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Efficient Combination of Mineral Admixture (Reactive and Micro Filler) for High Strength and Durable Concrete

Poonam Nagraj Petkar[1], Madhulika Sinha[2]

[1]PG Student, Dept of Civil Engineering, Pillai HOC College of Engineering and Technology, Rasayani, Maharashtra, India
[2]Assistant Professor, Dept of Civil Engineering, Pillai HOC College of Engineering and Technology, Rasayani, Maharashtra, India

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Abstract - *In this paper an experimental investigation is carried out on High Strength Concrete by using an appropriate combination of reactive and micro filler mineral admixtures. The analysis of result was carried out for water demand, heat of hydration, setting time, bleeding, and rate of reactivity, strength and density to find the best combination of the two. The experimental work carried out by replacing cementitious material with an appropriate proportion and combination of reactive and micro filler mineral admixture. The behavior and properties of concrete is recorded at every stage. Important changes were noticed in workability and compressive strength of concrete at various stages (3, 7, 28 and 56 days).The results are very encouraging for preparing high strength and durable concrete using combination of reactive and micro filler mineral admixture in suitable proportion.*

Key Words: *Durable concrete, reactive and micro filler mineral admixtures.*

1. INTRODUCTION

The challenging nature of modern infrastructures and durability requirement has gain the attention of concrete technologist to produce not only high strength but also durable concrete which can tackle severe environmental conditions in its life span. Due to the limitations of cement as a binding material addition of mineral admixtures has gain popularity in attempt of producing such concrete. The mineral admixture plays the role as reactive and or micro filler material in concrete. In this process they affect workability, heat of hydration, reactivity, density. Each mineral admixture influences the properties of concrete differently.

1.1 Admixtures

Fly Ash is residue from the combustion of pulverized coal which is collected either mechanically or by electrostatic separators. Fly Ash reduces the heat of hydration in concrete. Its pozzolanic action is slow and reduces the rate of gain of strength at early stage. It imparts strength to concrete predominately by improving the paste pore structure through filler effect and some amount by pozzolanic reaction with Calcium Hydroxide $Ca(OH)_2$ and converting them into additional Calcium Silicate Hydrate (C-S-H) gel.

Metakaolin is the anhydrous calcined form of the clay mineral kaolinite. The particle size of Metakaolin is smaller than cement particles but not as fine as silica fume. The production process of Metakaolin is closely controlled so as to obtain a pure and reactive product. These react with calcium hydroxide $Ca(OH)_2$ produced during the hydration of cement to form calcium hydro silicate (C-S-H) and calcium hydro alumina silicate.

Silica Fume is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production. When silica fume is added in concrete, much more active SiO_2 react with $Ca(OH)_2$ to produce C-S-H in the secondary reaction. Silica Fume being finer than the other cementitious material works as filler in filling the voids, reducing the porosity and increasing the density of the structure. Both the chemical active function and physical filling functions act together to increase the strength of concrete, especially the early strength.

Ground granulated blast-furnace slag (GGBS) is a non-metallic product consisting of silicates and aluminates of calcium and other bases. It imparts strength to concrete predominately by improving the paste pore structure through micro filler effect and some amount by pozzolanic reaction with Calcium Hydroxide $Ca(OH)_2$ and converting them into Calcium Silicate Hydrate (C-S-H).

1.2 METHODOLOGY AND MATERIALS

The combinations of reactive and micro filler mineral admixtures for producing high strength and durable concrete is identified as Micro Silica + Fly Ash (M2), Micro Silica + GGBS (M3), Metakaolin + Fly Ash (M4) and Metakaolin + GGBS (M5). A design mix of M60 grade (M1) as a reference mix and four sets of each combination with different proportion are casted. Compressive strength test is performed on the casted cubes at 3, 7, 28 and 56 days and the results of the combination mix are compared with reference design mix of same grade. A conclusion is derived from the results and an efficient combination for high strength and durable concrete is suggested.

The table given below gives the percentage cement replacement with different proportions of additives.

Table -1 Combination and Proportion

Cement Replacement (%)	20	20	20
Additives Mix (Reactive + Micro filler)			
M_1 (M-60Reference Mix)	-	-	-
M_2 (Micro Silica + Fly ash)	M_{21} (5+15)	M_{22} (10+10)	M_{23} (15+5)
M_3 (Micro Silica + GGBS)	M_{31} (5+15)	M_{32} (10+10)	M_{33} (15+5)
M_4 (Metakaolin + Fly ash)	M_{41} (5+15)	M_{42} (10+10)	M_{43} (15+5)
M_5 (Metakaolin + GGBS)	M_{51} (5+15)	M_{52} (10+10)	M_{53} (15+5)

2. RESULTS AND ANALYSIS

The compressive strength test results for 3, 7, 28, and 56 days are obtained for different combination.

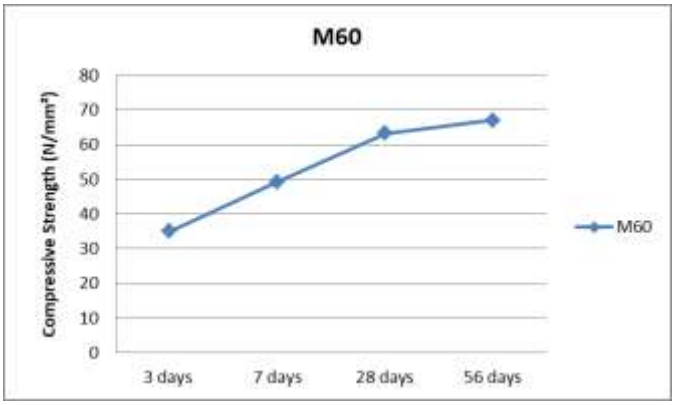

Fig No. 1 Reference Mix (M1) Graph

Figure No.1 shows the compressive strength of reference mix M60. The other combination is compared with the results of reference mix.

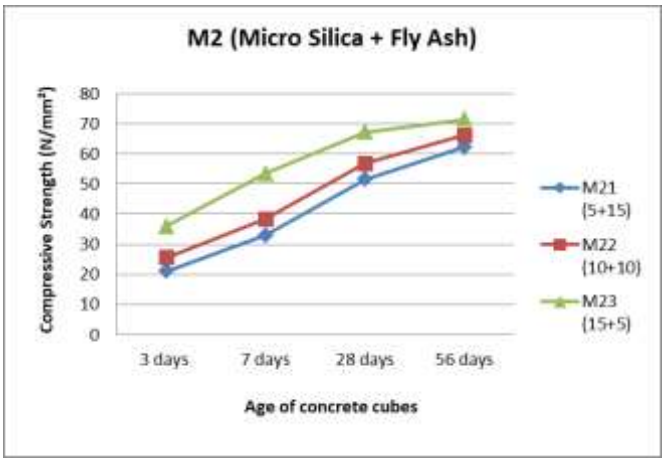

Fig No.2 Micro Silica + Fly Ash (M2) Graph

Figure No. 2 shows the compressive strength results of Micro Silica and Fly Ash combinations. The graph shows 15% micro silica and 5% Fly ash combination gives higher compressive strength as compared to other combination. Micro silica predominately works as a reactive type of mineral admixture and Fly Ash more as filler. Using more quantity of Micro Silica makes the concrete dense and gives better strength.

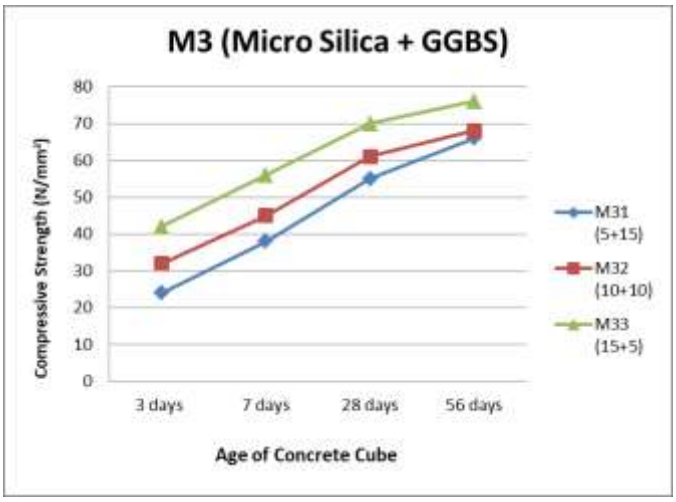

Fig No. 3 Micro Silica + GGBS (M3) Graph

Figure no. 3 shows the compressive strength results of Micro Silica and GGBS combinations. The graph shows 15% Micro Silica and 5% GGBS combination gives higher compressive strength as compared to other combination. Micro silica predominately acts as reactive mineral admixture but also imparts strength by filler effect. Using more quantity of Micro Silica makes the concrete dense and gives better strength.

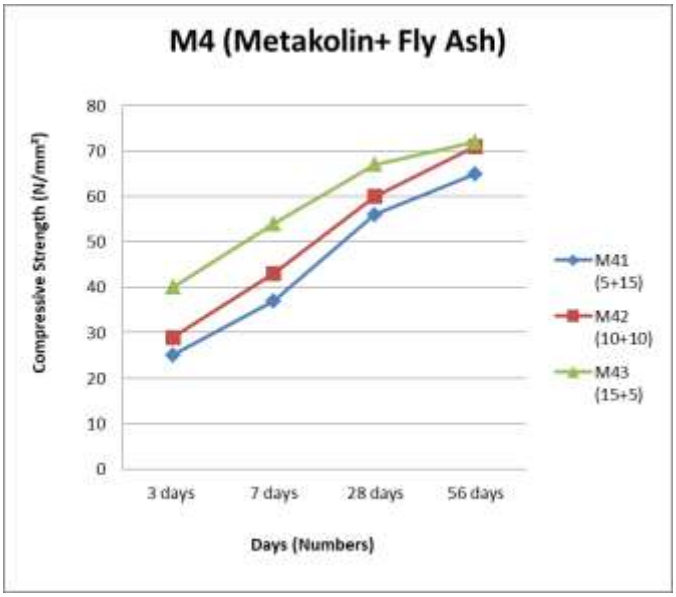

Fig No.4 Metakolin + Fly Ash (M4) Graph

Figure no. 4 shows the compressive strength results of Metakaolin and Fly Ash combinations. The graph shows 15% Metakaolin and 5% Fly Ash combination gives higher compressive strength as compared to other combination. Metakaolin works as a reactive type of mineral admixture and Fly Ash as filler; it makes the concrete dense and gives good strength

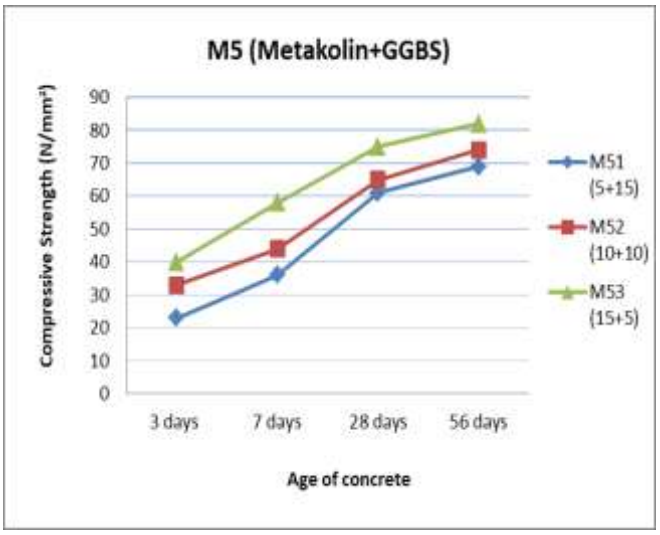

Fig No. 5 Metakaolin + GGBS (M5) Graph

Figure no. 5 shows the compressive strength results of Metakaolin and GGBS combinations. The graph shows 15% Metakaolin and 5% GGBS combination gives higher compressive strength as compared to other combination. The graph shows continuous strength gain even after 28 days. This gain of strength is due to secondary and tertiary reactions which is very essential for durable concrete.

3. CONCLUSIONS

The experimental investigation was aimed to design a high strength and durable concrete with partial replacement of cementititous material. Some of the broad conclusions are drawn as: The Micro Silica and Metakaolin predominately act as reactive mineral admixture and Fly Ash as filler. GGBS acts reactive as well as micro filler in similar manner. The appropriate replacement of reactive and filler admixtures with cement impart positive changes in concrete namely:

1. Reduces heat of hydration
2. Improves density by dense packing of particles
3. Increase early and ultimate compressive strength
4. Helps in reduction of CO_2 to environment

The experimental investigation shows the combination Micro Silica and GGBS (M33) and Metakaolin and GGBS (M53) in (15+5) % proportion are the most effective combination for producing high strength, durable concrete. With lower cost, naturally available material handling and workability aspects the Metakaolin outplays the Micro Silica.

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BIOGRAPHIES

Ms. POONAM N. PETKAR
Bachelor of Engineering degree in Civil Engineering from the Sardar Patel College of Engineering in 2015. Master`s Degree in Construction Engineering and Management from Pillai HOC College of Engineering and Technology Rasayani.

Ms. MADHULIKA SINHA
Ph.D (Pursuing) NIT Patna, Research area: Structural Engineering, Advanced Concrete Technology, Maintenance and Repairs of Concrete Structures.