and underdeveloped countries.[12]

NOTABLE ADVANTAGES OF RCA

1) Concrete wastes are not dumped in landfills, which helps to reduce the amount of landfill space used.
2) It will reduce the need for gravel mining if recycled material is used in place of coarse aggregate and fine aggregate in the construction industry.

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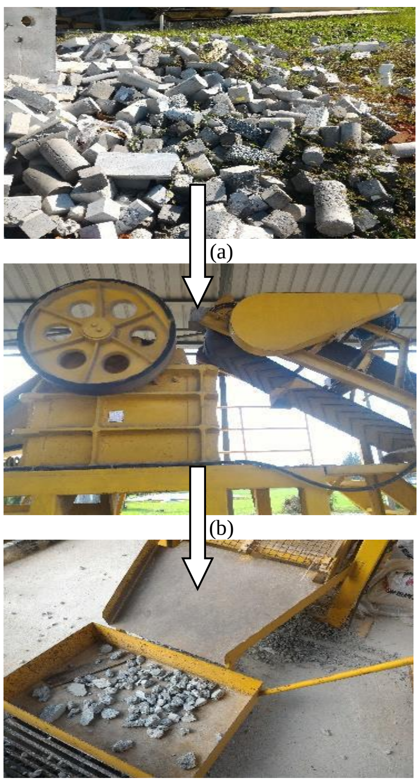
3) The recycling of cement can save approximately 1 ton of water and approximately 900 kg of CO2. [13]
4) If recycled concrete is used as the base material for roadways instead of virgin concrete, the amount of pollution is reduced.

A. Obtaining the RCA from C&D Wastes

The C&D wastes are mechanically crushed to make aggregates. Those small C&D waste particles are again crushed into smaller pieces using a jaw crusher. After crushing, RCA is filtered by sieve analysis.



(c)

Fig. 1 Process of Obtaining RCA; (a) C&D Wastes;(b) Jaw Crusher ; (c) Sieving[13]

RCA is typically mortared and permeable. Property of RCA depends on amount of adhering mortar on surface. RCA can be used as aggregate in concrete after attaining the attributes of grain size, bulk density, specific gravity, water absorption, crushing value, and impact value.[14]

B. Improving the attributes of RCA

The mortar on the surface of the RCA is porous, resulting in more water absorption capacity and lower density. Different two stage mixing procedures are used to improve the mechanical and durability attributes of RCA concrete. [15]

Self-compacting Recycled Aggregate Concrete (SCRCA) can be made without affecting the mechanical or durability attributes of standard concrete. SCRCA can make RCA more sustainable. SCC made with RCA has no set mix design procedure. The same mix design process used for SCC utilizing VCA, dubbed self-compacting virgin aggregate concrete (SCVAC), can be used for SCRCA.[16]

The traditional ITZ of RCA is improved by using different admixtures and modern mixing techniques - The SCC mix uses two mixing procedures, Normal Mixing Approach (NMA) and Two Stage Mixing Approach (TSMA), to achieve distinct RCA ratios.[1]

C. Mixing Approach

Normal Mixing Approach (NMA)

First, the fine and coarse aggregates (FA & CA) were combined for 30 seconds. Flame retardant additives (fly ash and cement) were applied. they were blended for thirty seconds again Finally, a super plasticizer (SP) and water mixture was added before mixing for the following 120 seconds.[1], [17]

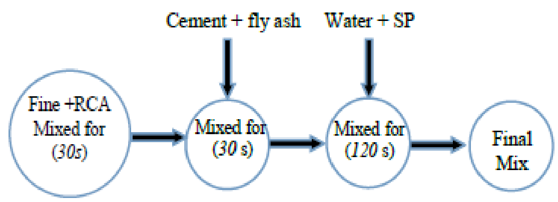


Fig. 2 Normal Mixing Approach (NMA)

Two Stage Mixing Approach (TSMA)

First, coarse and fine aggregates (CA & FA) were mixed for 60 seconds. Then 50/50 water and SP were added and stirred for 60 seconds. Then came fly ash and cement. 30 seconds of mixing followed. Finally, for the remaining 120 seconds of mixing, 50% water and 50% SP were added.[1], [17]

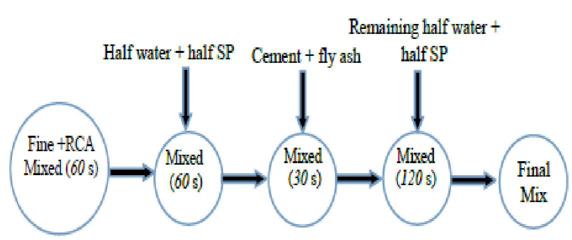


Fig. 3 Two Stage Mixing Approach (TSMA)

PREPARING THE SPECIMEN USING RCA

A. Materials Used and Its Properties

In SCC mixes, the cementitious materials used were 43-grade Portland cement, Silica Fume, and Class F Fly Ash. Cement with a specific gravity of 3.15 was utilized, in accordance with IS 8112 (1989). Tables I–III[1] detail the characteristics of cement, class F fly ash, and silica fume, respectively.

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The fine aggregate was sand, and the coarse aggregate was crushed stone (4.75 mm to 20 mm). The fine aggregate fineness modulus was 2.45 (IS 383 compliant) (1970). RCA from a 30-year-old building in Dhanbad, Jharkhand. Concrete was crushed to 5-20 mm and then manually screened to make RCA.
Table IV shows the physical and mechanical parameters of VCA, RCA and fine aggregates. [1]
All concrete mixtures used potable water. To improve SCC flowability, Super Plasticizer (SP) was commonly mixed with dry concrete. The study employed GLENIUM B233, a modified poly carboxylic ether admixture.[1]

TABLE I
Physical properties of cement.

Sl. No.	Characteristics	IS: 8112-1989 Specifications	Obtained Value	Author Reference
1	Normal consistency (%)	-	29	P. Rajhans et al., 2017[1]
2	Initial setting time (min)	30 (minimum)	75	
3	Final setting time (min)	600 (maximum)	217	
4	Fineness (%)	10	7	
5	Specific gravity	-	3.15	
6	Soundness (mm)	10 (maximum)	2.55	
7	Compressive strength (N/mm2) 3 days 7 days 28 days	 23 33 43	 25 35.59 45.48	

TABLE II
Physical properties of fly ash.

Sl. No.	Test Property	Obtained Value	Author Reference
1	Specific Gravity	2.15	P. Rajhans et al., 2017[1]
2	Fines passing 150 µ sieve (%)	99.3	
3	Fines passing 90 µ sieve (%).	96	
4	Blaine's fineness (cm^2/gm)	3894	

TABLE III
Physical properties of silica fumes.

Sl. No.	Test Property	Obtained Value	Author Reference
1	Specific Gravity	2.20	P. Rajhans et al., 2017[1]
2	Specific Surface Area	20,000 m^2/kg	
3	Particle Size.	0.1 mm	
4	Bulk Loose Density	232–300 kg/m^3	

TABLE IV
Physical properties of aggregates.

Sl. No.	Test Property	VCA	RCA	Fine Aggregates	Author Reference
1	Specific Gravity	2.66	2.60	2.68	P. Rajhans et al., 2017[1]
2	Water Absorption (%)	0.5	4.78	0.82	
3	Bulk density (kg/m^3)	1450	1250	1500	
4	Crushing value (%)	28	33	-	
5	Impact value (%)	23	28	-	

B. *Mix Proportion and Casting of Specimens*

The Nan Su approach was used to prepare the SCC mix design for M30 concrete. This study used one reference mix, SCVAC, which includes 100% VCA. The other four mixes were labelled SCRAC20, SCRAC40, SCRAC60, and SCRAC100, with RCA replacing natural aggregate at 20, 40, 60, and 100%. Table V - VI lists the mix proportions and standard test results of the mix.[18]
The specimens were casted using mixed proportioned concrete and examined for standard durability tests, as stated in Table VII.

TABLE V
Mix design for f_{ck} = 30MPa concrete by Nan Su method.

% RCA	Mix Designation	Cement (kg/m^3)	FA (kg/m^3)	Coarse Aggregates VA (kg/m^3)	Coarse Aggregates RCA (kg/m^3)	Fly ash (kg/m^3)	Water (kg/m^3)	SP (kg/m^3)	Author Reference
0	SCVAC	300	826	815	-	160	194	4.6	P. Rajhans et al., 2017 [1]
20	SCRAC-20	300	826	640	147	160	194	4.6	
40	SCRAC-40	300	826	480	294	160	194	4.6	
60	SCRAC-60	300	826	320	442	160	194	4.6	
100	SCRAC-100	300	826	-	337	160	200	4.6	

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TABLE VI
Fresh Properties of SCC having f_{ck} = 30MPa

Mixing Methods	% Of Replacements	Mix Designation	T_{50}, (sec)	Slump flow (mm)	J-ring (mm)	V- funnel time (s)	Author Reference
NMA	0	SCVAC	3	755	7.5	7.6	P. Rajhans et al., 2017[1]
	20	SCRAC-20	3	730	8.4	7.9	
	40	SCRAC-40	4	725	8.6	8.4	
	60	SCRAC-60	5	700	9.1	8.5	
	100	SCRAC-100	5	680	9.3	10.6	
TSMA	0	SCVAC	3	760	7.5	7.3	
	20	SCRAC-20	4	740	8	7.5	
	40	SCRAC-40	4	729	8.4	8.2	
	60	SCRAC-60	5	709	8.8	8.4	
	100	SCRAC-100	5	685	9.2	9.6	

TABLE VII
Properties of casted specimen with SCC for f_{ck} =30 MPa

Mixing Methods	% RCA	Mix Designation	Compressive Strength (N/mm2)			Flexural Strength (N/mm2)			Splitting Tensile Strength (N/mm²)			Author Reference
Days Curing			7	14	28	7	14	28	7	14	28	
NMA	0	VASCC	23.5	25.9	36.4	3.25	4.23	4.6	2.55	2.78	3	P. Rajhans et al., 2017[1]
	20	SCRAC-20	22.9	24.1	35.2	3	4	4.5	2.38	2.59	2.74	
	40	SCRAC-40	21	23.9	34.7	2.63	3.45	4.08	2.08	2.29	2.4	
	60	SCRAC-60	20	22.9	32.6	2	3.34	3.43	1.68	1.86	2.05	
	100	SCRAC-100	19.5	21	30.1	1.87	3	3	1.42	1.67	2	
TSMA	0	VASCC	24.1	26	38.3	3.67	4.53	4.71	2.7	3	3.09	
	20	SCRAC-20	23	25	37.1	3.18	4.24	4.53	2.46	2.69	3.04	
	40	SCRAC-40	22	24.8	36	2.78	4	4.33	2.14	2.44	2.64	
	60	SCRAC-60	21.5	23.8	35.2	2.42	3.48	4	2	2.18	2.35	
	100	SCRAC-100	20	22.1	34	2	3.23	3.48	1.57	2.02	2.3	

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FINITE ELEMENT METHOD ANALYSIS ON THE CASTED SPECIMENS

ANSYS Workbench is a popular engineering simulation tool. It uses finite element analysis (FEM). ANSYS workbench can tackle problems ranging from linear analysis to nonlinear simulations, among others. It works from geometry preparation through optimization and all intermediate processes. Geometry, Modelling, Meshing, Load Application, Analysis and Post-Processing can all be done on a single platform.[19]

In this study, maximum mid span deflection of RCA Beams casted is estimated analytically using ANSYS WORKBENCH.

TABLE VIII
ANSYS Parameters.

Sl. No.	Parameters	Description
1	Beam Size	(500*100*100) mm
2	Supports	Simply Supported
3	Concentrated Center Loading Applied on each Beam	Calculated using Flexure Formula ($F = \frac{PL^3}{bd^2}$)
4	Meshing Size	10 mm
5	Static Modulus of Elasticity (EI)	31000 N/mm^2

TABLE IX
Loading and Mid Span Deflection Comparison of Specimens.

Mixing Methods	% RCA	Mix Designation	Center Point Load (N)			Actual mid span deflection (mm)			Theoretical mid span deflection (mm)		
Days Curing			7	14	28	7	14	28	7	14	28
NMA	0	VASCC	8125	10575	11500	0.043	0.055	0.06	0.042	0.054	0.058
	20	SCRAC-20	7500	1000	11250	0.04	0.053	0.059	0.039	0.052	0.057
	40	SCRAC-40	6575	8625	10200	0.036	0.046	0.054	0.034	0.045	0.053
	60	SCRAC-60	5000	8350	8575	0.027	0.045	0.046	0.026	0.044	0.044
	100	SCRAC-100	4675	7500	7500	0.026	0.041	0.041	0.025	0.04	0.039
TSMA	0	VASCC	9175	11325	11775	0.049	0.059	0.059	0.048	0.057	0.057
	20	SCRAC-20	7950	10600	11325	0.043	0.055	0.059	0.041	0.054	0.057
	40	SCRAC-40	6950	10000	10825	0.037	0.053	0.057	0.036	0.051	0.055
	60	SCRAC-60	6050	8700	10000	0.033	0.047	0.054	0.032	0.045	0.052
	100	SCRAC-100	5000	8075	8700	0.027	0.044	0.047	0.026	0.042	0.045

Conclusion

The RCA made from TSMA outperforms the NMA. After 28 days, TSMA had 12.96% higher compressive,16% split tensile, and 15.96% flexural strength than NMA with 100% RCA. Beams cast using TSMA have stronger flexural strength than NMA beams, and consequently higher load carrying capacity. That is, TSMA deflection exceeds NMA. Beams cast using TSMA have stronger flexural strength than NMA beams, and consequently higher load carrying capacity.

According to the plot of load vs deflection, NMA concrete with 100% RCA has lower maximum deflection than 0% RCA concrete. TSMA's load carrying capacity exceeds NMA's. Increasing the percentage of RCA causes the maximum deflection to decrease. Increasing the percentage of RCA will decrease the maximum shear stress. Deflection is around 3.38% greater than what is theoretically possible.

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