Study of Fresh and Hardened Properties of Concrete Modified with Recycled Concrete Aggregates

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Abstract- Rapid urbanization in the last few decades has led to the ever rising demand of construction materials especially aggregates and mining of these aggregates has led to a strain on the environment and is a concern of rapid ecological damage. Shortfall of construction aggregates is a serious problem and necessitates the use of other recycled aggregates as its replacement. Recycled Aggregates (RA) are obtained from old demolished construction waste and are transported to a landfill site where they are disposed. The expansion of cities in the past decades has not only made landfill sites farther but also at the same time made the transportation of these aggregates costlier. The solution is to use them as a replacement for natural aggregates in concrete mixes. This has the potential to significantly reduce the need for mining new aggregates and also at the same time reduce disposing costs. This paper deals with the study of effect of replacement of Recycled Aggregate Concrete (RAC) in varying proportions on fresh and hardened properties of concrete. Hardened properties considered are compressive strength and split tensile strength of concrete made by replacement in varying proportions of RA. Fresh properties include measurement of slump and rate of strength development by measuring Ultrasonic Pulse Velocity.

Keywords- Recycled; Waste; Aggregates; Compressive Strength; Split Tensile Strength; Ultrasonic Pulse Velocity.

1. INTRODUCTION

With greater emphasis on reducing carbon footprint for construction, recycling concrete from old demolished structures is now coming into practice. It is estimated that close to 16 billion tons of waste concrete is produced approximately every year. Earlier the demolished concrete used to be disposed in landfills which were far off from the cities. Reducing the consumption of energy and raw materials is a major concern for the world at present. The recycling of materials or waste has gained considerable attention in industry over the past few decades. Demolished concrete is becoming popular as replacement for aggregate in new concrete and in mass concreting applications. The use of Recycled Aggregate Concrete or RAC offers considerable potential in the field of waste recycling and also reduces the need for disposal on far off land.

There has been significant research on the use of RAC in last few decades, especially after the world war in Europe, when a number of buildings although new, were badly damaged. Most research shows that the strength of Recycled Aggregate Concrete (RAC) is comparatively weaker than that of conventional concrete made with natural aggregates.

Some researchers have found RAC to be stronger than that of conventional concrete which leaves considerable space to study the strength of RAC. There are many reasons for the varying behavior of RAC primarily due to the origin, strength and proportion of the RAC in the concrete mix. Also, it is difficult to maintain the standard or quality or type of the recyclable waste aggregates being procured.

The use of RAC internationally has led to a large pool of data on the mechanical and durability properties of concrete containing RAC. In many countries, RCA has been found suitable for large-scale non-structural applications such as in the base and sub-base layers of new road pavements, but when used in structural concrete the tendency is to blend RAC with normal aggregates (NA) and to limit the proportion of RAC. The limit varies internationally from 10% to 30% and even up to 45% for specific applications.

Recycled concrete aggregate is a broad term used to denote both fine and coarse aggregate reused in various engineering applications. These aggregates are obtained from a multitude of sources pertaining to industrial waste, construction and demolition waste. The properties of these recycled aggregates vary on many factors such as characteristic strength of old concrete, the size of gravel used, the percentage of sand and gravel fraction in the concrete mix, amount of lime in the sand fraction of the old mix etc. They can be substituted with varying percentages of replacement for fine and coarse aggregates in new mixes. The use of recycled concrete aggregate started early in West but is still not very common in India. The potential of using recycled concrete aggregate as a way to mitigate environmental pollution is tremendous and must be studied in Indian Context.

The various types of recycled aggregates have been broadly classified according to their sources and are put in two broad categories as

a) Industrial waste aggregates which include plastic waste, e-plastic waste, rubber tire waste, mining waste, industrial slag, organic waste, glass, ceramic waste etc. Alternate aggregate materials such as blast furnace slag, glass waste such as fiber glass waste or float glass waste, mining waste such as aggregate particles which are waste can be used in construction industry as a major quantity can directly be used as concrete aggregates. This use of industrial waste aggregates can significantly reduce the cost of waste disposal of the metals industry and at the same time reduce the cost of concrete production.

b) Construction and demolition waste aggregates which include aggregates obtained from existing concrete forms such as building or other structures. These kinds of wastes are obtained from old structures made of reinforced or plain concrete. But it is important to clean the old demolished concrete of impurities such as plastics, organic matter, metals and other impurities before use. The demolished concrete is then processed in a grading machine which separates the matter according to size. Since there is a considerable expenditure in transporting demolished concrete to landfills, using demolished concrete brings down the transportation cost.

The aim of this study is to determine the suitability of using waste concrete aggregates in structural concrete in varying proportions of replacement of coarse aggregates and investigating the hardened and fresh properties of the hence, made RAC.

In this study four types of RAC designated as RAC 0, RAC 30, RAC 60 and RAC 100 was investigated involving replacement percentages of 0%, 30%, 60% and 100% by recycled old concrete to replace Natural Aggregates (NA). The focus of the study is to investigate the suitability of using recycled concrete as replacement of NA in concrete and to find out the optimum level of NA replacement satisfactory for structural applications. The suitability was studied by investigating fresh and mechanical properties of prepared concrete with RA in varying proportions at different ages of curing.

2.0 REVIEW OF LITERATURE

Several investigators have reported the properties of concrete made with recycled aggregates in recent past. Some of the important works and the effect of RA on RAC can be summarized as below:

- Majority of researchers have concluded that RAC has lower density as compared to nominal aggregates. This is due to the presence of mortar on the surface of these aggregates, since the mortar has a relatively high volume of porosity. So in essence, the properties of recycled aggregates are influenced by the type and amount of adhered mortar on their surface. It is important to understand that RA contains not just the hydrated mortar but also nominal aggregates present in the old concrete [1-8].

- Recycled concrete aggregates are used both as replacement of coarse and fine aggregates. Most of the researchers have concluded that recycled concrete has low specific gravity and high water absorption [1-11].

- Topcu [2-3] reported that Los Angeles abrasion percentage and crushing values are also much higher compared to nominal aggregates.

- Workability of recycled concrete aggregate is low compared to concrete produced from nominal aggregates. The reason for this could be attributed to the presence of lime on the surface of the concrete aggregates which absorbs water.

- Hansen [1] stated that the weakest link in recycled aggregate concrete is the adhered mortar during the crushing of concrete. The use of recycled fine aggregates in concrete does not affect the strength of the new concrete much but has a considerable influence over the workability of the mix.

- Katz [5] investigated the properties of concrete made with recycled aggregate from partially hydrated old concrete and studied the resulting properties of new concrete made with these recycled aggregates. The results indicated that concretes made with 100% recycled aggregates were weaker than concrete made with natural aggregates at the same water to cement ratio. When the new concrete was made from the same type of OPC and the same w/c as the old concrete, the strength reduction was up to 25% regardless of the crushing age of the old concrete. Other properties such as flexural and splitting strengths, absorption, drying shrinkage and depth of carbonation exhibited similar trends.

- Topcu and Sengel [9] investigated the physical and mechanical properties along with freeze-thaw durability of recycled aggregate concrete produced with waste concrete aggregate. While experimenting with fresh and hardened concrete, mixtures containing recycled concrete aggregates in amounts of 30%, 50%, 70% and 100% were prepared. The results indicated that specific gravity of RAC's was lower than that of natural aggregates. It was also found that the water absorption ratio was much higher for recycled aggregates. Compressive strength decreased in both control concrete and concrete with RAC in parallel to w/c ratio. The major point reported was that workability of concrete significantly reduces when proportion of recycled aggregate in the mix exceeds 30% conventional concrete to maintain the same slump without the use of admixtures. This affects the quality and strength of the concrete, resulting in lower concrete strength.

- Tsung-Yueh et al. [12] studied the properties of HPC with recycled aggregates and examined the properties of HPC produced from recycled aggregates originating from demolished construction wastes.

- Etxeberria et al. [13] investigated the influence of amount of recycled coarse aggregates and production process on properties of recycled aggregate concrete. They investigated four different recycled concretes made with 0%, 25%, 50% and 100% of recycled coarse aggregates. The mix proportions of the four concretes were designed in order to achieve the same compressive strengths. The results indicated that absorption capacity and the humidity level of recycled aggregates must be considered for concrete production. The humidity content in recycled coarse aggregates must be high and they should be used in concrete production with little absorption capacity in order to produce controlled quality concrete. In addition to this, concrete made with 100% recycled coarse aggregates has 20-25% less compression strength than conventional concrete at 28 days with same w/c ratio. Medium compression strength (30-45 MPa) concrete made with 25% of recycled coarse aggregates achieves the same mechanical properties as that of conventional concrete having the same w/c ratio.

- Tabsh and Abdelfatah [14] studied the influence of recycled concrete aggregates on strength properties of concrete. The focus of the study was to investigate the quality of crushed old concrete and determine the factors that influence the compressive and tensile strengths of concrete. The results indicated that the percentage loss in compressive or tensile strength due to the use of recycled concrete aggregate is more significant in a weak concrete than in a strong one. The authors also reported that the use of coarse aggregate made from recycled concrete with strength equal to 50MPa will result in concrete compressive and tensile strengths comparable with that achieved when using natural coarse aggregate. Recycled concrete mixes require more water than conventional concrete mixes.

- Kou Shi-Cong et al. [15] drew a **c**omparison of natural and recycled concrete aggregates prepared with addition of different mineral admixtures and performed a systematic study on the effect of different mineral admixtures in the strength, drying shrinkage, chloride ion penetration and UPV of recycled concrete aggregate. In the concrete mixtures the replacement levels of cement were chosen at 10% silica fume, 15% metakaoline, 35% fly ash and 55% GGBS. The different mixes were subjected to destructive tests (compressive and tensile splitting tensile strength test), drying shrinkage tests, chloride ion penetration tests and UPV tests. The results indicated that the compressive strength of concrete containing recycled aggregate at 1, 4,7,28 and 90 days was lower than that of the control specimen, but could be compensated by the use of 10% silica fume or 15% metakaoline. However, it was reported that the use of 30% fly ash or 55% GGBS lowered the strength. The tensile splitting strength of natural and recycled aggregate concrete made with SF and MK was higher than that of the corresponding concrete at all test ages, whereas fly ash and GGBS decreased the tensile splitting strength of the concretes. The test results show that SF and MK can improve both mechanical and durability properties of recycled aggregate concrete. The results show that the contributions of the mineral admixtures to performance improvement of recycled aggregate concrete are higher than that of natural aggregate concrete.

- Paul [16] also investigated the mechanical behavior and durability performance of concrete containing Recycled Concrete Aggregate with varying proportions of RAC. RAC replacement percentages of 0%, 30% and 100% to partially replace natural aggregate (NA) in concrete were tested at different ages. Cube strength classes 30-40 MPa concrete were made to investigate the mechanical properties of RAC. Creep, shrinkage and durability properties were also tested for concrete with 0% and 30% RAC replacement of NA. It was found that RAC replacement by 30% (RAC30%) of NA does not lead to any significant difference in strength and stiffness compared to concrete containing 100% NA in concrete. RCA100% replacement does show reduced strength and stiffness, but this is not significant and can be compensated for in standard ways. Durability index tests indicated similar durability performance of concrete with reasonable quality RAC30% compared with NA100%. Increased creep was however observed for RAC30% which must be considered in structural design.

The literature of the last decade shows that recycled waste concrete aggregates can be used an effective replacement of normal aggregates in varying proportions.

As outlined, different sources of waste aggregates give different results hence; the objective of this study is to find out optimum replacement percentage of recycled old concrete in making new concrete to prepare RAC. The waste concrete aggregates used are procured from M50 cubes which were at least 56 to 90 days old.

3.0 EXPERIMENTAL INVESTIGATIONS

3.1 Preparation of RAC and Test Program

RAC was procured from M50 cubes which were at least 56 to 90 days old. M 50 cubes were broken down by hammering and then the aggregates were made to pass through the following set of sieves. 20mm-12mm-10mm-4.75mm-Pan.For choosing 20 mm aggregates, the criterion was passing through 20mm and retained on 10mm IS sieve. For 10 mm aggregates, the criterion was passing through 10 mm sieve and retained on 4.75mm IS sieve. The RAC were hence, kept and named as RAC 20 and RAC 10 for replacement of 10mm and 20mm sized coarse aggregates to be replaced in concrete.

The experimental program is divided into two phases:

i) Hardened Properties: The test specimens were subjected to compressive strength and split tensile strength testing to determine the effect of using waste concrete aggregates in increasing proportions on the strength of the prepared concrete. Standard Cubes of 150mm size are cast and tested after 3, 7 and 28 days of curing on UTM for compressive strength test. For split tensile strength testing, standard cylinders of 150mmm diameter and 300mm height are cast and tested after 3, 7 and 28 days of curing by placing it horizontally in UTM.

ii) Fresh properties: The test specimens were subjected to the slump and Ultrasonic Pulse Velocity measurements (UPV) measurements. For UPV measurements, TICO- model ZI 10006 was used.

The test program involves preparation of four mixes with varying proportions of 30%, 60% and 90% as replacement of coarse aggregates The emphasis of the testing is to compare the results of compressive strength, split tensile strength, slump and ultrasonic pulse velocity of the mixes with varying replacements of coarse aggregates to prepare RAC and determine the optimum dosage.

3.2 Materials Used

Following were the stipulations for mix design:

a) Grade designation : M 25
b) Type of cement : OPC 43
c) Type of mineral admixture : Fly ash
d) Maximum nominal size of aggregate : 20 mm
e) Minimum cement content :320kg/m^3

The mix design for control mix was prepared according to IS Code Mix Design procedure and is outlined in **Table 1** below. **Table 2** gives the quantities for various mixes with varying replacements of NA.

Table 1: Mix Design Proportions for Control Mix (RAC0)

Target Strength	M25
Cement	267 kg/m^3
Fly Ash	67 kg/m^3
Water	160 kg/m^3
Sand	717 kg/m^3
Aggregates (20 mm)	642.95 kg/m^3
Aggregates (10 mm)	526.05 kg/m^3
% Admixture	3.34
% of super plasticizer	1 %
w/c	0.48

3.3 Accelerated Curing Test according to ASTM C684-99(2003)

The accelerated curing test procedures provide, at the earliest practical time, an indication of the potential strength of a specific concrete mixture. These procedures also provide information on the variability of the production process for use in quality control. The accelerated early strength obtained from any of the procedures in this test method can be used to evaluate concrete strengths in the same way conventional 28-day strengths have been used in the past, with suitable changes in the expected strength values. Since the practice of using strength values obtained from standard-cured cylinders at 28 days is long established and widespread, the results of accelerated strength tests are often used to estimate the later-age strength under standard curing. Such estimates should be limited to concretes using the same materials and mixture proportions as those used for establishing the correlation.

Table 2: Constituents for various prepared mixes

Property	RAC 0	RAC 30	RAC 60	RAC 100
w/c	0.48	0.48	0.48	0.48
Cement (kg/m^3)	267	267	267	267
Super-Plasticizer (ltr)	1.35	1.45	1.6	1.6
Flyash (kg/m^3)	67	67	67	67
Water (kg/m^3)	160	160	160	160
Sand (kg/m^3)	726	726	726	726
Coarse aggregate (20mm) (kg/m^3)	714	499.8	285.6	0
Coarse aggregate (10mm) (kg/m^3)	476	333.2	190.4	0
RAC 20 (kg/m^3)	0	214.2	428.4	714
RAC 10 (kg/m^3)	0	142.8	285.6	476

This test conforms to ASTM C684-99(2003). Three cubes of the trial mix are cast and put in accelerated curing tank for a period of 24 hours. During the period of 24 hours, steam produced by heating water to boiling temperature in the tank. After 24 hours, the samples are checked for their compressive strength. If the cubes pass this test, the trial mix is selected. **Table 3** shows the ACT values for the control mix prepared.

Table 3: ACT test values

Peak Load (kN)	Absolute stress(N/mm^2)	Average stress(N/mm^2)
451.125	20.05	19.85
480.375	21.35	
408.375	18.15	

For trial mixes the calculated strength given by (1) should be greater than 1.5(Target Mean Strength)

Calculated Strength = Average stress (ACT Test) x 1.64 + 8.09 **(1)**

From **Table 3**, average stress obtained was 19.85 x 1.64 + 8.09 = 40.64 > 1.5 x 25 = 37.5 MPa (OK)

4.0 RESULTS AND DISCUSSIONS

4.1 Hardened Properties

4.1.1 Compressive Strength Results

36 cubes of 150mm size were cast in total for compressive strength testing for testing at 3 days, 7 days and 28 days for each of the four mixes. **Table 4** and **Fig. 1** gives the variation of compressive strength for 3,7 and 28 days of curing for all mixes prepared by replacing with increasing proportions of recycled waste concrete aggragates.

From the compressive strength results, following observations were made:

- At 3 days, it can be seen from the results that RAC 60 and RAC 100 show early strength gain in comparison to control mix. RAC 100 shows significantly higher compressive strength than all the other mixes.

Table 4: Comparison of compressive strength

Mix	Compressive load (kN)			Average Compressive Strength (N/mm^2)		
Curing in days	**3**	**7**	**28**	**3**	**7**	**28**
RAC 0	305.5	410.1	672.3	13.5	19.3	29.3
	309.8	439.5	664.3			
	298.7	454.1	644.5			
RAC 30	349.2	417	660.2	14.7	19.1	29.6
	291.4	460.1	644.5			
	352.6	412.6	694.2			
RAC 60	318.7	510	668.9	14.1	22.9	30.4
	312.4	548.4	701.2			
	321.2	490.2	684.2			
RAC 100	419.8	699.9	801.2	20.7	30.3	34.4
	495.6	650.0	774.5			
	484.4	697.5	746.7			

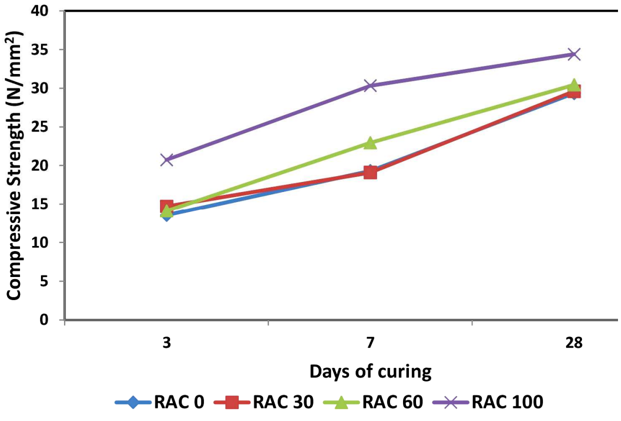

Fig. 1: Compressive Strength Variation of Different Mixes

- At 7 days, all the mixes with replacement of waste concrete aggregates show increased strengths than RAC 0. With the increase in replacemnet percentages, 7 day strength of the resulting mixes increases. RAC 100 shows exceptionally higher strength as compared to the other mixes. But RAC 0, RAC 30 and RAC 60 values show marginal difference.

- At 28 days, all mixes with increasing replacment of waste aggregates show enhanced strengths in comparison to control mixes. But the compression test results indicate highest increase for RAC 100. The percentage increase is about 24% rise for RAC 100, 3.7% rise for RAC 60 and 0.92% rise for RAC 30 as compared to RAC 0.

- Higher strength was attained at all days for RAC 100. It is believed that quicker hardening and setting of RAC 100 caused higher values of strength. Also 3 days compressive strength for RAC 30 was marginally higher. But at 7days 1.1% strength reduction was noticed for RAC 30 when compared with RAC 0. This means that RAC 30 shows a higher early strength development but that after 7 days strength development is very low. This has also been noticed in other mixes. It is important to note here that the average compressive strength of RAC100 had the greatest difference with RAC 0 or NAC.

- It is worth mentioning that **Fig. 1** graphically shows the average 28 day strength of all three types of concrete from different steps, indicating no significant influence of RAC replacement. This can be attributed to the higher quality of the aggregate present in the old concrete which acts just like NAC. Alternatively, it is seen that the strength at the plane between the mortar and RAC was no different from the plane between NAC and mortar. This can also be attributed to a strong bond between the old mortar and new mortar or the lack of presence of much mortar adhering to the surface of the RAC.

4.1.2 Split Tensile Strength Results

Table 5 and **Fig. 2** shows variation in split tensile strength values for all mixes. From the results, following observations are made:

- At 3 days, it can be observed that split tensile strength for RAC 0, RAC 30 & RAC 60 does not differ much in value. RAC 100 value is a lot higher than the other mixes.

- At 7 days, RAC 0 shows lower split tensile value as compared to the other mixes. RAC 100 shows the highest value although there is no significant difference between RAC 60 and RAC 100 values. RAC 30 values are lesser than RAC 60 and RAC 100 is generally greater than the values obtained for RAC 0.

- At 28 days, RAC 100 shows the highest split tensile value. Also, there is not much difference in the values obtained for the other mixes. It is important to note that RAC 30 showed lower value than RAC 0.

- Lower the proportion of RAC in the mix, lower is the split tensile strength. Adding increasing proportions of recycled waste concrete aggregates results in higher split tensile strength values. RAC contributes directly to making the split tensile strength more than that of NAC.

- Average characteristic strength (i.e the strength at day 28) for RAC 100 tends to be 8.5% more, for RAC 60 it tends to be 4% and for RAC 30 it tends to -5.4% less than that of RAC 0 at 28 days.

- It is again important to note here that the average split tensile strength of RAC100 had the greatest difference with RAC0 or NAC. It was also observed that the failure plane for RAC 60 and RAC 100 was at the interface between aggregate and mortar. The reason for this can be attributed to the presence of a higher quality aggregate in the old concrete, somewhat lesser mortar adhering to the surface of this aggregate or a stronger bond between the mortar and natural aggregates of old concrete.

- In the beginning of the experiment it was assumed that splitting strength of RAC 0 would be higher than that of RAC 30, RAC 60 and RAC 100. Lower splitting strengths were confirmed for RAC

30 at 28 days. A possible explanation is the existence of micro-cracks in RAC caused by crushing the old concrete from which the RAC is produced. Also, comparing the fracture surfaces of both RAC0 and RAC 30 showed that most of the failure in RAC0 occurred along the interfaces between the mortar and the aggregate particles. However, in RAC the failure plane goes through or around the aggregates. This type of failure may cause a somewhat more abrupt collapse of the concrete due to the brittleness of the aggregate, which may explain why in some cases RAC is more brittle than NAC.

Table 5: Variation in Split Tensile Strength

Mix	Split Tensile load (kN)			Average Split Tensile Strength (N/mm^2)		
Days of Curing	**3**	**7**	**28**	**3**	**7**	**28**
RAC 0	62.1	82.3	106.1	0.91	1.25	1.85
	67.8	88.8	137.9			
	63.7	94.6	148.9			
RAC 30	67.8	98.2	131.9	0.92	1.47	1.75
	60.0	109.8	104.6			
	69.2	104.5	135			
RAC 60	59.3	111.6	135.8	0.94	1.57	1.92
	66.4	116.5	140.21			
	64.9	105.3	131.2			
RAC 100	77.7	110.3	145.3	1.12	1.59	2.02
	78.3	105.6	140.2			
	82.1	122.4	144.2			

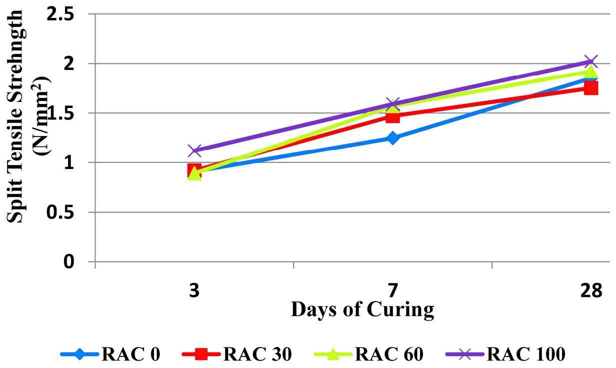

Fig. 2: Comparison of split tensile values for various mixes

4.2 Fresh Properties

4.2.1 Slump variation

- **Table 6** shows the variation in slump values for all different mixes prepared by adding increasing proportions of waste concrete aggregates. It is observed that the slump values decrease with increasing replacement of recycled aggregates. With increasing percentage of waste concrete aggregates, water absorption increases and slump decreases.. RAC 60 and RAC 100 showed zero final slumps.

Table 6: Variation in Slump values for different mixes

Mix	Initial Slump (mm)	Final Slump (mm)
RAC 0	180	126
RAC 30	165	110
RAC 60	155	0
RAC 100	140	0

4.2.2 Ultrasonic Pulse Velocity (UPV)

Fig. 3 shows the variation in UPV values for all the prepared mixes during first 24 hours of pouring concrete. It is an indication of strength development and setting phenomenon of RAC. Following observations are made from UPV measurements:

- It can be clearly seen that RAC 100 has higher readings of ultrasonic velocities as compared to the other mixes. It is because of the maximum absorption of water by the mortar adhereing to the surface of the recycled concrete aggregates present in RAC 100 as compared to other mixes.
- As the proportion of recycled aggregates in the concrete increases, ultrasonic pulse velocities show higher readings in the first 24 hours.
- The UPV values show similar trends as strength test results on the hardened properties.

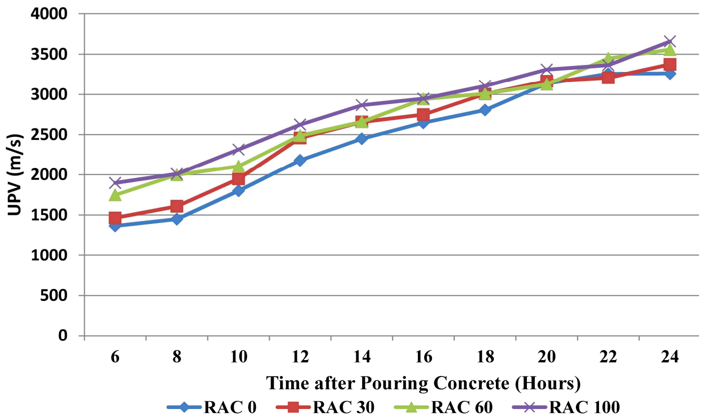

Fig. 3: Comparison of UPV values

5.0 CONCLUSIONS

Following conclusions can be derived from study of strength and fresh properties of concrete made by replacing normal aggregates with recycled old concrete aggregates:

- With increase in the proportion of RAC in the mix, the slump value goes down. This means RAC might have problems in transportation, pumpability and/or workability during structural use in construction. There will be increasing requirements of other additives like Super-Plasticizers (SP) to counteract these problems.

- RAC can successfully be used as a replacement for NCA in concrete without significant difference in the compressive strength values at 28 days. With increasing replacements, higher strengths are obtained. Similar results were obtained for split tensile values at 28 days for all the mixes. With increasing replacements, split tensile strength values were marginally higher.

- Since water absorption of RAC is high, it necessitates the use of a higher measure of super-plasticizers in the mix. Also for the same target mean strength of mix, the water content of a RAC mix would always be higher compared to a NAC mix if SP is not used or is the same.

- RAC requires higher quality control to ensure that waste concrete is free from impurities as much as possible, mixing is done properly and ensure sufficient water availability for the hydration of cement.

- Increasing UPV vlaues with time indicates strength development and setting of concrete.

- UPV values increase with increasing replacment of waste concrete aggregates. It can be clearly seen that RAC 100 has higher readings of ultrasonic velocities as compared to the other mixes.

6.0 SCOPE OF FUTURE WORK

RAC has tremendous potential in developing countries like India. The use of industrial wastes as well construction waste together in a mix and its effects on the strength properties, fresh properties and durability properties proves to be exciting research work in the future. In addition to this, the presence of both kinds of industrial and construction wastes in concrete and their monitoring is essential to develop and enhance their use in concrete. The use of both industrial waste like GGBS, etc and RAC has the potential to eliminate the need for mining new aggregates.

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