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COMBINED EFFECT OF GGBS AND METAKAOLIN ON MECHANICAL PROPERTIES OF STRENGTH OF CONCRETE

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Abstract : In this experimental studies it is focused on the partial replacement of cement by Metakaolin which is produced by heat-treating kaolin, one of the most abundantly natural available mineral and also waste material GGBS obtained from ins manufacturing industries as by-product. In this attempt is made to reduce the production of green house gases and protecting environment and also the natural resources of calcareous material by reducing the production of Cement.

In this study, concrete of M25 grade were considered for w/ ratio 0.50 for the replacement of cement by Metakaolin of 5% 10% 15%and 40% is tried and optimum parentages replacement is fixed. For this optimum percentage of Metakaolin, further. cement is replaced by different percentage of GCBS e. 6%, 9%, 12% is tried. Then the investigation revealed improvement in compressive strength, split tensile strength and flexural strength for various percentage replacement of cement by Metakaolin(MK) and GGBS. Based on the overall observation, it could be recommended that 15%MK and 9%GGBS replacement for cement be effectively utilized in all the concrete Works.

***Index Terms* – Metakaolin, GGBS, Compressive strength, Split tensile strength, Flexural Strength.**

I. INTRODUCTION

Into construction field, the utilization of cement is very much large, as it produces high compressive strength. The cement production is energy consuming also leads to the release of harmful green house gases which are detrimental to environment and also reduces the natural resource of calcareous stone in the nature.

The developing country like India, is the infra structural development is very fast like huge multi-storied buildings, industrial structures, roads and highways, irrigation projects etc, which needs large quantity of cement. Hence an attempt is made to use Metakaolin along with the waste products like GGBS, Husk Ash, Silica fumes Rice, Fly Ash into several proportions of cement replacement with these waste materials to achieve high strength concrete.

It is a pozzolanic substance known as metakaolin (MK). Kaolinite is a clay mineral that has been dehydroxylated. It is made by heating kaolinitic clay to between 500 and 800 degrees Celsius. Clay minerals lose much of the water they have absorbed between 100ºC and 200ºC. Dehydroxilization of kaolinite occurs between 500 and 800 degrees Celsius, at which point the mineral is calcined. Kaolin clay is utilised like an raw material for producing metakaolin ($Al_2Si_2O_7$). Porcelain has historically been made from kaolin, a fine, white clay material. The mineralogical word for kaolin clays is kaolinite. The most common component of kaolin is kaolinite, a common mineral composed mostly of hydrated aluminium disilicate. [10].

GGBS isbyproduct of blast furnace process of iron production. Because it is less dense, molten slag floats on top of iron. Using high-pressure water jets, molten slag is cooled and granulated in the process. Granular particles less than 5mm in diameter are formed as a consequence of rapid cooling of slag. Drying and milling the slag to a fine powder, known as GGBS, is next step in process (Ground Granulated Blast Furnace Slag). A spinning ball mill is used to grind granulated slag into a fine powder, which may then be utilised for replacing for several cement into concrete mixes. Cement and concrete composites may both benefit from cementatious properties of GGBS, pozzolanic material, many researchers have used GGBS to improve cement-based materials properties, and have achieved great successes. This supplementary material improves many of theperformance characteristics of the concrete.

Between 30 and 85 percent of GGBS is replaced each year. In most cases, 50% of time, this percentage is utilised. High-replacement proportions till 85% have employed into particular applications, like into inimical settings as well as lowering the hydration heat. GGBS may be utilised for lean mix concrete at a 70 percent replacement level.

II. LITERATURE REVIEW

Erhan Guneyisi, Mehmet Gesoglu & Kasim Mermedas[15] (2007), Metakaolin has been examined for its ability to improve shrinkage, pore structure as well as concrete's strength. In investigation, MK replacement amounts of 10% as well as 20% of Portland cement utilised were used. At 0.35 and 0.55 w/c ratios, plain PCMK concrete mixtures was developed for use in construction industry. As a result of testing, it was shown that MK significantly decreased drying shrinkage strain while increasing cement's strengths, which depended heavily upon MK's concentration and age at which testing was carried out. The ultrafine MK also significantly improved pore structure of concrete and decreased detrimental pore content, making concrete more impermeable, particularly at level of replacement of 20%.

Sanjay. N. Patil, Anil. K. Gupta, Subhash. S. Deshpande[11], investigated Metakaolin-Pozzolanic Material for Cement into M55 grade Concrete. As a result of the excellent effects it has on many characteristics of concrete, metakaolin is becoming more popular as component in high strength concrete. This study examines utilisation of metakaolin.

To get the best results, they recommend substituting 7 to 15 percent of cement using metakaolin to get optimum performance. It is possible that after 28 days, concrete's compressive strength with 15% metakaolin will be 20% greater. The suspension's workability decreases with time when given dose of 15% metakaolin. More metakaolin into concrete mix appears to necessitate greater dosages of superplasticizer in order to maintain workability for longer.

J. M. Khatib and J. J. Hibbert[12] (2000), Particular engineering characteristics of concrete containing metakaolin as well as slag have been examined. Incorporating GGBS and MK (metakaolin) into concrete is being studied for their impact on its strength. As a result, Portland cement was substituted with mixture of 0–80% GGBS with 0–20% MK. All mixes had water to cementitious material proportion of 0.5. In early stages of curing, adding of MK outcomes into increased strength. It's worth noting as concrete strength decreases within first 28 days when GGBS is used. With the addition of up to 60% GGBS, strength of product improves significantly after 28 days. MK is added to GGBS concrete to compensate for lack of compressive strength in early stages of curing. The long-term strength of GGBS-concrete isn't diminished with adding of MK. And over 10% MK in concretes including up to 12 percent GGBS doesn't subsidize to an improvement in compressive strength..

Ping Duan, Zhonghe Shui, Wei Chen, Chunhua Shen[16], used ground granulated metakaolin as well as slag for cement replacement materials to improve microstructure as well as durability of concrete. This study focuses on pores and their structure.

Researchers examined the concrete's interfacial transition zone (ITZ) after adding GGBS and metakaolin. Methods like mercury intrusion porosimetry, micro hardness testers and SEM have been used for examining impact of GGBS and MK upon pore structure, micro hardness, and ITZ morphology after 28 days of exposure to these materials. ITZ and pore characteristics were used to assess durability as well as compressive strength including freeze-thaw resistance, carbonation and chloride penetration resistance resistance of materials. Furthermore, thermodynamic instability of hydrate phases were subsequently studied in relation to primary component of GGBS and MK, silicon. Researchers found as GGBS and MK had good effect on concrete's porosity and ITZ improvement. ITZ and pore structure are directly linked with developing durability and compressive strength. Silicon, which is primary component of GGBS and MK, has been shown to affect integrity of hydrate phases by altering the Gibbs free energy of reaction, according to thermodynamic stability analysis GGBS, metakaolin, and the combination of GGBS and metakaolin reduced the cumulative incursion volume by 94.5 percent, 78.5 percent, and 70 percent, respectively, according to the results of this study. The critical pore widths are similarly reduced, and this drop is most pronounced when GGBS and metakaolin are included. Pore structure is improved, and the distribution of pore sizes is more uniform. Admixtures of minerals improve concrete's pore refinement. The most notable impacts of GGBS and metakaolin inclusion are increases in performance.

GGBS and metakaolin have a pozzolanic action that reduces total pore volume of concrete and shifts distribution of pore diameters to smaller end of the scale. Because of pozzolanic action and tiny particles that bridge space between the cement particles, CSH gel compacting hydration product occurs. microstructure of concrete may be improved by using CSH gels with better strength..

Murli.g and Sruthee[21] (2012), : experimented with using metakaolin like an replacement for cement in concrete.

Adding metakaolin to concrete resulted in a significant increase in its strength. Metakaolin at 12.5% boosted concrete's compressive strength with 14.2%, its split tensile strength with 7.9%, as well as its flexural strength with 9.3%, according to results.

III. OBJECTIVES

- For conducting feasibility study of producing concrete with G.G.B.S and Metakaolin combination like partial cement replacement.
- Scopes of current study is studying as well as comparing strength parameters of cement concrete, replacing cement by Metakaolin and GGBS combination for grade of concrete of M25 after curing for 7 & 28 days.
- Studying properties of concrete in fresh and hardened state by replacing cement by different percentage of Metakaolin(5%,10%,15%,40%) and G.G.B.S (6%,9%,12%).

IV. MATERIALS AND ITS PROPERTIES

The following are materials and their properties:

- Cement
- Fine Aggregate
- Coarse Aggregate
- G.G.B.S
- Metakaolin
- Water

4.1 Cement:

With presence of water, cement is described as a substance with cohesive and adhesive qualities. Hydraulic cements are a kind of cement in this case. Limestone and clay are the primary sources of these silicates and aluminates. We've utilised Ordinary Portland Cement, which is one of many forms of cement (OPC).

Portland cement got its name from Joseph Aspdin in 1824 due to similarity with Portland stone in terms of colour and hardness. In the Isle of Portland, Dorset, a white grey lime stone known as Portland stone is found. A 53-grade ultratech cement branch accessible locally that meets ISI criteria has been purchased, and the following tests were performed in accordance with IS:8112-198.

Table 1: Chemical Compositions (%) of OPC

Fe_2O_3	2.45
Al_2O_3	6.19
CaO	60.29
MgO	3.55
SO_3	2.38
SiO_2	18.24
Loss on Ignition	4

Table 2: Physical properties of OPC

Sl no	Properties	Test Values	Values according to I.S code
1	cement Consistency	34%	-
2	Specific Gravity	3.10	3.15
3	IST	45 min	>30min
4	FST	260 min	<600min

4.2 : Fine Aggregates:

Natural sand having maximum size of 4.75mm is utilised for fine aggregates.

River sand that is locally accessible and devoid of organic contaminants is employed. During research, we utilised sand that had been sieved down to an IS sieve 150 and measured to be 4.75mm in diameter. Sieves must be thoroughly cleaned before they are put to work. Part-I of (IS: 2386 (Part I) – 1963).

Table 3: Physical Properties of Fine Aggregate

Sl. No	Properties	Test Values
i.	Specific Gravity	2.71
ii.	Fineness Modulus	2.63
iii.	Water absorption	1.4%
iv.	Silt Content	Nil
v.	Bulk Density i) Loose ii) Compacted	 1.80g/cc 1.97g/cc
vi.	Grading	Zone-II

4.3 : Coarse Aggregate:

Coarse aggregates having a diameter of 20mm to 4.75mm are employed. In this case, a coarse aggregate with a maximum diameter of 20mm is chosen. We based our calculations on the IS 383:1970 standard, which specifies a 60-40% mix of 12.5mm and 20mm coarse aggregate in our sample.

Table 4: Physical Properties of Coarse Aggregate

Sl no.	Properties	Test Value
1	coarse aggregate shape	Angular
2	Sp. Gr.	2.80
3	Fineness Modulus	8.34
4	Bulk Density 1. Loose 2. Compacted	1.40g/cc1.59g/cc
5	Water absorption	1.1%

Table 5: Shape test

Sl. no.	Tests conducted	Test results	Values asper IS code
1.	Flakiness Index	13.17%	15%
2.	Elongation index	17.06%	15%
3.	Angularity number	5.08	0-11

4.4 Manufacturing Process of High Reactive Metakaolin:

When kaolin is heated, it becomes metakaolin, which is most common natural minerals. In production of porcelain and paper, kaolin has historically been utilised as a fine, white clay. "Kaolin" comes by town in China Kao-ling, means "high ridge," which is also where kaolin's first to be exported from China came from. Since Georgia is home to great majority of world's kaolin mining, production, processing, and use, it is often regarded as a global leader. The Atlantic Ocean covered most of the southern part of Georgia during Cretaceous until Tertiary geological eras. Known as the "kaolin belt," Piedmont Plateau met the Atlantic at "Fall Line," which stretches from Columbus to Augusta. As the weather degraded the granitic rocks, they were transported out to sea and created enormous sedimentary deposits under this area. Kaolin and many other minerals are abundant in these subterranean deposits; the depth of the deposits ranges from 50 to 100 metres below the surface of the ground. Kaolin is mined in Georgia at a rate of more than 8 million metric tonnes annually, including an average worth of more than $1 billion.

Table 6: The Physical properties of Metakaolin

Specific gravity	2.56
Appearance	White Colour
Density	2590 Kg/m^3
Brightness	81%
Fineness	15600 – 29700 m^2/Kg

Table 7: The Chemical Composition (%) of Metakaolin

Al_2O_3	40-42
Sio_2	52-55
Fe_2O_3	< 1.90
CaO	< 0.18
MgO	< 0.25
SO_4	< 0.40
K_2O	< 0.20
P_2O_5	< 0.35
Loss On Ignition at 1000^0C	1.20

4.5 Ground Granulated Blast Furnace Slag

Following are chemical compostions as well as physical propertiesof GGBS:

Table 8: Chemical Composition% of G.G.B.S

Al_2O_3	17.11
Sio_2	34.26
Fe_2O_3	1.23
CaO	35.17
MgO	6.41
SO_3	1.72
K_2O	0.30
Loss on Ignition	0.15

Table 9: Physical Properties of G.G.B.S

Physical Arrangement	Off White Powder
Specific Gravity	2.78
Bulk Density	100.0-11.00 Kg/m^3
Explicit Surface area	40.0-60.0 m^2/Kg
Bulk Density(Vibrated)	12.00-13.00 Kg/m^3

4.6 Water (IS: 456-2000):

It is essential that water utilized during curing as well as mixing concrete be devoid of any harmful chemicals such as acids, oils, sugars, salts or organic compounds. In the process of making concrete, potable water is utilised.

V. RESULTS AND DISCUSSION

5.1 Result of fresh concrete

Table 10: Concrete Workability

Sl. no.	Mix	M25 Grade Slump, mm
1.	MK1	100
2.	MK2	96
3.	MK3	93
4.	MK4	89
5.	MKG1	85
6.	MKG2	81
7.	MKG3	78

From the table 10 it can be noted that as the percentage of replacement for cement by MK and GGBS is increased, the workability get reduced. The graph shows the variationof slump for different percentage of replacement. The curve is pointing downward indicating the decrease of workability.

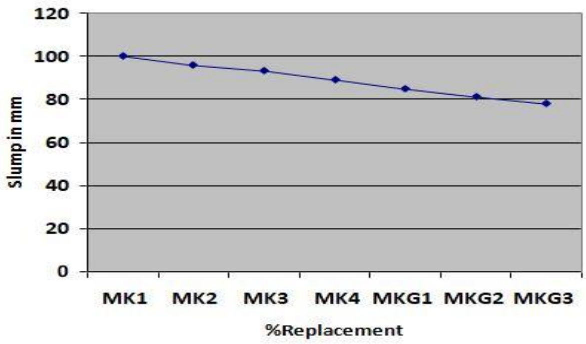

Fig 1: Slump Variation

5.2 Results of Compressive Strength Test:

Compressive strength for M25 graded of concrete (afterward 7 & 28 days curing) at replacement of cement by GGBS and Metakaolin.

Table 11: Compressive strength test result for M25 grade in N/mm^2

Sl. no.	Mix	Avg. Compressive Strength in N/mm^2	
		7 days	28 days
1.	MK1	20.49	30.96
2.	MK2	21.31	32.98
3.	MK3	22.67	34.73
4.	MK4	24.85	37.2
5.	MK5	19.62	27.61

From the table 11 it could be noted as, compressive strength is increased when replacing ratio is increased till 15% replacement of MK.

Table 12: Compressive strength test result for M25 grade in N/mm^2 for 15% Metakaoline and varying %of GGBS

Sl no.	Mix	Avg. Compressive Strength in N/mm^2	
		7 days	28 days
1.	MKG1	21.94	39.09
2.	MKG2	23.25	41.12
3.	MKG3	23.10	40.98

From the table 12 it can be noted as, compressive strength is increased as replacement ratio is increased till 9% replacement of GGBS then it reduces.

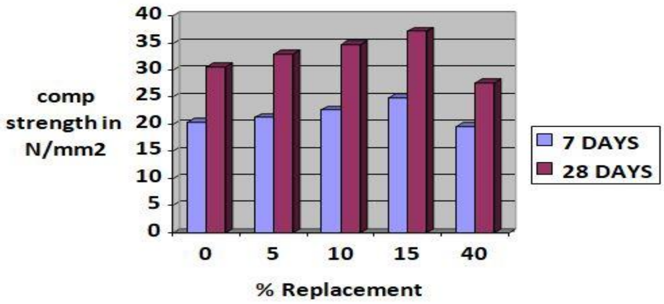

Fig. 2: compressive strength discrepancy for varying % of metakaolin

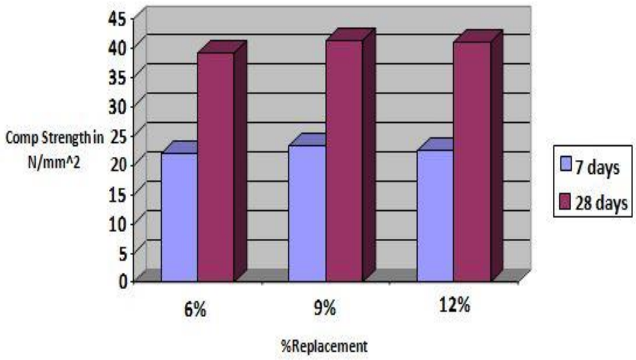

Fig .3: Compressive strength variation for 15% metakaolin and varying % of GGBS

5.3 Results of Split Tensile Strength Test:

Split tensile strength of M25 grade of concrete (afterward 7 & 28 days curing) at replacement of cement by Metakaolin and GGBS.

Table13: Split Tensile Strength test result for M25 grade in N/mm^2

Sl no.	Mix	Avg Split Tensile Strength in N/mm^2	
		7 days	28 days
1.	MK1	2.35	3.19
2.	MK2	2.49	3.49
3.	MK3	2.63	3.61
4.	MK4	2.91	3.88
5.	MK5	2.08	2.77

By table 13 it' s noted as, split tensile strength is increased when replacement proportion is increased till 15% replacement of MK.

Table 14: Split Tensile Strength test result for M25 grade in N/mm^{2}for 15% Metakaolin and varying %of GGBS

Sl no.	Mix	Avg Split Tensile Strength in N/mm^2	
		7 days	28 days
1.	MKG1	2.35	3.95
2.	MKG2	2.63	4.16
3.	MKG3	2.49	4.09

From the table 14 it's noted as, split tensile strength increases as percentage of replacement is increased till 9% replacement of GGBS then it reduces.

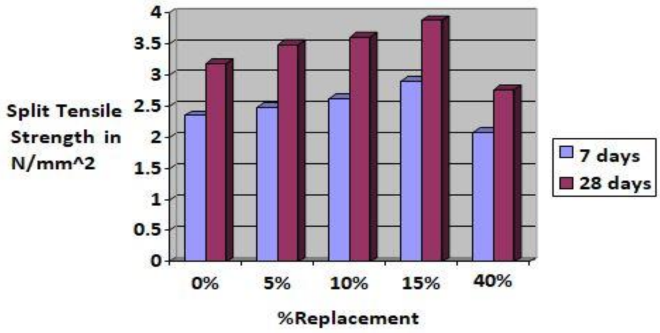

Fig .4: Split Tensile strength variation for varying % of metakaolin

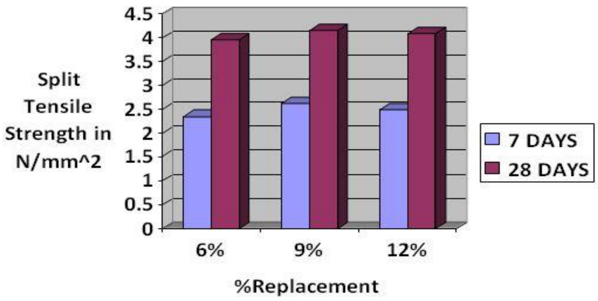

Fig.5. Split Tensile strength variation for 15% metakaolin and varying % of GGBS

5.4 Results of Flexural Strength Test:

Flexural strength for M25 grade of concrete (afterward 7 & 28 days curing) at replacement of cement by Metakaolin and GGBS.

Table 15: Flexural strength test results for M25 grade in N/mm^2

Sl no.	Mix	Avg. Flexural Strength in N/mm^2	
		7 days	28 days
1.	MK1	2.74	3.92
2.	MK2	2.89	4.12
3.	MK3	3.04	4.36
4.	MK4	3.28	4.7
5.	MK5	2.5	3.58

From the table 15 it could be noted as, flexural strength is increased when replacing ratio is increased till 15% replacement of MK.

Table 16: Flexural strength test results for M25 grade in N/mm^2 for15% Metakaolin and varying %of GGBS

Sl no.	Mix	Avg. Flexural Strength in N/mm^2	
		7 days	28 days
1.	MKG1	2.64	4.90
2.	MKG2	2.84	5.15
3.	MKG3	2.74	5.05

From the table 16 its noted as, split tensile strength increases as percentage of replacement is increased till 9% replacement of GGBS then it reduces.

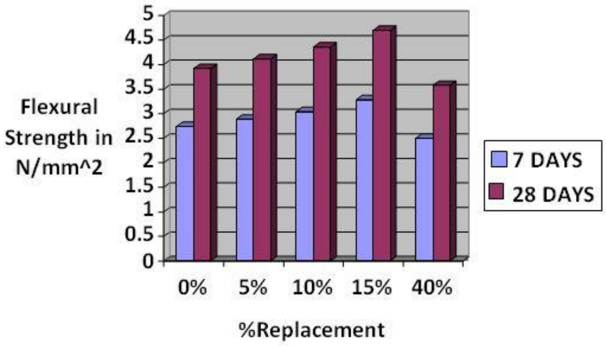

Fig .6.: Flexural strength variation for varying % of metakaolin

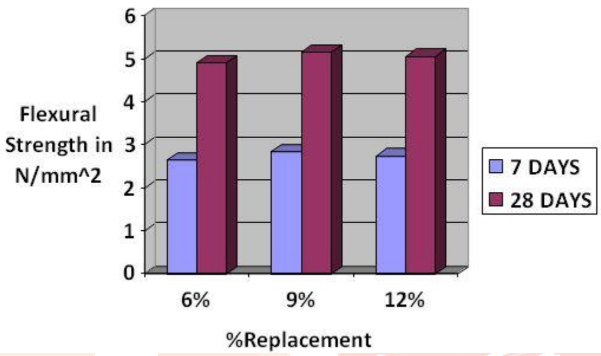

Fig..7: Flexural strength variation for 15% metakaolin and varying % of GGBS

VI. CONCLUSIONS

Ground Granulated Blast Furnace Slag (G.G.B.F.S) as well as Metakaolin (M.K) had been used as partial replacements for concrete in this investigation, which was conducted in line with time and laboratory requirements. It was shown that

- Raising the amount of Metakaloin and GGBS decreased slump value.
- Metakaolin and GGBS were found to substitute cement at an optimal rate of 15% and 9%, respectively.
- At 15% substitution of cement by metakaolin, M25 grade's compressive strength was determined to be 20% higher than standard mix after 28 days of curing.
- At 9 percent GGBS and 15 percent Metakaolin as partial substitute for cement, the M25 grade's compressive strength was shown to rise by 33% over usual mix after 28 days of curing.
- It was determined that optimal proportion of substitution of cement by metakaolin, 15%, boosted the M25 grade's split tensile strength over 28 days curing by 22%.
- A 30% improvement in split tensile strength for M25 grade at 9% GGBS and 15% Metakaolin as partial replacement of cement were discovered after 28 days of curing.
- If you substitute cement with metakaolin at or above 15 percent, flexural strength of M25 grade concrete is boosted with 20% over a standard mix after 28 days curing.
- It was described as flexural strength of M25 grade with 9 percent GGBS and 15 percent Metakaolin like an partial replacement of cement were raised by 31% over the standard mix after curing for 28 days.

VII. SCOPE OF FURTHER STUDY

G.G.B.S, for example, and Metakaolin, as a partial substitute for cement, are currently under investigation. However, there is a lot of room for further research. Future research and examination will focus on the following topics.

- G.G.B.S and Metakaolin may be utilized like an partial replacements for higher classes of concrete like M30, M35, M40, and High Strength Concrete.

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