Performance Evaluation and Cost Optimization of High Strength Concrete Amended with Fly Ash, GGBS and Micro Silica

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Abstract –*Cement is the most widely used building material and also most used material after water. Cement production includes a series of process which emits Co2. Usually, production of 1 ton of cement releases 1 ton of co2 which gives negative impact on the environment by releasing carbon dioxide into the atmosphere. Minimizing these emissions while meeting the increasing demand for infrastructure around the world is a challenge for the industries for long-term sustainability, and it has brought a revolution for academics, domain experts, and researchers to investigate alternatives to cement. As a result of the researchers' endeavor, a number of alternatives have emerged for further investigation in order to sustain their use in the industry. This paper examines the performance ofhigh strength concrete amended with fly ash, Ground granulated blast furnace slag (GGBS) and micro silica. The increasing demand for cement in the construction industry is causing environmental degradation; as a result, waste materials such as GGBS and Fly Ash are being used for the replacement of cement. The main aim of this work is to evaluate the performance of high strength concrete amended with partial replacement of fly ash, GGBS and micro silica with various percentages. "To study the freshproperties slump test are conducted.'' To study hardened properties compressive strength, Flexural strength, water permeability tests are conducted and Cost comparison studywill be done.*

Key Words: **Fly Ash, GGBS, Micro silica, permeability, Fresh and Hardened Test, HPC, HSC.**

1. INTRODUCTION

With an 8.2 percent share of the national GDP, India's construction sector is a key indication of the country's progress. India's expanding population and burgeoning economy need new and better infrastructure, such as skyscrapers, dams, and bridges. Ordinary cement manufacturing is thought to be responsible for 6–8% of worldwide CO2 emissions. ''Using industrial solid waste or by-product materials instead of cement is the ideal practice since it has no impact on the characteristics or strength of the final product."

High strength concrete is defined in Indian standards as concrete with a 28-day compressive strength higher than 55 Mpa. After replacing cement with by-product materials not only cost optimized but the performance of concrete such as workability, strength and durability also increases.

"According to American concrete institute High Performance Concrete which meets special performance and uniformity requirements that cannot always be achieved routinely by using only conventional materials and nominal mixing placing and curing practices.''

High Strength Concrete (HSC) can be achieved by lowering the w/c ratio and can be achieved with the help of Super plasticizers or high range water reducer admixtures. When mineral admixtures are added in high strength concrete its performance such as workability, strength and durability start increasing. According to Henry G. Russell (former chairman of ACI) states that all high strength concrete is high performance concrete but not all high-performance concrete is high strength concrete.

High performance concrete helps in reduction in member size, resulting in increase in plinth area and direct savings in the concrete volume. ''It reduces the overall cost of construction and more durable than conventional concrete."

2. LITERATURE REVIEW

High volume fly ash concrete by Dr. R.R Singh (june-2014)

In this paper he mainly concentrated on replacement of cement with Fly ash. In his work he presented a design of M40 and M25 grade concrete containing 28%, 50% and 70% fly ash content, and compressive and flexural strengths at 7 and 28 days are compared. "From the study he concluded that the compressive strength of M25 and M40 concrete at 50% replacement are satisfactory and may be utilized in construction practices.''

Experimental investigation on optimum usage of micro silica and GGBS for the characteristics strength of concrete by V.B Reddy Suda and P. Srinivasa Rao (Dec-2019)

In this paper various combinations of micro silica and ground granulated blast furnace slag were used to produce optimum ternary concrete mixture. Cement is partially replaced with MS and GGBS. A total of 12 ternary mixtures in three groups (S2, S3 and S4) and one control mix (S1)

with 324 kg/m3 of cement content were prepared and all the mixture had the same water cement ratio of 0.55. All the mixtures were tested for workability, compressive strength and flexural strength. GGBS concentration rises to a certain point, and then the workability of ternary mixes diminishes as the MS content increases. When MS and GGBS are compared to one other, some combinations result in stronger concrete when compared to either MS or GGBS alone; the minerals delay early age strength while the micro silica accelerates early age strength, the researchers said. It also demonstrates that ternary mixed concrete outperformed binary concrete in terms of performance. A 28-day strength combination with 10 percent Micro silica and 30 percent GGGBS was shown to be the best choice.

Experimental study of Concrete using Silica Fume by Akshatha K.B (May-2018)

In this research an attempt has been made to determine SF and steel fibers on M45 grade concrete are studied for their impact. In the experiment, silica fume was added in different amounts such as 5%, 7%, 10%, and 12.5% by weight of cementitious materials. Aspect ratio 35 steel fibers are also used to boost the concrete's tensile strength. The volume fractions at which steel fiber is added range from 0.5 percent to 1 percent. He tested the workability, compressive strength, flexural strength, tensile strength, and modulus of elasticity of fresh and cured concrete to see what impact silica fume and steel fiber had on the material. This research showed that adding 7.5% SF and 0.75 percent hooked end steel fiber to concrete increased its density while also improving its strength. When silica fume was employed, comparable variations were observed in the split tensile and flexural strengths. When comparing regular concrete to silica fume concrete, the modulus of elasticity does not show any discernible trend.

A R Hariharan, A S Santhi, and G Mohan Ganesh: Strength Development of High Strength Concrete Containing Coal Ash and Silica Fume (Apr 2011)

In this experiment, they used fly ash and silica fume in lieu of 6% and 10% of the cement weight, respectively, to make a high-strength concrete. Class C fly ash was utilized in different amounts (30%, 40%, and 50%) together with silica fume (6%) and cement (10% by weight). They utilized a super plasticizer for the necessary workability and maintained the water cement ratio constant throughout the mix at 0.4. Compressive strength of the concrete specimens was tested at intervals up to 90 days after curing. They found that adding 6% SF to various FA replacements for fly ash resulted in higher compressive strength than using 10% SF ternary mix. This is according to other research that has been done. With 6% SF and 40% FA, the ideal and high-strength Concrete may be produced.

3. OBJECTIVES OF THE STUDY

- To study the strength, durability and workability of high strength and high-performance concrete by replacing a part of cement with green or locally available materials.
- To put the concrete in to service in earlier age.
- To build high rise buildings by increasing available space and by reducing column sizes.
- To satisfy the needs of special applications such as durability, modulus of elasticity and flexural strength.

4. MATERIALS

High performance concrete was made of cement, sand, Mineral admixtures such as fly ash, GGBS, Micro silica etc. and chemical Admixtures.

4.1 Cement: Wonder cement OPC 53 grades conforming to IS: 269:2015 used in this research work.

4.2 Sand: Locally available sand confined to zone II of Yamuna Nagar (U.P) referred to IS: 383-1970.

4.3 Fly ash: Fly ash is a byproduct obtained from burning pulverized coal in electric power generating plants, and is ransported from the combustion chamber by exhaust gases. They're of two types but during this study i preferred class F fly ash.

- Class F fly ash
- Class C fly ash

Class F fly ash:

In this research Fly ash of NTPC Dadri was used. Due to pozzolanic, this ash doesn't contain much lime (7 percent). In order to create and react cementitious compounds, glassy silica and aluminum found in class F fly ash must be mixed with a cementing agent like hydraulic cement, quick lime, or hydrated lime mixed with water.

Loss on ignition	45u	Sio2+Al2o3+Fe2o3	Sio3	So3	Cao
0.37	18	93	55.16	0.13	7

Table: 1 Chemical Composition of Fly Ash

4.4 GGBS. Blast-furnace Granulated Gravel A cementitious material used in concrete is made from blast-furnaces' by-product, slag. With Portland cement and/or other pozzolanic ingredients, GGBS is utilized to create long-lasting concrete constructions.

If the quantity of GGBS in the cementitious material is higher, the concrete will set more slowly, but it will maintain its strength for a longer length of time than concrete produced with regular Portland cement. About half of the Portland cement used in ready-mix concrete manufacturing is replaced with GGBS; however, ''this may go as high as 70%. The greater the percentage, the longer the durability will be. Higher replacement levels have the drawback of delaying the development of early age strength." GGBS may also be found in precast and site-batched concrete.

4.5)Micro Silica: The Silicia fume is a byproduct of producing silicon metal or ferrosilicon alloys. use of micro silica in concrete increases the durability and strength of the concrete mix by increasing the amount of hydration products while also reducing the average pore size. One of the most beneficial uses for silica fume in concrete because of its physical and chemical properties. It is very reactive pozzolan. Concrete containing silica fume can be very durable and have very high strength.

4.6) Coarse Aggregate: Concrete relies heavily on aggregates. They help the concrete take shape, as well as minimize shrinkage and save money in the process. Prior to this discovery, aggregates were thought to be chemically inert materials. However, it has since been shown that certain aggregates are chemically active, and that chemical bonds may form between aggregate and paste. Because aggregates account for 70–80 percent of the volume of concrete, they have a significant influence on the material's different features and properties. Knowing more about aggregates, which make up the bulk of concrete, is critical to understanding concrete. The investigation of concrete isn't complete unless the aggregate is thoroughly examined. Concrete has just one standard component: cement. Water and aggregates are examples of natural materials, and their characteristics may vary greatly from one to the next. To fully understand aggregate impacts and influences on concrete characteristics, it is necessary to do extensive research on a broad variety of aggregates.

4.7) Water: Fresh Water from a bore well, devoid of any biological debris, was utilized. It was odorless, colorless, and tasteless. Water plays a crucial role in the chemical process that creates concrete, and it is thus an essential component. Because it aids in the formation of the strength-giving cement gel, water amount and quality must be carefully considered. The amount of mixing water has been covered extensively in this chapter, but the quality of the water has yet to be addressed. In fact, cement and aggregate characteristics are often well monitored, while water quality is frequently overlooked. Because water quality has an impact on strength, ''it's important for us to learn about water purity and quality."

4.8) Chemical admixture: Other than Portland cement, water, and aggregate, chemical admixtures are substances added to the mix just before or during mixing to improve the characteristics of concrete. This experiment makes use of a water reducer with a high operating range, often known as a super plasticizer. In terms of chemical composition, they vary from standard plasticizers. "Super plasticizers can reduce water up to 30% without compromising workability, while plasticizers can only reduce water use by up to 15%.'' Flowing, self-leveling, and self-compacting concrete as well as high-strength and high-performance concrete are all made with the help of super plasticizers. Super plasticizers work in a manner similar to regular plasticizers, with the exception of a few key differences. Super plasticizers, on the other hand, are more potent dispersion agents and water reducers over a wider range. American writers refer to them as High Range Water Reducers. Using super plasticizers has allowed w/c to be reduced to 0.25 or even lower while still producing flowing concrete with a strength of 120 MPa or higher. High performance concrete may now be produced using fly ash, slag, and, in particular, silica fume thanks to the use of super plasticizers.

5. Mix Design

The mix design procedure adopted in the present work to obtain M-30 grade concrete is in accordance with IS: 10262-2009 and IS: 456-2000.
W/C Ratio -0.44
Cement (kg/m3) -447.73
Fine aggregate (kg/m3) -
632.44 Coarse aggregate
(kg/m3) -1115.4Water
(kg/m3)-197

Trial Mix	Description
T1	C543FA0MS0GGBS0
T2	C443FA100MS0GGBS0
T3	C411FA100MS32GGBS0
T4	C251FA130MS32GGBS130
T5	C300FA118MS25GGBS100

Table: 2 Mix Design of M60 Grade

Fig.1: Material Mixing and Handling

6. RESULTS AND DISCUSSIONS

6.1 workability Strength

The workability of freshly mixed concrete, according to IS: 1199-1959, was assessed immediately after mixing, and the resulting Slump Values are shown in Figure 2.
The consistency of the concrete mixture was evaluated using a slump test. ''The primary purpose of the slump is to determine the proper quantity of cementitious waste to be put to the medium paste by using or evaluating it in an indirect manner."
Workability of concrete is determined by the value of the slump test results, as shown in Figure 2.

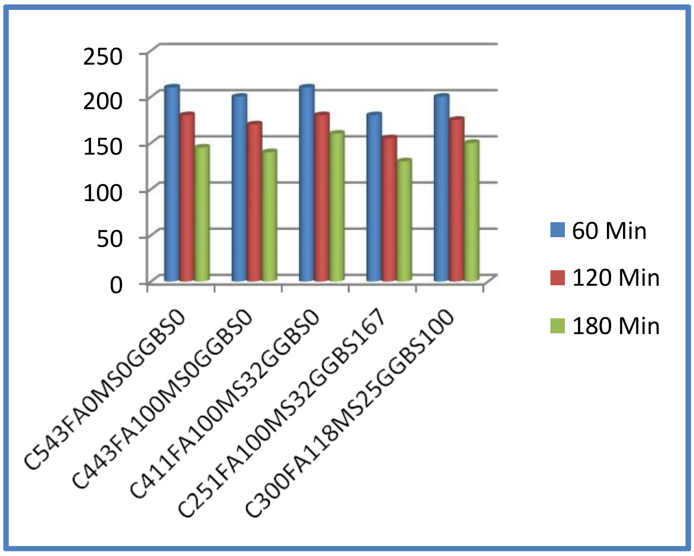


Fig.2: Slump Values

6.2 Compressive strength

Compressive strength is tested on three 150x150x150 mm cubes after seven and twenty-eight days of cure for each concrete mix. Using fly ash, micro-silica, and GGBS as partial cement replacement, the following table shows the results of compressive strength tests on control and experimental concrete.

S.No.	Mix Code	7 Days	28 Days
1	**C543FA0MS0GGBS0**	**54.71**	**73.53**
2	**C443FA100MS0GGBS0**	**52.33**	**68.81**
3	**C411FA100MS32GGBS0**	**54.03**	**70.29**
4	**C251FA100MS32GGBS167**	**40.39**	**56.76**
5	**C300FA118MS25GGBS100**	**43.77**	**61.46**

Table: 3 Compressive strengths of M60 Grade Concrete

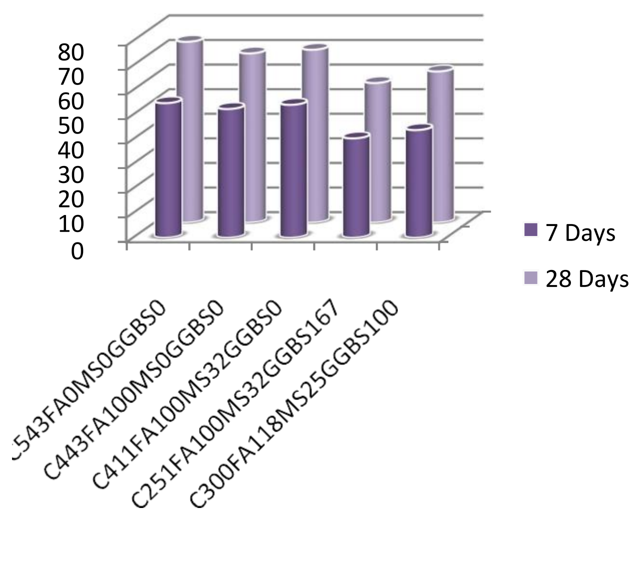


Fig.3: Compressive strength Values

6.3 PERMEABILITY TEST

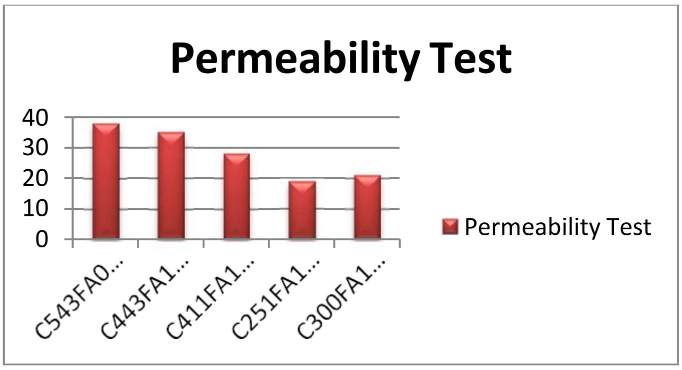
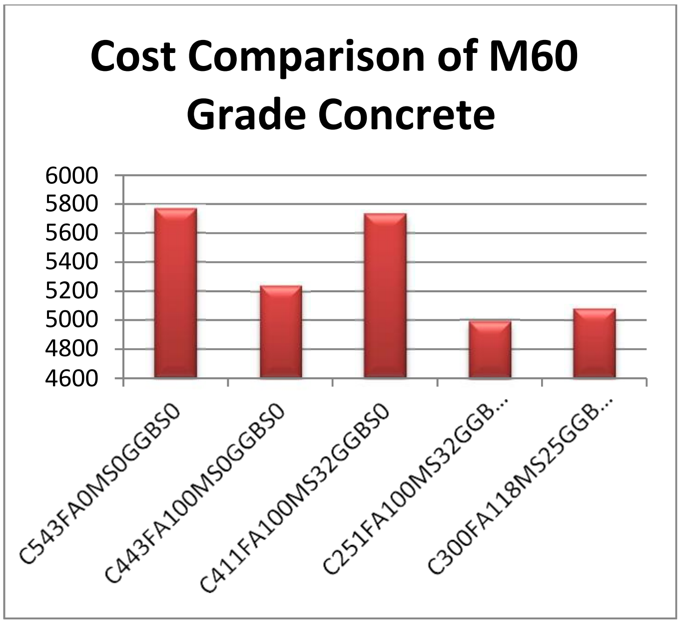


Fig.4: Permeability Test

7. COST COMPARISION



8. SUMMARY AND CONCLUSIONS

In the present work, an attempt has been made to use fly ash, micro silica and GGBS as a blending supplementary material for cement.

1. For High grade Concrete w/c ratio plays a vital role, W/c ratio to be kept minimum to achieve compressive strength in 7 & 28 days.
2. As much as cement optimized the cost and carbon content reduces and performance of concrete enhances.
3. As we reduced w/c ratio workability of concrete decreases and mix was little sticky but strength of hardened concrete increases.
4. As referred to trial Mix-2, after introducing Fly ash, concrete mix got more cohesive as compared to conventional concrete i.e. trial Mix-1.
5. As referred to trial Mix-3, after introducing Micro silica in concrete mix, workability of concrete increases and cohesiveness of concrete also increases.
6. As referred to trial mix-4&5, after adding GGBS and micro silica water content, Cost and carbon content reduced, and workability of concrete also increases.
7. As referred to trial 5, it is observed that mix was optimized with 21.7% fly ash, 4.6% micro silica and 18.4% GGBS can be used as high-performance concrete because it gains strength more than 99% in 28 days, less permeable and also have low cost than conventional concrete mix.

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REFERENCES

[1] Patel V and Shah N, A Survey of High-Performance Concrete Developments in Civil Engineering Field, Open Journal of Civil Engineering, 2013, 3, 69-79, pp.

[2] Kmita A, A New Generation of Concrete in Civil Engineering, Journal of Materials Processing Technology, Vol. 106, No. 1-3, 2000, pp.80-86.

[3] IS 456:2000 Plane and reinforced concrete-code of practice.

[4] IS 10262-2019 Guidelines to concrete mix design.

[5] R.P Khatri and V.sirivivatnonon, Effect of Different supplementary Cementitious Materials on Mechanical properties of High performance Concrete, Cement and concrete Research , Vol25, pp.209-220,1995.

[6] R.P Khatri and V.sirivivatnonon, Effect of Different supplementary Cementitious Materials on Mechanical properties of High performance Concrete, Cement and concrete Research , Vol25, pp.209-220,1995.

[7] M. N. Sautsos and P. L. J. Domone, Strength development of low water-binder ratio mixes incorporating mineral admixtures, Utilization of High-Strength Concrete, vol. 2, pp. 945–952, 1993.

[8] F. de Larrard, A method for proportioning high-strength concrete mixtures, Cement, Concrete and Aggregates, vol. 12, no. 1, pp. 47–52, 1990.

[9] Conference on Super-Plasticizer in Concrete, pp. 185–213, Ottawa, Canada, June 1981.