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REPLACEMENT OF CONSTRUCTION AND DEMOLITION CONCRETE WASTE AS AGGREGATES IN THE PRODUCTION OF CONCRETE BLOCKS

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ABSTRACT

The sustainability is a major concern around the globe. It is a challenging task todispose tons of construction waste and demolition debris produced day to day from construction activities. Reuse of such wastes has becomes a burning issue. In engineering applications the use of recycled concrete aggregate is very rare due to its inadequate compressive strength and variations of physical and mechanical properties. This study proposes a novel conceptofself healing and two stage mixing methodto enhance the compressive strength and also the physical and mechanical properties of recycledconcrete aggregate. A comparative analysis was made on M_{20}grade concrete, using Self Healed Recycled Concrete Aggregates (SHRCA) and new method of mixing a concrete by using Two Stage Mixing Recycled Concrete Aggregates (TSMRCA). The blocks were evaluated for its dimensional, block density, compressive strength and water absorption properties.

Key words:*Aggregate, RAC, SHRCA, TSMRCA, Slef healing, Two stage mixing*

I INTRODUCTION

The rate of growth of cities becomes high due to urbanization. It demands rapid infrastructure developments, henceold buildings are demolished& new structures are constructed with natural aggregates. The survey predicts that the construction wastes such as Construction and Demolition (C&D) waste contributes a majorproportion of wastes in developed and developing countries. As on today the demolished wastes are dumped on low laying areas& not used for any purpose, such activities will affect the environment and wastage of large proportion of potentially useful material. In this process the landfill areas and available natural aggregates will soon get exhausted in near future andalso a greater awareness forenvironment protection. Concrete is preferred as a construction material due to its longer life, low maintenance cost & better performance.The infrastructure industry consumes a large amount of energy and also responsible for 5 to 8 percent of the world's CO_2emission in production of cement. As on today protecting an environment ismajor concern for the survival of the human and habitats in future. It is a need for the day to protect the natural resources, environmental and sustainable development plays an important role in modern infra structure development works. Concrete solid blocks have an important role in construction industry because of their cost. It is also used as an alternative to burnt clay bricks due to its durability, resistance to fire and sound, thermal insulation, reduced mortar and high speed of construction.

Central Pollution Control Board (CPCB) Delhi, reports that the total annual production of solid waste in India alone ismore than 48 million tons, inwhich 14.5 million ton is fromconstruction waste sector only. In this waste 3% of which is used for embankment and the remaining is used as landfill. In C&D waste, concrete waste is around 70 % of the total C&D waste. There is a need for motivation and encouragement to use the recycledconcrete aggregate for new construction works will reduce the amount of landfill areas that can improve environment sustainability. The purpose using the recycling aggregate in concrete structures is to safeguard the natural aggregates for future generation of human life, protection of environment, and to increase the durability of concrete structures. The Recycled Aggregate (RA) can be reused as a fine aggregates and coarse aggregate in concrete to reduceC & D waste materials.

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Recycle Concrete Aggregate can be manufactured by crushing and screening to acceptable limits. The RA has great potential for use in concrete with better performance over natural aggregates andis lighter weight per unit of volume,which reduces material costs, transportation costs, and overall project costs. In the present study basic properties of recycled fine aggregates and recycled coarseaggregate were determined and compared with properties of natural aggregates as per the codal standards.

Self Healing: The reasons for not to usethe recycled aggregates in concrete are due to less strength, lack of codal provisions, specifications, lack of knowledge and awareness in the construction industry. As the C & D waste is collected from various locations and different types of structures hence the properties of the aggregate are sometimes find it difficult to compare. To increase the properties of recycled concrete aggregatesfew researchers tried with pre processing of aggregates (pre soaking recycled aggregates)in HCl and H_2SO_4. In thepre processing stage it will remove the adhering old cement mortar on the aggregates. This study proposes a technique to enhance properties of recycled concrete aggregateby using self healing (SH)of recycled concrete aggregates. The self healing canbe done by immersing the recycled concrete aggregates infresh water up to 30 days which improves the mechanical properties of recycled concrete aggregates atlow cement content. In this process the unhydrated cement particles of the recycled aggregates will reactonce again with water and hence enhances themechanical properties of recycled aggregate concrete.

Two Stage Mixing: In this method, the mixing of concrete matrix is done in two stages. In first stage the recycled coarse aggregate is mixed with cement for ten minutes to make a one coatof cementslurry on RA.In this process the existing cracks and voids of recycled course aggregates will fill with cement slurry which reduces the porosity of RA and improves the interfacial zone of aggregate by penetrates.The Interfacial zone which createsa greater surface area to cement mortar and increases strength of concrete. In the second stage the fine aggregates are mixed with product of first phase. In Two Stage Mixing (TSM) methodwill improve the mechanical properties of recycled aggregate concrete. This indirectly it encourages in a wider spectrum to use the construction and demolition wastes in an engineering application of concrete withgreater level of utilization of recycled aggregate in the construction industry.

The organization of this paper is as follows; section II describes about the related work, section III describes about materials and methodology adopted in the paper, section IV has a detailed results and discussions and conclusions included in section V.

II RELATED WORK

To improve the existing mechanical properties of recycled concrete aggregates Ali Abd Elhakam et al. [1] has proposed three techniques (i) **Self healing of RA**: It is done by immersing recycled concrete aggregates in water for about 30 days, in this process the unhydrated cement particles of the aggregates will react again with water which will enhance the existing properties of concrete. The author claimed that the Recycled aggregate cement concrete showsan improved compressive strength by 30%.(ii) **Two stage mixing method**: In this method water, cement, recycled aggregates are first mixed then natural sand and natural coarse aggregates were added. This increasesthe properties of recycled aggregate (Compressive and tensilr strength) concrete due to increased properties of recycled aggregates and its bond.(iii) **Silica fuming method**: Here 10% of silica fume is added for 75%RA which enhances the properties of concrete. Thecompressive strength of the recycled aggregate concrete increases as the porosity decreases. The Ka-hung et al. [2]also adopted Two-Stage Mixing Approach (TSMA), in this method a layer of cement slurry is formed around the recycled aggregates and fill the cracks and voids in the Recycled aggregate if any and also improves the interfacial zone of aggregate. Use of TSMA improves the properties RAC in comparing with natural aggregate concrete. Using this method a thin layer of cement slurry willcoatedon the surface of RA, which helps to fills up the existing cracks and voids and reduce the porosity of RA. The author also claimed that the concrete with 20% recycled aggregates gives an optimum performance in creep, shrinkage and water absorption.

Vivian et al.[3] also worked on Two Stage Mixing Approach (TSMA) as Ali Abd Elhakam et al. and Ka-hung et al has worked and also proved the improved compressive strength for recycled concrete aggregates. The effect of existing porous in the recycled concrete aggregate can be cured by premix, it results a denser concrete. This is due to an increased interfacial bond all around recycled concrete aggregate andyields high strength compared to the traditional mixing method. Results of obtained compressive strengthwith varied proportions of recycled concrete aggregates with Natural Mixing Approach (NMA) and TSMA shows the improved strength enhancement. Limbachiyaet al.[4] worked on the plain and reinforced concrete by adopting the primary and secondary crushed aggregate with an acceptable quality as per codal standards. They have used up to 100% recycled concrete aggregate with varied proportion and then tested for fresh engineering and durability properties as per the standards and also states the suitability and use in a varied range of designated

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applications. It is also found that the density of these recycled concrete aggregates loweredby 3% to 10% and water absorption increases by by 3 to 5 times more than the natural aggregates. It also predicts the importance of density and water absorption of recycled concrete aggregates with large variations in hardened concrete properties and workability of fresh concrete.

Micronized Biomass Silica (MBS) from rice husk has been used by Suraya et al[5] for their study and shows the improved performance of RAC with different percentages of RA and MBS after 28 days. The optimum compressive strength obtained at 12 % of MBS and 100% recycled aggregate and water penetration and water permeability coefficient reduces to 7.5 % and 47.10 % respectively. From this research, it is concluded that RAC with MBS have lower slump value compared to RAC without MBS. RAC with MBS have higher compressive strength than RAC without MBS. Water permeability of recycled concrete aggregates with MBS is better compared to recycled concrete aggregates without MBS and MBS improves the performance of recycled concrete aggregates in terms of compressive strength and water permeability. So recycled concrete aggregateswith MBS showsbest performance in comparison with recycled concrete aggregates without MBS.Dina et al.[6],have conducted an experiment on concrete manufactured fromclay crushed bricks as recycled aggregates with varied cement content of 100, 150, 200 and 300 kg/m^3. So, the bricks made up of from crushed bricks shows better physical and mechanical properties.The authors tried by using natural fine aggregate, natural coarse aggregate and both with crushed brick aggregates (CBA) at with varied proportions of 0%, 50% and 100% by their volume. The results of solid cement blocks evident that asthe % of natural aggregates increases the unit weight and compressive strength decreases and the water absorption increases which does not depends on amount cement content. When % of crushed clay brick increases the unit weight of solid cement bricks decreases and the water absorption increases and which does not depends on either size of crushed clay brick or the amount of cement content. The authors also observed that the compressive strength of solid crushed brick aggregates cement bricks willgradually decreaseswith increasing in the size and content of crushed bricks.

Mamery et al.[7], have used variedproportion of fine aggregates and coarse aggregates with natural and recycled concrete coarse aggregated and fine aggregates. They obtained the recycled aggregates by crushing the same Fresh Concrete Waste (FCW) after 30 days of curing and found that the % of water absorption of recycled fine aggregates and recycled coarse aggregates from fresh concrete waste is more than the natural aggregates and decreases the mechanical performance of the new concrete. As the percentage of recycled aggregates increases the compressive strength decreased gradually and also the behavior is not dependent on the aggregates size. The mix of natural aggregates with 25%, 50%, and 100% with recycled aggregates decreases the compressive strength by about 15%, 25%, and 32% respectivelyand also decline iin tensile strength by 18% when the concrete has 100% recycled aggregates. The experimental results also shows, with the increase in recycled aggregate proportion the compressive, splitting and flexural strength decreases. The variation in strengths due to different proportion of natural and recycled aggregate was determined by Parekh [8] et al.,and their effects on concrete strength were discussed.They have discussed in brief codal guidelines for recycled aggregates concrete from different countries with their effects and also present the status of today's usage of recycled concrete aggregate in India, with its future need and its successful utilization.

Herbert (9) et al., used self healing method to study the behavior of Engineered Cementitious Composites (ECC) under resonant frequency and uniaxial tensile load. The ECC is prepared from type-1OPC, Class-F normal fly ash as per ASTM C618 with average particle size 110 µm fine silica, polycarboxylate (water reducer) and polyvinyl alcohol (PVA) fibers. For their study they have considered PVA fibers having 1600 MPa of tensile strength, 1300 kg/m^3 density, 42.8 GPa of elastic modulus and maximum of 6% elongation. It shows a significant recovery of resonant frequency and stiffness in the damaged specimens once they exposed to the natural environment. After one to three months of exposure, the recovery goes up to 90% of its original pre damage; resonant frequency goes up to 31% to 68% of their initial stiffness with 20 µm cracks widthfor self healing. The **ECC** is capable to perform selfhealing in controlled laboratory conditionsas well as in natural environment. Kumutha et al.[10, they consideredrecycled concrete aggregates with varied proportions of crushed concrete or crushed bricks obtained from the demolition wastes along with natural aggregates for the study. They carried out the tests on engineering properties like density, compressive strength, split tensile strength, flexural strength and modulus of elasticity of concrete with and without recycled concrete aggregates. It is observed that the recycled concrete aggregates will influence more on hardened properties of concrete.

III MATERIALS AND METHODOLOGY

Cement: The physical properties of cement is tested as per IS 4031-1988 and their test results are tabulated in Table1.

Characteristics	Unit	Value	Requirement as per IS 8112-1989
Specific gravity	-	3.15	around 3.15
Specific surface	m^2/Kg	373	minimum 225
Standard consistency	%	31	28 - 33
Initial setting time	minutes	77	minimum 30
Final setting time	minutes	260	maximum 600

Table 1: The physical properties of ordinary Portland Cement (OPC)

Fine Aggregates: Locally available manufactured sandand natural sand of zone-II is used as a fine aggregate it passes through the sieve of 4.75mm. IS: 383 (1970) is followed for fine aggregates. The physical properties of manufactured sand have been checked as per IS 2386 (part 3): 1963(7) and the obtained results are tabulated in Table 2.

Properties	Unit	Natural Sand	Manufactured Sand	Requirement as per IS 383 - 1970
Fineness modulus	-	2.85	3.06	2.20 - 3.20
Specific gravity	-	2.64	2.45	2.50 - 2.80
Water absorption	%	1.30	1.45	0.3 - 2
Zone	-	Zone-II	Zone-II	Zone- I to Zone-IV

Table 2: The physical properties of manufactured sand and river sand

Coarse Aggregates: Natural coarse aggregate(NCA) has been obtained from a local stone crushing industry and recycled coarse aggregates (RCA) were procured from the Bangalore metro demolition waste and Christ University concrete laboratory wastes. The properties (physical and mechanical) of NCA,RCA and Self healing recycled concrete aggregates (SHRCA)have been verified as per IS 2386 (part 3): 1963(7) and the obtained results are tabulated in Table 3.

Properties	Unit	NCA	RCA	SHRCA	Requirement as per IS 383 - 1970
Specific Gravity	-	2.65	2.60	2.63	2.50 - 2.80
Water absorption	%	1.20	2.65	2.40	0.3 - 2
Aggregate crushing value	%	14.30	30.00	28.00	-
Aggregate impact value	%	19.70	30.40	26.50	-

Table 3: Properties of NCA, RCA and SHRCA

Water: For the present study clean portable water was used to prepare recycled coarse aggregate based solid concrete blocks and concrete mixes. The varying quantity of water is considered as per IS: 10262-2009 and IS 2185 (part 1): 1979 in order to prepare various mixes for the manufacture of solid blocks and concrete.

Concrete Mix Design: The following proportions of recycled fine and coarse aggregate, self healed recycled concrete coarse aggregate and two stage mixed recycled concrete coarse aggregate have been used for the study and M20 grade concrete as per IS 10262-2009 is used.The natural coarse aggregate is replaced with recycled fine aggregateand coarse aggregate, self healed recycled coarse aggregate and two stage mixed recycled fine and coarse aggregate at a rate of 25%, 50%, 75% and 100% respectively their corresponding mixes are abbreviated as RAC25, RAC50, RAC75, RAC100, SHRAC25, SHRAC50, SHRAC75, SHRAC100, TSMRAC25, TSMRAC50, TSMRAC75 and TSMRAC100 respectively. Their corresponding mix proportions are shown in Tables 4, 5 and 6.

Mix	W/C Ratio	Cement (Kg/m^3)	RCA (%)	RCA (Kg/m^3)	Water (liter)	FA (Kg/m^3)	CA (Kg/m3)
M_{ref}	0.5	383.00	0	0	191.5	792	989.00
RAC_{25}	0.5	383.00	25	247.25	191.5	792	742.75
RAC_{50}	0.5	383.00	50	494.50	191.5	792	494.50
RAC_{75}	0.5	383.00	75	742.75	191.5	792	247.25
RAC_{100}	0.5	383.00	100	989.00	191.5	792	0

Table 4: Mix proportion for the series RAC

Mix	W/C Ratio	Cement (Kg/m^3)	SHRCA (%)	SHRCA (Kg/m^3)	Water (liter)	FA (Kg/m^3)	CA (Kg/m^3)
M_{ref}	0.5	383.00	0	0	191.5	792	989.00
$SHRAC_{25}$	0.5	383.00	25	247.25	191.5	792	742.75
$SHRAC_{50}$	0.5	383.00	50	494.50	191.5	792	494.50
$SHRAC_{75}$	0.5	383.00	75	742.75	191.5	792	247.25
$SHRAC_{100}$	0.5	383.00	100	989.00	191.5	792	0

Table 5: Mix proportion for the series SHRAC

Mix	W/C Ratio	Cement (Kg/m^3)	TSMRCA (%)	TSMRCA (Kg/m^3)	Water (liter)	FA (Kg/m^3)	CA (Kg/m^3)
M_{ref}	0.5	383.00	0	0	191.5	792	989.00
$TSMRAC_{25}$	0.5	383.00	25	247.25	191.5	792	742.75
$TSMRAC_{50}$	0.5	383.00	50	494.50	191.5	792	494.50
$TSMRAC_{75}$	0.5	383.00	75	742.75	191.5	792	247.25
$TSMRAC_{100}$	0.5	383.00	100	989.00	191.5	792	0

Table 3.6: Mix proportion for the series TSMRAC

IV EXPERIMENTAL RESULTS AND DISCUSSION

(A) Effect of Recycled Coarse Aggregate on the Properties of Concrete

Thetestresults of compressive strength of RACseries are as shown in Fig.1. The tests were carried on concrete with natural coarse aggregates replaced by recycled fine and coarse aggregates. The tests were conducted as per the standard specifications

Mix	RCA (%)	Compressive strength (N/mm²)		
		3 days	7 days	28 days
M_{ref}	0	17.65	22.76	28.10
RAC_{25}	25	13.64	21.97	27.29
RAC_{50}	50	14.81	20.38	26.02
RAC_{75}	75	14.69	19.93	24.71
RAC_{100}	100	13.28	17.75	24.16

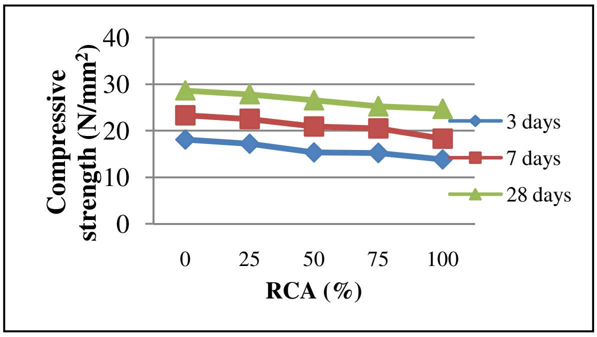

Fig 1: Compressive strength for the series of RAC

(B) Effect of Self Healed Recycled Coarse Aggregate on the Properties of Concrete

The test results of compressive strength of SHRAC series are as shown in Fig. 2.The tests were carried on concrete with natural coarse aggregates replaced by self healed recycled coarse aggregate. The tests were conducted as per the standard specifications.

Mix	SHRCA (%)	Compressive strength (N/mm²)		
		3 days	7 days	28 days
M_{ref}	0	17.55	22.76	28.10
$SHRAC_{25}$	25	16.68	21.71	27.85
$SHRAC_{50}$	50	15.77	20.63	27.19
$SHRAC_{75}$	75	14.51	19.25	26.40
$SHRAC_{100}$	100	13.46	18.02	26.41

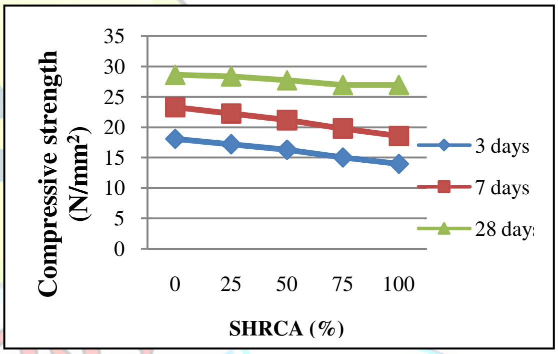

Fig. 2: Compressive strength for the series SHRAC

(C) Influence of Two Stage Mixed Recycled Coarse Aggregate on the Properties of Concrete

The test results of compressive strength of TSMRAC series are as shown in Fig. 3.The tests were carried on concrete with natural coarse aggregates replaced by two stage mixed recycled coarse aggregates. The tests were conducted as per the standard specifications.

Mix	TSMRCA (%)	Compressive strength (N/mm²)		
		3 days	7 days	28 days
M_{ref}	0	18.55	22.76	28.10
$TSMRAC_{25}$	25	16.66	22.05	27.54
$TSMRAC_{50}$	50	15.40	20.53	25.55
$TSMRAC_{75}$	75	14.73	20.11	25.37
$TSMRAC_{100}$	100	13.02	17.97	25.00

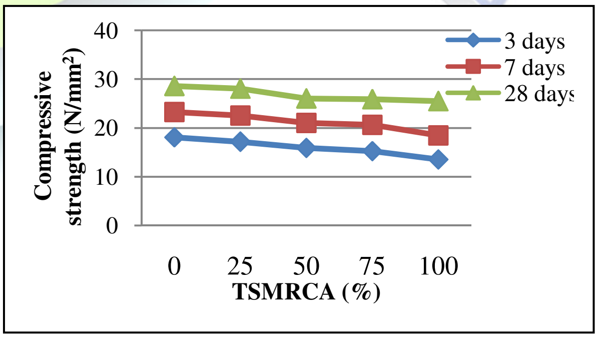

Fig. 3: Compressive strength for the series TSMRAC

The comparative compressive strengths at 3 days, 7 days and 28 days have been shown in Fig.4-6 with different mix proportions of RAC, SHRAC, TSMRAC.

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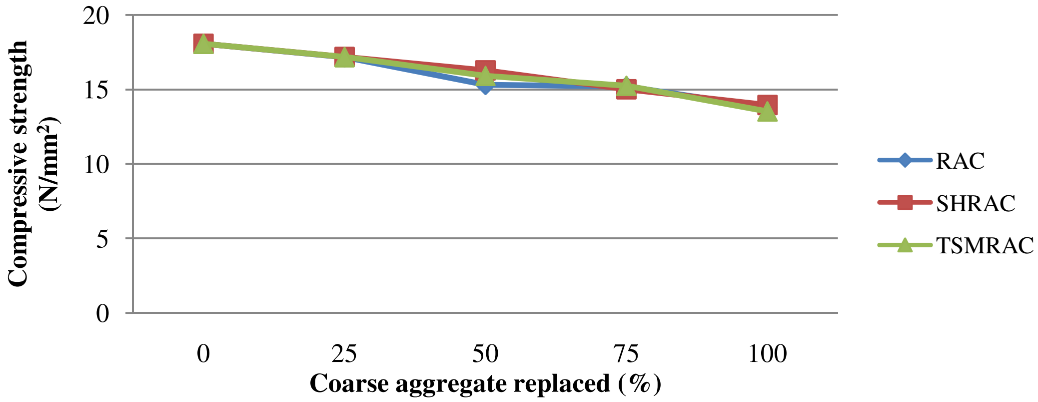

Fig. 4 3-days Compression strength for the series RAC, SHRAC and TSMRAC

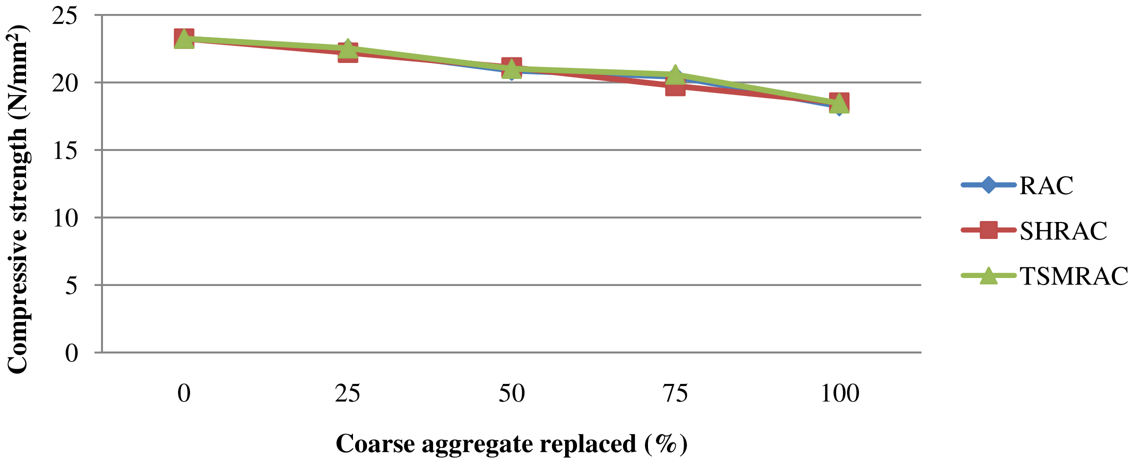

Fig 5 7-days Compression strength for the series RAC, SHRAC and TSMRAC

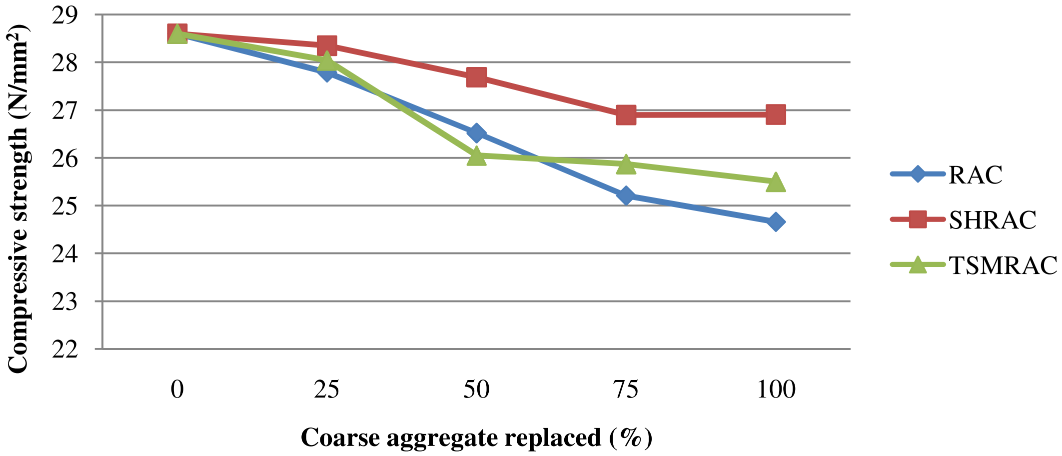

Fig 6 28-days Compression strength for the series RAC, SHRAC and TSMRAC

V CONCLUSIONS

The production cost of concrete with partial replacement of recycled concrete aggregates is low when compared to plain cement concrete. The results show that the mechanical properties of recycled concrete aggregates are nearly adjacent to plain cement concrete and well within the codal provisions. The rate of pollution of environment can also be controlled in a great extent by using recycled concrete aggregates.The experimental investigations shows that, with the increase in the RAC, SHRAC and TSMRAC content has decreased the 28 days concrete compressive. It is found that up to 25% of recycled aggregates may not have significant effect on concrete properties. The results of slump test for different proportions of recycled concrete aggregate shows that the workability is lower than the conventional concrete because the rate of absorption of water by recycled concrete aggregates is higher than normal aggregate.

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