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Influence of Recycled Aggregate on Strength Properties and Elastic Modulus of Concrete

K. Usha Nandhini, S. Jayakumar, S.Kothandaraman

***Abstract*— In this Industrial world, recycling construction material plays an important role to conserve the natural resources, to reduce the consumption of energy and space required for land fill disposal. As widely proved by significant researches that recycle aggregate are reliable alternate as aggregate in production of concrete. This paper investigates the influence of recycled concrete aggregate obtained from a demolished RC beam. To analyses the behavior of strength and elastic property of concrete with RCA replacement of 0%, 30%, 60% & 100% with NA of M20 and M40 grade concrete. The properties namely compressive, split tensile and flexural strength, young's modulus, water absorption are studied. From the experimental results it is observed that the increase in strength of RCA is more during early age of 7days compared to later ages. Compressive, flexural and split tensile strength of concrete with 60% RAC replacement attain maximum strength than conventional concrete of M20 & M40. The Elastic modulus obtains 10% higher in replacement up to 60% of RAC.**

***Index Terms*— Conventional concrete (CC), Construction & waste(CW), Coarse Aggregate(CA), Construction and demolition waste(C&D), Fine Aggregate(FA), Interfacial transition zone (ITZ), Natural aggregate concrete (NAC), Technology, Information, Forecasting and Assessment Council (TIFAC), Recycled aggregate concrete (RAC), Recycled Concrete (RC), Recycle Aggregate(RA)**

I. INTRODUCTION

Utilization of C&D waste is quite common in construction industries. Construction industry is largest economic expenditure in India. According to eleven five year plan, construction industry is the second largest economic activity. As per (CPHEEO) central public health & environment engineering, the construction industry facing shortage of 55000million cubic meter. Aggregate. In addition, 750million cubic meter of aggregate would be required to achieve the target of road construction sector, which will lead to pressure to natural resources. Construction industry consumed high volume of raw materials and its impact caused to the Environment in very large. (CPHEEO Solid Waste Technical advisory, 2015)

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K. Usha Nandhini, Research Scholar of Civil Engineering Department, Pondicherry Engineering College, Pondicherry, India

S. Jayakumar, Professor of Civil Engineering Department, SMV College of Engineering, Pondicherry, India

S.Kothandaraman, Professor of Civil Engineering Department, Pondicherry Engineering College, Pondicherry, India

According to studies done by Technology information forecast assessment council (TIFAC, 2000) the total construction work in

Country 5 year plan during 2006-2011 has estimated $847 billion. The total quantity of C&D waste generated in India is estimated to 11.4 to 14.69 million tons per annum, out of which 7 – 8 million are construction and brick waste. [Job Thomas, Wilson P.M (2013)].

In construction industry the material cost is nearly 40-60% of project cost. This cost saving potential for India is expected by adopting measure for C&D waste. [Job Thomas, Wilson P.M (2013)].

1.1 C&D WASTE GLOBAL PRACTICE

Utilization of C&D waste in global practice, India the built up area expected to be 21 billion square feet in 2005 to 104 billion square feet by 2030. Globally, cities generate about 1.3 billion Tons of solid waste per year and this is expected to be 2.2 billion tons by 2025, says a 2012 report by World Bank. As per ministry of environmental and forest (MOEF) 2008 estimate 0.53 million tons per day of waste generated in country. Central pollution control board has estimated current quantum of social waste generation in India to tune of 48million per annum and out of which construction industry only accounts for more than 25%. Hong Kong has serious land constraints and has very stringent controls like impose waste charges over C&D waste. It also reduced needing disposal at landfills by 60%. Singapore yet another land constraint counts recycle 98% of its C&D waste. South Korea, adopt separate building codes and recommend increase of use of recycle C&D material. The effective recycling rate in Korea is 36% with target of increase 45% by 2016. European Union has clear rules & EU2004 regulation for aggregate from natural, recycled and manufactured material. The European member countries reported 20% of national consumption is from recycle material. In United Kingdom, Northern Ireland has set agency for production of aggregate from waste and achieved 28% of C&D waste reused every year. US, New York has stringent measure like forces developers to segregate waste at site, dismantle and not demolish. In 2010 ministry of environmental and forest (MOEF) shows Scotland have recycled about 63% in 2000. Denmark and Nether land has 80% of C&D waste. In Japan 95% of waste concrete reused. [C&D waste India, 2014].

In practice the recycled aggregate are obtained from different types of demolished structures. The properties of recycled aggregate vary from structure to structure and consequently the properties of recycled aggregate concrete. Hence, in the present work there is a need to study the mechanical properties of recycled aggregate concrete such as compressive strength, split tensile strength, flexural strength and Young's modulus.

II. RECYCLED AGGREGATE CONCRETE

The compressive and split tensile strength and pore structure of two different sources of recycled aggregate replaced with 100% RA were studied. Result show that after 5 years of long term curing split tensile strength of NAC is has increased by 37% between 28days and RAC had highest gain of 65%. This is due to the RAC improved the microstructure of the interfacial transition zone (ITZ) and increased bond strength between the new cement paste and the old aggregate after continuous hydration, self-cementing ability of RA. The compressive strength at 28days was reduced by 21.7%, however after 5 years decreased to 6.3%. The pore structure shows that 44.9% reduction in RAC and 28.9% in NAC. [Shi, Chi and Miren Etxeberria (2011)].

The research of RAC on site tested concrete specimen states that RAC has higher water absorption and moisture content and this is due to cement paste adhered to RA is high in porosity. The compressive strength with 100% RAC has highest 3 days and 28Days strength. Saturated surface dry (SSD) aggregate shows higher compressive strength at 28days but lower compressive strength during later stage at 56 days. The split tensile strength with 50% of RAC is same with split tensile strength of control concrete. For 100% RAC and 100% SSD RAC have high split tensile strength than control concrete. It also recommended to saturate the RAC to saturated surface dry condition before casting. The flexural strength of RAC is lower compared to control concrete. This is due to the RAC tend to deform more due to lower Modulus compared to natural aggregate.[Yong P.C, and Teo, D.C.L (2009)]

RAC obtained from demolished RCC culvert 15years old are studied found that with lower values of micro hardness Interfacial transition zone (ITZ) indicate the higher percentage of porosity. The porous interfacial transition zone in RAC may be attribute to the higher absorption capacity of Recycled aggregate. Density and water absorption are directly related to the quantity of adhered mortar and this affect the water demand and reduce the workability. The strength properties depends on quality of RA. Lower density is the advantage for light weight construction with decrease in the self-weight of the structure. Recycled aggregate with 100% replacement have attained early strength than normal aggregate and this is due to the high absorption capacity of RA and rough texture of RA provide improved bonding and interlocking characteristic between mortar and RA. Compressive strength of air dried RA had better strength than SSD recycled aggregate due to improvement of old ITZ and new ITZ of cement paste that has lower w/c ratio. Split tensile strength decreases with increase in RA content and failure is due to old ITZ. Flexural strength observed that RAC and NA not much difference in strength. The reduction in modulus of elasticity for 100% replacement is up to 34.8%, [M. Chakradhara Rao, S.K Bhattacharyya, S.V Barai(2011)]

Concrete mixture R50 and R100 requires about additional 10% and 20% more total water quantity than NA. Compressive strength increase up to 25% for R100 and this shows the RAC obtained from quality concrete with good mechanical properties than on quantity of RA. The modulus of elasticity of R100 is lower than the modulus of elasticity of control concrete R0 by about 18%. RC beam shows 4% and 10% deflection for R50 and R100 and this is due to the lower modulus of RAC. [Mirjana Malesev , Vlastimir Radonjanin and Snezana Marinkovic]

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III. EXPERIMENTAL PROGRAM

3.1 Materials

Ordinary Portland cement (OPC) 43 grade conforming to IS: 8112 (1989) was used for research work. Physical properties of cement with specific gravity 3.14 and specific surface area 250 square meter per kg is used. The compressive strength of cement motor at 3 days, 7 days and 28days are 28.0 Mpa, 36.9Mpa and 46.0 Mpa.

The natural coarse aggregate obtained locally were tested in accordance with IS: 2386(1963) for gradation and other physical properties. The locally available natural sand conforming to grading Zone II (IS: 383) is used in both normal and recycled aggregate concrete.

3.1.1 Source of Recycled aggregates

The recycled coarse aggregate obtained from the demolished RC beam specimen in Department of Civil Engineering, Pondicherry Engineering College. Using Jaw crusher the RC beam were broken into smaller pieces and sieved through 4.75mm and 20mm sieve sizes. The physical properties of Aggregates are shown in Table 3.1.

Table 3.1 Physical properties of Aggregates

Property	Test Results		
	NA	RCA	FA
Water absorption (%)	0.80	3.8	0.12
Specific gravity	2.77	2.41	2.65
Fineness modulus	9.15	7.53	2.28 (Zone- II)
Impact value (%)	23.83	30.88	---
Crushing value (%)	20.30	33.72	---

3.1.2 Concrete Mixtures

Two concrete mixes are designed for different grades of concrete such as M20 and M40 with the replacement of RCA in 0%, 30%, 60% and 100% with natural aggregate. To reduce the water demand Super plasticizer "super flow" is added as admixture in concrete mixture. The details of mixture proportions are tabulated in Table 3.2

Table 3.2 Details of Mixture proportions for M20&M40

S.No	MATERIALS	M 20 Concrete	M 40 Concrete
1	Cement (kg/m^3)	330	450
2	Water (lit/ m^3)	170	175
3	Fine aggregate (kg/m^3)	730	650
4	Coarse aggregate (kg/m^3)	1270	1220
5	Super plasticizers (lit/m^3)	3.0	3.4
6	w/c ratio	0.5	0.39

3.1.3 Preparation of concrete mixes and Testing of Concrete

In this research work, eight concrete mixture for M20 and M40 grade are prepared with RCA in 0%, 30%, 60% and 100% with natural aggregate. The specimens were cured under wet curing and tested for 7, 28days. The compressive, split tensile, flexural and young's modulus of concrete specimen are tested and tabulated.

IV. RESULT AND DISCUSSION

Compressive strength, split, flexural tensile strength and young's modulus of recycled aggregate concrete for all RCA replacement are presented in Table 4 to 8. It is observed that compressive strength of RAC is almost higher at 60% RAC replacement with strength increment approximately 13% - 22%. This is due to higher the RAC replacement, higher absorption capacity of old adhered motor which leads to low w/c ratio and effective new interfacial transition zone and attained higher compressive strength of RAC. However at 100% replacement the strength increment level is reduced and this is due to the increase in the RAC replacement with more absorption capacity and increase the amount of water which leads to weaker ITZ, causes the strength reduction.

Table 4.1 Compressive Strength for M20 & M40 grade concrete

Group	Mix Designation	Compressive Strength (MPa)	
		7 days	28 days
A	RM1	23.8	28.76
	RM1-30%	26.93 (+13%)	29.0 (+0.8)
	RM1-60%	28.34 (+19%)	32.416 (13%)
	RM1-100%	23.75 (-0.2%)	26.66 (-7%)
B	RM2	37.19	48.06
	RM2-30%	40.2 (+8%)	50.8 (+6%)
	RM2-60%	45.22 (+22%)	55.09 (+15%)
	RM2-100%	35.33 (-5%)	42.78 (-11%)

Note: The bracketed values indicate the percentage increase (+) or decrease (-) in strength compared to the respective control concrete

Split and flexural strength have similar behavior as that of compressive strength. However the percentage gain is slightly different compared to compressive strength.

Table 4.2 Split Tensile Strength for M20 & M40 grade concrete

Group	Mix Designation	Split Tensile Strength (MPa)
		28 days
A	RM1	3.45
	RM1-30%	3.63 (+5%)
	RM1-60%	3.94 (+14%)
	RM1-100%	3.54 (+3%)
B	RM2	4.08
	RM2-30%	4.28 (+5%)
	RM2-60%	4.77 (+17%)
	RM2-100%	4.18 (-2%)

Note: The bracketed values indicate the percentage increase (+) or decrease (-) in strength compared to the respective control concrete

Test result shows that young's modulus increase with RAC replacement up to 60 % of NA. This may be due to presence of interfaces between old cement mortar and aggregate, new cement mortar and old cement mortar.

Table 4.2 Flexural Strength of Prism for M20 & M40 grade concrete

Group	Mix Designation	Flexure Strength (MPa)
		28 days
A	RM1	5.5
	RM1-30%	6.27 (+14%)
	RM1-60%	6.43 (+17%)
	RM1-100%	6.15 (+12%)
B	RM2	6.43
	RM2-30%	6.56 (+3%)
	RM2-60%	6.88 (+6%)
	RM2-100%	6.70 (+7%)

Note: The bracketed values indicate the percentage increase (+) or decrease (-) in strength compared to the respective control concrete.

For 100% replacement the E value decreased, this is due to the recycled aggregate tend to deform than the natural aggregate and is due to weaker interfaces between new cement mortar and old recycled aggregate.

CONCLUSIONS

Based on experimental studies on different strength properties and modulus of elasticity of recycled aggregates the following conclusion are drawn from the study:

Increase in compressive strength with 60% RAC replacement due higher absorption of RA leads to low w/c, thus increase in cement hydration and compressive strength properties.

Split, flexural strength also attained higher strength at 60% RA replacement, is due to stronger interfacial bond between the RA and new cement motor.

For 100% RAC replacement compressive, split and flexural strength properties are less.

Young's modulus had similar trend as compressive strength. The E value obtains 10% higher in replacement up to 60% of RAC.

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