

Influence of Fly Ash as Cement Replacement on the Properties of Recycled Aggregate Concrete by Different Mixing Approaches

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ABSTRACT: Nowadays protection & pollution of environment is the major problem of our society. That deals with adopting some fact to overcome the effect of pollution & to protect the environmental natural resources. Those fact are, minimization of (a) Consumption of energy & (b) natural raw materials and (c) Maximization of consumption of waste materials (that provide guideline for the recycled use of material). The use of recycled aggregates from construction and demolition wastes is showing prospective application in construction, as partly an alternative to primary (natural) aggregates. It conserves natural resources and reduces the space required for the landfill disposal. A new concrete mixing method, that is the two-stage fly ash slurry soak mixing approach (TSMA_{FS}), was developed to improve the quality of RA concrete (RAC) by splitting the mixing process into two parts. Cube, Cylinders and beam are casted using recycled coarse aggregate (RCA) and replacing natural aggregate (NCA) with 30%, 50% and 100% recycled coarse aggregate. In addition, fly ash was used as 10% by weight replacements of cement. The concrete mixtures were prepared with w/c ratio 0.43. This method in making recycled aggregate concrete can improve the strength of fly ash concrete made from 30% recycled aggregate concrete up to 6.23% by partial replacing 10% of cement mass with fly ash for concrete made from recycled aggregate has shown preferable result in strength, and can be improved by using TSMA_{FS} method in mixing process.

KEYWORDS: Recycle aggregate, natural aggregate, fly ash, Two-stage fly ash slurry soak mixing approach(TSMA_{FS}), Normal mixing approach(NMA).

I. INTRODUCTION

Recycled aggregates are broken concrete, bricks and broken pavement generally RA are produced in the process of construction of various types new concrete structures and demolition old concrete structures [buildings, bridges supports, airport runways, concrete roadbeds etc.], by manually and time to time of Natural disasters such as Wenchuan earthquake in 2008, Yashu earthquake in 2010 and Yuman earthquake in 2011 in China, Bhuj earth quake in 2001 in India and recently in Nepal 2015. According to the statistics data 15.5 million tons of C&D waste produced every years in China, 180 million tons in Europe [laurite report 2004], 27.7 million tons C&D waste produced as per report of Dubai waste management department [2007] and Shrivastava et al [2009] likewise in India 1.46 million tons C&D waste generated according to 11th five plan [2007]. Initially C&D waste were used for filling material on low land Area and base material of road but large production C&D materials waste disposal possess serious problems in the world as well as negative effect of environment. So therefore the many country attention towards reuse this C&D waste to overcome environmental problems and preservation of natural resources and increasing of sustainable development.

The most of authors reported that fresh and hardened properties of different mix grade RAC are lower than the Normal aggregate concrete such as Katz et al.(2003) concluded that the Concrete made with 100% recycled aggregates was weaker than concrete made with natural aggregates at the same w/c ratio. Tam et al. (2005) experimentally shows

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that the two-stage mixing approach can provide an effective method for enhancing hardened properties [compressive strength, splitting tensile strength and flexural strength] and durability properties [creep, shrinkage, permeability, chloride penetration] and other mechanical performance. Xiao et al. (2005) reported that the compressive strengths including the prism and the cube compressive strengths of RAC generally decrease with increasing RAC contents. Etxeberria et al. (2007) concluded that the concrete made with 100% of recycled coarse aggregate has 20 to 25% less compressive strength than conventional concrete at 28 days, Rahul et al (2007) also reported that the 28 days target compressive strength for all five mixes of RCA (20, 25, 30, 40 and 50MPa) were achieved except for the 40 and 50MPa where the observed strength was slightly lower than the target strength. ChakratharaRao et al. (2011) observed that the concrete cured in air after 7 days of wet curing shows better strength than concrete cured completely under water for 28 days for all coarse aggregate replacement ratios.

II. LITERATURE REVIEW

Tam V.W.Y. et al [2005], suggested a modified and enhanced way for the mixing of concrete. His research results that, higher water absorption due to higher porosity cause for poor quality of RAC. Also Weaker transition zone(ITZ) between new cement mortar and Recycled Aggregates(RA), confined its uses for higher grade application. This weak link present in ITZ of RAC is strengthened by two stage mixing approach. This two stage mixing approach is a way in which cement slurry gel up the RA, that fills the cracks and pores within the RA, and result in stronger ITZ. Desirable mechanical and physical property of the RAC like compressive strength, porosity etc. can easily improved by using this two stage mixing method.

Shi Cong Kou; et al [2007], investigated that The effects of fly ash on the compressive strength, tensile splitting strength, static modulus of elasticity, drying shrinkage, creep, and resistance to chloride ion penetration on the recycled aggregate concrete. He showed that compressive strengths, tensile strengths, and static modulus of elasticity values of the concrete at all ages decreased as the recycled aggregate and the fly ash contents increased. Further, an increase in the recycled aggregate content decreased the resistance to chloride ion penetration and increased the drying shrinkage and creep of concrete.

Yong P.C. and Teo D. C. L. [2009], stated that the higher value of compressive strength, split tensile strength and flexural strength of RAC can be obtained. 28-Day, Compressive strength and split tensile strength of RAC is higher than that of natural concrete. Whereas 28-Day flexural strength of RAC is lower than that of natural concrete. Also use of Recycled Coarse Aggregate(RCA) gives much better result in comparison with coarse aggregate in casting of a new concrete.

III. MATERIAL

A. Cement and fly ash:

Lafarge concrete (PSC), conforming to IS: 455. The chemical properties of cement have been obtained from IS: 455:1989. The specific gravity of cement was 3.106. Fly ash is used as partial replacement of cement which replaces 10% of total cementitious material in all the cases of the experiments. Class F fly ash is used from BTPS Bokaro, Jharkhand having specific gravity as 2.1 and satisfying IS 3812-1999. Chemical composition of cement and fly ash are given in table 1.

B. Fine aggregates:

The sand generally collected from Barakar river, Dhanbad(Jharkhand). Sand is the main component of grading zone-II of IS: 383-1978 was used having specific gravity of 2.678 and water absorption of 0.6 % at 24 hours.

C. Coarse aggregates:

(a) Natural Coarse Aggregate- Mechanically crushed stone from a quarry situated in Dhanbad with maximum size as 20 mm, satisfying to IS: 383-1978 was used. The specific gravity was found to be 2.84 and water absorption is 0.5 % at 24 hours.

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(b) Recycled coarse aggregates- It is obtained from demolition of concrete cubes at the concrete testing laboratory, Civil Engg. Dept. BIT Sindri Dhanbad having specific gravity 2.72.

Table 1. Chemical Compositions of Cement and Fly Ash

Sample name	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	TiO ₂	CaO	MgO	P ₂ O ₅	SO ₃	Na ₂ O	K ₂ O
cement	28.17	14.10	1.64	0.72	43.43	5.93	0.03	4.88	0.43	0.67
Fly ash	56.01	26.19	13.54	1.50	0.31	0.36	0.36	0.40	0.20	1.11

IV. METHODOLOGY

NMA follows certain steps. First, coarse and fine aggregate are mixed. Second, water and cementitious materials are added and mixed. However, TSMA_{FS} follows different steps. First, NCA and RCA aggregates are mixed for 60 seconds and then slurry made from half of water for the specimen is added and mixed for another 120 seconds. Second, cementitious material and fine aggregate are added and mixed for 60 seconds. Thirdly, the rest of water is added and mixed for 120 seconds.

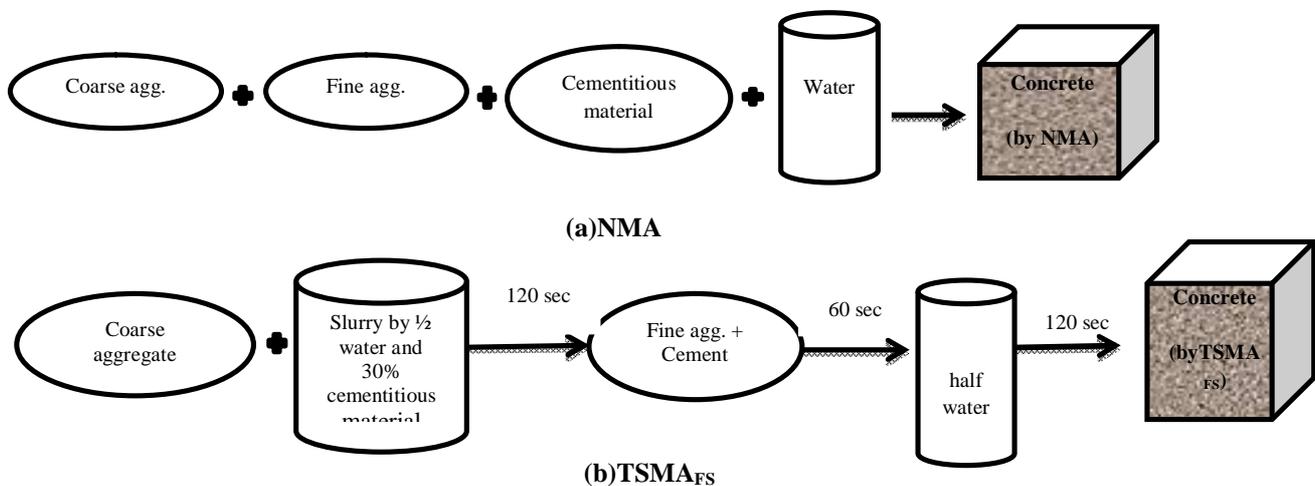


Fig. 1 Line diagram of different mixing approaches

In this TSMA_{FS} procedure, creates a thin film of cement slurry on the surface of RA which is expected fill the old cracks and voids. Pollution involved in trucking material can be reduced by using recycled concrete as the base material for roadways.

V. RESULT AND ANALYSIS

1) Recycled Aggregate Test and Natural aggregate

In this study, the recycled aggregate has been used from a crushed concrete cube from laboratory waste. The physical properties of natural and recycled aggregate are shown in table 2.

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Table 2. Physical properties of NCA and RCA

Types	Moisture content (%)	Water absorption (%)	Specific gravity	Bulk density	
				Loose(gm/cm ³)	Dense(gm/cm ³)
NCA	0	0.31%	2.84	1.712	1.845
RCA	0	2.48%	2.72	1.329	1.52
FA	0.2%	0.6%	2.678	1.495	1.617

2) Properties of Fresh Concrete

Slump test is the most common method to determine the consistence of fresh concrete. The details of the mix proportioning for various mixes of both normal and recycled aggregate concrete made with different percentages of Recycled Coarse Aggregate are presented in Table 3.

Table 3. Test results of workability of both normal concrete and RCA

Source	Mix designation	RCA (%)	w/c ratio	Slump (mm)
Normal concrete	NAC	0	0.44	NMA-41
RCA	RAC30+F10	30	0.46	NMA-39
				TSMA _{FS} -40
	RAC50+F10	50	0.47	NMA-34
				TSMA _{FS} -36
	RAC100+F10	100	0.49	NMA- 27
				TSMA _{FS} -27
RAC100+F0	100	0.49	NMA- 26	
			TSMA _{FS} -27	

It is observed that in all the mixes the workability decreases with increase in recycled coarse aggregate percentage. This may be due to the high absorption capacity and rough surface texture of Recycled Coarse Aggregates.

3) Properties of Hardened Concrete

(a) Compressive Strength

The compressive strength of concrete were determined using a compression machine with a loading capacity of 3,000 kN. The compressive strength was measured at the ages of 7 and 28 days.

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Table 4. Improvement of compressive strength of concrete by using TSMA_{FS}

S.No	Specimen	Mixing approach	Compressive Strength					
			7 days	Increase or decrease in 7 days w.r.to. Nominal Concrete	Increase in 7 days w.r.to corresponding NMA	28 days	Increase or decrease in 28 days w.r.to. Nominal Concrete	Increase in 28 days w.r.to corresponding NMA
1	NAC	NMA	27.81	-	-	38.0	-	-
2	RAC30+F10	NMA	28.516	(+)2.54	1.101	38.27	(+)0.71	5.487
		TSMA _{FS}	28.82	(+)3.63		40.37	(+)6.23	
3	RAC50+F10	NMA	32.29	(+)16.11	4.614	38.02	(+)0.05	0.763
		TSMA _{FS}	33.78	(+)21.47		38.31	(+)0.79	
4	RAC100+F10	NMA	23.56	(-)15.28	20.713	35.56	(-)0.064	5.596
		TSMA _{FS}	28.44	(+)2.26		37.55	(-)0.012	
5	RAC100+F0	NMA	26.367	(-)5.189	6.686	35.03	(-)7.816	6.79
		TSMA _{FS}	28.13	(+)1.15		37.41	(+)1.553	

It is observed that the variation in compressive strength of RAC prepared with NMA and TSMA_{FS} recycled aggregate concrete made with 30% RCA is almost similar from 7 days to 28 days curing period. Whereas, a relatively slower strength gaining rate is observed for RAC made with higher percentage of recycled coarse aggregates (50 and 100%). It is reported in the literature that the increase in compressive strength of RAC at early age is mainly due to high absorption capacity of old mortar adhered to the recycled aggregates and the rough texture of recycled aggregates that improved bonding and interlocking characteristic between the mortar and recycled aggregate themselves.

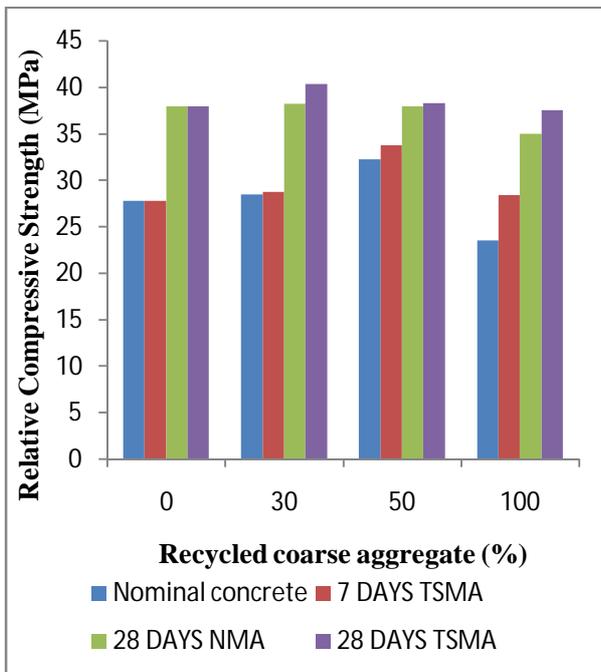


Fig. 2 Compressive strength of specimens with 10% of fly ash as cement replacement

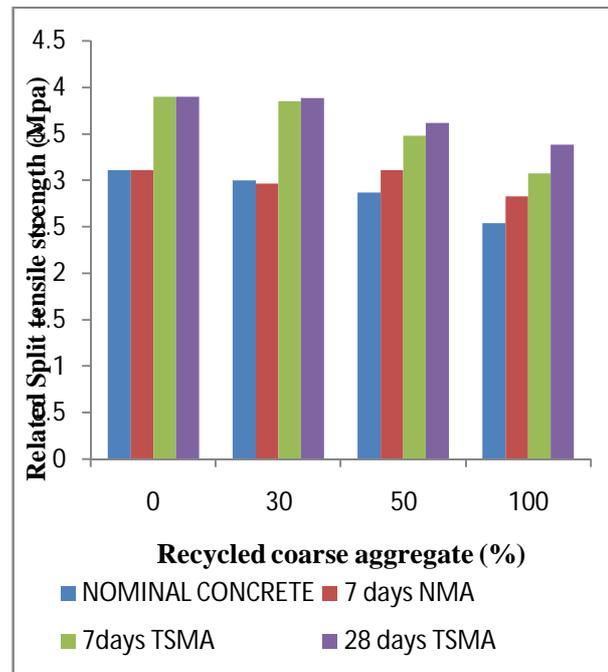


Fig. 3 split tensile strength of specimen with 10% fly ash as cement replacement

(b) Split tensile and flexural strength

The direct tensile strength of concrete is not often carried out due to development of secondary stress induced by specimen holding device which can't be ignored. The strength determined by using flexure test is referred as Modulus of Rapture of Flexural Strength. In general the tensile strength and Flexural strength of concrete are in the order of 10% and 15% respectively of compressive strength. The flexural strength of concrete is mainly useful in the design of pavement slabs and runways but less important in RCC structures where tensile strength is provided by steel reinforcement.

Test results for Split Tensile Strength and Modulus of Rapture after 28th days of both normal and recycled aggregate concrete made with different percentages of recycled coarse aggregate are presented in Table 5.

It observed that the Split Tensile Strength and flexural strength of RAC decrease with the increase of RCA percentage. Fig. 3 and fig. 4 represents the effect of different mixing approach to the split tensile strength and flexural strength of concrete made with different percentage of recycled coarse aggregate.

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Table 5. Tensile strength and flexural strength of both Normal and Recycled Aggregate concrete

S.NO.	Mix Designation	Mixing Approach	Split Tensile strength (MPa)		Flexural strength (MPa)
			7 days	28 days	
1	Nominal mix M30	NMA	3.11	3.901	6.36
2	RAC30+F10	NMA	3.005	3.855	6.25
		TSMA _{FS}	2.97	3.89	6.36
3	RAC50+F10	NMA	2.87	3.48	5.15
		TSMA _{FS}	3.11	3.62	5.34
4	RAC100+F10	NMA	2.545	3.075	4.23
		TSMA _{FS}	2.83	3.39	4.23
5	RAC100+F0	NMA	2.445	3.02	4.23
		TSMA _{FS}	2.69	3.18	5.15

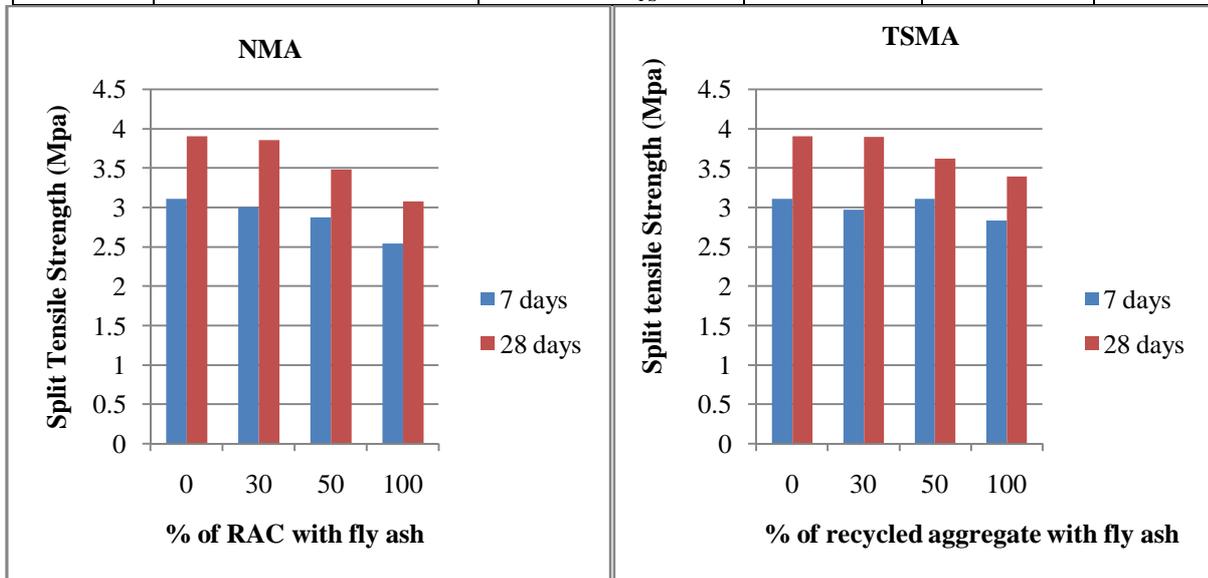


Fig. 4 relative split tensile strength of RAC made with RCA

The failures of split tensile specimens of both normal concrete and recycled aggregate concrete made with different percentage of recycled coarse aggregate are presented in Fig. 5.

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Fig. 5 Split tensile failure surfaces of Recycled aggregate concrete

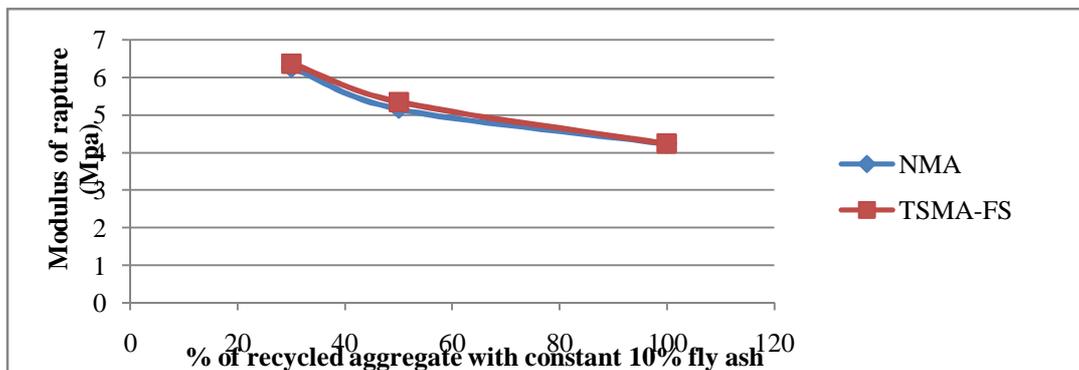


Fig. 6 Modulus of rupture (Flexural strength) against percent of recycled aggregate

In general the failure is through the interface between aggregate and cement mortar, as it is weakest zone in case of normal aggregate. Whereas, this is not so in case of recycled aggregate concrete. In case of recycled aggregate concrete, it is observed that the failure occurred not only through the interface, but also through the recycled aggregate. The failure surface showed that the crushed aggregates are the pieces of old cement mortar which is adhere to recycled coarse aggregate.



Fig. 7 Flexural strength surface of recycled aggregate concrete

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VI. CONCLUSIONS

Experimental works on the use of recycled aggregates with the effect of fly ash on RAC have proven that good quality concrete could be produced with recycled aggregates. The use of aggregates produced from recycled construction and demolition waste should be further promoted. Based on the experimental investigation reported in the work, the following conclusions are drawn:

1. Presoaking fly ash slurry Two Stage Mixing Approach (TSMA_{FS}) is an effective technique for increasing strength of RAC due to the filling up slurry paste in fissures and of pores in old ITZ.
2. The workability of recycled aggregate concrete mix is lower than natural aggregate, concrete mix with 30.0% recycled aggregate concrete has satisfied workable concrete.
3. The outcome of this work reveals that concrete made by replacement of 30% and 50% NA by RCA and addition of 10% fly ash slurry using TSMA_{FS} gives more compressive strength for both 7 day and 28 days strength than the referred concrete specimen made by NMA however on using 100% RCA the concrete shows decrease in compressive strength than the Nominal concrete.
4. Maximum 28 day strength is obtained by concrete made by using TSMA_{FS} involving replacement of 30% RCA and addition of 10% fly ash. This concrete so made will be cost effective as well as strong and can be used in any constructional works in place of nominal concrete.
5. Larger quantity of RCA (more than 30%) in RAC reduces the compressive strength of concrete. However, replacement of natural aggregates with lower (<30%) RCA has no significant influence on compressive strength of concrete. The tensile strength of RAC is lower than that of concrete with natural aggregate. This is apparently because of poor mechanical strength of recycled coarse aggregates..
6. The Interfacial Transition Zone (ITZ) in RAC is less dense than the concrete with natural aggregates. Possibly the adhered mortar to the aggregates in RCA consume more water in the initial stages, thereby making the surrounding more porous.

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