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Experimental Study of GGBS with Metakaolin

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Abstract-*Construction industry is dominated by new materials which are ecologically violable and feasible solution for ever growing architectural industry. Effort are in progress all over the world to develop environment friendly construction materials which minimizes the utility of natural resources and helps to decrease green house gas emissions in to the atmosphere. The green house gas releases in the atmosphere is increasing day by day due to ordinary Portland cement production. In this connection, Geopolymer is in need, where the binders used in the production of geopolymer concrete is inorganic polymers. Geopolymer concrete will be introduced as an alternative concrete which did not use any cement in its mixture and used Metakaoline and GGBS as alternative cement. NaOH and Na2SiO3 were used as activator solution. The fixed ratio of sodium silicate to sodium hydroxide is 2.5 and the concentration of sodium hydroxide is 8 Molar. The geopolymer concrete specimens are casted and tested in the laboratory for compressive strength, Split Tensile Strength and Flexural Strength for 3 Days, 7 Days and 28 days and cured at ambient temperature. This study helps in gaining knowledge about the morophological composition of geopolymer concrete which might result in path-breaking trends in research and construction industry.* *Keywords - Geopolymer Concrete, Alkali Activators, Compressive Strength, Split Tensile Strength, Flexural Strength.*

INTRODUCTION

Concrete is the most widely used man-made construction material in the world. It is obtained by mixing of fine aggregates, coarse aggregates and cement with water and sometimes admixtures in required proportions. Fresh concrete or plastic concrete is freshly mixed material which can be molded into any shape hardens into a rock-like mass known as concrete. The hardening is because of chemical reaction between water and cement, which continues for long period leading to stronger with age. The utility and elegance as well as the durability of concrete structures, built during the first half of the last century with ordinary Portland cement (OPC) and plain round bars of mild steel, the easy availability of the constituent materials (whatever may be their qualities) of concrete and the knowledge that virtually any combination of the constituents leads to a mass of concrete have bred contempt. Strength was emphasized without a thought on the durability of structures. As a consequence of the liberties taken, the durability of concrete and concrete structures is on a southward journey; a journey that seems to have gained momentum on its path to self–destruction.

1.2 High Strength Concrete

High strength concrete has been defined as a concrete which compressive strength is high compared to the regular grades of concrete. American Concrete Institute (ACI) defines a high-strength concrete as concrete that has a specified compressive strength for design of 6000psi(41MPa) or greater. Other countries also specify a maximum compressive strength, whereas the ACI definition is open-ended.

The strength of concrete primarily depends upon the cement paste and in more the strength of paste increases with the fineness of cement contents. Hence as the water cement (W/C) Ratio decreases the concrete gets higher Strength but concrete become unworkable.

Certain organic compounds are used in the concrete. Which having the pozzolanic properties some of cementitious materials like Fly ash, silica fume and ground granulated blast-furnace slag (GGBS), are used in different percentages for different grade of concrete.Designed with different percentage of Fly ash and ground granulated blast-furnace slag (GGBS) then it is observed in improving of flexural strength and also compressive strength of concrete, at the same time it is also observed that the cost of the concrete is reducing.

The specification of high-strength concrete generally results in a true performance specification in which the performance is specified for the intended application, and the performance can be measured using a well-accepted standard test procedure. The same is not always true for a concrete whose primary requirement is durability.

Durable concrete Specifying a high-strength concrete does not ensure that a durable concrete will be achieved. In addition to requiring a minimum strength, concrete that needs to be durable must have other characteristics specified to ensure durability. In the past, durable concrete was obtained by specifying air content, minimum cement content and maximum water-cement ratio. Today, freeze-thaw resistance, abrasion resistance or any combination of these characteristics. Given that the required durability characteristics are more difficult to define than strength characteristics, specifications often use a combination of performance and prescriptive requirements, such as permeability and a maximum water-cementitious material ratio to achieve a durable concrete.

The end result may be a high-strength concrete, but this only comes as a by-product of requiring a durable concrete.

High Performance Concrete

High performance of concrete (HPC) is widely been used in recent years, not only for its increased compressive strength, and to improve durability and economic benefits, but also for its positive impact on the environment.

Cement and concrete are key components of both commercial and residential construction in worldwide; the cement and concrete industries are huge. Worldwide, cement production of 1.25 billion tons in 1991, according to the U.SBureau of mines. And now it may be more than 3.5 billion tones.

EXPERIMENTAL INVESTIGATION

Introduction

The Quality of concrete can be achieved by the selection of suitable materials, cementitious materials, admixtures, the choice of mix proportion, water cement ratio and use of proper methods of mixing, placing and curing. All these aspects depends upon the selection of materials and admixtures.

The scope of present investigation is to high strength concrete on plain concrete, concrete with replacement of varying percentages of GGBS and METAKAOLIN in different total percentages of 0%,10%,20%,30%,40% and 50% for M60 grade concrete mix.

Ground Granulated Blast Furnace Slag

Ground Granulated Blast furnace slag (GGBS) is a by-product for manufacture of pig iron and obtained through rapid cooling by water or quenching molten slag. Here the molten slag is produced which is instantaneously tapped and quenched by water. This rapid quenching of molten slag facilitates formation of “Granulated slag”. Ground Granulated Blast furnace Slag (GGBS) is processed from Granulated slag. If slag is properly processed then it develops hydraulic property and it can be effectively used as a pozzolanic material. However, if slag is slowly air cooled then it is hydraulically inert and such crystallized slag cannot be used as pozzolanic material. Though the use of Ground Granulated Blast furnace slag (GGBS) in the form of Portland slag cement is not a common in India, experience of using Ground Granulated Blast furnace slag (GGBS) as partial replacement of cement in concrete in India is very less quantity. Ground Granulated Blast furnace slag (GGBS) essentially consists of silicates and alumino silicates of calcium and other bases that is developed in a molten condition simultaneously with iron in a blast furnace. The chemical compositions of oxides in ground granulated blast furnace slag (GGBS) are similar to that of Portland cement but the proportions may vary.

Fig no.1.1GGBS

CHEMICAL COMPOSITION OF GGBS

SiO_2	30-38
Al_2O_2	16-23
Fe_2O_3	1.6-3.5
CaO	30-42
MgO	8-13
Mno	0.1-0.4
S	0.5-0.8

Table No. 3.2.Physical Properties of GGBS:

Fineness	390 m^2/kg
Specific gravity	2.875

Metakaolin:

Metakaolin is a dehydroxylated form of the clay mineral kaolinite. Stone that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. The particle size of metakaolin is smaller than cement particles, but not as fine as silica fume.

Table No. 3.3.Physical Properties of Metakaolin:

Fineness	280 m^2/kg
Specific gravity	2.2

Fine Aggregate

Fine aggregates are materials passing through an IS sieve that is less than 4.75mm gauge. Simply the aggregates which are passing 4.75mm sieve are called as Fine Aggregates. The most important function of the fine aggregate is to provide workability and Uniformity in the mixture. The fine aggregate also helps the cement paste to hold the coarse aggregate particle in suspension.

Table 3.6 Physical properties of fine aggregate

S. No.	Property	Value
1	Specific Gravity	2.74
2	Fineness Modulus	2.73
3	Bulk density Loose Compacted	 14.67 kN/m3 16.04 kN/m^3
4	Grading	Zone –II

Table 3.7 Sieve analysis of fine aggregate

S. L No	IS Sieve Size	Weight Retained	Cumulative weight retaine	Cumulative % weight retaine	Cumulative % Passing

		(g)	d	d (g)	
1	10mm	0.00	0.00	0.00	100.00
2	4.75 mm	10.00	10.00	1.00	99.00
3	2.36 mm	46.50	56.50	5.65	94.35
4	1.18 mm	188.00	24.50	24.45	75.55
5	600 mm	288.00	532.50	53.25	46.75
6	300 mm	358.00	890.50	89.005	10.95
7	150 mm	109.00	1000.00	100.00	0.00

Coarse aggregate

Coarse aggregates are materials which retains on an IS sieve 4.75mm gauge. Simply the aggregates which are retaining on 4.75mm IS sieve are called as Coarse Aggregates.

The coarse aggregate used here with having maximum size of 20mm. We used the IS 383:1970 to find out the proportion of mix of coarse aggregate, with 60% 20mm size and 40% 10mm.

Table 3.8 Physical properties of coarse aggregate

Properties	Results Obtained
Specific gravity	2.74
Fineness Modulus	7.61

Table 3.9 Sieve analysis of coarse aggregate

S. L No	Is Sieve Size	Weight retained (g)	Cumulative weight retained	Cumulative % weight retained (g)	Cumulative % passing
1	80mm	0.00	0.00	0.00	100.00
2	40mm	0.00	0.00	0.00	100.00
3	20mm	3376.50	3376.50	67.52	32.48
4	10mm	1385.00	4761.00	95.22	4.78
5	4.8mm	169.00	4930.00	98.60	1.40
6	2.4mm	70.00	5000.00	100.00	0.00
7	1.18 mm	0.00	5000.00	100.00	0.00
8	600 mm	0.00	5000.00	100.00	0.00
9	300 mm	0.00	5000.00	100.00	0.00
10	150 MM	0.00	5000.00	100.00	0.00

Water

General water has been used in this experimental program for mixing and curing.

Super plasticizer

The super plasticizer used in this experiment is SP430. It is manufactured by FOSROC, Bangalore.

Super Plasticizers are new class of generic materials which when added to the concrete causes increase in the workability. They consist mainly of naphthalene or melamine sulphonates, usually condensed in the presence of formaldehyde.

Super plastised concrete is a conventional concrete containing a chemical admixture of super plasticizing agent. As with super plasticizer admixtures one can take advantage of the enhanced workability state to make reductions in water cement ratio of super plasticized concrete, while maintaining workability of concrete. The use of super plasticizers in ready mixed concrete and construction reduces the possibility of deterioration of concrete for its appearance, density and strength. On the other hand, it makes the placing of concrete more economical by

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increasing productivity at the construction site. Upto 4% by weight of cement is used to maintain the workability.

Concrete mixes were designed for compressive strength and flexural strength of 60MPa and 80MPa with a water cement ratio 0.37 respectively adopted by experience In the design mixes the Portland cement was replaced by fly ash with 0%, 10%, 20% and 30% and GGBS of 10% to 40% and the specimens are casted.

The mix design procedure and calculations are shown in Appendix -A. The proportions of constituent materials i.e., cementitious material (cement, fly ash and GGBS), aggregates (Coarse and Fine) and water for two grades of mixes were done and presented in tables.

RESULTS AND DISCUSSIONS

PRESENTATION OF RESULTS

Compressive strength results

The results of compressive strength of M60 concrete is tested after 7 days & 28 days curing and are tabulated from table 4.5 to 4.10.

Flexural strength results

The results of flexural strength of M60 concrete is tested after 7 days & 28 days curing and are tabulated from below table

Table 3.1 Physical properties of cement

S.L. No	Designation	Specific Gravity	Fineness (blains) Cm^2/gm
1.	Cement	3.15	2600
2.	GGBS	2.23	2700-2900

Table No. 3.2.Physical Properties of GGBS

Fineness	390 m^2/kg
Specific gravity	2.875

Table No. 3.3.Physicial Properties of METAKAOLIN

Fineness	280 m^2/kg
Specific gravity	2.2

Table 3.4 Chemical properties of Cement

S.L. No	Characteristics	Result (0% by Mass)
1	Loss of ignition	3.15
2	Silica (sio_2)	2.27
3	Alumina (Al_2o_3)	4.42
4	Iron (fe_2o_3)	11.38
5	Calcium (cao)	58.51

Table No. 3.5 Chemical properties of METAKAOLIN

Ox.e name	Ox.e compound	Percentage
Calcium	Cao	4.6
Silica	Sio2	38.10
Alumna	Al2o3	8
Iron ox.e	Fe2o3	5.4
Magnesium ox.e	Mgo	2.1
Sulphate	SO3	1.2
Others	(Alkalis)	0.09

Table No. 3.6 Chemical properties of GGBS

Ox.e name	Ox.e compound	Percentage

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Calcium	Cao	36
Silica	Sio2	34
Alumna	Al2o3	18.5
Iron ox.e	Fe2o3	2.5
Magnesium ox.e	Mgo	11.5
Sulphate	SO3	0.65
Others	(Alkalis)	----

Table 3.7. Properties of fine aggregate

Properties	Results Obtained
Specific gravity	2.74
Fineness Modulus	2.73

Table 3.8. Properties of coarse aggregate

Properties	Results Obtained
Specific gravity	2.74
Fineness Modulus	7.61

Table 3.9 Sieve analysis of Fine aggregate (Weight of sample 1000g)

S. L N o	IS Sieve Size	Weight Retained (g)	Cumlative weight retained	Cumulative % weight retained (g)	Cumulative % Passing
1	10mm	0.00	0.00	0.00	100.00
2	4.75 mm	10.00	10.00	1.00	99.00
3	2.36 mm	46.50	56.50	5.65	94.35
4	1.18 mm	188.00	24.50	24.45	75.55
5	600mm	288.00	532.50	53.25	46.75
6	300mm	358.00	890.50	89.005	10.95
7	150mm	109.00	1000.00	100.00	0.00

Fineness modulus of sand = Σg/100

= 273.35/100

= 2.73

Table 3.10. Sieve Analysis of coarse Aggregate (Weight of sample 5000 g)

S. L N o	Is Sieve Size	Weight retained (g)	Cumulative weight retained	Cumulative % weight retained (g)	Cumulative % passing
1	80mm	0.00	0.00	0.00	100.00
2	40mm	0.00	0.00	0.00	100.00
3	20mm	3376.50	3376.50	67.52	32.48
4	10mm	1385.00	4761.00	95.22	4.78
5	4.8mm	169.00	4930.00	98.60	1.40
6	2.4mm	70.00	5000.00	100.00	0.00
7	1.18 mm	0.00	5000.00	100.00	0.00

8	600 mm	0.00	5000.00	100.00	0.00
9	300 mm	0.00	5000.00	100.00	0.00
10	150 MM	0.00	5000.00	100.00	0.00

Fineness modulus of Coarse aggregate = Σg/100

= 761.1/100
= 7.61

Table No.4.1 Details of Concrete Mix Proportions for M60

TRIAL MIX	% of METAKAOLIN	% of GGBS	% of Cement	W/C Ratio
M0-G0-C100	0	0	100	0.37
M10-G10-C80	10	10	80	0.37
M10-G20-C70	10	20	70	0.37
M10-G30-C60	10	30	60	0.37
M10-G40-C50	10	40	50	0.37
M10-G50-C40	10	50	40	0.37
M20-G10-C70	20	10	70	0.37
M20-G20-C60	20	20	60	0.37
M20-G30-C50	20	30	50	0.37
M20-G40-C40	20	40	40	0.37
M20-G50-C30	20	50	30	0.37
M30-G10-C60	30	10	60	0.37
M30-G20-C50	30	20	50	0.37
M30-G30-C40	30	30	40	0.37
M30-G40-C30	30	40	30	0.37
M30-G50-C20	30	50	20	0.37

Table No. 4.3 Workability of various Concrete mixes

TRIAL MIX	SLUMP (mm)
M0-G0-C100	90
M10-G10-C80	85
M10-G20-C70	90
M10-G30-C60	80
M10-G40-C50	80
M10-G50-C40	70
M20-G10-C70	90
M20-G20-C60	80
M20-G30-C50	80
M20-G40-C40	70

M20-G50-C30	75
M30-G10-C60	80
M30-G20-C50	85
M30-G30-C40	80
M30-G40-C30	75
M30-G50-C20	70

Table No. 4.4 Consistency values of various concrete mixes

% of Metakaolin	% of GGBS	% of Cement	Consistency
0	0	0	-
10	10	80	41
10	20	70	43
10	30	60	45
10	40	50	46.5
10	50	40	47
20	10	70	35
20	20	60	45
20	30	50	47
20	40	40	49
20	50	30	51
30	10	60	40
30	20	50	42
30	30	40	46
30	40	30	49
30	50	20	52

Table No 4.5. Compressive strength of concrete for different percentages of GGBS and constant 10% of Metakaolin for M60

TRIAL MIX	7 days	28 days	56 days	90 days	180 days
M0-G0-C100	52.68	66.8	74.87	78.18	80.6
M10-G10-C80	57.4	70.7	80.1	85.1	86.2
M10-G20-C70	59.7	72.1	81.7	87.4	86.5
M10-G30-C60	61.9	73.73	83.69	89.11	87.4
M10-G40-C50	55.3	69.23	78.34	83.1	86.7
M10-G50-C40	46.6	62.94	71.5	75.08	76.91

Table No. 4.6. Compressive strength of concrete for different percentages of GGBS and constant 20% of METAKAOLIN for M60

TRIAL MIX	7 days	28 days	56 days	90days	180 days
M0-G0-C100	52.68	66.8	74.87	78.18	80.6
M20-G10-C70	54.2	66.98	76.8	83.52	88.3
M20-G20-C60	56.5	70.2	80.3	87.6	89
M20-G30-C50	51.8	64.3	74.2	80.6	84.9
M20-G40-C40	45.44	59.8	78.2	72.9	74.6
M20-G50-C30	42	55.4	52.13	57.26	59.02

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Table No. 4.7. Compressive strength of concrete for different percentages of GGBS and constant 30% of METAKAOLIN for M60

TRIAL MIX	7 days	28days	56days	90days	180days
M0-G0-C100	52.68	66.8	74.87	78.18	80.6
M30-G10-C60	38.8	64.2	69.9	74.2	77.3
M30-G20-C50	48.2	72.2	78	82.5	85.76
M30-G30-C40	36.04	59.23	62.96	66.68	68.57
M30-G40-C30	32	41	56.66	59.34	62
M30-G50-C20	27.1	28.7	40.19	53.16	55.8

Table No.4.8 Flexural strength of concrete for different percentages of GGBS and constant 10% of METAKOALIN for M60

MIX ID	7 days	28 days	56 days	90days	180 days
M0-G0-C100	3.04	5.04	6.01	6.37	6.75
M10-G10-C80	3.83	6.03	6.73	7.25	7.72
M10-G20-C70	3.59	5.81	6.58	7.06	7.47
M10-G30-C60	4.46	6.24	6.98	7.56	8.26
M10-G40-C50	3.29	5.3	6.24	6.79	7.2
M10-G50-C40	2.73	4.72	5.72	5.96	6.25

Table No. 4.9 Flexural strength of concrete for different percentages of GGBS and constant 20% of METAKAOLIN for M60

MIX ID	7 days	28 days	56 days	90 days	180 days
M0-G0-C100	3.04	5.04	6.01	6.37	6.75
M20-G10-C70	3.23	5.26	6.14	6.72	7.12
M20-G20-C60	3.98	5.53	6.54	7.09	7.5
M20-G30-C50	2.77	4.69	5.77	6.22	6.52
M20-G40-C40	2.56	4.4	5.31	5.89	6.22
M20-G50-C30	2.32	4.01	4.46	5.04	5.19

Table No. 4.10. Flexural strength of concrete for different percentages of GGBS and constant 30% of METAKAOLIN for M60

MIX ID	7 days	28 days	56 days	90 days	180 days
M0-G0-C100	3.04	5.04	6.01	6.37	6.75
M30-G10-C60	2.83	4.9	5.8	6.27	6.62
M30-G20-C50	3.43	5.24	6.3	6.73	7.15
M30-G30-C40	2.59	4.1	4.78	5.26	5.62
M30-G40-C30	2.35	3.47	4.11	4.4	4.57
M30-G50-C20	2.03	2.53	3.19	3.81	4.07

FIGURES

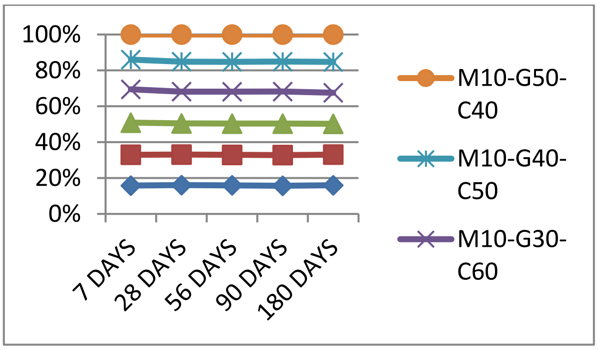

Figure No.4.1 Compressive strength for different percentages of GGBS and constant of 10% metakaolin for M60

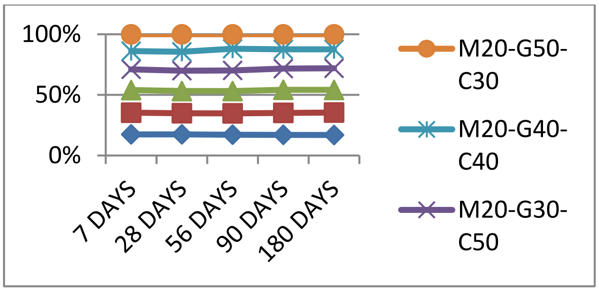

Figure No..4.2. Effect of Compressive strength by increasing of GGBS for constant of 20% metakaolin for M60

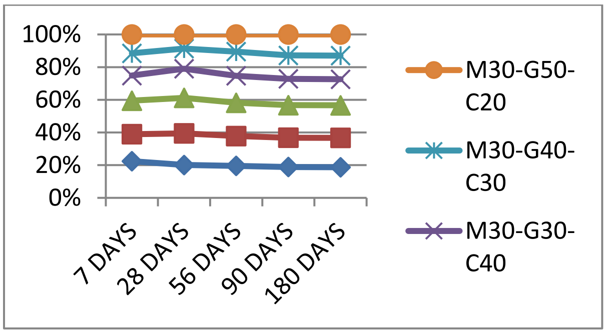

Figure. No.4.3. Compressive strength for different percentages of GGBS andconstant of 30% metakaolin for M60

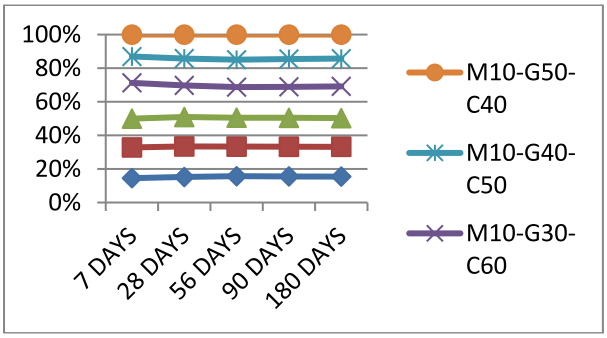

Figure. No.4.4. Flexural strength for different percentages of GGBS and constant of 10% metakaolin for M60

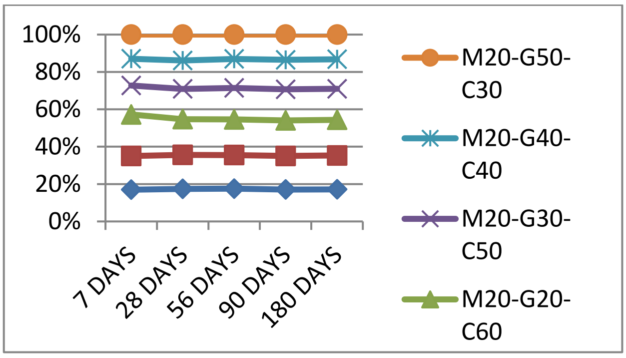

Figure. No.4.5. Effect of Flexural strength by increasing of GGBS for constant of 20% metakaolin for M60

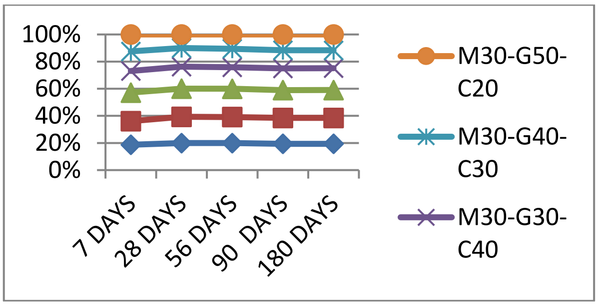

Figure. No.4.6. Flexural strength for different percentages of GGBS and constant of 20% metakaolin for M60

Conclusions

Based on experimental investigations the following conclusions are drawn.

1. Cement replacement by in combination of metakaolin and adding Ground granulated blast furnace slag leads to increase in compressive strength and flexural strength up to 40% to 50% replacement for M60 grade of concrete. Beyond 50% replacement of metakaolin and ground granulated blast furnace slag compressive strength and flexural strength decreased.
2. It is observed that at 28days compressive strength and flexural strength of M60 grade concrete are increased for different combination of mix proportions .

3. It is observed that at 90days compressive strength and flexural strength of M60 grade concrete are increased.
4. It is observed that at 180days compressive strength and flexural strength of M60 grade concrete are increased.

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