COMPARATIVE STUDY OF CONVENTIONAL CONCRETE AND POLYMER MODIFIED RECYCLED AGGREGATE CONCRETE

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ABSTRACT. This paper deals with the durable and sustainable recycled aggregate concrete. In this work detailed experimental investigations carried out on Polymer Modified Recycled Aggregate Concrete (PMRAC) aiming better strength, durable and inert Recycled Aggregate Concrete (RAC) for general use. Generally Recycled Aggregate (RA) has lower values for specific gravity, fineness modulus, aggregate crushing strength, impact value and higher water absorption compared with natural aggregate (NA) substantially the RAC has low strength,low modulus of elasticity,high creep and shrinkage, due to higher porosity and permeability of RA.Suitable Polymer (Styrene Butadiene Rubber – SBR Latex) formulation as an additive in concrete improves the propertiesof RA like reduced porosity, increase water tightness and adhesion resulting the better strength, resilience, chemical resistance and durability of PMRAC. Also strength like compressive, split tensile, flexural and bond of PMRAC withpolymer dosages of 0%, 2%, 5% and 10% are compared with virgin concrete. Utilization of recycled aggregates is widely accepted for pavements and to the some extent for foundation. The use of recycled aggregate can be extended in general construction with utmost constraints and caution.

Keywords: Recycled Aggregate Concrete, Natural Aggregate, Water Cement Ratio, Polymer Modified Recycled Aggregate Concrete

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INTRODUCTION

Buildings are being demolished due to various reasons, like reconstruction, obsolescence, natural disasters, and war-inflicted damages. In many urban areas, concrete aggregates are locally unavailable. There is depletion of natural coarse aggregate reserves. For environmental and other reasons the number of readily accessible sites for debris around cities has decreased. Distance between disposal sites and disposal area has become longer and therefore disposition cost has increased. Very little demolished concrete is currently recycled and is reused elsewhere in the world. The small quantity, which is recovered, is mainly reused in highway construction. The rest is dumped or used for filling. Utilization of recycled aggregates is widely accepted for pavements and to the some extent for foundation. This use of recycled aggregate is being extended for general construction also but with utmost constraints and caution. Even though several studies have been made for recycled aggregate concrete, most of earlier studies on recycled concrete have adopted only nominal mixes. Properties of Recycled aggregates produced in factories would be quite different from those obtained by crushing the parent concrete manually or through a jaw crusher. Recycled aggregates are the future aggregates.

In this work an investigation is carried out for Polymer-Modified Recycled-Aggregate-Concrete (PMRAC) to produce Recycled Aggregate Concrete (RAC) with better strength and durability. SBR Latex is milky white colloidal fluid containing 30 to 45 % of rubber, the remainder being mainly water and small amounts of protein and resinous materials. The primary aim of this experimental program was to study the effect of known dosages of polymer (SBR Latexor Monobond2000) on the strength and workability characteristics of RAC and hence its suitability for the construction industry. The properties of PMRAC are advantageous over RAC by compensating the demerits of RAC. Hence, this scope is used to evolve a superior concrete for construction using polymer in recycled aggregates.

The experimental program is carried out for concrete, prepared by using a) natural or virgin aggregatesb) recycled aggregates (RAC) and c) polymer dosages and recycled aggregate (PMRAC).43-grade of OPC cement is used to preparethese three types of concrete.

RESEARCH SIGNIFICANCE

Even though several studies have been made of recycled aggregate concrete, most of earlier studies on recycled concrete have adopted only nominal mixes. Recycled aggregates are the future aggregates. The present study is an attempt to reuse waste concrete as recycled aggregate.The properties of polymer concrete are advantageous for recycled aggregate concrete to compensate demerits of recycled aggregate concrete.

EXPERIMENTAL DESIGN

The aim of an experimental investigation is to studythe effect of SBR Latex on workability and strengthof RAC to discoverappropriate applicationinthe construction industry. Experimental program is divided into two parts i) Aggregate and ii) Concrete testing.

Part-I: Aggregate Testing

The physical and mechanical properties of recycled and conventional aggregates are determine like i) Fineness modulus of fine and coarse aggregates ii) Impact iii) Los Angeles abrasion iv) Specific Gravity v) Crushing vi) Water absorption.

Part-II: Concrete Testing

Concrete testing is carried out on three types of concrete using different material combination like concrete prepared by using i) virgin aggregate ii) recycled aggregate and iii) recycled aggregate and known dosages of SBR Latex i.e. 2%, 5% and 10% by parts weight of cement.

The various tests are performed on the above concrete like i) Workability (slump test) ii) Flexural strength iii) Split tensile strength iv) Compressive strength v) Bond strength vi) Ultrasonic Pulse Velocity. Also the effect on compressive strength of concrete due curing of specimens in5% NaCl solution (corrosive environment).

The recycled aggregates were obtained by crushing the used concrete testing laboratory specimens (waste) in a jaw crusher. Concrete test specimens using 43-grade of OPC two proportions as per mix design are considered i.e.1:1.13:2.65 and 1:1.3:3.04, these proportions are denoted as A and B and results are tabulated in Table 1 to 6 and graphical in figure 1 to 7 format.

MATERIALS

Cement

Table 1 Cement Properties

DESCRIPTION	RESULTS
Setting Time	
Initial setting time	91min
Final setting time	201 min
Compressive strength, N/mm^2	
3 days	32.90 N/mm^2
7 days	46.43 N/mm^2
28 days	57.70 N/mm^2
Consistency	27.5%
Specific gravity	3.15

A comparative test results are of Recycled Aggregate and Natural Aggregate are presented in Table 2 & 3. The former has a high specific gravity, high absorption capacity and low fineness modulus. Resistances to mechanical actions such as aggregate crushing strength, impact value of recycled aggregates are significantly weaker than that of conventional aggregates.

Fine Aggregate

Table 2 Properties of Fine Aggregates

TEST	RESULTS	PERMISSIBLE LIMIT
Specific gravity	2.71	2.55 min.
Water absorption	1.2%	3 % max.
Silt content	3%	< 5%
Fineness modulus	3.68	Between 2.4 to 3.2

Coarse Aggregate

Table 3 Properties of Coarse Aggregates

TEST	NATURAL/VIRGIN AGGREGATE (NA)	RECYCLED AGGREGATE (RA)
Specific gravity	2.62	2.70
Fineness modulus	7.49	5.25
Abrasion test	12.4 %	16.32 %
Water absorption	0.5 %	3.95 %
Impact value	14.37 %	18.57 %
Crushing test	15.24 %	23.40 %

Styrene-Butadiene-Rubber (SBR Latex)

SBR Latex is the milky white liquid containing from 30 to 45 % of rubber, the remainder being mainly water and a small of protein and resinous materials of specific gravity of 1.05 to 1.10 and viscosity is 300-500 in cps. The SBR Latex dosage of 2%, 5% and 10% by weight with respective weight of cement is used in this study.

CONCRETE MIXING AND SPECIMEN CASTING

The concrete mix of recycled aggregate concrete required pre-soaking of recycled aggregate at least for 10 minutes before adding the other materials, so that aggregates absorb a sufficient quantity of water to avoid the loss of SBR Latexin absorption and reduced the formation polymer matrix (Intermolecular polymer structure) in the concrete.About 300 testing specimens are prepared like cubes, cylinder and beams to perform the various concrete tests.

Water Cement Ratio and workability of concrete

To cater the needs of workability, two separate w/c ratios for both A and B concrete proportions is adopted. Water cement ratio decreases with increase in percentage of polymer.Workability (slump) and w/c ratio values for both proportions are mentioned in Table 4.

Curing

The test specimens with 5 % and 10 % polymer are water cured for initial 3 days and later on air cured for effective polymerization, but the specimens with 2% polymer are insufficient for fast polymerization so, such specimens are water cured for 28 days and later on air cured.

RESULTS AND DISCUSSION

An experimental investigation for part I and II results are elaborated to drawn the conclusions.

Aggregates Testing Results

Specific gravity and water absorption

It is generally observed that, specific gravity of RA is lower than that of NA. But in this case the specific gravity of RA is higher than NA, as the used recycled aggregates are exposed to rain water for three months before its use because of that unhydrated attached old cement particles to the recycled aggregate hydrated resulting higher specific gravity. The water absorption RA is 3.45% higherwater absorption than the natural aggregate, hence, it is necessary to presoak the aggregates before using them for preparing the concrete, for higher specific gravity and to control water-cement ratio Table 2.

Crushing, Impact and Abrasion values

It is in general the mechanical properties recycled aggregate is lower is lower than the natural aggregate. But, in this work the mechanical properties of recycled aggregates are found to be relatively higher than that of conventional aggregates.

Concrete Testing Results

Due to the addition of polymer in recycled aggregates concrete, water demands of mix changes as per polymer percentage. The water demand of recycled aggregate concrete is 8.51% to 28.57% higher than conventional concrete Table.4. Due to lower surface tension in polymer molecules required less water. The water cement ratio for 10% PMRACand conventional concrete is 73.7 % and 46.21 % lower than RAC respectively Table 5.

Table 4 Test Results for A and B Mixes (A-1:1.13:2.65:0.42 and B-1:1.35:2.98:0.47)

TYPES OF CONCRETE	POLYMER CEMENTRATIO OR (%)	W/C RATIO	SLUMP (cm)	DENSITY OF CONCRETE (kg/m^3)
N_A	00.00	0.42	11.0	2696.29
R_A	00.00	0.54	10.5	2666.67
R_{A1}	02.00	0.37	14.0	2755.56

R_{A2}	05.00	0.32	10.0	2766.67
R_{A3}	10.00	0.28	17.0	2755.56
N_B	00.00	0.47	16.0	2696.29
R_B	00.00	0.51	14.0	2686.29
R_{B1}	02.00	0.43	Collapse	2696.29
R_{B2}	05.00	0.36	Collapse	2703.70
R_{B3}	10.00	0.33	Collapse	2755.56

Compressive Strength

The compressive strength of RAC is lower than conventional concrete, the results are presented in Table 5 and Figure 1 and 2. The reduction in compressive strength is about 28 %, 14 % and 19 % at the concrete age of 7, 28 and 90 days, respectively.With increase in dosage of polymer in RAC, (2%, 5%, 10%) there is substantial increase in compressive strength of concrete.

Split Tensile Strength

The split tensile strength of 10 % PMRAC gives a considerable increase in tensile strength than that of RAC, the results are presented in Table 5 and Figure 3 and 4. Polymer addition in RAC builds inter-molecular network in the concrete mass, therefore it strongly binds the aggregates.10% polymer in PMRAC gives 45 % higher split tensile strength than RAC, after 90 days curing.

Flexural Strength Tests

The flexural strength of RAC is very less than conventional concrete, the results are presented in Table 5 and Figure 5 and 6.The flexural strength of 10 % polymer in PMRAC increases by 47 % than RAC, and rise is 19% in period from 28 to 90 days.

Bond Strength Test

The bond between reinforcement and concrete increases with percentage of polymer (*i.e.* polymer -cement ratio), relation between the bond stress (τ_{bd}) for 28 days and the percentage of polymer in RAC is presented in Figure 7 and Table 6.

The proposed equation for bond strength for W/C ratio = 0.42 : τ_{bd}= 10.006+0.2516 (m_p /m_c) ……….……………(1)

The proposed equation for bond strength for W/C ratio = 0.47 : τ_{bd}= 09.5398+0.2628 (m_p /m_c) ……………………(2)

Where,

τ_{bd}= Bond stress in N/mm^2

m_p = Mass of polymer

m_c = Mass of cement

Table 5 Test Results for A and B Mixes (A-1:1.13:2.65:0.42 and B-1:1.35:2.98:0.47)

TYPE OF CONCRETE	AFTER 7 DAYS CURING			AFTER 28 DAYS CURING			AFTER 90 DAYS CURING		
	COMP. (N/mm^2)	SPLIT TENSILE (N/mm^2)	FLEXURAL (N/mm^2)	COMP. (N/mm^2)	SPLIT TENSILE (N/mm^2)	FLEXURAL (N/mm^2)	COMP. (N/mm^2)	SPLIT TENSILE (N/mm^2)	FLEXURAL (N/mm^2)
N_A	28.48	3.29	2.39	38.31	3.81	4.25	44.67	4.29	4.85
R_A	23.67	3.06	1.63	33.13	3.53	2.40	36.98	4.14	2.70
R_{A1}	22.33	3.10	1.70	31.36	3.86	2.48	38.16	4.42	2.81
R_{A2}	21.15	3.15	1.93	34.76	4.28	2.75	39.05	5.03	3.13
R_{A3}	20.26	3.43	2.50	35.94	4.66	3.45	42.90	5.89	4.08
N_B	27.36	2.87	1.97	34.61	3.72	3.15	40.38	4.14	3.50
R_B	20.12	2.30	1.40	31.21	3.53	2.27	34.47	3.81	2.55
R_{B1}	19.23	2.50	1.72	33.00	3.72	2.52	35.95	4.23	2.86
R_{B2}	18.64	2.87	1.94	33.28	4.09	2.79	36.54	4.76	3.27
R_{B3}	18.00	3.20	2.20	34.17	4.19	3.14	41.42	5.55	3.74

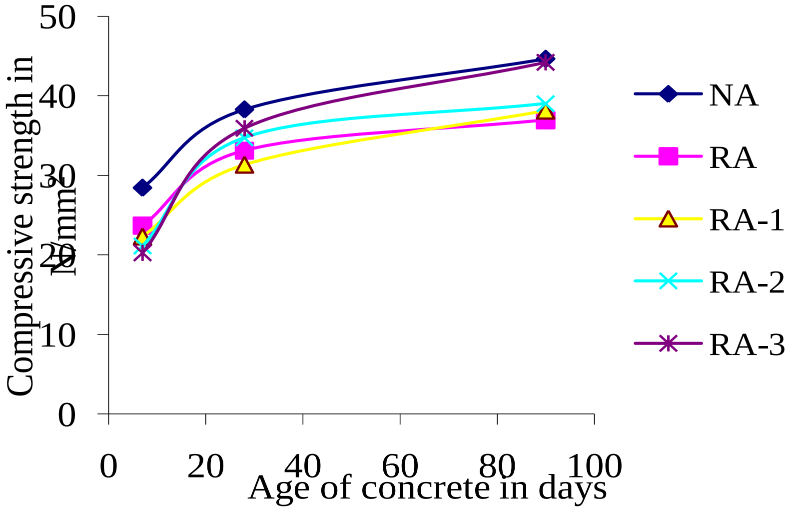

Figure 1 Relation between age of concrete and compressive strength of concrete for A mix

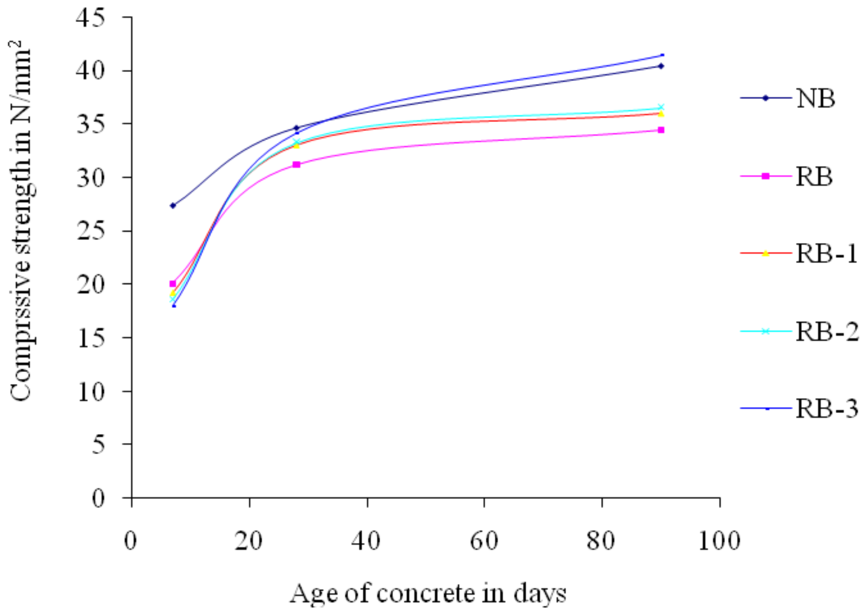

Figure 2 Relation between age of concrete and compressive strength of concrete for B mix

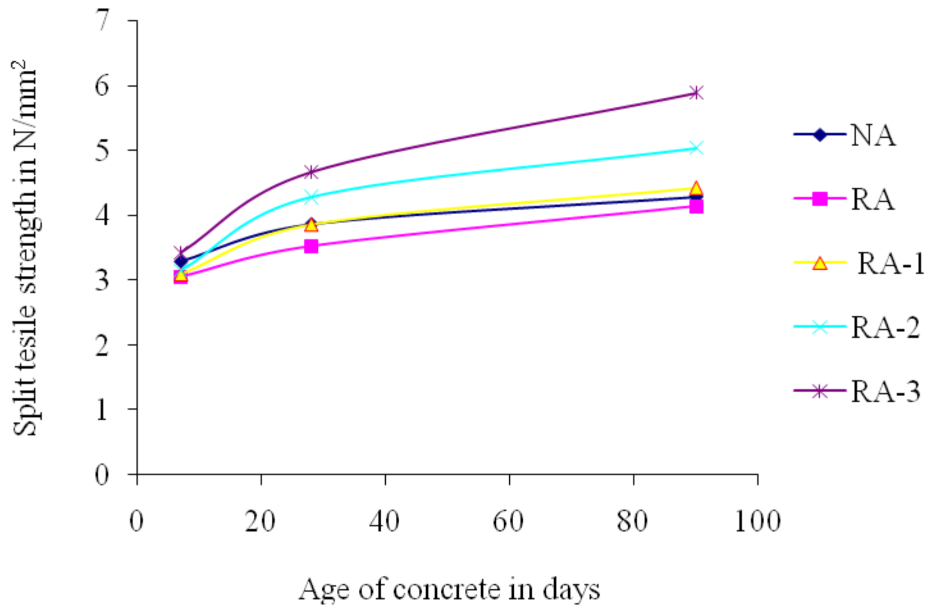

Figure 3 Relation between age of concrete and Split tensile strength of concrete for A mix

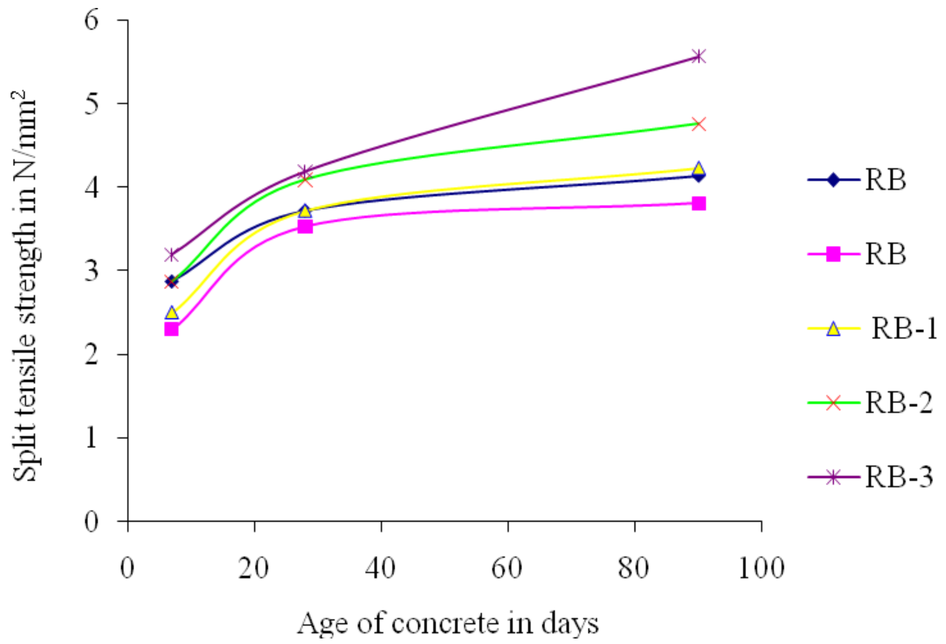

Figure 4 Relation between age of concrete and Split tensile strength of concrete for B mix

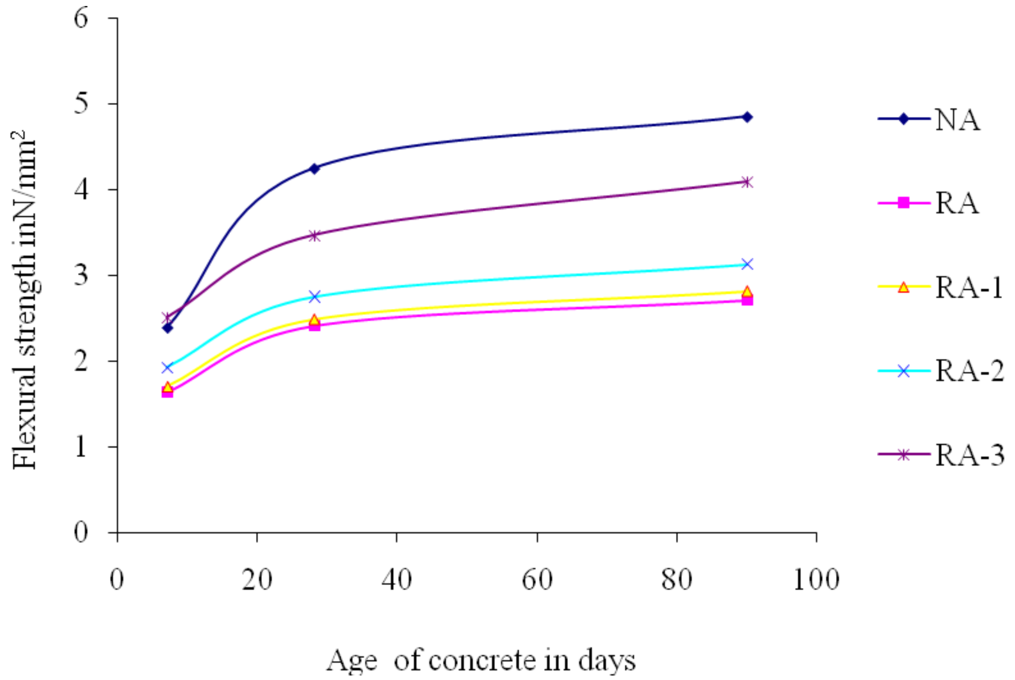

Figure 5 Relation between age of concrete and Flexural strength of concrete for A mix

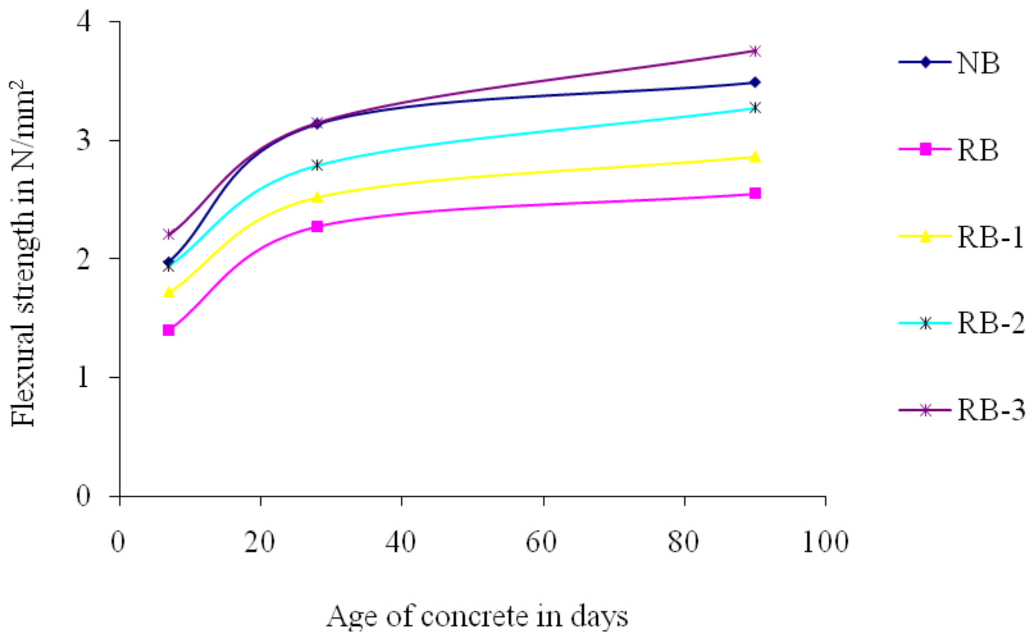

Figure 6 Relation between age of concrete and Flexural strength of concrete for B mix

Table 6 Bond strength Results

IDENTIFICATION OF SPECIMENS	POLYMER / CEMENT (%)	AVERAGE PULL OUT LOAD (N)	BOND STRENGTH (τ_{bd}) N/mm^2
N_A	00.0	37500	11.94
R_A	00.0	31600	10.06
R_{A1}	02.0	33000	10.51
R_{A2}	05.0	35000	11.14
R_{A3}	10.0	39500	12.58
N_B	00.0	20400	06.50
R_B	00.0	29000	09.23
R_{B1}	02.0	32850	10.46
R_{B2}	05.0	34000	10.83
R_{B3}	10.0	38000	12.10

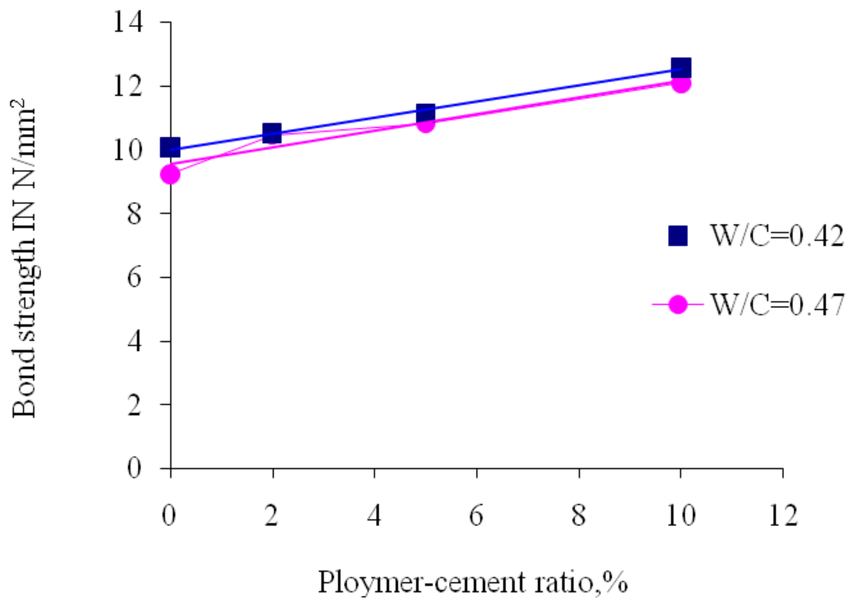

Figure 7 Relation between bond strength and % of polymer for RAC

CONCLUSIONS

- A comparison of Recycled Aggregate and Natural Aggregate shows that the former has high specific gravity, high absorption capacity and low fineness modulus.
- Resistances to mechanical actions such as aggregate crushing strength, impact value of recycled aggregates are significantly weaker than that of conventional aggregates.
- For the same mix, PMRAC has a higher slump than that of conventional concrete. Therefore the addition of polymer improves the workability of recycled aggregate concrete.

- The addition of polymer in recycled aggregate concrete reduces the water demand. As the quality of water reduced ultimately the water cement ratio has a lower value than that of conventional concrete.
- Increase in the compressive strength due the addition of 10% polymer in recycled aggregate concrete.
- Significantly increase in flexural strength and split tensile strength, it is at age of 90 days in PMRAC with 10 % polymer 47% and 45% respectively.
- Bond strength increase in PMRAC with 10 % polymer is about 28 % than that of RAC at the age of 28 days and the variation in bond strength shows linear increment.

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