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Effect of Metakaoline and Recycled Fine Aggregate on Workability and Compressive Strength of Concrete

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Abstract

Metakaoline is a reactive alumina–silicate pozzolana produced by heating kaolinite at a specific temperature regime. In this work, the cement (OPC) was replaced partially with metakaoline by weight to determine the optimum dose of pozzolana in concrete. Concrete cubes were tested at the age of 7 and 28 days. The optimum dose of metakaoline was found to be 13% by weight of OPC. Recycled fine aggregate (crushed concrete aggregate) obtained from concrete of the demolition wastes, available locally, was used as for replacement of natural fine aggregate in concrete using the optimum dose of metakaoline in concrete mix. Natural fine aggregate in concrete was replaced with 0%, 25%, 50%, 75%, and 100% of recycled fine aggregate. The workability was found to decrease as the percentage of recycled fine aggregate was increased. Compressive strength of above mixes was determined using destructive and non-destructive tests. A Slight decrease in the compressive strength was observed as the percentage of recycled fine aggregate was increased.

***Keywords**: Recycled Fine Aggregate; Metakaoline; Compressive Strength; Non-Destructive Test.*

1. INTRODUCTION

Huge quantities of construction materials are required in developing countries due to continued infrastructural growth. Also, huge quantities of construction and demolition wastes are generated every year in developing countries like, India. The disposal of this waste is a very serious problem because on one side it requires huge space for its disposal while on the other side it pollutes the environment. It is also necessary to protect and preserve the natural resources like stone, sand etc. Continuous use of natural resources, like river sand is another major problem area. This increases the depth of river bed resulting in drafts and also changing the climatic conditions. So, the sustainable construction concept was introduced in construction industry due to growing concern about the future of our planet because it is a huge consumer of natural resources as well as waste producer. The proportion of concrete rubbles is maximum in the demolition waste. It has been reported by several researchers (Hansen, 1992, Mehta *et al.* 1993, Collins, 1994 and Sherwood, 1995) that the crushed concrete rubble can be used as a substitute of natural coarse aggregates in concrete or as a sub-base or base layer in pavement, after separating these from the construction and demolition wastes. Some construction projects have been successfully completed using the recycled aggregates (Desmyster *et al*. 2000). Hendricks et al. (1998) prepared concrete in which up 20% natural aggregate was replaced with recycled aggregate, and noticed a little effect on the properties of resulting concrete. It is reported by Barra et al. (1996) that the concrete strength decreases when recycled aggregate was used. However, Dhir et al (1999) reported that there is no decrease in strength for concrete containing up to 20% fine or 30% coarse recycled aggregates, but beyond these levels, there was a systematic decrease in strength as recycled aggregate content was increased. The strength parameters were not affected by the quality of recycled aggregate at high water/cement ratio; however these were affected only when the water/cement ratio was low (Ryu, 2002 and Padmini

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et al. 2002). A Lesser reduction in compressive strength of recycled aggregate concrete is reported at higher water/cement ratio (Chen *et al*., 2003; Dhir *et al*, 1999 and Ryu, 2002). The rate of strength development in concrete containing crushed concrete or crushed brick is higher than that of referral concrete indicating further cementing action in presence of fine recycled aggregate, beyond the 28 days of curing (Khatib, 2005). Metakoline, a highly efficient pozzolona, reacts with the excess calcium hydroxide resulting from hydration of cement and produces calcium silicate hydrate and calcium alumina silicate hydrates (Courard *et al*. 2003). It is quite useful material for improving concrete quality by enhancing strength and reducing setting time and may prove to be a promising material for manufacturing high performance concrete (Li and Ding, 2003). Metakaoline may be used as supplementary cementitious material in concrete to reduce the cement consumption and permeability; increase strength and rate of strength gain; and make more durable concrete (Aquino et al, 2001; Asbridge et al. 2001, Boddy et al. 2001; Justice et al. 2005; Khatib and Wild 1998). Workability of concrete is decreased with increase in metakaoline content in concrete. The aim of this research was to assess the properties of concrete, made using recycled fine aggregate (<5mm) derived from old /used concrete. From literature, it is found that compressive strength of concrete decreases on use of recycled aggregate, when natural aggregate was partially replaced, and strength of concrete increases on addition of pozzolanic material in concrete. If the loss of strength in concrete due to recycled aggregate is over come another addition of pozzolona, it would be more suitable for construction. In the experiment, OPC was replaced partly with metakaolin (in the range of 10-20%) to determine optimum dose of metakaoline. The compressive strength and workability of concrete are compared using natural fine aggregate and recycled fine aggregate metakaoline.

2. MATERIALS AND MIX PROPORTIONING

The concrete mix consisted of 43- grade JAYPEE brand Ordinary Portland Cement (OPC) having specific gravity of 3.15, fine aggregate (natural river sand) and coarse aggregate. Fine and Coarse aggregates were obtained from local quarries. The fineness modulus of fine aggregate was 2.46. Coarse aggregates of two different sizes were used; one fraction passing through 20 mm sieve and another fraction passing through 10 mm sieve having fineness modulus of 7.02 and 6.65, respectively. Concrete of M_{25} grade was used in this investigation with mix proportion (by weight) of cement : fine aggregate : coarse aggregate as 1 : 1.23: 2.60 with water cement ratio of 0.43. Metakaoline was procured from M/S Riddhi Enterprises, Mumbai. The physical and chemical properties of Metakaoline as supplied by manufacturer are given in Table-1. The recycled fine aggregate (CC) was prepared by crushing the tested concrete cubes in laboratory. Sieve analysis of natural fine aggregate and recycled fine aggregate is given in Table-2. The concrete was prepared by hand mixing during which first, second and third layer consisted of coarse aggregate, fine aggregate and cement respectively. Trowel was used for mixing. To investigate the effect of metakaoline and recycled fine aggregate inclusion (as part replacement of cement and natural fine aggregate respectively), 100 mm cubes were cast for referral and other mixes , having variable metakaoline content and recycled aggregate content. The workability was determined using slump test. The compressive strength of different mixes were determined at 7 and 28 days. Rebound Hammer Test was conducted for Non Destructive Test (NDT) to determine the compressive strength of different concrete mixes at 7 and 28 days. This test was carried out using Schmidt Rebound Hammer. The results obtained from the above investigation are presented below.

Table 1. Physical & Chemical Properties of Metakaoline

S.No.	Properties	Value
	Physical	
1	Specific gravity	2.5
2	Specific area (cm^2/gm)	150000 - 180000
3	Colour	White
	Chemical composition	
4	Aluminium oxide (Al_2O_3)	30-34
5	Silicon dioxide (SiO_2)	60-65
6	Iron oxide (Fe_2O_3)	1.00
7	Calcium oxide (CaO)	0.2-0.8
8	Magnesium oxide (MgO)	0.2-0.8
9	Sodium oxide (Na_2O)	0.5-1.2
7	Potassium oxide (K_2O)	
8	Loss on ignition	<1.4

Table 2: Sieve Analysis of Natural Fine Aggregate and Recycled Fine Aggregate

Sieve Size	Fine Aggregate (% passing)	
	Natural Aggregate	Recycled Aggregate
4.75 mm	95.6	98
2.36 mm	81.6	52.8
1.18 mm	71.6	38.6
600 micron	58.4	25.2
300 micron	38.8	11.2
150 micron	8.4	6.4
< 150 micron	-	-

3. RESULTS & DISCUSSION

3.1 Optimum Dose of Pozzolana

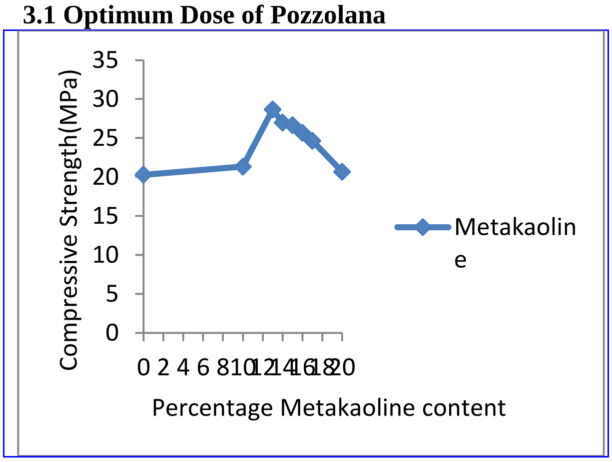

Fig 1: Compressive Strength of Concrete at Different Percentage of Pozzolana at 7 days

Optimum dose of pozzolana is that percentage which gives maximum compressive strength of concrete. In the first stage, different samples of concrete cubes were cast replacing cement with metakaolin by 10, 15 and 20% of total cement weight. The results are shown in Fig.1. It is seen that in general, the strength first increases between 10% to 15% replacement level and thereafter it decreases between 15% to 20% replacement level. The compressive strength at 20 % replacement is almost same as referral concrete. Therefore to obtain more accurate value, concrete mixes were prepared with replacement levels of 13, 14, 16 and 17% and tested. These results are also plotted in Fig.1. It is observed that the strength increases between replacement level of 10% to 13% and beyond that it decreases. Therefore the optimum dose of metakaoline inclusion is 13 percent in concrete and strength gain is approximately 41% compared to the referral concrete at 7 days. This metakaolin content was used for further studies.

3.2 Workability of Concrete

The different concrete mixes were prepared by replacing part of natural fine aggregate with CC at 25, 50, 75 and 100 % (by weight). OPC used was replaced with 13% metakaoline (by weight) in each mix. The slump values of different mixes and referral mix are presented in Fig.2. It is observed that workability decreases with increase in percentage of recycled aggregate. This decrease is in the range of 7 to 40 mm.

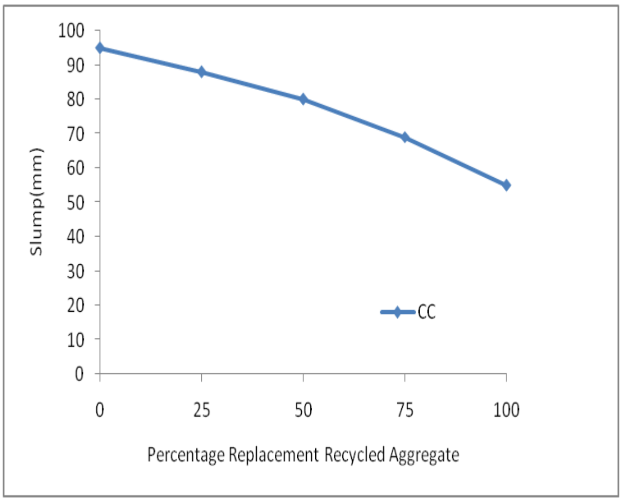

Fig.2: Slump Values at Different Percentage replacement of Recycled Concrete Aggregate

3.3 Compressive Strength of Different Mixes

The compressive strength of cubes prepared using optimum doze of metakaolin content and varying replacement levels of fine aggregate was determined by both destructive testing and nondestructive tests. The result are presented below

3.3.1 Destructive test (DT)

The compressive strength of the different mixes was determined at 7 and 28 days and is plotted in Fig. 3. It is observed from this figure that the compressive strength increases linearly upto 25% replacement level and beyond that it decreases as percentage of recycled aggregate increases. It is also observed that the increase in compressive strength is 41.3% and 21.6% at replacement levels of 25% and 50% respectively at the age of 7days. However, the strength decreases by 9.6% and 34.3% at replacement levels of 75 % and 100 % respectively. Similar trend in compressive strength change is obtained at the age of 28 days. Fig.4 presents the percentage change in compressive strength of cubes at 7 and 25 days with varying replacement level of material; fine aggregate by recycled aggregate. It is observed from Fig.4 that replacing natural fine aggregate with recycled fine aggregate in range of 65-67% gives approximately the same strength as given by the referral concrete. Hence, it can be inferred that crushed concrete aggregate can be used to replace natural aggregate up to 65%; along with 13% replacement of cement by metakaoline, without much affecting the strength of the mix.

3.3.2 Non destructive test (NDT)

The specimens prepared were also test to obtain compressive strength by non-destructive method using Rebound Hammer. As such the estimation of strength of concrete by rebound hammer method cannot be held to be very accurate and probable accuracy of prediction of concrete strength in a structure is ± 25 percent. Hence, the results obtained from NDT tests cannot be considered reliable enough to compare the destructive test values. However, this was carried out to see the trend of both the tests and judge the suitability of non-destructive test in the present case. The result of NDT is found to be lower for all the samples, except where the replacement level was 100% and are plotted in fig.5. However, the trend of strength variation is same in both the test methods.

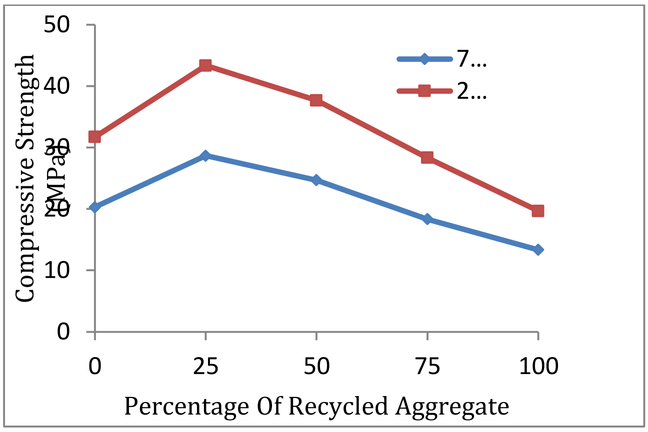

Fig.3: Compressive strength of concrete at different percentage of crushed concrete aggregate at 7 days and 28 days

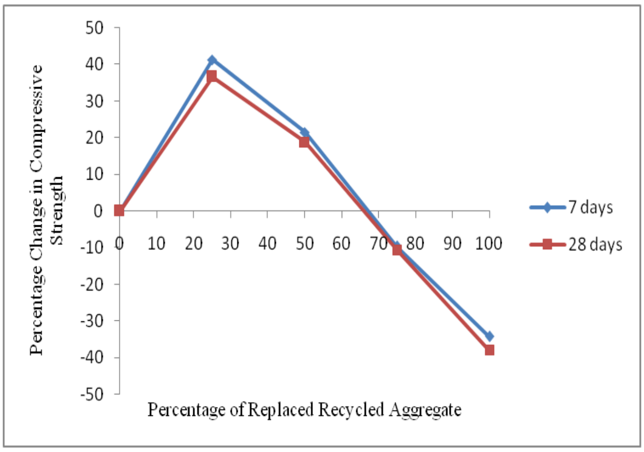

Fig. 4: Percentage change in compressive strength of concrete at different percentage of recycled aggregate at 7 days and 28 days

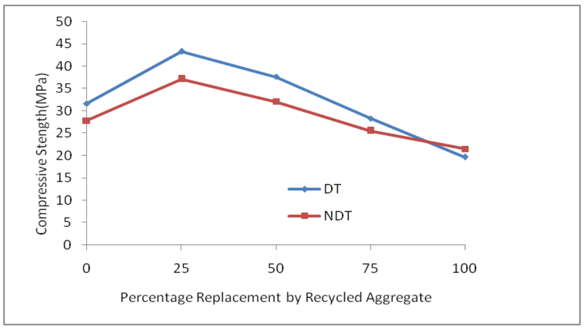

Fig.5: Comparison between DT and NDT Results for Recycled Concrete Aggregate at 28 days

CONCLUSION

The following conclusions are drawn from this study:

1) The optimum replacement level of cement by metakaoline is found 13% (by weight) .
2) The increase in strength due to replacement of cement by metakaoline is 41 % at the age of 7 days.
3) The workability of concrete is found to decrease as the replacement level of natural fine aggregate by recycled aggregate is increased.
4) The Compressive strength increases upto 50 % replacement of natural fine aggregate by recycled aggregate and beyond that it decreases.
5) In general, the results obtained from (NDT) are lower than those obtained by (DT), except at 100% replacement level.

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