Experimental Study of Partial Replacement of Cement by Metakaolin and Flyash

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Abstract - *Concrete is extensively habituated construction material. Product of Portland cement releases significant quantum of Co2. One tonne of Portland cement clinker product releases roughly one tonne of Co2 and other gases. Environmental issues play essential part in the sustainable development of concrete industry. One of the major challenges now in concrete industry in India is to meet the demand created by massive structures, fast industrialization and urbanization needs early stripping formwork. Moment numerous inquiries are going for the relief of Portland cement, using numerous waste materialss like fly ash and GGBS. The use of Mineral Amalgamation to drop the content of Portland cement results not only in an environmentally friendly product but also gives multitudinous gains to the parcels of fresh and toughened concrete similar as enhanced plasticity, better unity, low heat of hydration, lower permeability etc. I'm studying on the strength and continuity by blend design, compressive test and plasticity test of concrete cell by partial relief of cement by metakaolin. Metakaolin is one of the innovative complexion products developed in recent times. It's produced by controlled thermal treatment of kaolin.*

Key Words: **Metakaolin, Flyash, Portland cement, GGBS.**

1. INTRODUCTION

Cement And its Forecast

Cement demand increase shows that by the time 2050 it'll reach 6000 million tons. Portland cement product results to major CO2 emissions, results from calcination of limestone (CaCO3) and from combustion of fossil energies, including the energies needed to induce the electricity power factory, counting for nearly0.7 tons of CO2 per tonne of cement, which represents nearly 7% of the total CO2 world emissions. This is particularly very serious in the current environment of climate change caused by carbon dioxide emissions worldwide, which causes a slow rise in ocean position and which becomes responsible for a meltdown in the world economy.

Pozzolanic/ Mineral Cocktails

Since Portland cement is used substantially in concrete product, the most important structure material on Earth (10.000 billion tons per time), partial relief by pozzolanic by- products and mineral additions will allow necessary carbon dioxide emissions reductions. Pozzolanic cocktails reply with Ca (OH) generating fresh CSH phases, performing in a further compact concrete with increase in durability. Some supplementary cementitious material, like fly ash has veritably slow hydration characteristics therefore furnishing veritably little donation to early age strength, while others like metakaolin retain a high reactivity with calcium hydroxide having the capability to accelerate cement hydration. Since current concrete structures present advanced permeability situations that allows aggressive rudiments to enter, leading erosion problems, using pozzolanic cocktails not only reduce carbon dioxide emissions but also allows structures with longer service life, therefore lowering their environmental impact.

Fly Ash

Fly ash or stovepipe ash, coal ash, and also known as pulverised energy ash in the United Kingdom, or coal combustion residuals (CCRs), is a coal combustion product that's composed of the particulates (fine patches of burned energy) that are driven out of coal- fired boilers together with the stovepipe feasts. Ash that falls to the bottom of the boiler's combustion chamber (generally called a firebox) is called nethermost ash. In ultramodern coal- fired power shops, fly ash is generally captured by electrostatic precipitators or other flyspeck filtration outfit before the stovepipe feasts reach the chimneys. Together with nethermost ash removed from the bottom of the boiler, it's known as coal ash. Depending upon the source and composition of the coal being burned, the factors of cover ash vary vastly, but all fly ash includes substantial quantities of silicon dioxide (SiO2) (both unformed and crystalline), aluminium oxide (Al2O3) and calcium oxide (CaO), the main mineral composites in coal- bearing gemstone strata.

Metakaolin

Metakaolin (MK) is produced by controlled thermal treatment of kaolin. Different optimum temperature (600 – 850 °C) and period (1 – 12 h) for heating kaolin to gain MK with a high pozzolanic indicator has been introduced by different experimenters. Thus, MK can replace cement in concrete because of its pozzolanic parcels still the strength and continuity of MK concrete is still unknown. The engineering parcels of MK are controlled as it isn't a by-product. Thus, by proving the hardened parcels of MK concrete, it'll have promising advantages compared to other cement relief accoutrements.

Objectives of Study

To Determine Plasticity of concrete after incompletely adding Metakaolin and Fly Ash.

To determine Compressive strength of Concrete Cells after 7 days and 28 days of Curing by adding metakaolin and Fly ash.

Preparing Concrete cubes of M25 grade for checking its Plasticity (Slump cone test) and testing Compressive strength after 7 days and 28 days of curing of cubes.

Comparing Plasticity and Strength parameters of Conventional Concrete and concrete after adding metakaolin and fly ash.

2. MATERIALS AND METHODS

2.1 Introduction

The main end of this trial is to study the effect of partial relief of cement by Metakaolin and Fly ash on the parcels of Concrete. The Experimental programme is divided in four phases.

• Material Testing for Concrete Mix proportioning.

• Sieve Analysis of Coarse total.

• Sieve Analysis of Fine total.

• Specific graveness of Metakaolin.

• Specific Graveness of Fly ash.

• Specific Graveness of Coarse total.

• Specific graveness of Fine aggregate

• Concrete Mix Design As per IS 10262-2019 for M25 grade of Concrete with Partial relief of cement with varying probabilities of metakaolin and fly ash.

• Casting of Cubes and Workability Test (Slump Cone Test)

• Curing of Cells for 7 days and 28 days.

• Testing for compressive strength of Cubes after 7 days and 28 days of curing.

2.2 Sieve Analysis

This system is used to determine of particle size distribution of fine, coarse and each- by- summations by seiving or screening.

Apparatus:

Sieves-Sieves of the sizes 25 mm, 20 mm, 16 mm, mm, mm, mm, mm, mm.600 Micron, 300 Micron, Micron, Pan, conforming to IS460-1962.

Balance-The balance or scale readable and accurate to0.1 percent of the weight of the test sample.

Procedure

• The sample was brought to an air-dry condition before doing weight and seiving. This may be achieved either by drying at room temperature or by hotting at a temperature of 100" to 110 °C. The air-dry sample was counted and settled consecutively on the applicable sieves starting with the largest.

• Each sieve was shaken independently over a clean charger until not further than a trace passes, but in any case, for a period of not lower than two twinkles. The shaking was done with a varied stir, backwards and on, left to right, indirect clockwise and anti-clockwise, and with frequent jarring, so that the material is kept moving over the sieve face in constantly changing directions. Material was no way forced through the sieve by hand pressure, but on sieves coarser than 20 mm, placing of patches is permitted. Lumps of fine material, if present, was broken by gentle pressure with fritters against the side of the sieve. Light brushing with a soft encounter on the underpart of the sieve was used to clear the sieve openings.

• Light brushing with a fine camel hair encounter was used on the 150-micron and 75-micron IS Sieves to help aggregation of greasepaint and bedazzling of orifices. Stiff or worn-out skirmishes weren't used for this purpose and pressure shall not be applied to the face of the sieve to force patches through the mesh.

• On completion of sieving, the material retained on each sieve, together with any material gutted from the mesh, was counted.

1. Sieve Analysis of Coarse total (20 mm)

Source/ Factory of total Used = Kashid Plant

Table -1: Sieve Analysis of 20mm aggregate

Sr. No	Sieve Size	Weight Retained	Percentage Weight retained	Cumulative weight retained	Percentage Passing
1	25mm	0	0	0	100
2	20mm	250	10	10	90
3	16mm	1030	41.2	51.2	48.8
4	12.5mm	1060	42.4	93.6	6.4
5	10mm	160	6.4	100	0
6	4.75mm	0	0	100	0
7	2.36mm	0	0	100	0
8	1.18m	0	0	100	0

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	m				
9	600 µ	0	0	100	0
10	300 µ	0	0	100	0
11	150 µ	0	0	100	0
12	Pan	0			
	Total	∑=2500		∑=854.8	

Fineness Modulus = $\frac{\text{Sum of Cumulative weight retained}}{100}$

Fineness Modulus = $\frac{854.8}{100}$

Fineness Modulus = 8.55

2. Sieve Analysis of Coarse aggregate (10mm)

Source/Plant of aggregate Used = Manthalkar Plant

Table -2: Sieve Analysis of Coarse aggregate (10mm)

Sr. No	Sieve Size	Weight Retained	Percentage Weight retained	Cumulative weight retained	Percentage Passing
1	25mm	0	0	0	100
2	20mm	0	0	0	100
3	16mm	0	0	0	100
4	12.5 mm	110	4.4	4.4	95.6
5	10mm	1000	40	44.4	55.6
6	4.75 mm	1390	55.6	100	0
7	2.36 mm	0	0	100	0
8	1.18 mm	0	0	100	0
9	600 µ	0	0	100	0
10	300 µ	0	0	100	0
11	150 µ	0	0	100	0
12	Pan	0			
	Total	∑=2500		∑=648.8	

Fineness Modulus = $\frac{\text{Sum of Cumulative weight retained}}{100}$

Fineness Modulus = $\frac{648.8}{100}$

Fineness Modulus = 6.5

3. Sieve Analysis of Fine aggregate

Source/Plant of aggregate Used: Kashid Plant

Table -3: Sieve Analysis of fine aggregate

Sr. No	Sieve Size	Weight Retained	Percentage Weight retained	Cumulative weight retained	Percentage Passing	Percentage passing as per IS 383:2016
1	25mm	0	0	0	100	100
2	20mm	0	0	0	100	100
3	16mm	0	0	0	100	100
4	12.5 mm	0	0	0	100	100
5	10mm	0	0	0	100	100
6	4.75 mm	20	1.33	1.33	98.67	90-100
7	2.36 mm	420	28	29.33	70.67	60-95
8	1.18 mm	400	26.67	56	44	30-70
9	600 µ	210	14	70	30	15-34
10	300 µ	260	17.33	87.33	12.67	5-20
11	150 µ	100	6.67	94	6	0-10
12	Pan	90				
	Total	∑=1500		∑=337.99		

As per IS 383:2016 Table 9 Fine aggregate falls within Zone – I

Fineness Modulus = $\frac{\text{Sum of Cumulative weight retained}}{100}$

Fineness Modulus = $\frac{337.99}{100}$

Fineness Modulus = 3.38

Specific Gravity As per IS 2386 Part-III 1963

Specific Gravity is defined as the rate of Weight of Aggregate to the Weight of equal Volume of water. The specific gravity of an aggregate is called as a measure of strength or quality of the material. Aggregates having low specific gravity are mostly weaker than those with high specific gravity. This property helps in a general identification of aggregates.

Apparatus Pycnometer of 1000 ml for summations finer than6.3 mm

Procedure

• A clean, dry pycnometer is taken and its empty weight is determined (M1)

• About 1000g of clean sample is taken into the pycnometer, and it's counted (M2).

• Water at 270C is filled up in the pycnometer with aggregate sample, to just immerse sample.

• Directly after absorption the entangled air is removed from the sample by shaking pycnometer, placing a galette on the hole at the top of the sealed pycnometer.

• Now the pycnometer is fully filled up with water till the hole at the top, and after attesting that there's no more entrapped air in it, it's counted (M3)

• The contents of the pycnometer are discharged, and it's gutted.

• Water is filled up to the top of the pycnometer, without any entangled air. It's also counted (M4)

• Apparent Specific Graveness (M2 – M1)/ ((M4 – M1)- (M3-M2))

1. Specific Gravity of metakaolin

Table -4: Specific Gravity of metakaolin

Sr.No	Description	Trial 1	Trial 2	Trial 3
1.	Mass Of Pycnometer(M1)	604	604	604
2.	Massof Pycnometer +Massof Sample (M2)	706	735	744
3.	Massof Pycnometer +Massof Sample + Mass of Water (M3)	1564	1581	1588
4.	Mass of Pycnometer + Mass of Water (M4)	1504	1504	1504
5.	Specific Gravity	2.428	2.425	2.5
6.	Average Specific Gravity	2.45		

2. Specific Gravity of Fly ash

Table -5: Specific Gravity of Fly ash

Sr.No	Description	Trial 1	Trial 2	Trial 3
1.	Mass Of Pycnometer(M1)	604	604	604
2.	Massof Pycnometer +Massof Sample (M2)	865	768	795
3.	Massof Pycnometer +Massof Sample + Mass of Water (M3)	1628	1583	1596
4.	Mass of Pycnometer + Mass of Water (M4)	1504	1504	1504
5.	Specific Gravity	1.905	1.929	1.929
6.	Average Specific Gravity	1.92		

3. Specific Gravity of Fine aggregate

Table -6: Specific Gravity of Fine aggregate

Sr.No	Description	Trial 1	Trial 2	Trial 3
1.	Mass Of Pycnometer(M1)	604	604	604
2.	Massof Pycnometer +Massof Sample (M2)	929	875	1023
3.	Massof Pycnometer +Massof Sample + Mass of Water (M3)	1716	1679	1777
4.	Mass of Pycnometer + Mass of Water (M4)	1504	1504	1504
5.	Specific Gravity	2.88	2.82	2.87
6.	Average Specific Gravity	2.86		

4. Specific Gravity of Coarse aggregate (As per IS 2386 Part - III: 1963)

Specific Gravity = C/(A-B)

A = Weight of Saturated aggregate in Water = (A1- A2)

B = Weight of the Saturated surface dry aggregate in air.

C = Weight of Oven dried aggregate in air.

A1 = Weight of aggregate and basket in water.

A2 = Weight of empty basket in water.

3. RESULTS AND DISCUSSION

Compressive Strength Results of Cubes

Size of cube – 150X150X150mm

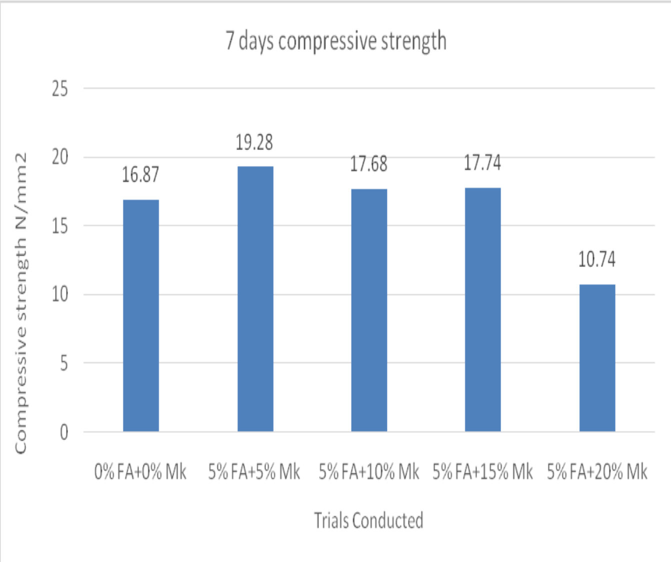

Fig -1: Comparison of 7 days Compressive Strength of Conventional concrete with Concrete of (5% fly ash and varying percentage of metakaolin)

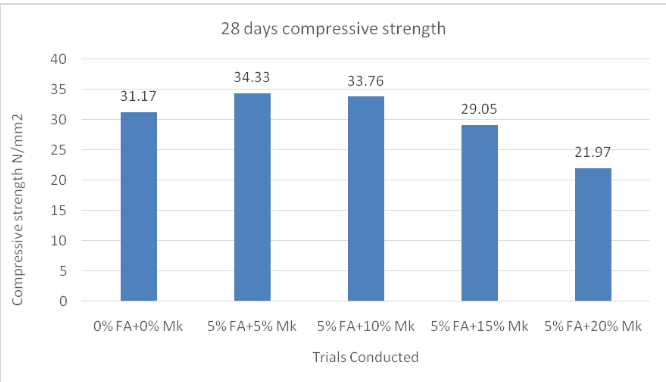

Fig -2: Comparison of 28 days Compressive Strength of Conventional concrete with Concrete of (5% fly ash and varying percentage of metakaolin)

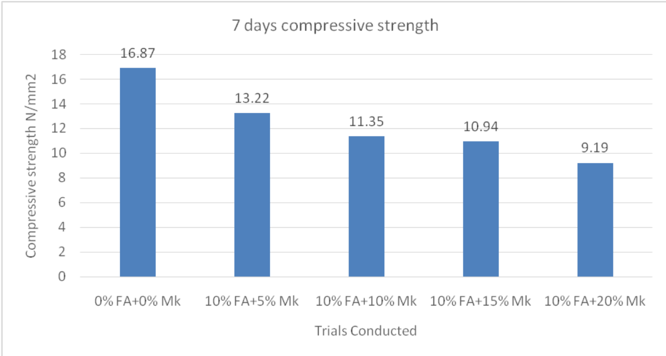

Fig -3: Comparison of 7 days Compressive Strength of Conventional concrete with Concrete of (10% fly ash and varying percentage of metakaolin)

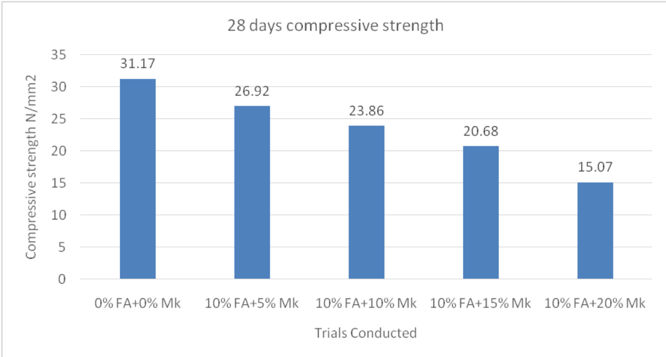

Fig -4: Comparison of 28 days Compressive Strength of Conventional concrete with Concrete of (10% fly ash and varying percentage of metakaolin)

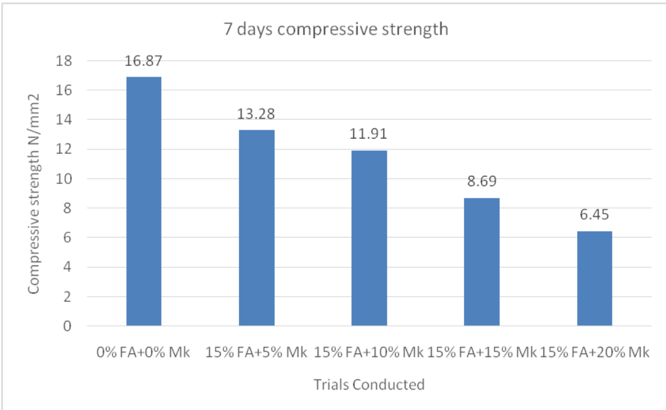

Fig -5: Comparison of 7 days Compressive Strength of Conventional concrete with Concrete of (15% fly ash and varying percentage of metakaolin)

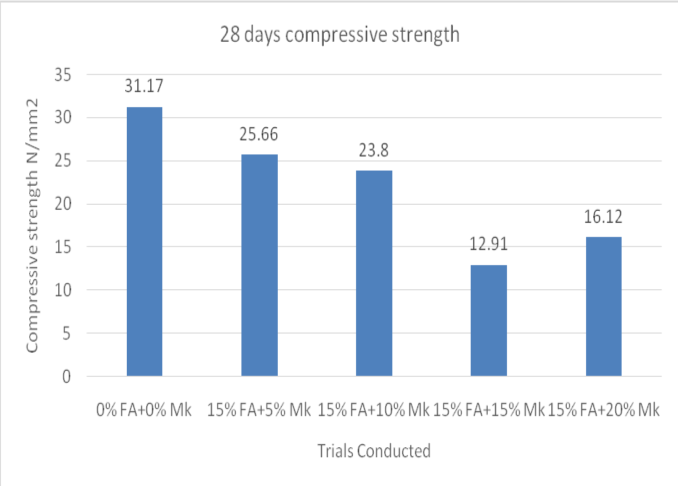

Fig -6: Comparison of 28 days Compressive Strength of Conventional concrete with Concrete of (15% fly ash and varying percentage of metakaolin)

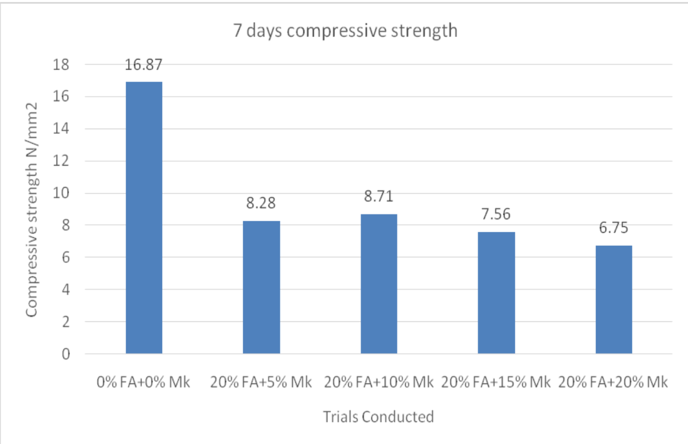

Fig -7: Comparison of 7 days Compressive Strength of Conventional concrete with Concrete of (20% fly ash and varying percentage of metakaolin)

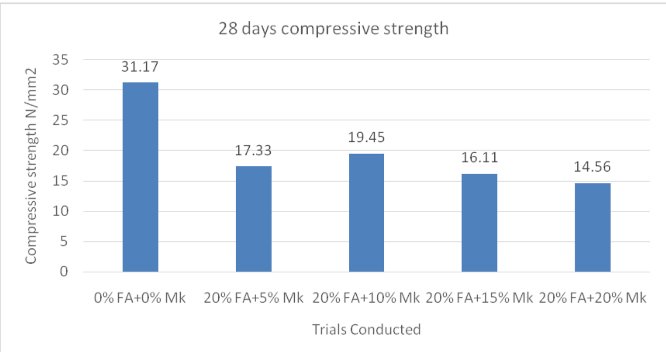

Fig -8: Comparison of 28 days Compressive Strength of Conventional concrete with Concrete of (20% fly ash and varying percentage of metakaolin)

Table -7: Results of Workability (Slump)

Sr. No	Trial	Workability Slump (mm)
1	0% FA + 0% MK	120mm
2	5% FA + 5% MK	0
3	5% FA + 10% MK	0
4	5% FA + 15% MK	0
5	5% FA + 20% MK	0
6	10% FA + 5% MK	0
7	10% FA + 10% MK	0
8	10% FA + 15% MK	0
9	10% FA + 20% MK	0
10	15% FA + 5% MK	150mm
11	15% FA + 10% MK	100mm
12	15% FA + 15% MK	0
13	15% FA + 20% MK	0
14	20% FA + 5% MK	150mm
15	20% FA + 10% MK	100mm
16	20% FA + 15% MK	50mm
17	20% FA + 20% MK	30mm

4. CONCLUSIONS

• In this Study, Concrete Mix design of M25 grade is made and trials are Conducted for various percentages of Fly ash and Metakaolin ranging from 5 – 20 and Compressive strength and Plasticity has been compared for various cases.

• Grounded on over all trials, following Prominent Conclusions are drawn

• Plasticity (Slump) Decreases as percentage of metakaolin is Increased.

• The strength of concrete increases with increase in metakaolin up to 15% replacement of cement and 5% fly ash, and if we farther increase in fly ash and metakaolin Compressive Strength of Concrete is reduced.

• Use of Metakaolin in Concrete as a partial replacement of cement leads to Compressive strength improvement and Lower drying loss and advanced durability.

• Metakaolin accelerates the setting time of cement paste.

• Use of fly ash and Metakaolin in concrete makes concrete cohesive as compared to Cement concrete.

• Combination of metakaolin and fly ash for concrete, Compressive strength increased up to 10%-15%.

• Use of fly ash in concrete can save the coal & thermal assiduity disposal costs and produce a 'greener' concrete for construction.

• Use of Proper Chance of Fly ash and Metakaolin in Concrete Increases Compressive strength and durability and Reduces the Cost of Concrete

• Use of Metakaolin and Fly ash as a partial replacement for cement dropped the Plastic viscosity of the Concrete.

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