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Experimental Investigation on Drying Shrinkage Strains of Recycled Aggregate Concrete using Pozzolanas

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Abstract : *The main objective of this paper is to determine the drying shrinkage of concrete produced with 100% recycled aggregate using pozzolanic materials. Natural coarse aggregate is replaced with recycled aggregate and fly ash of 20%, silica fume of 10% is partially replaced with cement. The recycled aggregate concrete of grades RAC 20, RAC 25 and RAC 30 were made using laboratory crushed cubes of grades M20, M25 and M30. The water cement ratio was w/c ratios were finalized as 0.40, 0.40, and 0.38 for mixes without pozzolanic materials and 0.35, 0.32, 0.32 for mixes with pozzolanic materials for RAC 20, RAC 25 and RAC 30 respectively. The specimens of size 75mm x 75mm x 285mm with 100% recycled coarse aggregate concrete were prepared, cured for 7 and 28 days. The specimen were air dried for a period of 7,28,56 and 90 days. The drying shrinkage of natural aggregate concrete, recycled aggregate concrete with and without pozzolanas are compared. The results from the study revealed that the drying shrinkage of specimens with recycled aggregate is more compared to specimens with natural aggregate, due to greater porosity and absorption of water. The drying shrinkage increased with increase of drying period. The study concluded that the reduction in drying shrinkage was observed for the recycled aggregate concrete with pozzolanas as compared to the recycled aggregate concrete without pozzolanas but the compressive strength has followed the reverse pattern.*
Keywords*- Recycled aggregate concrete, drying shrinkage, length comparator, pozzolanic material.*

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I. INTRODUCTION

The major difference between recycled aggregate and natural aggregate is the amount of cement mortar attached on the surface of aggregate. Pozzolanic materials are mostly used as mineral admixture in concrete which are of siliceous and aluminous material and it self-possesses the cementing property. In concrete the interfacial transition zone (ITZ) is presented between the mortar paste and the aggregates. Concrete made with recycled aggregate have an additional interfacial transition zone between the old adhered mortar to the original aggregate and the new mortar. Pozzolanic materials such as fly ash which increases the strength of recycled aggregate concrete by filling air voids between aggregates and cement paste. When fly ash is mixed in recycled aggregate concrete, it improves workability and reduces drying shrinkage, water permeability, and segregation.

In India, an extensive research is being conducted for the usage of recycled materials in all types of structures. Recycled concrete with recycled aggregates have proven to be commercially practical and technically secure for non-structural applications. When recycled aggregate are used in concrete structure it should be serviceable, cracks must be controlled and deflections should not be excessive. Shrinkage and creep are long term effects observed in various structures. Drying shrinkage is a behavior in concrete which contracting of a hardened concrete mixture due to loss of capillary water. Shrinkage of concrete is the time-dependent strain measured in an unloaded and unrestrained specimen at constant temperature. The shrinkage of concrete is basically the volume variation of a certain concrete product caused by the loss of water by evaporation, hydration of cement and also by carbonation. Recycled aggregate concrete (RAC) tends to exhibit greater shrinkage than the corresponding natural aggregate concrete. The replacement of RAC level increases the shrinkage of RAC also increases.

II. LITERATURE REVIEW

Andreu Gonzalez-Corominas [1] et. al., studied the effects of using recycled aggregates concrete (RAC) on the shrinkage of high performance concrete. They considered the quality of recycled coarse aggregate (sourced from concrete of 100, 60, 40 MPa) and the replacement ratio of 20, 50, 100% were used with water/cement ratio 0.29 which was kept constant for all concrete mixes. The drying shrinkage readings were measured at 1, 4, 7, 14, 21, 28, 56, 90, 180, 360 days by using a length comparator. The highest drying shrinkages occurred in concretes contained the highest RCA replacement ratios and in lowest RCA qualities. The concretes produced using RCA100 achieved 54–56% higher shrinkage levels than those of NAC at 28 days of testing. The compressive strength results between NAC and RAC containing up to 100% of RCA100, 50% of RCA60 and RCA40 were similar. Vivian W.Y. Tam [2] et. al., investigated the long-term deformation behaviour of recycled aggregate concrete. The highest drying shrinkage is about 0.12108% for 100% RAC replacement ratio, and the lowest drying shrinkage is about 0.06137% for the sample with 0% c-RA replacement ratio, of water-to-cement ratio of 0.45.They concluded that the results of RAC deformation increase in drying shrinkage and creep behaviour, when increase in RCA replacement ratios. Valeria Corinaldesi [3] et. al., studied the mechanical and elastic behaviour of concretes made of recycled-concrete coarse aggregates. The recycled aggregate were pre-soaked in water for 24 hours to decrease the water absorption rate. It was observed that compressive strengths after 28 days of wet curing resulted 8% lower when finer coarse instead of coarse recycled fraction was used. The authors concluded that the correlation between elastic modulus and compressive strength of recycled-aggregate concrete was found that 15% lower elastic modulus is achieved by using 30% recycled aggregates. Finer coarse recycled-concrete aggregate is having lower shrinkage strains especially for earlier curing times. Nijad I. Fattuhi [4] et. al.,studied the shrinkage of concrete exposed to hot and arid climate. A long-term investigation was done on the drying shrinkage of concrete which is exposed to natural weather conditions. They considered 52 concrete mixes and the prisms which were exposed to natural weather after 28day of laboratory curing (water and/or air curing). Adopted water cement ratio of 0.5 and high range water-reducer and retarder were used in different dosage and Silica fume of 10% dosage of weight of cement. They concluded that the addition of silica fume or pulverized fly ash to concrete, at a dosage rate of 10% shows more initial swelling and drying shrinkage than normal concrete. Little practical benefit in respect of drying shrinkage to water cure for more than 6 days for more strains. A.N. Dabhade [5] et. al., studied effect of fly ash on recycle coarse aggregate concrete.They considered the cement replaced with fly ash in 10% and 20% in the production RAC. The compressive strength after 90days curing, RAC100+FA10 is more than RAC100.They also concluded that RAC with 10% fly ash has high compressive strength than normal recycled aggregate concrete.

III. OBJECTIVE AND MATERIALS

3.1. Objective Of The Study

The main objective of the current study is to investigate the drying shrinkage of recycled aggregate concrete produced with and without pozzolanas for the grades RAC 20, RAC 25 and RAC 30.

3.2. Materials Used

A. Cement: Ordinary portland cement (OPC),53 Grade confirming to Indian standard IS: 12269-1987[6]was used in the complete investigation.
B. Fine aggregate: The sand used for this investigation confirms to grading zone-II as per IS: 383-1970 [7]. The specific gravity and fineness modulus of fine aggregate were found to be 2.6 and 2.72 respectively.
C. Coarse aggregate: The natural aggregate and recycled aggregate of size more than 4.75 mm and confirming to IS 383:1980 [7] were used throughout the study.
D. Pozzolanic Material: Fly ash and silica fume were used as pozzolanic material at replacements of 20 and 10% respectively to cement.

IV. EXPERIMENTAL INVESTIGATION

The natural aggregate concrete cubes of grades M20, M25 and M30 were cast, cured for 28 days and crushed using laboratory jaw crusher (Fig.1.) to the required sizes to use them as a recycled coarse aggregate. The feasibility study of recycled aggregate were conducted by testing its physical and mechanical properties. The physical properties such as flakiness and elongation indices, the mechanical properties such as water absorption, Impact value and crushing value of recycled aggregate were determined to identify suitability of recycled aggregate as a replacement to natural coarse aggregate. Three sets of concrete namely, natural aggregate concrete, recycled aggregate concrete without pozzolanas and recycled aggregate concrete with pozzolanas were made to compare the compressive strength and drying shrinkage. Cubes of size 150mmX150mmX 150mm were cast to test its compressive strength and specimen of size 75mm ×75mm ×285mm were cast to test its drying shrinkage. The apparatus for compression testing machine and drying shrinkage were shown in Fig. 2 & Fig. 3. Table 1 & 2 shows the mix proportions of recycled aggregate concrete without pozzolanas and with pozzolanas respectively.

Fig. 1: Laboratory Jaw Crusher

Fig.2.: Compression Testing Machine

Fig.3.: Length Comparator Equipment

Table 1: Mix proportions for Recycled Aggregate Concrete without Pozzolanas

Grade of RAC	% of RAC	Cement (Kg/m3)	Fine aggregate (Kg/m3)	Recycled coarse aggregate (Kg/m3)	w/c ratio	SP (ml/ kg of cement)
RAC 20	100%	300	756	1192	0.4	0.8
RAC 25	100%	300	752	1236	0.4	0.8
RAC 30	100%	330	724	1242	0.38	0.8

Table 2: Mix proportions for Recycled Aggregate Concrete with Pozzolanas

Grade of RAC	Cement (Kg/m3)	Fly ash (Kg/m3)	Silica fume (Kg/m3)	Fine aggregate (Kg/m3)	Recycled coarse aggregate (Kg/m3)	w/c ratio	SP (ml/ kg of cement)
RAC 20	210	60	30	756	1192	0.35	10
RAC 25	210	60	30	752	1236	0.32	10
RAC 30	231	66	33	724	1242	0.32	10

V. RESULTS AND DISCUSSIONS

5.1. Feasibility Study of Recycled Aggregates

The mechanical and physical characteristics of natural aggregate are compared to that of recycled aggregate to determine its suitability. Table 3 represents the results of the tests conducted on both the aggregate which were compared with the values specified in IS codes. The specific gravity of recycled aggregates is lower than natural aggregates and also it decreased with increase in parent concrete strength. The percentage decrease in specific gravity varies from 0.74% to 2.97% and 0.73% to 2.18% from 10mm to 20mm aggregates. It can be observed that the percentage difference of 10mm aggregate is more than 20mm aggregates because of more adhered mortar present in 10mm aggregates.

It is evident from the table that the water absorption of recycled aggregate is higher than the natural aggregate. Comparing 20mm and 10mm aggregates, 20mm aggregates having low water absorption than 10mm aggregates. Recycled coarse aggregate has water absorption of 9 to 10 times and 10 to 12 times higher than natural aggregates of size 20mm and 10mm respectively. The water absorption of recycled aggregate was reduced by pre-soaking them for 24 hours before using them in concrete. From table 3, it can be concluded that the recycled aggregate can be better replaced with the natural aggregate. The test results were well within the limitations specified by IS: 383-1970[9].

Table 3: Physical and Mechanical Properties of Natural and Recycled Aggregate

Properties	Natural Aggregate		Recycled Aggregate made from Grade 20		Recycled Aggregate made from Grade 25		Recycled Aggregate made from Grade 30	
	10mm	20mm	10mm	20mm	10mm	20mm	10mm	20mm
Specific gravity	2.69	2.75	2.67	2.73	2.65	2.7	2.63	2.69
Water absorption (%)	0.5	0.3	5.33	2.98	5.75	3.12	5.83	3.28
Flakiness index	13.96	12.27	14.20	13.30	14.29	13.93	14.19	14.67
Aggregate impact value (%)	25.07	21.65	25.53	34.90	25.48	34.25	24.92	34.13
Aggregate crushing value (%)	25.46	26.46	29.79	42.92	28.66	42.74	27.55	39.55

5.2. Properties of Fresh Recycled Aggregate Concrete

5.2.1. Workability

Fig. 4 & 5 shows the workability of recycled aggregate concrete with & without pozzolonas respectively. It can be seen from figures that the workability of recycled aggregate concrete is lower than natural aggregate concrete and decreases with increase in grades of aggregates in both the cases. Two stage mixing approach was used to obtain similar workability with less water to cement ratio. The slump of recycled aggregate concretes was reduced after two stage mixing and were shown in figures 5.1 & 5.2. It was observed from figures that the slump of recycled aggregate concrete with pozzolanas is more when compared to recycled aggregate concrete without pozzolanas. This might be attributed to the lesser particle size of pozzolanas.

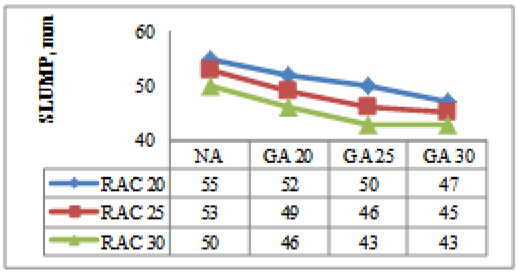


Fig.4.: Slump of recycled aggregate concrete with pozzolanas

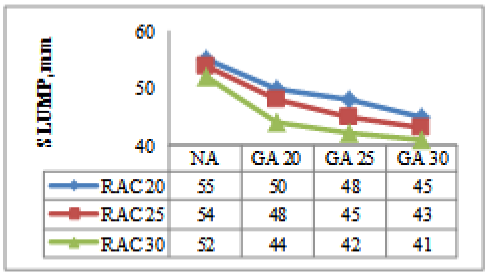


Fig.5: Slump of recycled aggregate concrete without pozzolanas

5.2.2. Density of recycled aggregate concrete

Figures 6 & 7 shows the density of recycled aggregate concretes with and without pozzolanic material. It can be seen from figures that the density of natural aggregate concrete is higher than recycled aggregate concrete. The density decreased with the increase in grade of recycled aggregate which may be attributed to the increase of adhered mortar with increase in grade of recycled aggregate. Further, it was also observed that the density decreased for the concrete made with pozzolanas for all the grades.

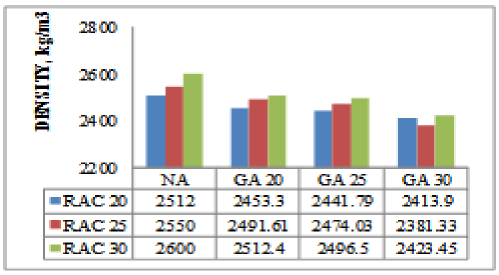


Fig.6.: Density of recycled aggregate concrete with pozzolanas

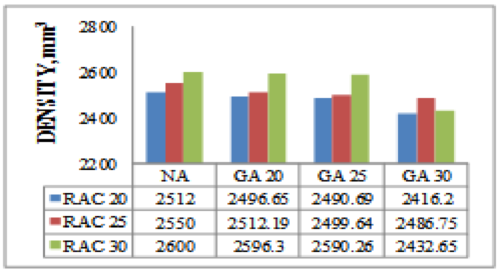


Fig.7: Density of recycled aggregate concrete without pozzolanas

5.2.3. Water absorption of recycled aggregate concrete

Figures 5.5 & 5.6 represent the water absorption of recycled aggregate concretes with & without pozzolanas. It can be perceived from figures that the water absorption of recycled aggregate concrete is higher than natural aggregate concrete. The water absorption increased with increase in grade of recycled aggregate concrete in both the cases. This may be because of higher void content in higher grade of recycled aggregate. The higher water absorption was observed for the concrete made without pozzolanic material. Hence, it can be concluded that higher is the grade of recycled aggregate, higher is the water absorption.

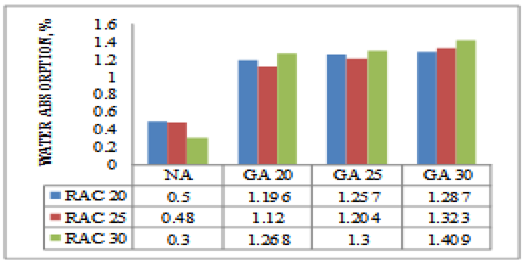


Fig.8: Water absorption of recycled aggregate concrete with pozzolanas

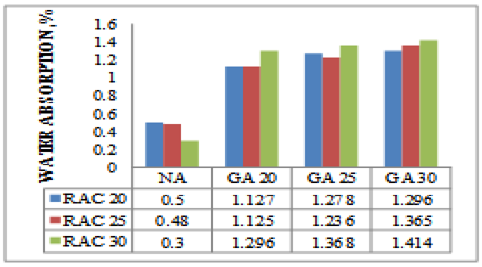
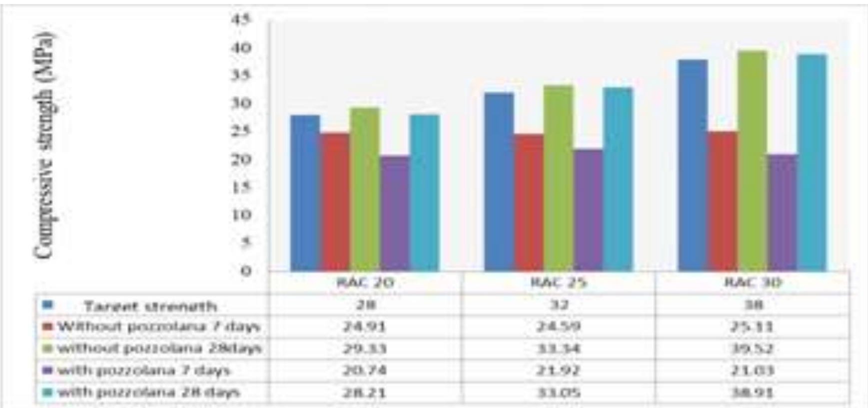


Fig.9: Water absorption of recycled aggregate concrete without pozzolanas

5.3. Compressive strength of recycled aggregate concrete

Figure 10 shows the compressive strength of recycled aggregate with & without pozzolanas at 7 & 28 days. The target strength of concretes were recorded as 28, 32 & 38MPa for RAC 20, RAC 25 & RAC 30 respectively. The recycled aggregate concretes with and without pozzolanas were achieved the target strength at 28 days curing. This is in good agreement with V.W.Y.Tam. It was observed from the figure that the compressive strength of recycled aggregate concrete with pozzolanas is less when compared to RAC without pozzolanas. The percentage decrease in strength at 28 days is 3.81, 0.86 & 1.54% for RAC 20, RAC 25 &RAC 30 respectively between RAC without and with pozzolanic material. In recycled aggregates, high porosity, high amount of cracks, high cement mortar remains will affect the mechanical performance of recycled aggregate concrete.



5.4. Shrinkage strains of Recycled Aggregate Concrete

The effects of 100% recycled concrete aggregates with and without pozzolanic materials on shrinkage strains of 7 days and 28 days cured prism concrete specimens were studied under the air dried condition. The results were compared to shrinkage strains of different recycled concretes and different days to the same experimental condition. Fig 11 to 16 shows the variation of shrinkage strains at 7 & 28 days of curing period for recycled aggregate concrete. It is observed that there is a general trend of increase of shrinkage strain with recycled aggregate concrete for all curing periods. It is observed that the adding of pozzolanic in recycled aggregate concrete the decrease of shrinkage strain than the recycled aggregate concrete without pozzolanic materials.

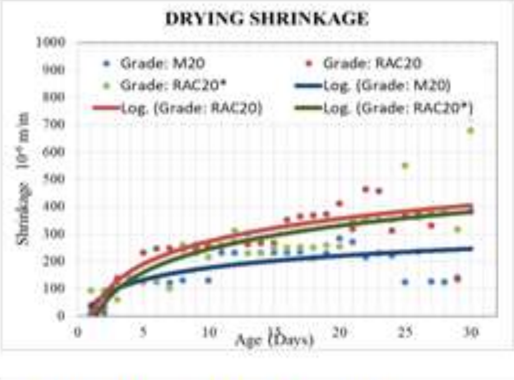


Fig. 11: Shrinkage strains of RAC 20 at 7 days

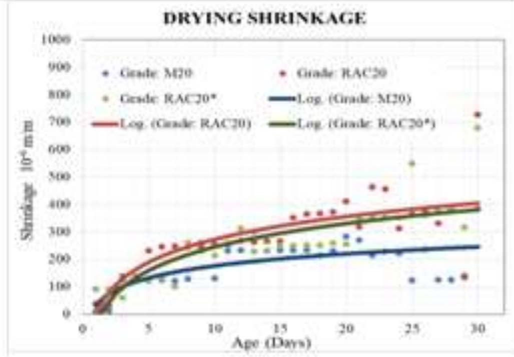


Fig. 12: Shrinkage strains of RAC 20 at 28 days

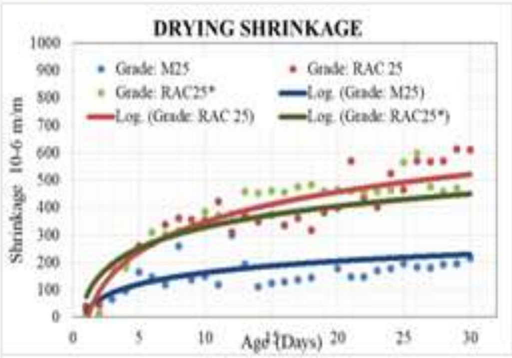


Fig. 13: Shrinkage strains of RAC 25 at 7 days

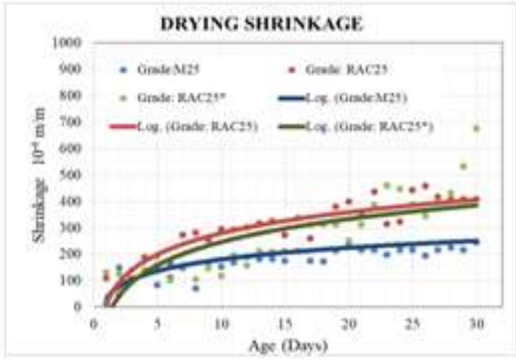


Fig. 14: Shrinkage strains of RAC 25 at 28 days

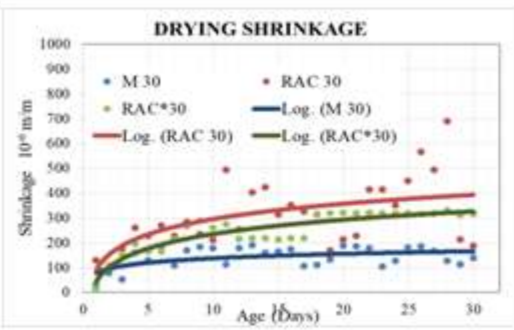


Fig. 15: Shrinkage strains of RAC 25 at 7 days

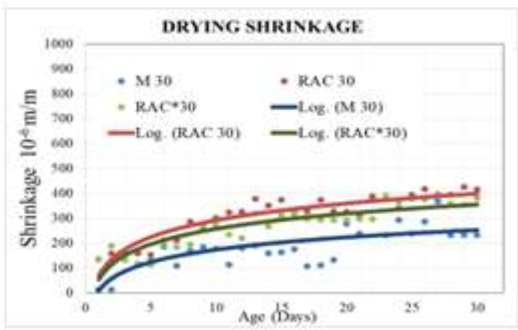


Fig. 16: Shrinkage strains of RAC 25 at 28 days

VI. Conclusions

- The physical and mechanical properties of recycled aggregates are were lower than natural aggregates but are in acceptable limits as per Indian standards. Hence, the recycled aggregate are suitable to replace the natural aggregate to prepare the concrete.
- The workability of recycled aggregate concrete is lower than the natural aggregate concrete. Lower slump values were recorded for the higher grade of recycled aggregate. Further, the recycled aggregate concrete with pozzolanas have higher slump values than the recycled aggregate concrete without pozzolanas.
- The density decreased with the increase in grade of recycled aggregate which may be attributed to the increase of adhered mortar with increase in grade of recycled aggregate. Further, it was also observed that the density decreased for the concrete made with pozzolanas for all the grades.
- Higher is the grade of recycled aggregate, higher is the water absorption for both recycled aggregate concrete with and without pozzolanas.
- The compressive strength of recycled aggregate concrete is lower than natural aggregate concrete. However, the compressive strength of recycled aggregate concretes prepared with 100% replacement of recycled aggregate obtained from pre saturation technique were archived the target strength.

- The shrinkage strains of concrete mixture with natural aggregate were lower than those of concrete mixtures withpozzolanic in recycled aggregate concrete.
- The rate of increase of shrinkage with time is uniform for 100% recycled aggregate concrete with pozzolanic materials, whereas it generally increases than natural aggregate concrete.
- The shrinkage strains of concrete mixtures with natural aggregate concrete and recycled aggregate concrete with pozzolanic materials were lower than those of concrete mixtures without pozzolanic in recycled aggregate concrete.
- The rate of increase of shrinkage with time is uniform for 100% recycled aggregate concrete with pozzolanic materials, whereas it generally increases than natural aggregate concrete.

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