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# Influence of Polypropylene Fibres on Recycled Aggregate Concrete*

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**Abstract**

This article presents the behavior of Recycle Aggregate Concrete (RAC) with and without addition of Polypropylene (PP) fibers. The natural coarse aggregate was replaced by recycle aggregate in the proportion of 0, 25, 50, 75 and 100%. The Polypropylene fibres (PP) were used in the recycle aggregate concrete by 1 and 2% by volume. In the present experimental study compressive, split and shear strengths were evaluated. The results showed that, the incorporation of PP fibers increases the strengths in RAC. Few Regression Models were deduced to estimate the strengths for RAC with respect to compressive strength.


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*Keywords:* Recycled aggregate; polypropylene fibres; compressive strength; split tensile strength; shear strength; regression models.

## 1. Introduction

Cement concrete is most important material for construction industry. Basically the concrete consists of cement, fine and coarse aggregates, these all mixed with the help of water and also with super plasticizers if it requires as per design requirements. In the present scenario for making concrete very acquit shortage of good quality aggregates. Hence, the concrete or industry people are looking towards alternative material for aggregates. Now days the researchers are focusing on recycle aggregate to establish as an alternative material for aggregates. In the


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past many works have been taken place in concrete area with the help of recycle aggregates. Still many research works are going to improve the properties of RAC with the help of fibre technology. In this concern a few recent past works are presenting herein. Nixon [1] has provided a review on RAC and from the article it is observed that, the compressive strength of RAC was decreased by 20% when compared to conventional concrete. Bairagi et al. [2] concluded that the average relative compressive strength varies from 98 to 94% when the replacement levels were varied from 25% to 50%. For 100% replacement of aggregate, there is decrease in compressive strength about 14%. Oliveira et al. [3] studied the effects of three different moisture conditions for the recycled aggregate, (dry, saturated and semi-saturated) and concluded a slight decrease in the compressive strength of the concrete made from dry saturated recycled aggregates. Otsuki et al. [4] concluded that the improvements in strength of recycled aggregate concrete can be achieved by using the double mixing method in the case of higher water binder ratio concrete. Chakhradhara rao et al. [5] 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 various replacements of recycle aggregate. Rosario Herrador et al. [6] conducted the studies on road works and focused the demolition waste aggregate for surface works. The study concluded that, the use of waste aggregate for road has shown remarkable load bearing capacity. Roland F [7] conducted the experimental studies on concrete with polypropylene fibres( 19mm long) and of acrylic material (10mm long).The results showed as the concrete with fibres have less shrinkage and crack width. Ahsana Fathima K M and Shibi Varghese [8] conducted the experimental work on concrete with addition of PP fibres and their study revealed that, splitting tensile and flexural strengths were increased for 0.5 % of PP addition. M.L.V. Prasad and P. Rathish kumar [9] conducted the research work on concrete with addition of polypropylene fibre and they noticed that, the flexural strength was enhanced by 6.13% and elasticity values decreased with increase in replacements of recycled coarse aggregate. Shreyas. M T et al. [10] obtained a marginal increase in split tensile strength at fibre dosage from 2kg/$m^3$. From the literature it is observed that no studies are conducted on RAC by using PP fibres at higher volume fractions. The present experimental study was planned to evaluate strengths of RAC with PP fibres.

## 2. EXPERIMENTAL PROGRAM

The research program was planned to evaluate compressive, split and shear strengths and also few regression models are to generate for estimating the strengths. Standard size of cubes and cylinders were cast to find compressive, split and shear strengths. Total 45 cubes and 90 cylinders were casted with M20 grade concrete and the mix was designed as per ACI211.1-91(2002) code. In this study five mixes were taken as RAC-0, RAC-25, RAC-50, RAC-75 and RAC-100, for each mix the PP fibres were added at 1 and 2% by volume of specimen. Few samples were (RAC-0 or NAC) taken as control specimens and these were considered for comparison purpose. For each mix three samples were cast and tested. The average strength of three samples was taken as result for each mix. In the nomenclature of the mix, the RAC indicates Recycle Aggregate Concrete and immediate value indicates the % of replacement for natural aggregate with recycle aggregate. NAC can be read as Natural Aggregate Concrete, in further discussion it may consider as control or reference mix. For experimental work the following material were used.

### *2.1 Materials*

*Cement:* Ordinary Portland cement of 43 grade confirming to IS 8112-1989 standards was used to cast the specimens. The specific gravity of cement was noticed as 3.1.

*Fine aggregate*: Nearby available sand from Bhadra River confirming to zone III conforming to IS 383-1970 has been used as fine aggregate. The specific gravity of sand was observed as 2.6.

*Natural Coarse Aggregate:* Crushed natural granite aggregate from local crusher has been used and which has maximum size of 20mm .The specific gravity of coarse aggregate was observed as 2.69.

*Recycled coarse aggregate:* The recycled coarse aggregate was obtained from demolished building wastes. In order to use as graded aggregate, the waste material was crushed in crusher and made as 12.5mm and 20mm aggregate. The specific gravity of the combined aggregate was 2.53.

*Water:* Clean fresh water was used for mixing and curing the specimens.

*Conplast SP-430:* To obtain better workability Conplast SP-430, super plasticizing admixture used in the present work. For the present experimental design work the dosage was varied from 0.6 to 0.9% by weight of cement.

*Polypropylene (PP) Fibres:* In the present work Macro synthetic fibres were used as reinforcement material for concrete. The PP fibres were purchased from Bajaj Reinforcements, Nagpur. The physical properties for these fibres are presented in Table 1. The used material of natural coarse aggregate, recycle aggregate and fibres can be viewed in the figure.1

Table 1: Physical properties of Polypropylene fibres

| Sl. No. | Specification | Description |
|---|---|---|
| 1 | Specific Gravity | 0.91 |
| 2 | Tensile strength | 550-640MPa |
| 3 | Young’s modulus | 6-10GPa |
| 4 | Melting point | 159 to 179$^0$C |
| 5 | Bulk density | 910 kg/m$^3$ |
| 6 | Fibre cut length | 47mm |
| 7 | Physical Form | Fibrillated |

Natural coarse aggregate | Recycle aggregate | Polypropylene fibres

Fig.1: Materials

*2.2 Casting*

The cubes of inner dimensions 150X150X150mm were cast to find out the compression strength of mixes. To evaluate the split tensile strength, cylinders of 150mm diameter with 300mm height were cast. A special ‘Z’ type of cylinders of dimension 150mm diameter and 300mm height were prepared to find the shear strength. The proportions for various mixes were evaluated for 75 to 100mm slump. The mixes are designed for M20 grade concrete. Soujendra Kumar Reddy [11] has made attempts to design the M20 concrete with various codes and he found that ACI code gave better results than other codes. Hence herein the ACI code procedure was adopted with target strength as 26.56 N/mm$^2$. The Table 2 gives the mix proportions for various mixes. The proportions are varying for each mix due to variation of properties such as specific gravity, dry rod density etc

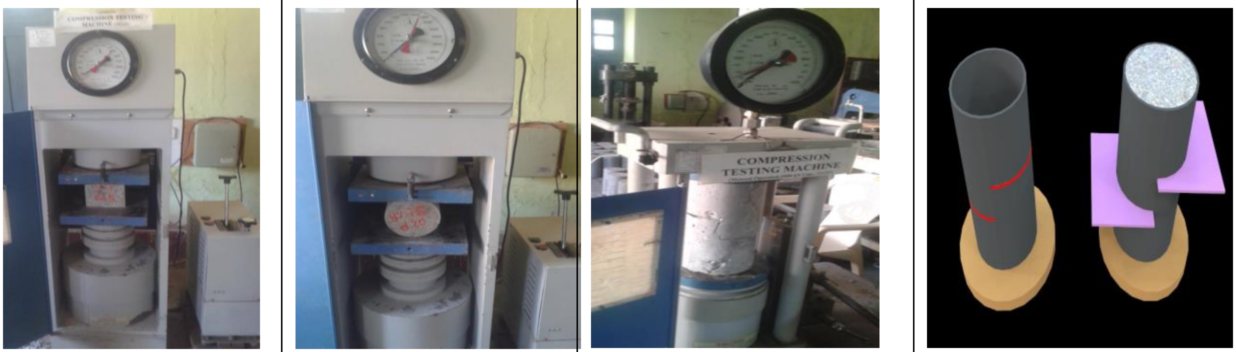
All materials were weighed as per mix design separately. The cement, sand, natural coarse aggregate and recycled coarse aggregate were dry mixed in pan mixer thoroughly till uniform mix is achieved. Required quantity of water is added to the dry mix along with super plasticizer. The fresh concrete was placed in the mould and the compaction was adopted by mechanical vibrator. The specimens were removed from moulds after 24 hours and placed in water tank for 28 days curing. After a period of 28 days the specimens were taken out and allowed to dry under shade, later the specimens are allowed for testing.

Table 2: Mix proportions per cubic meter of concrete

| Sl. No. | Mix | Cement (Kg) | FA (kg) | NCA (kg) | RCA (kg) | Water (Litres) | SP (Litres) | Mixing ratio |
|---|---|---|---|---|---|---|---|---|
| 1 | RAC-0 | 363.64 | 838.27 | 915.37 | --- | 200.00 | 0.000 | 1 : 2.31 : 2.52 |
| 2 | RAC-25 | 357.14 | 842.10 | 225.00 | 675.00 | 197.56 | 0.091 | 1 : 2.36 : 2.52 |
| 3 | RAC-50 | 333.33 | 917.50 | 417.06 | 417.06 | 197.33 | 0.098 | 1 : 2.75 : 2.50 |
| 4 | RAC-75 | 333.33 | 924.15 | 613.45 | 204.48 | 197.00 | 0.111 | 1 : 2.77 : 2.45 |
| 5 | RAC-100 | 333.33 | 962.28 | --- | 777.08 | 196.67 | 0.123 | 1 : 2.89 : 2.33 |

*2.3 Test set up and testing*

The cubes and cylinders were tested as per IS 516-1959 and IS 5816-1999 to obtain compressive and split tensile strengths respectively. Special ‘Z’ type specimens (figure 2) with inner dimensions of 150mm diameter and 300mm height have been used to determine the shear strength. The typical shear strength testing of mould is as shown in figure 2. The specimen was tested with manual operated compression testing machine of capacity 1000kN. The failure load was noted and the corresponding shear strength was calculated ( shear stress = failure load / shearing area). The tested specimens can be viewed in figure 2.




| Compression test | Split tensile test | Shear test | Shear specimen mould |
|---|---|---|---|

Fig.2: Testing of specimens

## 3. DISCUSSION OF TEST RESULTS

*3.1 Experimental results:*

*3.1.1 Compressive Strength:*

The test results of the cube compressive strength are presented in Table 3. From the Table it is observed that the compressive strength of RAC without PP fibres is in the range of 33 to 17N/mm$^2$. The compressive strength was increased at 25% replacement. At this stage the compressive strength is more than the other mixes including natural aggregate concrete (NAC or RAC-0). In general the natural aggregate concrete shows more results than the RAC. But here it showed lesser value, it may be due to super plasticizer effect. In this work for NAC super plasticizer is not used and also the water content is more. From 50 to 100% replacement of RA the strength decreases about 25 to 40%. The reason may be the bond between RAC and cement mortar (it may forms weak links). This type of observation was made by Rasheeduzzafar and Khan [12]. From the review paper of Torben C Hansen [13], it is observed that, there is strength decrement about 8-24% recycled aggregate concrete. The design strength of NAC mix is 20 N/mm$^2$. The replacement level of RA at 50% showed the 20.74MPa. Hence it is viable to use RAC up to 50% replacement without affecting the required strength. The compressive strength of RAC with PP fibres is in the range of 18 to 37% for 1% and 2% volume of fibres. As the percentage of fibre increases, compressive strength increases. This value coincides for 0% and 1% of PP fibre RAC at 50 and 75% replacement respectively. But RAC with 2% fibre up to 100% replacement of RA is permitted. The increase in compressive strength of RAC with PP fibre may be due to good bond strength between the surfaces of fibre and cement paste. The PP fibres have tuff feature embossed surface, due to this, the bond may enhance for the matrix. Sudheer Jirobe et. al [14] reported same trend of increase in compressive strength from 10.75% to 33.79% with increase in PP fibre of 0.5% to 1.5% respectively for natural aggregate concrete.

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*3.1.2 Split Tensile Strength:*

The split tensile strength test results are presented in Table 3. From the results, it is observed that as the % of RA content increases the tensile strength increases up to 25% then decreases. The % of decrease is about 7 to 33% for 50 to 100% replacement of RA. The split tensile strength of RAC with PP fibres is increases as % of PP fibre volume increases. The percentage of increment for 1% fibre is 35 to 60%, for 2% fibre is 66 to 125% when compared to reference mix. The increment in strength may be due to presence of PP fibres in the interfacial transition zone. The PP fibre rough surface produces good bond in the matrix of the mix. During application of load, the stress transfer may takes place in the matrix through the fibre and also the fibres have good adhesive nature with the concrete, so that it may not debond easily and also it takes more energy to failure. Shreyas M.T. et. al., [10] also reported marginal increase in split tensile strength with increase of PP fibre from 2 kg/m$^3$ to 4 kg/m$^3$ for fly ash blended self compacting concrete. During the experimentation it is observed that the concrete cylinders with PP fibres did not split in to two pieces after attaining the failure load. This may be due to the PP fibres may act as bridge between the two fractions.

*3.1.3 Shear Strength:*

The shear strength results are presented in Table 3. From the results, it has been observed that as percentage of RA content increases the shear strength increases up to 25% then decreases as RA content increases. G. Ghorpade [15] reported decrease of shear strength with increase of RA from 2.9 to 10.1%. This may be due to the recycled aggregates being more porous than the natural aggregates. This increased porosity may lower the bond strength between aggregate and cement paste thus leading to the loss of strength. The shear strength of RAC with PP fibres is increasing as percentage of PP fibre volume increases. The percentage of increment for 1% fibre is 10 to 20% and for 2% fibre is 17 to 38% when compared with reference mix. The increment in strength is due to effective interfacial transition zone, the rough surface of PP fibres causes stronger links between the fibre and concrete mass. Vaishali and H.Sudharshana Rao [16] founded higher shear strength values for concrete with PP fibres dosage 0.5% and 1.25% is about 15 to 40% respectively.

Table 3: Test Results

| Sl. No. | Mix | Compressive Strength (N/mm$^2$) | | | Split Tensile Strength (N/mm$^2$) | | | Shear Strength (N/mm$^2$) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0% PP Fibres | 1% PP Fibres | 2% PP Fibres | 0% PP Fibres | 1% PP Fibres | 2% PP Fibres | 0% PP Fibres | 1% PP Fibres | 2% PP Fibres |
| 1 | RAC-0 | 27.85 | 28.59 | 30.52 | 1.51 | 2.41 | 3.40 | 5.56 | 6.67 | 7.22 |
| 2 | RAC-25 | 32.88 | 36.89 | 37.33 | 1.98 | 2.69 | 3.58 | 6.85 | 7.78 | 8.04 |
| 3 | RAC-50 | 20.74 | 25.03 | 30.07 | 1.84 | 2.31 | 3.06 | 6.48 | 7.41 | 7.56 |
| 4 | RAC-75 | 17.33 | 18.96 | 23.41 | 1.65 | 2.26 | 2.88 | 5.56 | 6.11 | 7.15 |
| 5 | RAC-100 | 17.03 | 19.70 | 23.11 | 1.32 | 1.78 | 2.45 | 4.07 | 5.63 | 5.63 |



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*3.2 Comparison of test results with earlier research works:*

*3.2.1 Compressive Strength:*

From the literature work of Katrina McNeil and Thomas H K Kang [17], it is observed that the compressive strength of RAC decreases with the increases of RA content. In the similar lines, N. Venkata Ramana et. al., [18] proposed the equations to estimate compressive strength in terms of % RAC for the varying percentages of Polyethylene Terephthalate (PET) fibres. Here it would like to test the applicability of given equations for present work, so the quoted equations are furnished below:

$f_{ck}$ = 33.30 – 0.050(%RAC) -------------- for 0% PET fibres

$f_{ck}$ = 30.00 – 0.045(%RAC) -------------- for 1% PET fibres

$f_{ck}$ = 22.38 – 0.030(%RAC) -------------- for 2% PET fibres

$f_{ck}$ = 28 days cube compressive strength in N/mm$^2$

The present experimental results are tested with the above equations and the obtained results are presented in Table 4. From the results it is observed that the proposed equations are not fit well, because the variation of strength is about 40 to 50%. So from this it is understood that, the equations are not advisable to estimate the present results. Hence, in this aspect, it is to decide to evaluate some regression models to suit the experimental results. A statistical regression is established with the correlation co-efficient $R^2$ is 0.844 and standard deviation is 3.2 and it is presented below.

$f_{ck}$ = 35.21 + 3.24 (%PP) - 0.211(%RAC)

$f_{ck}$ = 28 days cube compressive Strength in MPa.

% RAC = percentage of recycle aggregate content in the mix.

% PP = percentage of Polypropylene Fibres.

The experimental (EXP) and regression model (RM) analysis results are presented in Table 4. From the results it is observed that the ratio EXP/RM is about 0.84 to 1.21. This indicates that the proposed regression model is suited to experimental values.

Table 4: Compressive Strength

| Sl. No | Mix | EXP Compressive strength (N/mm$^2$) | N. Venkata Ramana et. al (N/mm$^2$) | EXP/N. Venkata Ramana et al | Regression Model (RM) (N/mm$^2$) | EXP/RM |
|---|---|---|---|---|---|---|
| 1 | RAC-25 | 32.88 | 32.08 | 1.03 | 29.85 | 1.10 |
| 2 | RAC-50 | 20.74 | 30.83 | 0.67 | 24.57 | 0.84 |
| 3 | RAC-75 | 17.33 | 29.59 | 0.58 | 19.29 | 0.90 |
| 4 | RAC-100 | 17.03 | 28.33 | 0.60 | 14.02 | 1.21 |
| 5 | RACP1-25 | 36.89 | 28.87 | 1.27 | 33.09 | 1.11 |
| 6 | RACP1-50 | 25.03 | 27.75 | 0.90 | 27.82 | 0.90 |
| 7 | RACP1-75 | 18.96 | 26.62 | 0.71 | 22.54 | 0.84 |
| 8 | RACP1-100 | 19.70 | 25.50 | 0.77 | 17.27 | 1.14 |
| 9 | RACP2-25 | 37.33 | 21.63 | 1.72 | 36.33 | 1.03 |
| 10 | RACP2-50 | 30.07 | 20.88 | 1.44 | 31.06 | 0.97 |
| 11 | RACP2-75 | 23.41 | 20.13 | 1.16 | 25.78 | 0.91 |
| 12 | RACP2-100 | 23.11 | 19.38 | 1.19 | 20.51 | 1.13 |

*3.2.2 Split Tensile Strength:*

In practical applications, many codes suggests that, the tensile strength of concrete is often estimated from the compressive strength. Here in ACI 318-M-11 code and Chinese codes (GB 50010-2002) are taken for estimating the split tensile strength in terms of compression. Though the codes specified equations are fit for conventional concrete. But the present work is pertaining to recycled aggregate concrete (RAC). However, it would like to test the equations for suitability of present results. So the ACI and GB code equations are expressed below.

$f_{sp}=0.49\sqrt{f_{ck}}$-----------------------------------As per ACI

$f_{sp}=0.19(f_{ck})^{0.75}$-------------------------------As per GB

$f_{ck}$ = 28 days cube compressive strength in N/mm$^2$
$f_{sp}$ = 28 days split tensile strength in N/mm$^2$
The experimentally obtained compressive strength results are incorporated in the equations and the output values are presented in Table 5. Here also the results are varying about 40%.Hence the available equations are not made good agreement with the present results. Hence, it is decided to develop a regression model. To improve the equations suggested by various researchers, a regression analysis was performed to the obtained test results and the following regression equations are deduced with correlation coefficients $R^2$ as 0.8, 0.82 and 0.93 with SD as 0.18, 0.215 and 0.19 for 0%, 1% and 2% PP fibres RAC respectively.
$f_{sp} = 0.3643\sqrt{f_{ck}}$---------------- for 0% PP RAC
$f_{sp} = 0.4539\sqrt{f_{ck}}$---------------- for 1% PP RAC
$f_{sp} = 0.5650\sqrt{f_{ck}}$---------------- for 2% PP RAC
$f_{ck}$ = 28 days cube compressive strength in N/mm$^2$
$f_{sp}$ = 28 days split tensile strength in N/mm$^2$
Comparison between the test results and that predicted by proposed equations are presented in Table 5. The ratio between EXP/RM is about 0.88 to 1.15. From this it came to know that the proposed equations are made good agreement with the experimental results.

Table 5: Split Tensile Strength

| Sl. No | Mix | EXP Split tensile strength in N/mm$^2$ | ACI in N/mm$^2$ | GB in N/mm$^2$ | EXP/ ACI | EXP/ GB | Regression Model (RM) (N/mm$^2$) | EXP/ RM |
|---|---|---|---|---|---|---|---|---|
| 1 | RAC-25 | 1.98 | 2.81 | 2.61 | 0.70 | 0.76 | 2.06 | 0.96 |
| 2 | RAC-50 | 1.84 | 2.23 | 1.85 | 0.83 | 1.21 | 1.64 | 1.12 |
| 3 | RAC-75 | 1.65 | 2.04 | 1.61 | 0..81 | 1.02 | 1.49 | 1.10 |
| 4 | RAC-100 | 1.32 | 2.02 | 1.59 | 0.65 | 0.83 | 1.48 | 0.89 |
| 5 | RACP1-25 | 2.69 | 2.97 | 2.84 | 0.91 | 0.94 | 2.73 | 0.98 |
| 6 | RACP1-50 | 2.31 | 2.45 | 2.13 | 0.94 | 1.08 | 2.25 | 1.03 |
| 7 | RACP1-75 | 2.26 | 2.13 | 1.73 | 1.06 | 1.31 | 1.95 | 1.15 |
| 8 | RACP1-100 | 1.78 | 2.17 | 1.78 | 0.82 | 1.00 | 1.99 | 0.89 |
| 9 | RACP2-25 | 3.58 | 2.99 | 2.87 | 1.19 | 1.25 | 3.42 | 1.04 |
| 10 | RACP2-50 | 3.06 | 2.68 | 2.44 | 1.14 | 1.25 | 3.07 | 0.99 |
| 11 | RACP2-75 | 2.88 | 2.37 | 2.02 | 1.21 | 1.43 | 2.71 | 1.06 |
| 12 | RACP2-100 | 2.45 | 2.36 | 2.00 | 1.04 | 1.23 | 2.69 | 0.91 |

*3.2.3 Shear Strength:*

Few studies were noticed in the literature for estimating the shear strength with the co-relation of compressive strength. Here also discussion is made, by taking a few past research works. Ha Ngoc Tuan et al [19] suggested $\tau_c = 0.1f_{ck} + 2.03$. A G Mphonde and G C Frantz [20] suggested the equation: $\tau_c = 1.92(f_{ck})^{0.33} + 0.48$. These relations were deduced for RAC concrete. By using the above equations the obtained values are placed in Table 6. The results are scattered widely and with the range of 10 to 50%. From this, it is understood that, here also a model is required to evaluate shear strength.
To improve the equations of earlier proposed authors, a regression analysis is performed to obtained test results and the following regression equations are deduced with correlation coefficients $R^2$ as 0.75, 0.88 and 0.8 with SD as 0.82, 0.53 and 0.62 for 0%, 1% and 2% PP fibre RAC respectively.
$\tau_c = 1.24\sqrt{f_{ck}}$---------------- for 0% PP RAC
$\tau_c = 1.35\sqrt{f_{ck}}$---------------- for 1% PP RAC
$\tau_c = 1.34\sqrt{f_{ck}}$---------------- for 2% PP RAC
$\tau_c$ = 28 days shear strength in N/mm$^2$
$f_{ck}$ = 28 days cube compressive strength in N/mm$^2$

Comparison between the test results and predicted values by the RM's are presented in Table 6. The ratio between EXP/RM is about 0.8 to 1.14. From this it came to know that the proposed equation has good compatibility with the experimental results.

Table 6: Shear Strength

| Sl. No | Mix | EXP Shear strength (N/mm$^2$) | Ha Ngoc Tuan et al (N/mm$^2$) | A G Mphonde (N/mm$^2$) | EXP/ Ha Ngoc Tuan et al | EXP/ AG Mphonde | Regression Model (N/mm$^2$) | EXP/ RM |
|---|---|---|---|---|---|---|---|---|
| 1 | RAC-25 | 4.44 | 7.62 | 6.55 | 0.58 | 0.68 | 7.11 | 0.96 |
| 2 | RAC-50 | 4.42 | 5.55 | 5.70 | 0.79 | 0.77 | 5.65 | 1.15 |
| 3 | RAC-75 | 4.27 | 4.98 | 5.40 | 0.86 | 0.79 | 5.16 | 1.08 |
| 4 | RAC-100 | 4.07 | 4.93 | 5.37 | 0.82 | 0.76 | 5.12 | 0.80 |
| 5 | RACP1-25 | 4.07 | 8.30 | 6.79 | 0.49 | 0.59 | 8.19 | 0.95 |
| 6 | RACP1-50 | 4.07 | 6.28 | 6.04 | 0.64 | 0.67 | 6.75 | 1.09 |
| 7 | RACP1-75 | 3.89 | 5.25 | 5.55 | 0.74 | 0.70 | 5.87 | 1.03 |
| 8 | RACP1-100 | 3.72 | 5.38 | 5.61 | 0.69 | 0.66 | 5.98 | 0.93 |
| 9 | RACP2-25 | 3.55 | 8.37 | 6.82 | 0.42 | 0.52 | 8.18 | 0.98 |
| 10 | RACP2-50 | 3.54 | 7.14 | 6.38 | 0.49 | 0.55 | 7.34 | 1.03 |
| 11 | RACP2-75 | 3.54 | 6.01 | 5.92 | 0.58 | 0.59 | 6.48 | 1.10 |
| 12 | RACP2-100 | 3.36 | 5.96 | 5.89 | 0.56 | 0.57 | 6.44 | 0.87 |

## 4. CONCLUSIONS

The following conclusions are made from the present experimental work.

- Use of recycle aggregates in the mix up to 50% is viable for construction works.
- Compressive, split tensile and shear strengths are increased for RA content of 25%. Then it decreases till to 100% RA replacement.
- As PP fibres volume increases in RAC, the compressive strength, split tensile and shear strengths get increased.
- The maximum permissible limit for RA with 1% PP fibre is 50%.
- The PP fibres volume with 2% can be used effectively without change in design mix.
- For 100% RAC with 1% PP fibre volume, compressive strength, split tensile strength and shear strength increases by 15.68%, 34.84% and 38.32% respectively when compared with reference mixes.
- For 100% RAC with 2% PP fibre volume, compressive strength, split tensile strength and shear strength increases by 35.7%, 85.6% and 38.32% respectively when compared with reference mixes.
- Proposed regression models presented herein are having good compatibility with the experimental results.

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