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Research paper

Effect of metakaolin on mechanical properties of different grades concretes inclusion of recycled aggregates from C& D waste and ceramic waste.

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Abstract

As concrete is the second highest utilized material after water in the world, the improvement in the performances of concrete is the requirement of today's era. In addition, the use of mineral admixture like Metakaolin helps to achieve good performance of concrete even prepared by utilizing recycled construction and demolition (C&D) waste aggregate and recycled ceramic waste aggregate. In present study Ordinary Portland cement has been partially replaced by Metakaolin in different grades selected recycled aggregate concrete(RAC) and recycled ceramic waste aggregate concrete(CAC). The deficiencies in different mechanical properties of these selected concretes with respect to reference concretes has been observed experimentally and there were retained by replacing cement with Metakaolin(MK) about 7.5% by weight of cement.

Keywords: *Use about five key words or phrases in alphabetical order, Separated by Semicolon.*

1. Introduction

Metakaolin is a mineral admixture which is a dehydroxilated form of kaolinite. The size of particles of Metakaolin is smaller compared to OPC particles and not that much smaller than of silica fume. Metakaolin reacts with the lime by products produced during cement hydration process. [1] For suitable concrete production, minimization of environmental impact and energy requirement is necessary. The use of supplementary cementious materials in concrete reduces the use of cement and also increases the use of the industrial waste materials in effective way [2]

2. Background

M devi [3] emphasized Metakaolin as partial replacement of cement at 5%, 10%, 15%, 20% by weight of cement in concrete having quarry dust as fine aggregate and find out the effect of Metakaolin on the strength properties like compressive strength, Tensile strength and flexural strength and as a result it is observed enhanced mechanical properties at 15% replacement level. Rahul M Jadav et al. [4] 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. Jion Tong Ding and ZongjinLi [5] studied different concrete with water/binder ratio of 0.35 with 0%, 5%, 10% and 15% cement replacement with Metakaolin and as a result the strength of Metakaolin modified concrete showed a better strength at all ages compare to conventional concrete. E.Badoginnis et al. [6] investigated the additional effect of Metakaolin on the concrete properties preparing five different concrete mixtures of high performance concrete where Metakaolin replaced an amount of cement. Fresh and hard properties along with durability, air permeability, sorptivity and porosity have been studied and as a result it found an excellent performance of concrete with Metakaolin. Abid nadim et al. [7] carried out research work to evaluate the performance of high performance concrete (HPC) made with flu ash and Metakaolin at elevated temperature and adopted variables were partial replacement of cement with Metakaolin from 5% to 20%, Fine aggregate from 20% to 60%, Temperature from 270C to 8000C and two types of cooling methods. As a result at temperature 4000C and above Metakaolin mixes (MK10 and MK20) showed degraded durability which gives an indication that Metakaolin mixes should be carefully utilized when it is subjected to the temperature which exceeds 400oC.

3. Materials and test methods

Physical properties of Metakaolin (ASTM C-618)
Metakaolin, a special calcined clay, is produced by low temperature calcination of high purity kaolin clay. The product is ground to an average particle size of about 1 to 2 micrometers. Metakaolin is used in special applications where very low permeability or very high strength is required. In these applications, Metakaolin is used more. Metakaolin is in conformity with the general requirements of pozzolana classified by ASTM C 618 as Class N pozzolans. Chemical properties of Metakaolin is listed in Table 1

Table 1: Chemical Properties of Metakaolin

Chemical Properties	Value (%)
LOI	2.35
IR	86.67
SiO2	51.78
Al2O3	42.66
Fe2O3	0.55
CaO	0.21
MgO	0.12
Equivalent alkali (as Na2O)	1.18

Fig. 1: Sample of Met kaolin.

Compression Test of Metakaolin

The compressive strength of mortar has been evaluated on a 2000kN capacity hydraulic testing machine. For the compressive strength test, cubes of size 7.05cm x 7.05cm x 7.05cm are tested.

Table 2: Pozzolanic Strength Index of Met kaolin

Material	Compressive Strength (7-days) (MPa)	Compressive Strength (28-days) (MPa)	Pozzolanic Strength Index (28-days)
OPC-53	34.1	55.12	1.00
Metakaolin (7.5% cement Replacement)	45.33	71.66	1.30

Materials

Ordinary Portland cement of 53 Grade as a binding material, Bhogavo river sand as a fine aggregate and locally available natural coarse aggregates (NCA) were used in the present study. The demolition construction wastes were used as a Recycled Aggregates. The physical properties of the NCA and Recycled course aggregate (RCA) are given in Table 3. Particle size distribution of RCA and NCA is shown in Figure-1. In this paper, RCA replacement percentages, i.e., 10%, 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 3: Properties of Aggregate

Mix	Cement	Coarse Aggregate		Fine Aggregate	Water	W/C
		20 mm	10 mm			
M-20	350 kg/m³	779.18 kg/m³	419.56 kg/m³	684.68 kg/m³	197 liter	0.54
M-30	438 kg/m³	757 kg/m³	407 kg/m³	665 kg/m³	197 liter	0.45

Table 4: Different Grade Mix Proportions

Properties	NCA	RCA
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

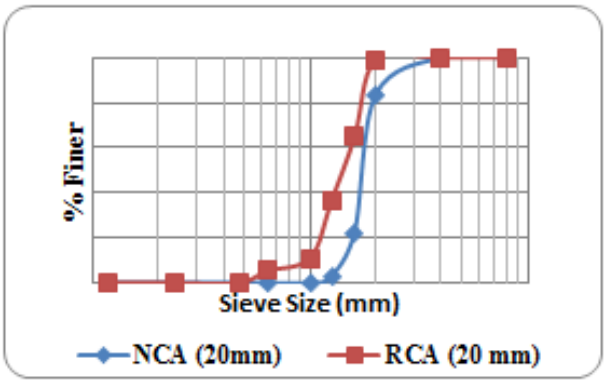

Fig. 2: Partial Size Distribution Curve of NCA and RCA.

Mix proportions.

In current research two types of mixes i.e. M-20 and M-30 were designed as per the Indian Standard method given in IS 10262(2009). The mix proportions of M-20 and M-30 grade of concrete are presented in Table 4.

From the literature it was concluded that up to 30% replacement level of Natural course aggregate with Recycled C&D waste aggregates or Ceramic waste aggregates do not have that much harmful effect on concrete strength [8-9] therefore in present study, selected RAC and CAC have been adopted which are having 30% replacement of Natural aggregate for both the grades to find out the effect of Metakaolin on to the performance of concretes.

Shear Strength of Concrete and its enhancement with Metakaolin replacement

The method to find out shear strength of concrete had been suggested by Dr. C.D. Modhera and Dr. N. K. Bairagi [10] was used to find shear strength for this experimental work (Refer fig 3and 4). 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 3 and fig 4.

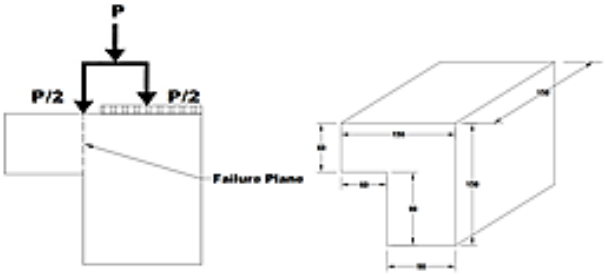

Fig. 3: Dimensions of Specimen and Loading Setup.

Fig. 4: Experimental Set Up for Shear Test.

Shear strength result were carried out after 7 and 28 days for selected RAC and CAC 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.

Compressive strength and its enhancement with Metakaolin replacement

Compressive strength of selected RAC and CAC with 5%, 7.5% and 10% Metakaolin replacement of cement was found at 7-days and 28-days casting and compared with NAC. 200 Ton capacity CTM used to find out the compressive strength.

4. Results and Discussions

As a result it can be clearly observed that addition of Metakaolin is the solution to enhance shear strength of concrete. Shear strength of selected RAC and CAC found 9.5% and 13% in M-20 and 6% and 9% in M-30 degraded in comparison 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 5.

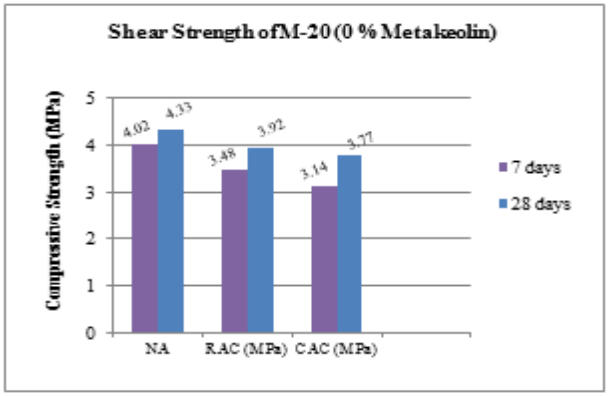

Fig. 5: At 7-Days & 28-Days Shear Strength of Selected RAC and CAC without Metakaolin for M-20.

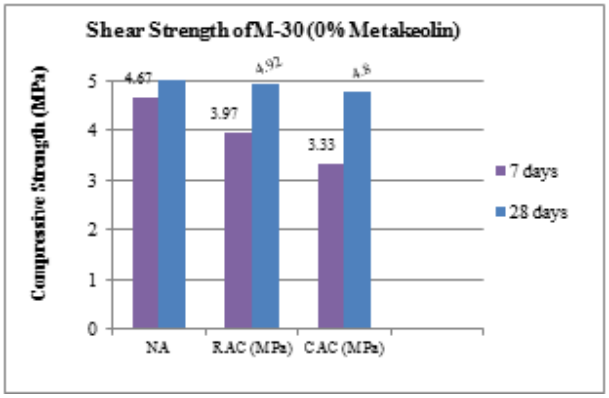

Fig. 6: At 7-Days & 28-Days, Shear Strength of Selected RAC and CAC without Metakaolin for M30.

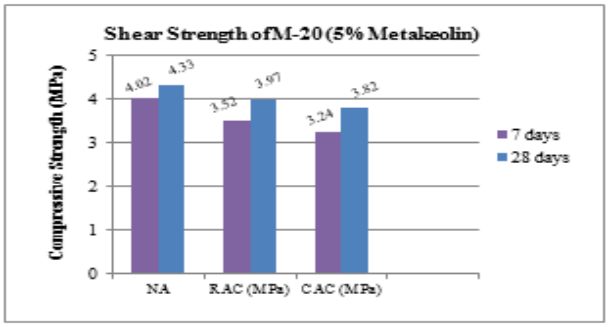

Fig. 7: Shear Strength of Selected RAC and CAC with 5% Metakaolin for M-20.

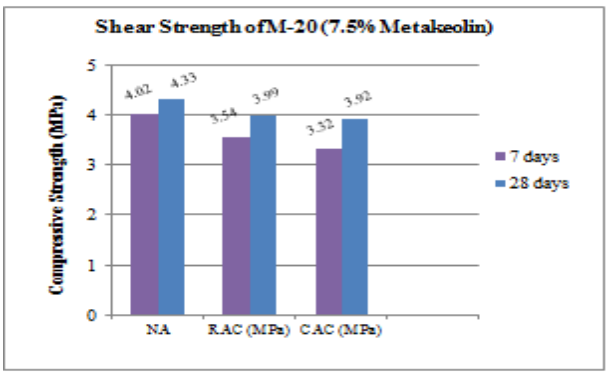

Fig. 8: Shear Strength of Selected RAC and CAC with 7.5% Metakaolin for M-20.

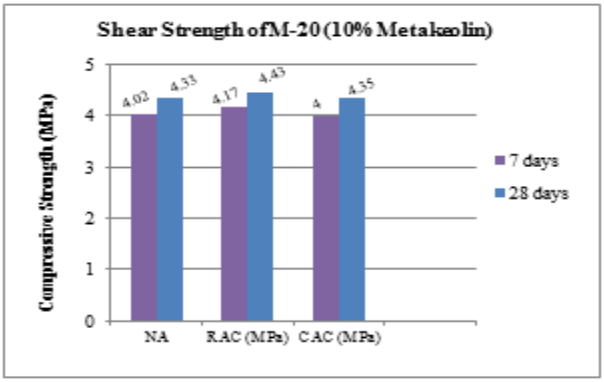

Fig. 9: Shear Strength of Selected RAC and CAC with 10% Metakaolin for M20.

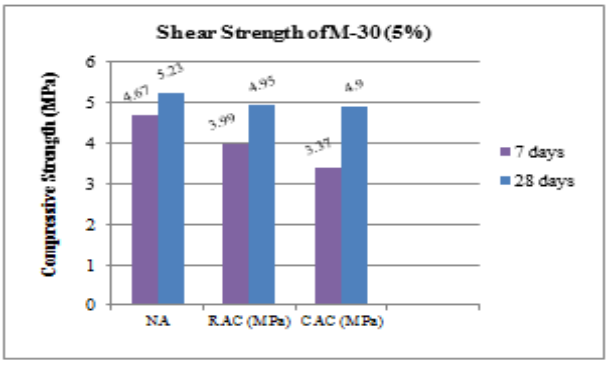

Fig. 10: Shear Strength of Selected RAC and CAC With 5% Met kaolin for M30.

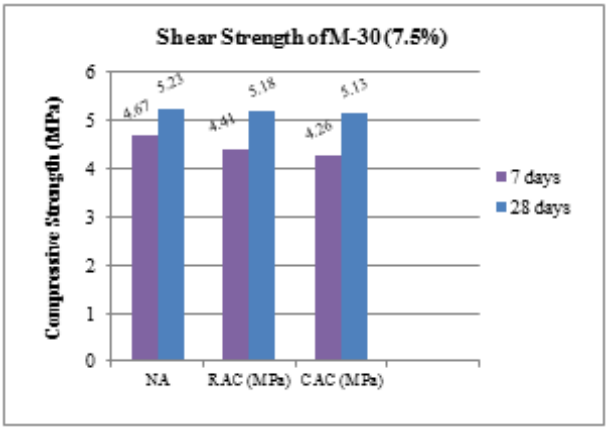

Fig. 11: Shear Strength of Selected RAC and CAC with 7.5% Met kaolin for M30.

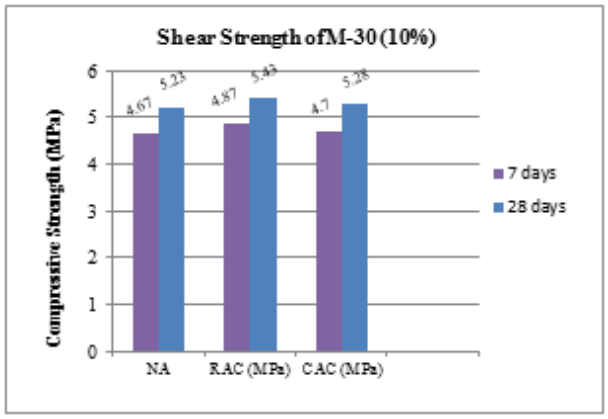

Fig. 12: Shear Strength of Selected RAC and CAC with 10% Met kaolin for M30.

Compressive Strength Improvement of selected RAC and CAC using Metakaolin

Compressive strength of optimized recycled aggregate concrete with 5%, 7.5% and 10% Metakaolin replacement of cement was tested after 7-daysand 28-days after casting. Compressive strength of recycled aggregate concrete, ceramic waste aggregate concrete and combined mix concrete with different percentage of replacement level of Metakaolin was compared with natural aggregate concrete. Result shows that compressive strength of RAC and CAC with the addition of Metakaolin enhanced the strength and within 7.5% of Metakaolin replacement, it can be reached up to the strength of NAC as shown in fig 12.

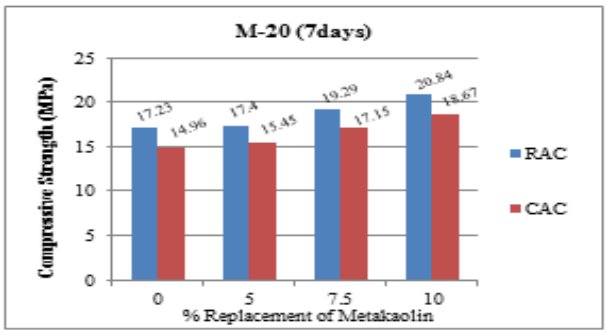

Fig. 12: At 7-Days Compressive Strength of RAC and CAC for M20.

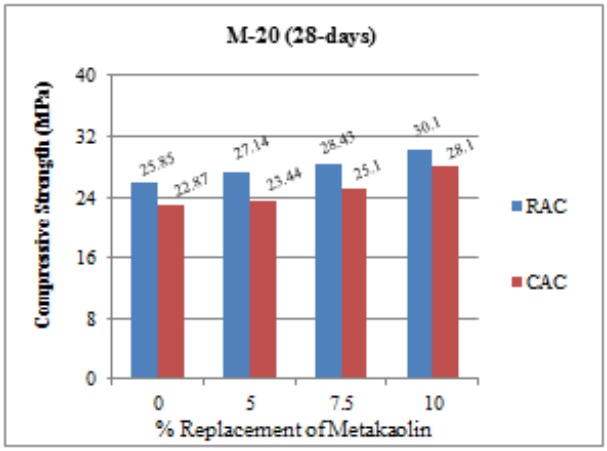

Fig. 13: At 28-Days Compressive Strength of RAC and CAC for M20.

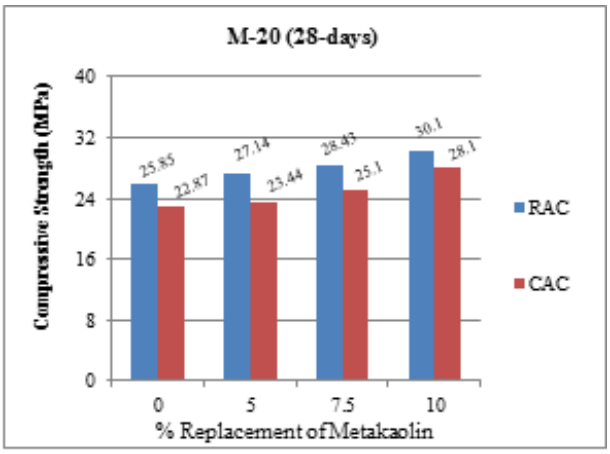

Fig. 14: At 7-Days Compressive Strength of RAC and CAC for M-30.

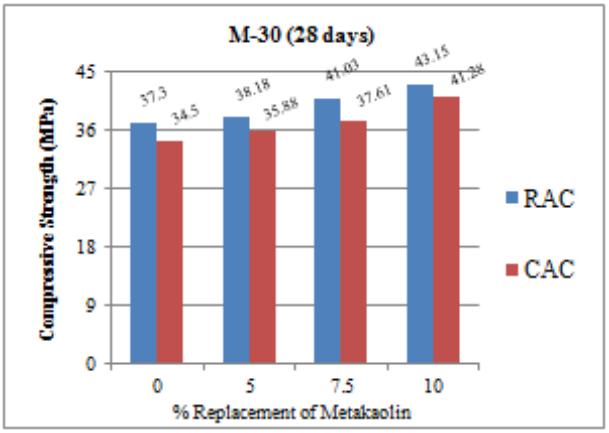

Fig. 15: At 28-Days Compressive Strength of RAC and CAC for M-30.

5. Conclusions

Following conclusions can be made after rigorous study

1) 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.
2) 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.
3) 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.
4) 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.
5) 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% .
6) If Metakaolin in selected RAC replaces 5% and 7.5% of cement, it gains same compressive strength that of NAC at 28 days in M20 and M30 respectively.
7) 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.
8) 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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