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Improved Flexural Strength of Shear Beam from Treated Recycled Coarse Aggregate

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***Abstract*--Recycle coarse aggregate concrete is widely most used in the recent construction industry because of its easily availability and cheap in the market. The partial replacement of RCA with NA in this experiment. In this experiment shear behavior of 12 self-compacting recycled coarse aggregate reinforced beams (SCRAC) were casted by Nansu method with two mixing approach namely NMA and $TSMA_{sfc}$. The results were maximum load at failure (P_{max}), ultimate shear force at failure (V_{ult}), shear strength, load-mid span deflection. It was found that shear strength of beams casted with treated RCA with $TSMA_{sfc}$ approach was maximum among all the beams as compared of beams with NMA mixing approach and natural aggregate beams.**

***Keywords*--Recycled coarse aggregate, self-compacting concrete, EMV, NMA, TSMAsfc Flexure strength test, Loading.**

I. Introduction

In the present world of advancement and population increment. Constructions of building and huge structure demand are on the peak. For this concrete is the basic unit of constructions now days. Due to its over demand its constituents like cement, sand, coarse aggregates are increasing. Raw materials are non-renewable materials especially natural Coarse aggregate [1]. On the other hand, demolition of structures led to the increasing waste and which is concrete. Demolition is increasing to a high level which causes landfill areas which in results in land and air pollution as well water pollution [2]. Moreover, it also badly effects on the economy of the Developing countries because a large amount of money is invested every year (a) Demolition of structures. (b) Transporting the wastes to the landfill sites. (c) Also to bury them environment friendly way. To solve the above mentioned problems, the use of recycled concrete coarse aggregate (RCA) is demanding on the wide scale [3].

This excess mortar would depend on the residual mortar content of the RCA and the replacement ratio of coarse virgin aggregate by RCA and due to this excess mortar content there would greater shrinkage, lower elastic modulus and higher creep properties of RCA concrete as compared to equivalent NAC.

To overcome this problem, we developed EMV Method. In this method RCA is treated as a two-phase composite of residual mortar and the original natural aggregate. This includes the volume fraction and the relevant property of each phase. The method ensures that a certain RCA concrete mix has the same total mortar and the total coarse natural aggregate as a comparable natural aggregate concrete mixture. This method gives RCA-concrete mixes that do not suffer from the deficiencies of the RCA-concrete mixes made by conventional methods. The validity of the EMV method has been established through a fresh and hardened property. The problem RCA that it forms weak bond with new concrete mortar can be solved by removing the adhered mortar around the RCA and filling the pores present in RCA by treatment process [4].

II. Materials And Methods

2.1 Cement

The cement used in all mixes was of ordinary Portland cement (OPC) 53 grade of Emami double bull cement as per IS 8112 (1989) **[11]**. The specific gravity of the cement was 3.15g/cm^3. The chemical composition is shown in following table: -

Table 1
Physical properties of cement

Sl. No	Properties	IS: 8112-1989	Value obtained
1.	Fineness (%)	7	6
2.	Normal Consistency (%)	-	28
3.	Specific gravity	-	3.15
4.	Initial setting time(min)	30(min)	65
5.	Final setting time(min)	600(max)	270
6.	Soundness(mm)	10(max)	2.55
7.	Compressive strength (N/mm^2)		
	3days	23	25.2
	7days	33	36
	28days	43	44.33

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2.2 Aggregates

2.2.1 Fine aggregates

The fine aggregates used in the experiment was a natural sand of RiverThe aggregates which were taken of different proportion by weight and aggregates are sieved between 4.75mm to 20mm.

2.2.2 Coarse aggregates

The coarse aggregate used in this experiment was of two types natural coarse aggregate(VCA) and RCA. The natural coarse aggregate used is crushed limestone. The maximum size used was 20mm.

Table 2
physical and mechanical properties of coarse aggregate

Property	Fine aggregates	VCA	RCA
Specific gravity	2.69	2.59	2.55
Water absorption (%)	0.90	2.39	2.882
Bulk density(kg/m^3)	1550	1432	1236
Crushing value (%)	-	29	35
Impact value (%)	-	22	27

2.3 Fly Ash

A special kind of ash extracted from flue gas through electrostatic precipitator in dry form was used in used in this experimental program of specific gravity of fly ash which was supplied Bokaro thermal power plant.

Table 3
Physical properties of Fly Ash

Sl. no	Property	Result obtained
1.	Fines passing 150 m sieve (%)	98
2.	Fines passing 90 m sieve (%)	97.2
3.	Specific gravity	2.10

2.4 Silica Fume

An ultrafine powder that used to enhance the mechanical properties of concrete is of specific gravity of 2.2g/cm^3. The calcium hydroxide formed during cement reaction reacts with silica fume to produce an extreme binder which is calcium silicate hydrate.

Cement reaction

$$2\left(3CaO.SiO_2\right)+6H_2O=3CaO.SiO_2.3H_2O+3Ca\left(OH\right)_2$$

Table 4
Physical properties of silica fume

Sl. no	Property	Result obtained
1.	Bulk loose density	270-300 kg/m^3
2.	Particle size	0.2
3.	Specific surface area	20,000m^2/kg
4.	Specific gravity	2.16

2.5 Super plasticizer

To increase the flow ability of concrete super plasticizer was used in order to gain the workability in the concrete mix.

2.6 Water

The water used in the whole experiment was tap water of SIET Jabalpur concrete laboratory.

2.7 Sodium Silicate

Sodium silicate solution was used in this experiment for treatment of RCA which will explain in further section.

Table 5
Physical properties of sodium silicate

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Physical state at 20°C	Liquid
Melting point/Freezing point [°C]	0.6°C
Vapour pressure [20°C]	14 mm of Hg
Density (g/cm³)	1.39
Colour	Opaque viscous
Boiling Point	100°C
Soluble in water (% weight)	Soluble in water
PH Value	11.2
Evaporation rate	>1
Vapour density	0.7

2.8 Brief Description of EMV method used in this experiment

In this present experiment we take different proportion of RCA and NA for calculating the final percentage of RCA in the mix by Equivalent Mortar Volume Method and the source of RCA.

$$RMC\% = [\frac{W_{RCA} - W_{OVA}}{W_{RCA}}] \times 100$$

Where W_{RCA} the initial oven-dry mass of RCA sample before test is W_{OVA} denotes the final oven-dry mass of the original natural aggregate after full removal of the residual mortar. The residual mortar content comes 50.3 %. In this experiment different grades of aggregates were used by weight. In coarse aggregate, different proportion of CA is taken in this experiment as 70% aggregates for CA particle passing through 20mm sieve but retain on 12.5 mm,secondly 20% of particles are there which passes through 12.5 mm sieve but retain on 10mm sieve and rest 10% taken as 10 mm pass but 4.75 mm retain.

2.9 Preparation of self-compacting concrete mixes

In this experiment self-compacting concrete is prepared by Nansu[9] method by two different mixing approaches namely Normal mixing approach (NMA) and two stage mixing approach with silica fume, fly ash and cement ($TSMA_{sfc}$). In this we design for mix:

Step1- Calculation of coarse and fine aggregate content.

Step2- Calculation of cement Content.

Step3- Calculation of fly ash (FA) and ground granulated blast furnace slag (GGBS) content.

Step4- Calculation of super plasticizer (SP).

Step5- Trial batches (mixes) and tests on SCC concrete.

Step6- Adjustment of mix proportion.

2.9.1 Slump flow test

About 6 litre of concrete is needed to perform the test, sample normally.

Fig.3.3 Slump Test

2.9.2 V –funnel test

Equipment required in this experiment was v- funnel, bucket (12litres), trowel, scoop, and stopwatch. In this test About 12 litre of concrete is needed to perform the test, sampled normally. Set the V-funnel on firm ground. Moisten the inside surface of the funnel. Keep the trapdoor to allow any surplus water to drain.

Fig.3.5 set up for V-Funnel test

2.9.3 J- Ring-ring test

This was performed to determine the passing ability of SCC. In this test, J-ring is composed of a ring with numbers of vertical reinforcing bar, a slump cone and a base plate. Slump conewas inserted in J-ring over the base plate.

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Fig .3.4 J-ring test

Table 6
Fresh Properties of SCC

	% of RCA		T50 (sec)	Slump flow (mm)	V-Funnel time (sec)	J-ring (mm)
NMA	0		3	759	6	7.6
	62.94		4	712	8	8.7
	62.94 (tr)		5	697	7	12
TSMAsfc	0		4.6	730	8.4	8
	62.94		5	662	12	9.7
	62.94(tr)		6	690	12.1	9.9

Table 7
Mixed Proportion of SCC

% of RCA	Mix Name	Cement (kg/m3)	Fine Aggregate (kg/m3)	Coarse Aggregates(kg/m3) VCA	RCA	Fly-Ash (kg/m3)	Water (kg/m3)	SP (Kg/m3)
0	SCVCA	380	898.56	645.84	–	131.11	218.5	2.555
62.94	SCRAC	323.758	765.568	333.5	566.42	111.70	186.16	2.77
62.94(tr)	SCRAC	300	826	–	737	160	200	4.6

III. Results And Discussion

3.1 Ultimate load test

All the beams failed in shear just after the appearance of diagonal cracks.Table shows the compressive strength (f_c), the maximum load (P_{max}), shear force at failure (Vu exp) and the nominal shear stress (Vu exp/bd) for all specimens where b and d are the beam width and effective depth. The behaviour of twelve tested beams is presented in fig and in respect of load applied versus mid-span deflections for different loading span

Pics of single beam

Fig 4.1 EMV (62.94%RCA), NMA, l=350mm

Fig 4.2 EMV(62.94%RCA),TSMA$_{sfc}$,l=350 mm

Fig 4.4 TSMA$_{sfc}$(0%RCA),l=350mm

Fig 4.5 EMV-T (62.94% RCA)TSMA$_{sfc}$, l=350 mm

4.2 Crack propagation during the test

Table 9
For loading span distance (l=350mm)

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Beam name	Mixing approach	f_c	P_{max}	V_{uexp}	V_{uexp}'	$\alpha = V_{uexp}/\sqrt{f_c}$
NMA(0%RCA)	NMA	27.82	60.110	30.055	1.615	5.698
TSMA*sfc*(0%RCA)	$TSMA_{sfc}$	29.4	64.253	32.125	1.727	5.924
EMV(62.94%RCA),NMA	NMA	30.33	63.963	31.981	1.719	5.807
EMV(62.94%RCA),TSMA*sfc*	$TSMA_{sfc}$	31.77	69.550	34.775	1.869	6.169
EMV-T(62.94%RCA),NMA	NMA	32.96	67.699	33.849	1.793	5.895
EMV-T(62.94%RCA),TSMA*sfc*	$TSMA_{sfc}$	33.43	74.110	37.055	1.992	6.408

Where-

l =distance between the loading span.

f_c = Average compressive strength of mix.

P_{max}= Maximum load at failure resisted by beam specimen till failure.

V_{uexp} = Experimental shear force resisted by beam specimen till failure or ultimate shear force

α = Constant depend upon the ratio of ultimate shear force and average compressive strength.

a = Shear span =400mm

V_{uexp}'= Shear Stress resisted at failure.

3.2 Figures of load vs mid-span deflection

For l= 500 mm

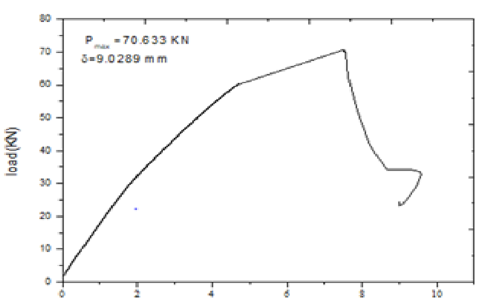

Fig.4.13 NMA (0%RCA)

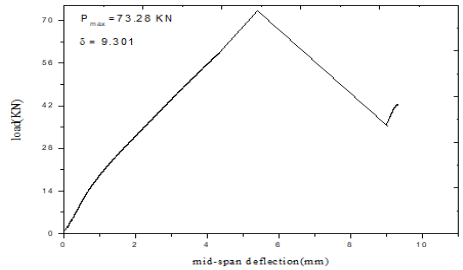

Fig .4.14.TSMAsfc (0% RCA)

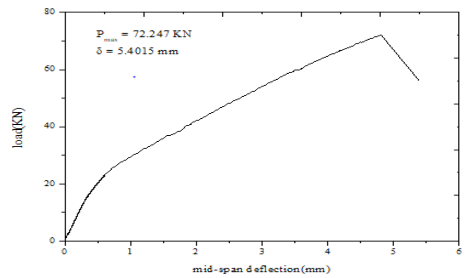

Fig. 4.15.EMV (62.94%RCA),NMA

IV. CONCLUSION

From the experimental investigation, following inclusions are noted as given below:

- UsingTSMA*sfc* approach in casting the increased the shear strength as compared to beams casted with natural aggregate and untreated RCA.
- The compressive strength of the treated one is maximum among untreated and natural aggreagate beams.
- Mid-span deflection is inversely proportional to shear strength of beams i.e the beams having more shear strength deflects less as compared to beams having less shear strength.
- Crack propogation along the beam till failure followed the same path regardless the strength and loading span distances.

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