Influence Of Fly Ash And Metakaolin On High Performance Concrete

O.R.Kavitha, G.Shyamala, G.Iyappan, K.Rajesh Kumar

Abstract : This investigation focuses on the effect of Fly Ash (FA) and Metakaolin (MK) on the High performance concrete of Grade 40. Ordinary Portland Cement content of 385 kg/m^3 was considered, while the FA was replaced with 30% by weight of cement and fly ash blended mix was produced. Again is replaced with MK (5,10,15 and 20 %) in fly ash blended mix and FA & MK blended mix was produced. To assess the mechanical properties of concrete compressive, split tensile and flexural strength tests were performed. And to assess the durability properties of concrete water absorption, Sulphate and Acid resistance tests were performed. The mechanical properties of concrete results show that mixes prepared with fly ash shows good strength and inclusion of MK also increase the strength of concrete upto 15% replacement level. Likewise durability properties shows inclusion of FA and MK shows more resistance. The optimum replacement of MK was 15 wt.% regarding mechanical properties and durability properties . The results shows 15% of MK enhances the strength and durability of concrete and consider that (OPC 70%,FA15% and MK15%) is suitable construction material to the both economic and social efficiency.

Index Terms: Acid Attack Fly ash, Mechanical properties, Metakaolin, , Sulphate attack, Superplasticizer Water absorption, ,

1. INTRODUCTION

The quest for the development of high strength and high performance concretes has increased considerably in recent times because of the demands from the construction industry. In recent years the utilization of industrial by-products is gaining momentum with increasing environmental awareness and its likely hazardous effects. Using materials that are nearly useless for any advantageous purpose to effectively increase the strength of concrete is an efficient way to counter the hazardous effects of such materials. Fly ash, slag and silica fume, Metakaolin are not a by-products and these are artificial pozzolanic materials [12, 13]. It is mostly manufactured by thermally activating purified kaolinite clay within a specific temperature range (650–800 ^{0}C) [7]. In this respect, Poon et al. 2001 [18] reported that the use of Metakaolin in concrete can increase the compressive strength of mixtures especially during early ages of hydration. Industrialization and population growth has led to the production of larger waste materials and by-products that upon dumping or disposal of these materials causes environmental problems. Therefore, there is an need to find and utilize alternative material for aggregates by utilizing the waste materials and by-products from industries with little or no property modification which leads to a sustainable environment along with the technical advantages. On the other hand, cement being one of the most widely used construction material has led to release of large quantityof CO_2 in the atmosphere which in turn affects the global environment. Such increase in carbon footprint might lead to undesirable climate change in the near future. With an aim of minimizing environmental impact and energy requirement, researchers have been continuously investigating on analyzing supplementary cementations materials (SCMs) as partial replacement for cement [18].

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However, limited test data are available regarding the performance of the commercially available MK and ordinary portland cements in the case of high strength concrete in the [7]. Metakaolin (MK) is very much different from other supplementary cementitious materials like fly ash, slag or silica fume as it is a not a by-product of an industrial process. MK is an artificial pozzolanic material . Metakaolin (MK) is a clay mineral, and it is dehydroxylated (at the temperature of 550–850 ^{0}C) to make them highly reactive pozzolanic materials. Usually MK particles are finer than ordinary Portland cement (OPC) with high alumina composition. Due t its fineness, the water demand is increased while replacing the OPC by MK. It is a thermally activated alumino silicate material with high pozzolanic activity comparable to or exceeded the activity of silica fume. Metakaolin (MK) or calcined kaolin, other type of pozzolan, produced by calcination has the capability to replace silica fume as an alternative material. In India MK can be produced in large quantities, as it is a processed product of kaolin mineral which has wide spread proven reserves available in the country [5]. The positive effect of MK addition on the corrosion resistance property of specimens was reported by researchers. Sulphate resistance of mortars was found to increase with the increase in MK content [17].

2. RESEARCH SIGNIFICANCE

Recently lots of investigations are carried out for replacement of industrial waste Fly ash in cement content. To reduce the OPC consumption there by protecting the environmental a greater extent and cost effective this leads to the sustainable concrete construction. From literature study it was found that the fly ash increases in cement content up to 25% increases compressive strength and reduces the flexural strength. In this study the pore filling pozzolanic material Metakaolin with fly ash in various compositions replacement with cement content and detailed investigation of mechanical and durability properties of in High P concrete(M40) was carried out.

3 EXPERIMENTAL INVESTIGATION

3.1 Materials

The materials used in the study comprised OPC 53 grade [10] , Class- F type fly ash collected from a nearby thermal power plant and commercially available Metakaolin .The physical and chemical composition of OPC,FA and MK was shown in Table 1. In this study the locally available river sand as a Fine Aggregate (Fine) [13] with specific gravity 2.65, Crushed stone as Coarse Aggregate (CA) [13] with Specific gravity 2.65 was used. Sulphonated naphthalene polymers based Super plasticizer (SP) Conplast SP430 with specific gravity of 1.22 and solid content 42% was used in the study.

TABLE 1
THE PHYSICAL AND CHEMICAL PROPERTIES OF OPC, FA, MK

Contents	OPC	FA	MK
Physical Properties			
Specific gravity	3.15	2.12	2.42
Initial setting time	65	-	-
Initial setting time	250	-	-
Soundness	1.0	-	-
Normal consistency	1.0	-	-
Chemical Properties			
SiO_2	21.04	47.5	52.4
Al_2O_3	5.02	21.7	43.15
Fe_2O_3	3.12	8.2	0.6
CaO	62.11	11.3	1.03
MgO	2.44	2.5	0.61
K_2O	0.56	-	-
Na_2O	0.28	-	-

3.2 Mix proportion

The grade 40 concrete was prepared by conducting the trails according IS 10262-2019 [14] is presented in Table 2. Initially Control Concrete (CC) is prepared .Then OPC is replaced by FA is 30% (CFA). After that reaming mixes carried of OPC was taken constant 70% and 30% of FA is replaced with MK5 % (CFAMK5), 10 % (CFAMK10)15 %, (CFAMK15) and 20% (CFAMK20%). The recommended dosage of super plasticizer (SP) is 1-3% by weight of cement/powder [1]. Here it was adopted 2% dosage of SP by weight cement content.

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TABLE 2: *MIX PROPORTION*

Mix	Quantity (kg/m3)				
	OPC	Fine	CA	FA	MK
CC	385	869	1106	0	0
CFA	270	869	1106	115	0
CFAMK5	270	869	1106	109.25	5.75
CFAMK10	270	869	1106	103.5	11.5
CFAMK15	270	869	1106	97.75	17.25
CFAK20	270	869	1106	92	23

3.3 TESTS ON HARDEN CONCRETE

3.3.1 Mechanical properties test

To determine compressive strength [11], Split tensile strength [12] and flexural strength [11] three cubes of size 150mm×150m×150mm,cylinders of 150mm×30mm and prims of 100mm×100mm×500mm respectively casted. After casting specimens were removed from moulds and kept for curing. All the specimens were tested at 7,14,28 days curing.

3.4 Durability tests

To study durability of concrete water absorption, Sulphate resistance and acid attack tests were carried out.

3.4.1 Water absorption test

The water absorption values for various mixtures of concrete were determined on 100mm x 100mm x 100mm cubes as per ASTM C 642 [2]. Concrete cube specimens were cast and kept in the aggressive medium for the period of 28 days. After 28 days specimens were taken out and placed in oven dry at the temperature of 105 ± 5^0 C to remove the moisture content. Then the dry weight of the specimen was measured by using electronic weighing balance and the specimens were immersed in curing tank .After 3 days of water immersion, the specimens were taken out. Dried and wet weights were recorded. Amount of water absorption were calculated with reference to dry weight of the specimen.

$$\text{Absorption in percentages} = (W_2\text{-}W_1)\ x100/W_1$$

Where,
W_2 - Weight of the specimen at fully saturated condition (gm)
W_1 - Weight of oven dried specimens (gm)

3.4.2 Sulphate resistance test

The acid resistance tests are carried out 100x100X100 mm size cube specimens. Then the cube specimens are allowed to dry and note the initial weight (W_1). The surface of the specimen is thoroughly prepared. Then 5% Na_2SO_4 is mixed per litre of ordinary water. Cube specimens are then immersed completely in the sulphate solution for 28 days. . After 28 days the cube specimen are taken out from the sulphate solution and kept dried and weighted (W_2). Reduction weight in sulphate attack = $(W_2\text{-}W_1)\ x100/W_1$

3.4.3 Acid resistance test

The acid resistance tests are carried out 100x100 mm×100mm size cube specimens at the age of 28 days curing(ASTM G20-8). Then the cube specimens are allowed to dry for 5 days and note the initial weight (W_1). The surface of the specimen is thoroughly prepared. Then 5% HCL is mixed per litre of ordinary water. Cube specimens are then immersed completely in the acid solution for 28 days. After 28 days the cube specimen are taken out from the acid solution and kept dried and weighted (W_2) .

$$\text{Reduction weight in acid attack} =(W_2\text{-}W_1)\ x100/W_1$$

4 RESULTS AND DISCUSSION

4.1. Hardened concrete results

4.1.1. Compressive Strength test

The compressive strength were evaluated at 7,14 and days and results illustrated in Figure1. It was found initially CC increases the compressive strength at early ages when compare with CFA decreased due to presence of fly ash it matches previous studies with results [16]. In CFAMK5,CFAMK10, CFAMK15 and CFAMK20 are increased compressive strength due to fast pozzolanic action MK [21] CFAMK15 give batter results of 8.1% higher than blended CC. It was found that decreases in CFAMK20C due to pozzolanic action and excess of pore filling effect of MK [17].

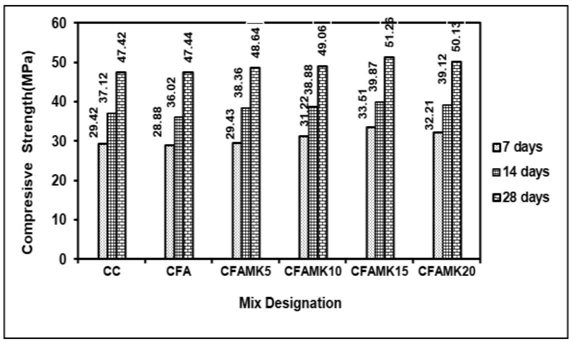

Fig. 1. *Compressive strength results*

4.1.2. Spilt tensile Strength test

The Split tensile strength were evaluated at 7,14 and days and results presented in Figure 2.This results similar to compressive strength and exhibited more strength in CFAMK15.Compartative analysis mix designation shows that little difference in high split strength value in economic point of view replacement of MK and FA in CFAMK15 gives 14.5% strength blended CC.

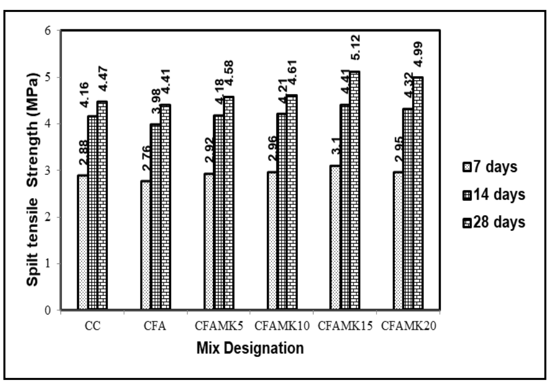

Fig 2. *Split tensile strength results*

4.1.3 Flexural Strength test

The flexural strength were estimated at 7,14 and 28 days and shown Figure 3.Flexural strength of concrete replace by FA 30% (Samhitha KV et nl.,2019) is reduces the flexural strength now overcome by our research in FA Replace by FA Combinations gives solution for Increases flexural strength on concrete. from result we found CFAMK15 gives better flexural strength.

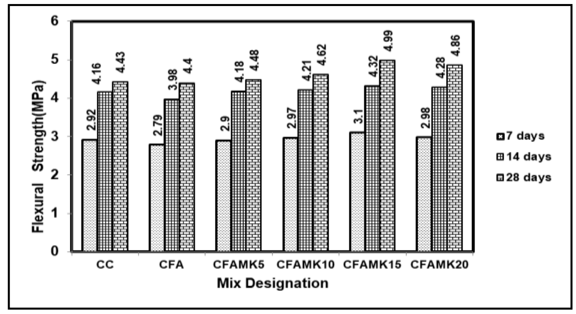

Fig. 3. *Flexural strength results*

4.2. Durability tests

4.2.1 Water absorption test

The effect MK and FA on the water absorption of concrete are shown in Figure 4.It was observed by adding the MK and FA increases the water absorption due to filling properties of MK is compared with [4] CC and CFA. Hence CFAMK5%, CFAMK10%,CFAMK15% and CFMK20% gives better results against water absorption.

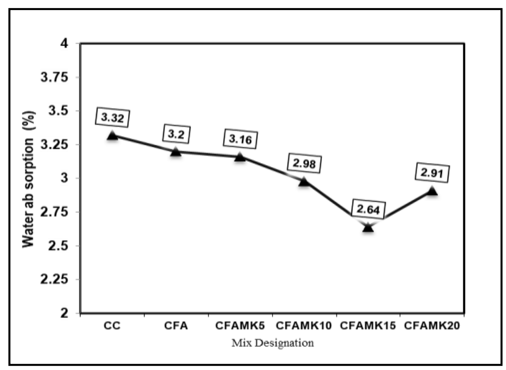

Fig. 4. *Water absorption test*

4.2.2 Sulphate resistance test

The effect MK and FA on the Sulphate resistance plotted of concrete are plotted in Figure 5. It shows that the MK and FAH increases the Sulphate resistance when compare with CC and CFA is CFAMK5,CFAMK10,CFAMK15 and CFAMK20 give good resistance against suphlate. This result is agreement with [16]. They reported that the increase in resistance is attributed to two mechanisms. The first mechanism is that replacement of OPC with MK reduces the total amount of tricalcium aluminate hydrate in the cement paste. The other is CH released during hydration of cement is partially consumed by pozzolanic reaction between CH and MK, thus quantity of gypsum formed by reaction of CH will be less in MK blended concrete than unblended concrete. The higher pozzolanic activity of MK resulted in an increased rate of strength development and pore structure refinement and CFAMK15 and CFAMK20 shows better results.

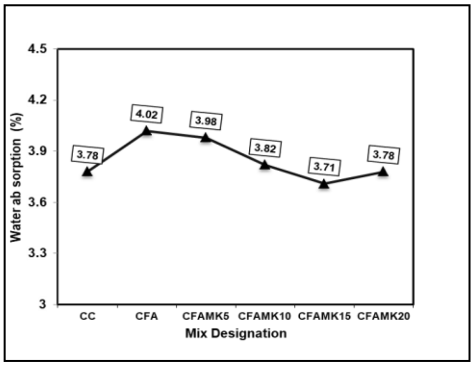

Fig 1.*5.Sulphate resistance test results*

4.2.2 Acid attack test

The average percentage of weight loss against acid attack is presented in Figure 6.It was observed that the contribution MK in fly ash improving resist against weight loss in acid attack when compare with blended mix (Mix 1) so all other mixes give good results. This result compare with the reduction of large capillary pores to small ones and shows blocking of these pores which is caused by formation of secondary C-S-H through pozzolanic reaction that refine the pore structure and protecting against harmuful chemicals.

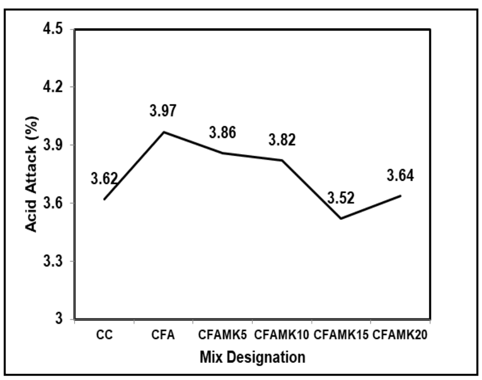

Fig 1.5*.Acid attack test results*

5 CONCLUSION

This study has reported the effect of FK and MK in OPC of various proportions. Based on results, the following conclusions were outlined:

- The mechanical properties compressive strength, spilt tensile strength and flexural strength of CFAMK 15 is (8.8%, 14.5%and 12.64%) higher than CC. After that CFAMK20 is reduce the properties due to filling effect of MK but that was higher than blended CC.
- This study also reveals the durability properties were increases of MK was increase the durability against water absorption, sulpahte resistance and acid attack when compare with CC and CFA.
- In this study finally reported that CFAMK15 gives the better results in both mechanically and durability properties. And also it was economic and sustainability material for construction.

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