International Journal of Engineering Research ISSN:2319-6890)(online),2347-5013(print)
Volume No.3, Issue No.6, pp : 369-373 01 June 2014

Compression Dispersion Efficiency of Recycled Aggregate Concrete Struts At Different Load Concentration Ratios

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ABSTRACT: Infrastructure development activities in India have increased many folds in recent times. This has resulted in increase in the demand of construction materials like cement, coarse aggregate, fine aggregate etc. Huge quantities of concrete wastes are produced due to demolition of old structures. If recycled aggregate from this waste is used for construction purpose, it will not only make the structures economical and eco-friendly butwill also solve the problem of waste disposal.Recycling old waste concrete by crushing and grading into coarse aggregates for use in new structural concrete is drawing the attention of engineers, environmentalists and researchers since last three decades. In this paper, an attempt has been made to study the compression dispersion behaviour of struts of natural coarse aggregate (NCA) and recycle coarse aggregate (RCA) at different load concentration ratio and aspect ratio. For the study, struts of 450 mm height and 75mm thickness with varying widths starting from 75mm to 450mm, using NCA and RCA concrete, were cast. The testing of struts was carriedout on loading frame of capacity 500 kN. The struts were tested to failure under in-plane compressive load applied through symmetrically placed steel plate (75×75×10) mm at top andbottom of the struts.

Keywords: Recycle coarse aggregate, Natural coarse aggregate, Struts, Compression Dispersion, Load concentration ratio, Aspect ratio.

INTRODUCTION

Concrete is the most widely used construction material among all the construction materials.Now a days, the infrastructural growth has increased many folds, world wide. The growing environmental concerns, increasing scarcity of landfills, rapidly depleting sources of quality (virgin) aggregate in some regions coupled with the increasing haulage and growing landfill costs are promoting the recycling of concrete demolition waste in new concrete. With increasing cost of construction materials and labour charges, it is in the best interest of everyone that effective use of recycled materials bepracticed. The construction of new structures as well as demolition of older ones is taking place simultaneously, generating huge amount of debris along with utilization of large amount of precious natural resources. Recycling of debris serves dual purpose on one hand it solve disposal problem, while on the other hand it reduces the load on natural resources thereby protecting the environment. Sustainableconstruction using recycled material has its own advantages. The crushing of demolished concrete to produce aggregate for the production of new concrete is one of the means for achieving a more economic and environment-friendly concrete. Since aggregates constitute approximately 70% of concrete volume, the utilization of waste concrete as recycled aggregate can yield significant environmental impact. The main hindrance in the use of recycled aggregateis its higher water absorption (two to three times of normal aggregate), and the increased shrinkage of the recycled aggregate concrete. These drawbacks are due to the old mortar/cement paste clinging to the surface of recycled aggregates as shown schematically in Fig. 1.The old Inter-transition zone and new Inter-transition zone is shown in the same figure. According to Hansen and Narud [1], the volume percentage of the old mortar attached to the surface of aggregate varies between 25% and 35% whenconcrete is made using RCA reduced to 16–32 mm particle size; however, it is about 40% in case of recycled aggregate with 8–16 mm particle size, and is nearby 60% when recycled aggregate is of 4–8 mm particle size. Hasaba et al. [2] have reported that 35.5% of old mortar is attached to natural gravel of recycled aggregate with 5–25 mm particle size produced from concrete having 24 MPa compressive strength. It is also reported that for the same size of recycled aggregate, the attached mortar fraction increased to 36.7% and 38.4% when the recycled aggregate was produced by crushing concretes having compressive strengths of 41 MPa and 51 MPa, respectively. Approximately, 20% of cement paste is attached to the recycled aggregate with 20–30 mm particle size[3]. Nixon [4] has reported that the most significant difference between recycled aggregate and natural (virgin) aggregate is the markedly higher water absorption of the recycled aggregate. Tavakoli and Soroushian [5] found that the water absorption capacity of recycled aggregate reflects the amount of cement paste adhering to the surface of the aggregate particles.

The workability of RCA concrete is relatively less and to overcome this, it is common to add more water there bycompromisingthe strength, or add super plasticizer which adds to the cost of concrete. There aresomeadverse effectsalso in RCA concrete properties, like drying shrinkage, elastic modulus etc., which raise questions aboutthe use of RCA as an efficient substitute for natural coarse aggregate. Choi et al [6] have reported that the shear strength of RCA concrete beams is less than that of the beams made using NCA.

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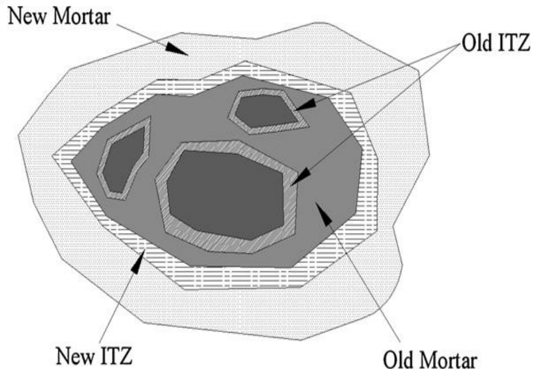

Fig. 1. Recycled aggregate within new mortar.

Varghese and Sahoo [7]have reported that the compression dispersion behaviour is a complex and not fully understood behaviour of concrete struts, which depends inter alia on the interplay of compressive and split tensile strengths of concrete, and considering the fact that RCA concrete and NCA concrete are two different types of concrete in terms of their major constituents, i.e., coarse aggregate. Varghese and Sahoo[8] have studied the compression dispersion efficiency of thin concrete panels made using RCA and NCA. The concretepanels of 300 mm height, 50 mm thickness, and 50, 75, 100, 150, 200 & 300mmwidthwere studied. Theyreported that: (i)the compression dispersion of RCA concrete struts, measured in strut efficiency factor, is comparable with the NCA concrete struts;(ii)the strut efficiency factor of RCAconcrete reaches its peak value for a panel aspect ratio of 2, while in case of NCA concreteit reaches at aspect ratio of 3; (iii) the highest strut efficiency was obtained for concentration ratio in the vicinity of 0.5.Tocheck the results of the previous study, the same authors [7] experimented on large size RCA and NCA concrete panels of height 600 mm, thickness 100 mm and having varying widths of 100, 200, 300, 400 & 600 mm. They have reported that the highest strut efficiency was noticed for a concentration ratio of 0.33 for both NCA as well as RCA concrete. The strut efficiency factor was found at aspect ratio of 2 for both concretetypes.It is thus clear from the studies that thebehaviour ofstrut changes as the height and thickness changes.

Therefore, in the present study, the rectangular concrete panels of 75 mm thickness and 450 mm height were cast with the variable widths of 75, 150, 225, 300, 375 and 450 mm using NCA and RCA concrete. M_{25} grade of concrete was used as referral concrete. The panels were tested to failure under in-plane compressive load applied through symmetrically placed steel Bearing Plates. The panels were tested on loading frame of capacity 500 kN till failure. The loads were applied on the specimen as per IS: 516-1981 [9], through symmetrically placed steel Bearing Plates of size 75×75×10 mm, in order to closely observe the cracking pattern as shown in Fig 2.

MATERIALS AND MIX PROPORTIONING

The Ordinary Portland Cement of 43 grade of JAYPEE Brand confirming to IS:8112-1989 [10] was used. The physical properties of the OPC as found in the laboratory are given inTable 1.The coarse aggregate (NCA) was procured from local quarry having two different sizes: one passing through 20 mm sieve and another section was passing through 10 mm sieve. The specific gravity of 20 mm and 10 mm coarse aggregate was 2.56 &2.63 respectively. Both the aggregates were mixed in the ratio of 1:1 to get well graded aggregate.The specific gravity and fineness modulus of fine aggregate were 2.64 and2.0 respectively. The fine aggregate lies in zone III, as perIS: 383-1997 [11]. The specific gravity of RCA was 2.57 and fineness modulus was determined to be 7.22. The crushing value and impact value of the natural aggregates were 16.63% and 20.9% respectively. Water absorption of NCA and RCA was 0.6% and 1.9% respectively. The results of sieve analysis of NCA, RCA, and fine aggregate are given in Table 2. Concrete mix of M_{25} grade as per IS: 456-2000 [12] was used in this investigation. The mix was designed as per SP: 23-1982 [13] and IS: 10262-1982 [14]. The resulting mix proportion (by weight) of cement: fine aggregate: coarse aggregate was 1:1.33:2.89 with water cement ratio of 0.44. The cement content was 418 kg/m^3. Super plasticizer SUPERPLAST-HS was added in RCA concrete to maintain the same workability. The concrete was prepared by hand mixing during which first, second and third layer consist of coarse aggregate, fine aggregate, and cement respectively. Trowel was used for mixingand preparing the specimens, as given in Table 3. Specimens were cast of NCA and RCA concrete mixes. The specimens were demoulded after 24 hours and were cured in tap-water. These were tested on loading frame after curing period of 28 days.

Table 1: Physical Properties of Cement

S.No.	Properties of cement	Experimental values	Codal Provision (IS:8112-1989) [10]
1.	Normal consistency	30%	----
2.	Initial setting time(minutes)	65	>30
3.	Final setting time(minutes)	255	<600
4.	Soundness of cement (Lechatelier expansion)(mm)	2	<10
5.	Specific gravity of cement	3.14	3.15
6.	Fineness of cement (% retained on IS 90µm sieve)	4	<10
7.	Compressive strength of cement 3 days 7 days 28 days	 24.48N/mm^2 35.16 N/mm^2 44.56 N/mm^2	 >23 N/mm^2 >33 N/mm^2 >43 N/mm^2

EXPERIMENTAL PROGRAMME

Panels of 75 mm thickness and 450 mm height were cast. The variables were panel width (75 - 450 mm) and the type of coarse aggregate (NCA/RCA). For each type of concrete, panels were cast with six different widths 75, 150, 225, 300, 375, 450 mm, representing height-to-width or aspect ratio (AR) of 6, 3, 2, 1.5, 1.2, and 1 respectively. The size of loading and supporting plate was 75×75×10 mm, representing load concentration ratios (CR) of 1, 0.50, 0.33, 0.25, 0.20, and 0.17 respectively. The load concentration ratio is taken as the ratio of the loaded area and the cross sectional area of strut. Referral cubes of size 150 mm and

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struts were cast, cured and tested along with the panels to assess the compressive strength of concrete. Cubes were tested on Universal Testing Machine. Specimen details aspect ratio, concentration ratio, ultimate failure load for NCA and ultimate failure load of RCA are given in Table.3.

RESULTS AND DISCUSSIONS

The average compressive strength of concrete cubes with NCA and RCA at 28 days was 35.16 N/mm^2 and 27.30 N/mm^{2}respectively. The cylinder strengths were assumed as 80% of the corresponding cube strengths. The strength of a strut in resisting compressive load can be expressed according to the formula given in Appendix-A of ACI 318-08 [15], as under

$F_{ns}=0.85\times\beta_s\times f'_c\times A_{cs}$..............................(1)

Where,F_{ns} in the nominal strength of the strut,$\beta_s$is the strut efficiency factor,$f'_c$is the specified concrete cylinder compressive strength and $A_{cs}$is the lesser of the loaded areas at the end of the struts. It is to be noted that the strut efficiency factor, β_s is the coefficient which takes into account all material and geometrical factors,uncertainties and unknown factors that influence the dispersion behavior of a strut.

The efficiency factors, β_s recommended in the concrete codes and the strut-and-tie literature have been devised for natural aggregate concrete. The same $\beta_s$can be used for RCA concrete also, if it is used in significant amount for structural purpose [8]. The efficiency of dispersion has been evaluated in terms of strut efficiency factor β_s, which is a function of the ultimate load resisted by a strut, the cylinder compressive strength of concrete and the loaded area.Now,F_{ns} is replaced with ultimate loads resisted by the strut P_u, conservatively ignoring the codal safety factor 0.85, the factor which is supposed to account for the long-term effect of loading, and then rearranging the terms in Eq.(1), β_s can be expressed as follows.

$\beta_s=P_U/(f'_c X A_{cs})$ ....(2)

A prismatic strut will form in the 75mm wide panels as the top and bottom loaded areas of the panel, and the areas of the bearing plates are equal.$\beta_s$for 450×75×75 mm NCA concrete strut is calculated below using Eq. (2).

The peak obtained in the study of Varghese and Sahoo [7]was at the concentration of 0.5 for RCA concrete and at 0.33 for NCA concrete struts. In another study of same authors [8], the higheststrut efficiency was noticed for the concentration ratio of 0.33 for both NCA and RCA, However, in the present study, it is found at the load concentration of 0.2 for both the concretes. Thus, it is clear that the aspect ratio is not a deciding factor for strut efficiency.However, further investigation is required to study this aspect in detail.

Dispersion Efficiencyβ_s

Panel width, mm

$\beta_s = \{122\times10^3/(0.85\times0.8\times35.16\times75\times75)\}= 0.91$ he strut efficiency factors for all the panels have been evaluated according to Eq. (2) and given inTable 3.

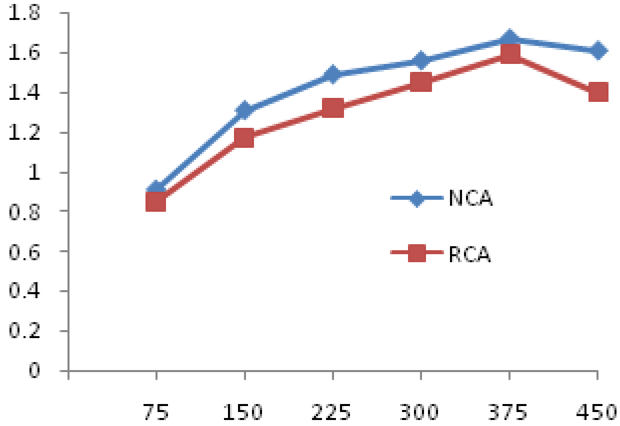
The graphical presentation of strut efficiency factor of NCA and RCA concrete struts is included in Fig 3. It is evident from Fig 3that dispersion efficiency factor is maximum for the aspect ratio 1.2, and is obtained at load concentration ratio of 0.2 for both the concretes.Also,the compression dispersion efficiency of RCA was approximately same as that of NCA. However, the decreasing trend in strut efficiency with increase in panel width starts beyond 375 mm (AR = 1.2).Therefore, aspect ratio and load concentration ratio is clearly an important influencing factor in strut efficiency. The results regarding the peak efficiency factors are different than the earlier studies.

(A) **(B)**

(C) **(D)**

Fig.2.Failure pattern of some NCA and RCA concrete strut

Fig3. Comparison of the efficiency factors of NCA and RCA concrete struts of different panel widths



CONCLUSIONS

The following conclusions can be obtained from this study:

1. Highest strut efficiency is obtained at a load concentration ratio of 0.2 for both NCA and RCA Concrete.
2. The compression dispersion efficiency RCA concrete is almost same as the compression dispersion efficiency of the NCA concrete.
3. Aspect Ratio is important factor for determining dispersion efficiency.
4. The strut efficiency factor shows increasing trend and reaches its peak value as the panel width increases to five times of panel height (AR=1.2 CR=0.20), and thereafter a decrease in observed.

REFERENCES

i. *Hansen, T.C. andNarud, H.,"Strength of Recycled Concrete made from Crushed Concrete Coarse aggregate," ConcreteInternational 1983; 5(compendex) pp-79–83.*

ii. *Hasaba S, Kawamura M, Toriik K, "Drying Shrinkage and Durability of Concrete made of Recycled Concrete Aggregates,"JpnConcreteInstitute 1981; 3:55–60.*

iii. *BCSJ.,"Study on Recycled Aggregate and Recycled Aggregate Concrete," Concrete J, Jpn 1978; 16(7):18–31.*

iv. *Nixon P., "Recycled Concrete as an Aggregate for Concrete—a Review," Mater Structure 1978; 11(5):371–78.*

v. *Tavakoli M, Soroushian P., "Drying Shrinkage behavior of Recycled Aggregate Concrete, "Concrete International 1996; 18(Compendex):58–61.*

vi. *Choi, H.B, Yi, C.K , Cho, H.H and kang, K.I, "Experimental Study on the Shear Strength of Recycle Aggregates Concrete Beams,"Magazine of Concrete Research, 62(2) , 2010, pp 103-114.*

vii. *Varghese, B.P. and Sahoo, D.K., "Compression Dispersion behavior of Recycled and Natural Coarse Aggregate Concrete: A Comparative Study," Recent Advances in Mechanics and Materials (RAMM-2012), 25-26 February 2012, VSS University of Technology, Burla: 221-228.*

viii. *Varghese, B.P. and Sahoo, D.K., "Studies on the Compression Dispersion Efficiency of Recycled and Natural Coarse Aggregate Concrete Struts," Proceeding of Innovative Challenges in Civil Engineering P.T.U. GianiZail Singh Campus, Bathinda , 15-16 March 2012, p.p.68-72.*

ix. *IS: 516-1981, "Method of Test for Strength of Concrete," Bureau of Indian Standard, New Delhi.*

x. *IS: 8112-1989, "Specification for 43 grade Ordinary Portland Cement," Bureau of Indian Standard, New Delhi.*

xi. *IS: 383 -1970, "Specification for Coarse and Fine Aggregate from Natural Sources of Concrete," Bureau of Indian Standard, New Delhi.*

xii. *IS: 456 -2000, "Code of Practice for Plain and Reinforced Concrete,"Bureau of Indian Standard, New Delhi.*

xiii. *SP: 23–1982, "Hand Book of Concrete Mixes,"Bureau of Indian Standard, New Delhi.*

xiv. *IS: 10262-1982, "Recommended Guidelines for Concrete Mixed Design," Bureau of Indian Standard, New Delhi.*

xv. *ACI Committee 318. "Building Code Requirement for Structural Concrete (ACI 318-08) and Commentary (318R-08)," American Concrete Institute, Farmington Hills, Mich, (2008).*

Table 2: Sieve Analysis of Aggregates

	% Retained	Cumulative % retained	% Retained	Cumulative % retained	% Retained	Cumulative % retained
80 mm	0	0	0	0	--	--
40 mm	0	0	0	0	--	--
20 mm	11.11	11.11	22.22	22.22	0	0
10 mm	55.03	66.14	77.17	99.38	0	0
4.75 mm	31.51	97.65	0.62	100	1.88	1.88
2.36 mm	1.2	98.85	100	100	4.13	5.31
1.18 mm	1.06	99.91	100	100	9.33	14.64
600micron	0.09	100	100	100	8.67	23.31
300micron	0	100	100	100	33.33	56.64
150micron	0	100	100	100	41.33	98.17
<150micron	--	--	--		---	---
Total		∑=673.66		∑=721.60		∑=199.95
Fineness Modulus		6.74		7.22		2.00

Table 3.Specimen Details and test results of panels with NCA and RCA concrete

Dimensions	Thickness (mm)	Height (mm)	Width (mm)	Aspect Ratio (AR)	Concentration Ratio (CR)	Ultimate Failure Load (kN)		*Dispersion Efficiency (β)*	
						NCA	RCA	NCA	RCA
Type 1	75	450	75	6	1	122	90	0.91	0.85
Type 2	75	450	150	3	1/2	176	124	1.31	1,17
Type 3	75	450	225	2	1/3	200	140	1.49	1.32
Type 4	75	450	300	1.5	1/4	210	156	1.56	1.45
Type 5	75	450	375	1.2	1/5	224	168	1.67	1.59
Type 6	75	450	450	1	1/6	216	148	1.61	1.40