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Effect of recycled coarse aggregate manufactured from different industry waste with mineral admixtures on the fresh and hardened properties of concrete

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ABSTRACT

In countries like India and elsewhere, the natural aggregate resources had already reached at alarming rate due to day by day high demand of construction activities in recent years. On the other hand, million tons of construction and demolition (C&D) residues and ceramic wastes are generated which are having hazardous effect on environment. These wastes can be utilized as a partial replacement of natural coarse aggregate in concrete and desired mechanical properties of recycled aggregate concrete can be achieved with the added use of mineral admixtures. Result shows that at 30% replacement level, compressive strength of recycled aggregate concrete is decreased by only 10% which is not significantly different than that of natural aggregate concrete and with 7.5% replacement of cement by Metakaolin can achieve the compressive and tensile strength of optimized recycled aggregate concretes same as that of Natural aggregate concrete.

Keywords: Recycled aggregates, Construction and demolition (C&D) waste aggregate, ceramic waste aggregate, Metakaolin

I INTRODUCTION

The use of natural aggregates in concrete leads to high environmental impacts firstly because of the amount of emissions of CO2 produced during their extraction and secondly because of the depletion of natural resources that this activity implies [1]. Each year, the construction sector – including several related industries such as ceramic products and other construction materials firms – generates a very significant amount of construction and demolition waste (CDW). The environmental problem posed by these wastes stems not only from their growing volume, but also from their treatment and disposal [2]. The recycling of different C&D wastes and ceramic industrial waste has long been accepted to have the possible to conserve natural resources and to decrease energy used in production. In some nations it is a stand as substitute for both construction and maintenance, particularly where there is a scarcity of construction aggregate.

II BACKGROUND

Patrick L. Maieret et al. [3] prepared concrete mixtures designed ranged from a 25% replacement to one 100% replacement with recycled materials. In addition, a standard concrete mixture using cement and virgin aggregates was designed for comparison purposes. Fresh and hardened concrete properties were examined including slump, air content, and unit weight, and compressive strength, rate of strength gain, freeze–thaw durability, permeability, and alkali-silica reactivity (ASR) potential. The 100% recycled materials concretehad very low permeability and a compressive strength of 4200 psi (29.0 MPa) with 6.5% air content. Concrete mixtures composed of 50% and 75% recycled materials achieved strengths of nearly 7000 psi (48 MPa) and 6350 psi (43.8 MPa) respectivelyH. Dilbas et al.[4] used demolished-building-rubble as recycled aggregate (RA) with and without SF in concrete mixtures. Twelve concrete mixtures in three groups are produced, and proved that the tensile splitting strength of the specimens containing 0% and 5% SF contents increases by replacing the NA with RA.Rahul M Jadav et al. [5] presented an experimental results of Recycled aggregate concrete prepared with different amount of recycled coarse aggregate in addition to this partial replacement to the weight of cement is done with Metakaolin(20%) for all mixes and got comparable results of different mechanical properties to conventional concrete.The feasibility of using ceramic wastes in concrete shows that concrete with 20% replacement has inferior strength loss possess increase durability performance [6].H. Dilbas et al.[4] used demolished-building-rubble as recycled aggregate (RA) with and without SF in concrete mixtures. Twelve concrete mixtures in three groups are produced, and proved that for all groups the value of the elasticity modulus is decreased with increased percentage ofRA.

III MATERIALS

Ordinary Portland cement of 53 Grade as a binding material, Bhogavo River sand as a fine aggregate and locally available natural coarse aggregates (NA) were used in the present study. The demolition construction wastes and ceramic waste were used as a Recycled Aggregates. The physical properties of the NCA and Recycled course aggregate (RA) are given in Table 3. Particle size distribution of RA and NA is shown in Figure-1. In this paper, RCA replacement percentages, i.e., 20%, to 100%, to the mass of NCA were used in the tests. Replacement level of Metakaoline, 5%, 7.5% and 10% to the mass of cement were used in this investigation.

TABLE 1Properties of Aggregate

Properties	NA	RA
Specific Gravity	2.79	2.37
Water Absorption (%)	0.75	2.47
Crushing Value (%)	17.15	22.47
Impact Value (%)	14.46	20.28
Abrasion Value (%)	18.4	22.56

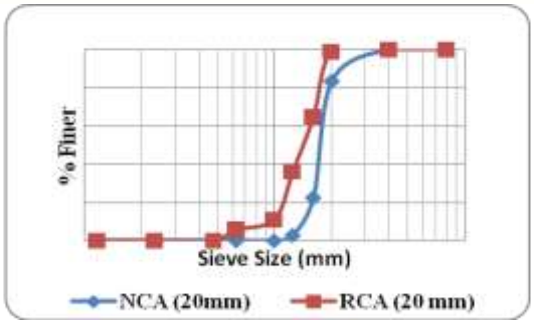

Fig.1 Partical Size Distribution Curve of NCA and RCA

3.1 Physical properties of Metakaolin (ASTM C-618)

Metakaolin is produced by low temperature calcination of high purity kaolin clay with particle size of about 1 to 2 micrometers. Metakaolin is utilized in special applications where very low permeability or very high strength is required. Metakaolin is in conformity with the general requirements of pozzolana classified by ASTM C 618 as Class N pozzolans. Chemical properties of Metakaolin is given in Table 2

TABLE 2Chemical Properties of Metakaolin

Chemical Properties	Value (%)
LOI	2.35
SiO2	51.78
Al2O3	42.66
Fe2O3	0.55
CaO	0.21
MgO	0.12
Equivalent alkali (as Na2O)	1.18

Fig.2Sample of Metakaolin

IV EXPERIMENTAL PROGRAM

Concrete Mix of M20 and M30 grade were designed as per Indian Standard method [7]and the same were used to prepare the test samples. The design mix proportions are shown in Table 3 and Table 4 respectively.

TABLE 3Concrete Mix Proportions

Cement (Kg/ m^3)	Grade of concrete	Coarse Aggregate (Kg/ m^3)		Fine Aggregate (Kg/ m^3)	Water (Kg/ m^3)	W/C
		20mm	10mm			
350	M20	779	419	684	197	0.55
438	M30	757	407	665	197	0.45

The evaluation of Recycled Aggregates produced from different industrial wastes like C&D waste and Sanitory ceramic waste had been carried out. Concrete contains cement, water, fine aggregate, coarse aggregates (Kapachi and grit). Natural coarse aggregate is replaced in different percentage i.e., 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% by both recycled coarse aggregates like Recycled C&D waste aggregate (RA)and recycled ceramic waste aggregate (CA) and test result data is compared with that of natural aggregate concrete. To understand the workability of recycled coarse aggregate concrete and conventional concrete, slump test was conducted as per IS 7320-1974. For each mix, nine cubes (three for 7 days, 14 days and 28days) of size 150mm were cast to determine compressive strength (IS: 516-1959), the specimens were de molded 24h after casting and were cured under fresh water at 27^o with 2^otolerance until the test age. Also cement is replaced by Metakaolin with 5%,7.5% and 10 % by its weight for optimized concretes in order to check the strength enhancement of concrete due to MK.

4.1 Fresh properties of concretes:

Slump test was conducted for throughout the concrete with different percentage of recycled aggregate in order to compare the workability of recycled aggregate concretes and natural aggregate concrete. Results of the slump test of both the mix were shown in Fig 3. The result shows that slump value is decreases in RAC and increased in CAC with increase in percentage of RA and CA respectively as replacement level of recycled aggregate is increases.

Fig.3 Slump Test

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4.2 Hardened properties of concrete

Different hardened properties of concrete like compressive and shear strength have been found by conducting experimental work on recycled aggregate concretes with different percentage of replacement of natural aggregate with recycled aggregate. Standard size Cubes wereprepared and CTM of 2000 KN capacity have been used to find compressive strength.Shear Strength of concrete were found using the method suggested by Dr. C.D. Modhera and Dr. N. K. Bairagi[8] as per the given experimental set up sown in figure 5. For testing the specimen, the loading arrangement is designed such that the intended plane for shear failure is in single shear as per fig shown in fig 4.

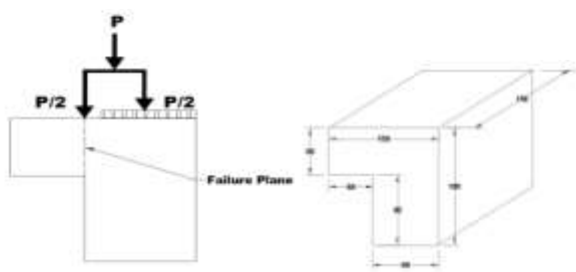


Fig 4Dimensions of specimen and Loading setup

Fig 5 Experimental set up for shear test

Shear strength result were carried out after 7 and 28 days for optimized recycled aggregate concretes for Both M20 and M30 grade concrete and further for both RAC and CAC 5%, 7.5% and 10 % cement replacement with Metakaolin was adopted and cubes were casted and tested after 7 and 28-days in order to find out its enhanced compressive and shear strength.

V RESULTS AND DISCUSSIONS

5.1 Workability of Recycled aggregate concretes

Slump value is shown In figure 5 and 6 as per given below and it is clearly shown that with the increase in percentage of RA, the value of slump is increased in case of recycled C&D waste aggregate concrete and slump decreased in case of recycled ceramic waste aggregate concrete because the water absorption is more in recycled C&D waste aggregate and very less in recycled ceramic waste aggregate. The adherent mortar attached with parent material in case of recycled C&D waste aggregate absorbs more water than natural aggregate and sanitary ceramic material is a highly burnet product so it absorbs very less water near to zero.

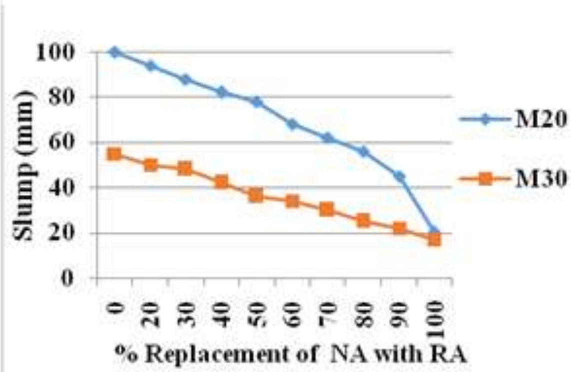


Fig.6Slump value of concrete replacement with RA

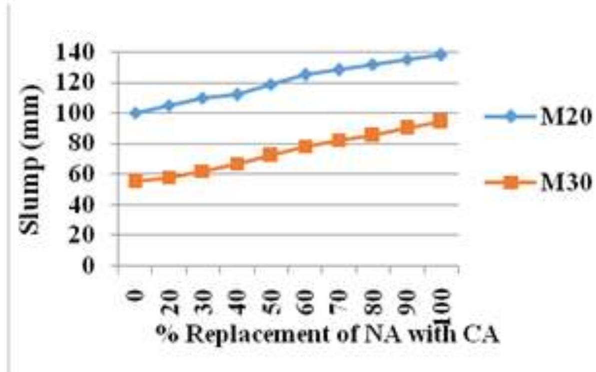


Fig.7Slump value of concrete replacement with CA

5.2 Compressive Strength of recycled aggregate concretes**Compressive strength of recycled aggregate concrete was tested after 7-days, 14-days and 28-days after casting. Compressive strength of recycled aggregate concrete (RAC) and recycled ceramic waste aggregate concrete (CAC) were compared with natural aggregate concrete. Result shows that compressive strength RAC and CAC is decreased with increase in replacement of RA and CA respectively, however at 30 % replacement level in both RAC and CAC compressive strength is not significantly decreased (not more than 10%) as compared to that of NAC so it can be designated as optimized concrete.**

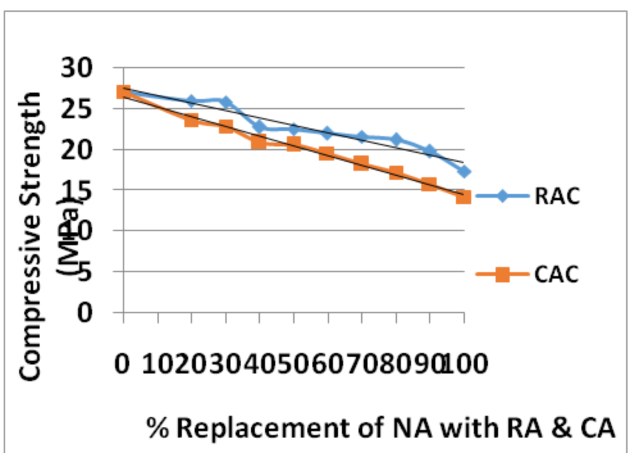


Fig.8Compressive strength for M20 mixtures with replacement of different Recycled aggregates

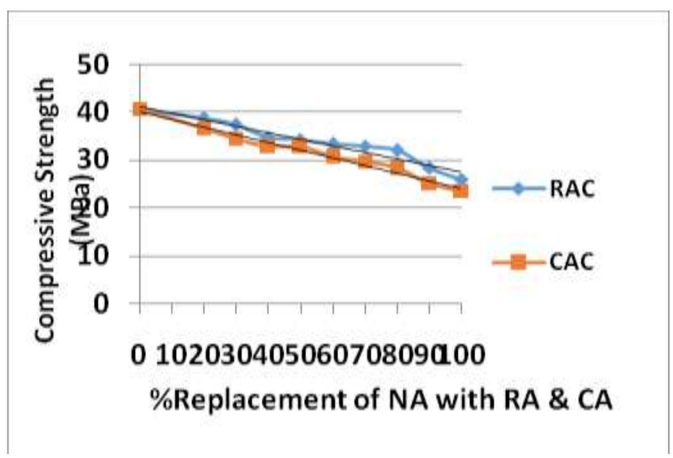


Fig.9 Compressive strength for M30 mixtures with replacement of different Recycled aggregates

5.3 Compressive Strength Improvement of optimized concretes using Metakaolin

Metakaolin is utilized specifically where very low permeability or very high strength is required. In these applications, Metakaolin is used to increase the Compressive strength of optimized recycled aggregate concrete with 5 %, 7.5% and 10% replacement of cement with MK was tested at 28-days after casting. Compressive strength of recycled aggregate concrete and ceramic waste aggregate concrete with different percentage of replacement level of Metakaolin was compared with natural aggregate concrete. Result shows that compressive strength optimized RAC and CAC with Metakaolin enhanced the strength in increasing manner with the increment of percentage of Metakaolin.

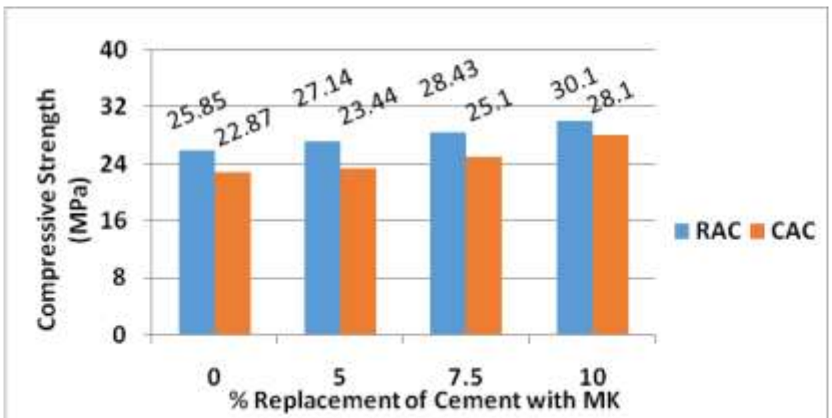


Fig.10 Bar chart of Compressive strength of optimized RAC and CAC at 28-days with different Percentage of Metakaolin replacement for M20

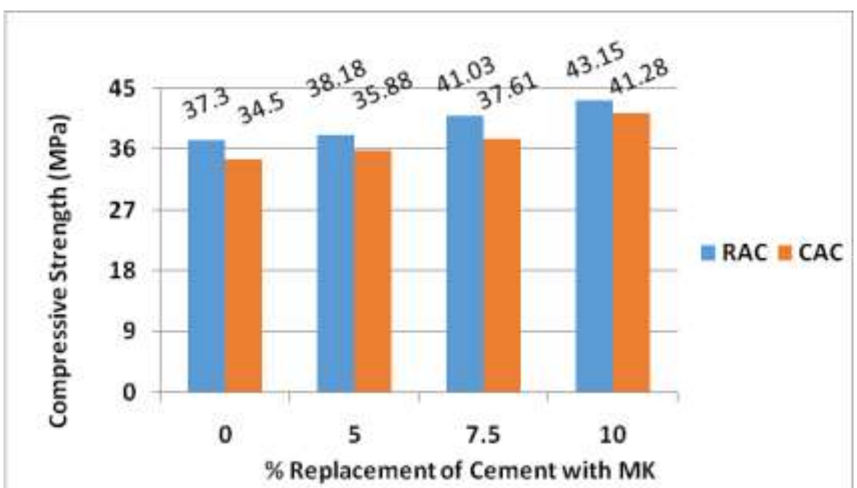


Fig.11Bar chart of Compressive strength of optimized RAC and CAC at 28-days with different Percentage of Metakaolin replacement for M30

5.4 Shear Strength of optimized Concretes and its enhancement with the use of Metakaolin

As described earlier in order find out shear strength of optimized recycled aggregate concrete, different L shaped specimens were prepared and tested under special experimental set up and tests were carried out at the age of 7 and 28 days. It observed minor decrement in shear strength in both optimized recycled aggregate concrete compare to that of natural aggregate concrete hence again Metakaolin is inserted as a partial replacement of cement at 5%, 7.5% and 10% in order to enhance the shear strength. As a result it can be clearly observed that addition of Metakaolin is the solution to enhance shear strength of concrete. Shear strength of optimized RAC and CAC decreased by 9.5% and 13% in M-20 and 6% and 9% in M-30 compared to that of NAC but the deficiency in shear strength can be reduced with the addition of Metakaolin as a replacement of cement as per shown in fig

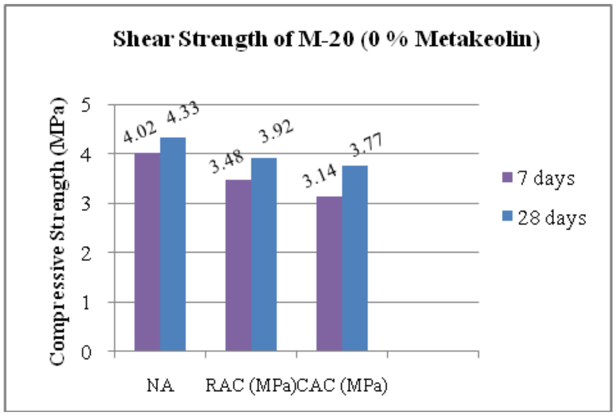


Fig 12shear strength of selected RAC and CAC without Metakaolin for M-20 at different ages for M20 without MK

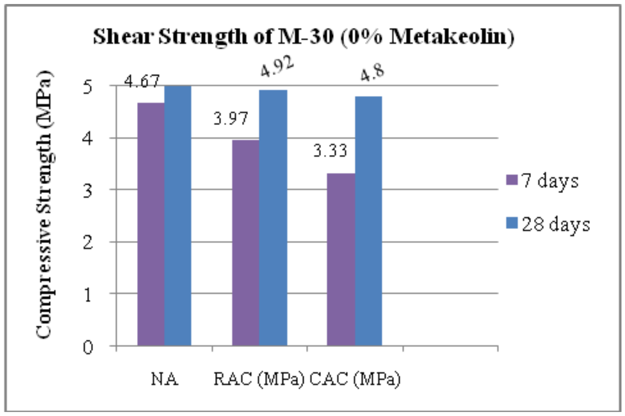


Fig.13shear strength of selected RAC and CAC without Metakaolin for M-20 at different ages For M30 without MK

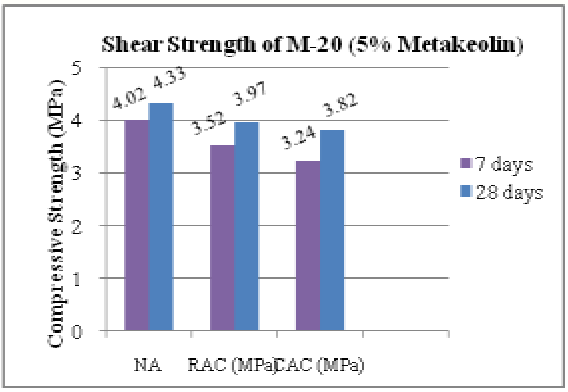


Fig 14shear strength of selected RAC and CAC without Metakaolin for M-20 at different ages for M20 with 5% MK

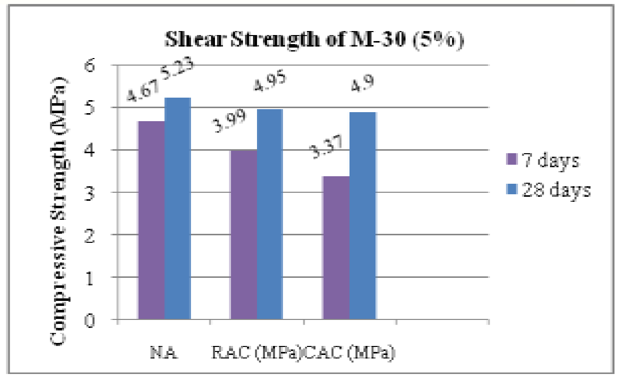


Fig 15shear strength of selected RAC and CAC without Metakaolin for M-20 at different ages for M30 with 5% MK

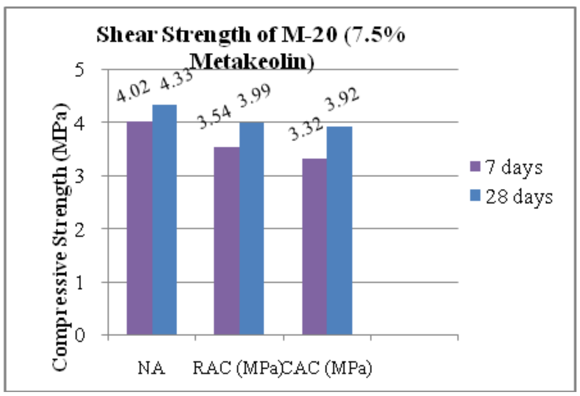


Fig 16shear strength of selected RAC and CAC without Metakaolin for M-20 at different ages for M20 with 7.5% MK

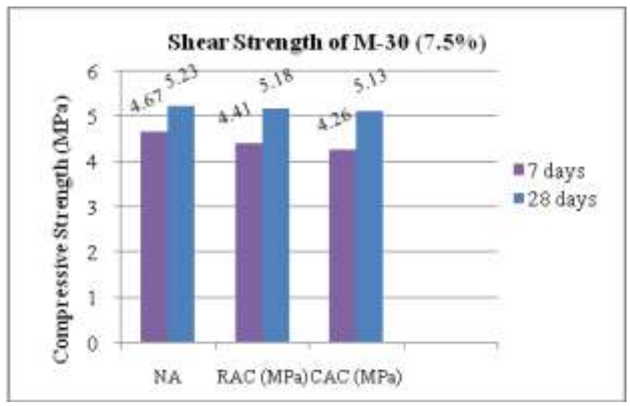
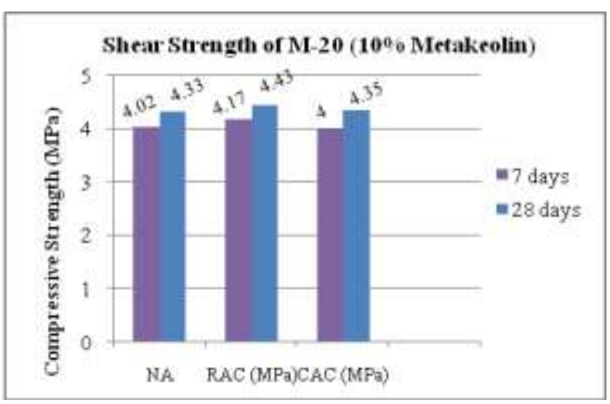


Fig 17shear strength of selected RAC and CAC without Metakaolin for M-30 at different ages for M30 with 7.5% MK



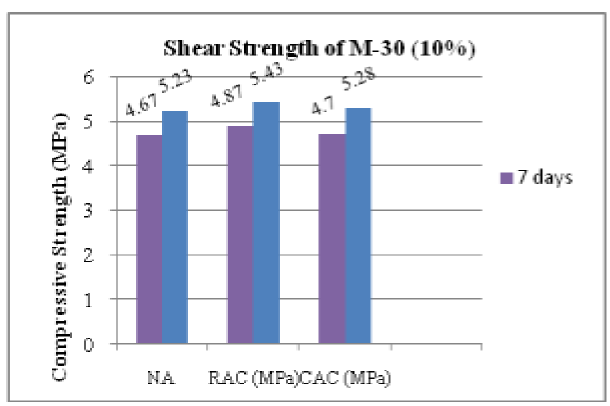


Fig.18shear strength of selected RAC and CAC without Metakaolin for M-20 at different ages for M20 with 10% MK

Fig.19shear strength of selected RAC and CAC without Metakaolin for M-30 at different ages for M20 with 10% MK

VI CONCLUSIONS

Based on experimental and literature studies, following conclusions are drawn.

1. Fresh ceramic waste coarse aggregate concrete observed more cohesive and workable than conventional concrete because of lower water absorption property of CA than NA
2. With the increase of percentage of RA, lower value of slump observed because of the higher water absorption property of RA than that of NA.
3. The compressive strength of RAC at 100% replacement level is decreased by 36% and 37%, while at 50% replacement level it reduced by 17% and 15% at the age of 28 days in M20 and M30 respectively compared to reference concrete.
4. The compressive strength of CAC at 100% replacement level is decreased by 47% and 42%, while at 50% replacement level it reduced by24% and 19% in M20 and M30 respectively compared to reference concrete at the age of 28 days.
5. 30% RA replacement in RAC shows only 4% and 8% reduction in Compression strength at the age of 28 days for M20 and M30 respectively, which is not significantly different from the conventional concrete.
6. 30% RA replacement in CAC shows only 15% reduction in Compression strength in both M20 and M30 grade of concrete for M20 and M30 respectively which is not significantly different from the conventional concrete.
7. When **5%** of Metakaolin added, the deficiency of RAC in shear strength compare to NAC is reduced from **9.5%** to **8.3%** and from **13%** to **11.8%** for CAC in M20 grade concrete mixture at 28 days age.
8. When **5%** of Metakaolin added, the deficiency of RAC in shear strength compare to NAC is reduced from **6%** to **5.3%**and from **8.7%** to **6.3%** for CAC in M30 grade concrete mixture at 28 days age.
9. When **7.5%** of Metakaolin added, the deficiency of RAC in shear strength compare to NAC is reduced from **9.5%** to **7.8%**and from **13%** to **9.5%** for CAC in M20 grade concrete mixture at 28 days age.
10. When **7.5%** of Metakaolin added, the deficiency of RAC in shear strength compare to NAC is reduced from **6%** to **1%**and from **8.7%** to **2%** for CAC in M30 grade concrete mixture at 28 days age.
11. All the deficiency in shear strength of RAC and CAC compare to that of in NAC became zero at 28 days age when cement replacement level with Metakaolin taken as **10%.**
12. If **5% and 7.5%** of cement is replaced by Metakaolin in selected RAC, it gains same compressive strength that of NAC at 28 days in M20 and M30 respectively.
13. It requires **10%** of cement replacement with Metakaolin in selected CAC to achieve 28 days of compressive strength same as NAC in both M20 and M30.

14. Partial Replacement of cement with Metakaolin in selected RAC and CAC is the solution of enhancing the deficiency of hardened properties of concrete.

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