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Experimental Investigation on High Performance Concrete Using Nano Material

Anjali Sharma¹, Shoaib Akhter², Yuvraj Nirmalkar³, MO.Mohib Nawaz Khan⁴

¹Assistant Professor, ^{2,3,4}U.G. Student, Department of Civil Engineering, J.K. Institute of Engineering, Bilaspur CSVTU, Bhilai, C.G.

ABSTRACT: *The construction business is growing fast and it needs strong and long-lasting materials. High Performance Concrete is a kind of material that is better than the usual concrete. It is stronger. Lasts longer. This study is about how High Performance Concrete works when we add Ground Granulated Blast Furnace Slag and Fly Ash to it. We want to see how these additions affect the concrete. We made mixes of concrete with Ground Granulated Blast Furnace Slag and Fly Ash. We tested these mixes in the lab after 7, 28 and 56 days. The results show that adding Ground Granulated Blast Furnace Slag and Fly Ash makes the concrete stronger overtime. It also helps to reduce the heat that is produced when the concrete is made. This makes the concrete more resistant to damage from sulphates and chlorides. Using Ground Granulated Blast Furnace Slag and Fly Ash is also good for the environment because it reduces the amount of carbon emissions from making cement. This study shows that using the amounts of Ground Granulated Blast Furnace Slag and Fly Ash can make High Performance Concrete that is good, for the environment and works well for building new infrastructure.*

Keywords: *High Performance Concrete, Ground Granulated Blast Furnace Slag, Fly Ash, Supplementary Cementitious Materials, Compressive Strength, Durability Sustainable Construction*

I. INTRODUCTION

Concrete has been used to build infrastructure for over a hundred years. It is used in things like homes, bridges, dams, highways and buildings that hold stuff. Concrete is very versatile. It can be moulded into shapes. It is very strong and not too expensive. That is why it is so important in building things. More people are living in cities. Industries are growing. So concrete needs to be even better. We need concrete that's not just strong but also lasts long. It should be good for the environment. Can handle tough conditions. Regular concrete is okay for some things. It has some problems.

- It lets water in easily.
- It can get damaged by chemicals.
- It can crack easily.

This can cause problems for buildings. Especially those near the ocean in areas or in places with extreme weather. So we created High Performance Concrete (HPC). HPC is not strong concrete. It is designed to do things. Like being easy to work with very strong not letting water in and lasting long.

HPC started being developed in the 1900s. Researchers found ways to make concrete better by adding material to it. One important thing that affects how well concrete works is how cement reacts with water. When cement mixes with water it creates a gel that makes concrete strong. Some of the stuff created during this reaction is not good for concrete. That is where Fly Ash and Ground Granulated Blast Furnace Slag (GGBS) come in. They react with the stuff. Make concrete even stronger and more durable. Using waste materials like Fly Ash and GGBS in concrete is good for the environment. It makes concrete better.

Cement production causes a lot of pollution. So, using these materials reduces that. Fly Ash is a residue from coal burning. GGBS is from the iron and steel industry. They both make concrete better. They are good for the environment. Fly Ash makes concrete workable and strong. GGBS makes concrete strong. It is resistant to chemicals and good for structures. When we combine Fly Ash and GGBS concrete gets even better. It becomes less porous and stronger.

This makes concrete longer. It resists damage. To make HPC we also use chemicals called superplasticizers. They help make concrete workable without adding water. Less water means durable concrete. Making HPC with Fly Ash and GGBS is good for countries that are building a lot. It helps the environment. It saves money. Makes buildings last longer. Making HPC needs planning and control. We need to make sure we use the amounts of materials and conditions. If not concrete might not be as strong or durable.

This study looks at how HPC works with a amount of Fly Ash and GGBS. We want to see how strong it is. We want to see how well it handles stress and how well it resists damage. By understanding how these materials work together we can create concrete for buildings. In short using Fly Ash and GGBS in HPC is a step for concrete technology. It makes buildings stronger and better for the environment. Our research will help create concrete that's durable, eco-friendly and affordable for future buildings. The use of GGBS and Fly Ash in High Performance Concrete shows a balance between performance and sustainability. Countries can utilize these industrial byproducts for their construction needs. The properties of HPC allow it to withstand conditions. The combination of materials used results in strength and durability.

High Performance Concrete integrating GGBS and Fly Ash offers both benefits. The study on HPC aids in creating an understanding of its applications. The use of waste products results in environmental impact. The optimized mix design process ensures HPC meets performance requirements. HPC applications range from residential to large-scale infrastructure projects. Engineers can utilize HPC for construction needs. The implementation of HPC aligns with sustainability goals. The study contributes to advancements in technology. The characteristics of HPC make it suitable for construction. The research on HPC supports its use in infrastructure development. The development of HPC supports the creation of eco-structures. The study, on HPC provides insights into its performance.

II. RESEARCH SIGNIFICANCE

The study on High Performance Concrete with GGBS and Fly Ash is very important for technology and the environment and money. We really need materials that will last for our buildings and roads that are growing fast. Normal concrete can have problems like water getting in and chemicals damaging it and rust eating away the metal. This costs a lot of money to fix. It makes the buildings not last as long as we want them to. By using GGBS and Fly Ash of some of the cement we can make the High Performance Concrete stronger and better. High Performance Concrete can handle chemicals and last longer which is what we need for our buildings and roads. Making cement uses a lot of energy and makes a lot of pollution which is not good for the environment. Using waste like slag and fly ash is better for the environment because it reduces pollution and helps manage waste and makes construction more eco-friendly.

The results of this study will help engineers make the mix for lasting High-Performance Concrete. This High-Performance Concrete is good for buildings and bridges and other important structures those near water. High Performance Concrete with GGBS and Fly Ash is a choice, for our buildings and roads. GGBS and Fly Ash make the High-Performance Concrete better and stronger. Engineers can use these findings to build eco-friendly buildings and roads. They can make High Performance Concrete that lasts long and is strong which's what we need for our fast-growing buildings and roads.

III. MATERIALS

A. ORDINARY PORTLAND CEMENT (OPC):-

Ordinary Portland Cement is the thing that holds concrete together. It does this by mixing with water and creating a kind of gel that gives concrete its strength. This gel is called calcium silicate hydrate. Ordinary Portland Cement is really important because it helps stick all the parts of concrete together. We use Ordinary Portland Cement as a standard to compare with materials that we mix with it to make High Performance Concrete.



Fig. Ordinary Portland Cement^[1]

B. FLYASH:-

Fly Ash is something that is left over when coal is burned. It does a job of helping to make things stronger. Fly Ash reacts with a kind of chemical called calcium hydroxide. This reaction helps to make a kind of gel that is really good, at making things last longer. The gel fills in all the holes and spaces so things are not as porous. This means that Fly Ash really helps to make things more durable. The particles of Fly Ash are shaped like spheres, which makes them really easy to work with.



Fig.FlyAsh^[2]

C. Ground Granulated Blast Furnace Slag (GGBS):-

GGBS is a type of waste from industry that's very good at mixing with water. When GGBS mixes with water it creates compounds that're similar to cement. This makes GGBS very good at helping to make things stronger as time goes on. GGBS also helps to keep things cool when they are being made. It makes them more resistant, to chemicals. GGBS is really useful because GGBS can do all these things for us.



Fig.GGBS^[3]

D. Fine Aggregate (Sand):-

Fine aggregate is really important for concrete. It needs to be clean and have the mix of big and small pieces. This helps the concrete be strong and last a long time. The fine aggregate fills in the gaps between the pieces of aggregate. It also helps share the weight that is put on the concrete. Fine aggregate is crucial for the concrete to be good. It makes the concrete strong and able to withstand a lot of weight. Fine aggregate plays a role, in making sure the concrete is durable and will last.



Fig.FineAggregate(Sand)^[4]

E. Coarse Aggregate:-

Crushed Gravel mixes with the cement paste to form a strong concrete. This makes the concrete dense. Gives it the strength to handle heavy weight. The crushed stone and gravel are key here they bind with the cement paste. This combination provides the compressive strength to the concrete.



Fig.CoarseAggregate^[5]

F. Superplasticizer(High-RangeWaterReducer):-

Superplasticizers help concrete mixes with a water-binder ratio to stay workable. This is especially important for High Performance Concrete mixes. They make the concrete stronger. Keep it easy to flow. The low water binder ratio mixtures stay workable because of superplasticizers, which is crucial for High Performance Concrete.

It helps to increase the strength of High Performance Concrete. Superplasticizers are key, in High Performance Concrete mixes as they improve workability and strength.



Fig Superplasticizer^[6]

IV. MIX DESIGN

High Performance Concrete (HPC) Using GGBS and Fly Ash (Designed as per IS 10262:2019 and IS 456:2000 Guidelines)

1) Target Parameters

- Grade of Concrete: M60
- Type: High Performance Concrete
- Exposure Condition: Severe (as per IS 456)
- Maximum Aggregate Size: 20mm
- Workability: 100–150mm slump
- Method of Compaction: Vibration
- Cement Replacement: GGBS + Fly Ash

2) Target Mean Strength

As per IS 10262:2019: Target Mean Strength

$$f_t = f_{ck} + 1.65S$$

Where:

- f_{ck} = Characteristic strength (60MPa)
- S = Standard deviation (5MPa for M60 assumed)

$$f_t = 60 + (1.65 \times 5) = 68.25 \text{ MPa}$$

Therefore, the mix must achieve $\geq 68 \text{ MPa}$ at 28 days.

3) Selection of Water-Binder Ratio

For M60 HPC:

Adopt $w/b = 0.30$ (low for durability & strength)

4) Calculation of Binder Content

Assume water content = 150 kg/m³ (for 20mm aggregate with superplasticizer)

Water 150

$$\text{Binder Content} = \frac{150}{0.30} = 500$$

kg/m³w/b 0.30

5) Binder Distribution

Forternary blended HPC:

OPC=50% GGBS= 30% FlyAsh=20%

Material %Quantity(kg/m³)

Cement 50% 250

GGBS 30% 150

FlyAsh 20% 100

Total Binder 100% 500

6) Aggregate Proportioning

Assume total aggregate content ≈ 65–70% of total volume. Using absolute volume method:

Step 1: Volume Calculations

- Volume of Cement = $250 / (3.15 \times 1000) = 0.079 \text{ m}^3$
- Volume of GGBS = $150 / (2.9 \times 1000) = 0.052 \text{ m}^3$
- Volume of Fly Ash = $100 / (2.2 \times 1000) = 0.045 \text{ m}^3$
- Volume of Water = $150 / 1000 = 0.15 \text{ m}^3$
 - Volume of Admixture ≈ 0.005 m³ Total volume of paste ≈ 0.331 m³ Remaining volume for aggregates: $1 - 0.331 = 0.669 \text{ m}^3$

Step 2: Fine and Coarse Aggregate Split

For HPC (20mm aggregate):

- Coarse Aggregate = 60%
- Fine Aggregate = 40%

Coarse Aggregate Volume = 0.401 m³ Fine Aggregate Volume = 0.268 m³

Convert to mass:

- Coarse Aggregate = $0.401 \times 2.7 \times 1000 = 1082 \text{ kg}$
- Fine Aggregate = $0.268 \times 2.65 \times 1000 = 710 \text{ kg}$

7) Superplasticizer Dosage

- 1–1.5% of binder
- Assume 1.2% of 500 kg = 6 kg/m³

FINAL MIX PROPORTION (PER m³)

Material Quantity (kg/m³)

Cement 250

GGBS 150

Fly Ash 100

Water 150

Fine Aggregate 710

Coarse Aggregate 1080

Superplasticizer 6

Water-Binder Ratio = 0.30 Mix Ratio (by weight)

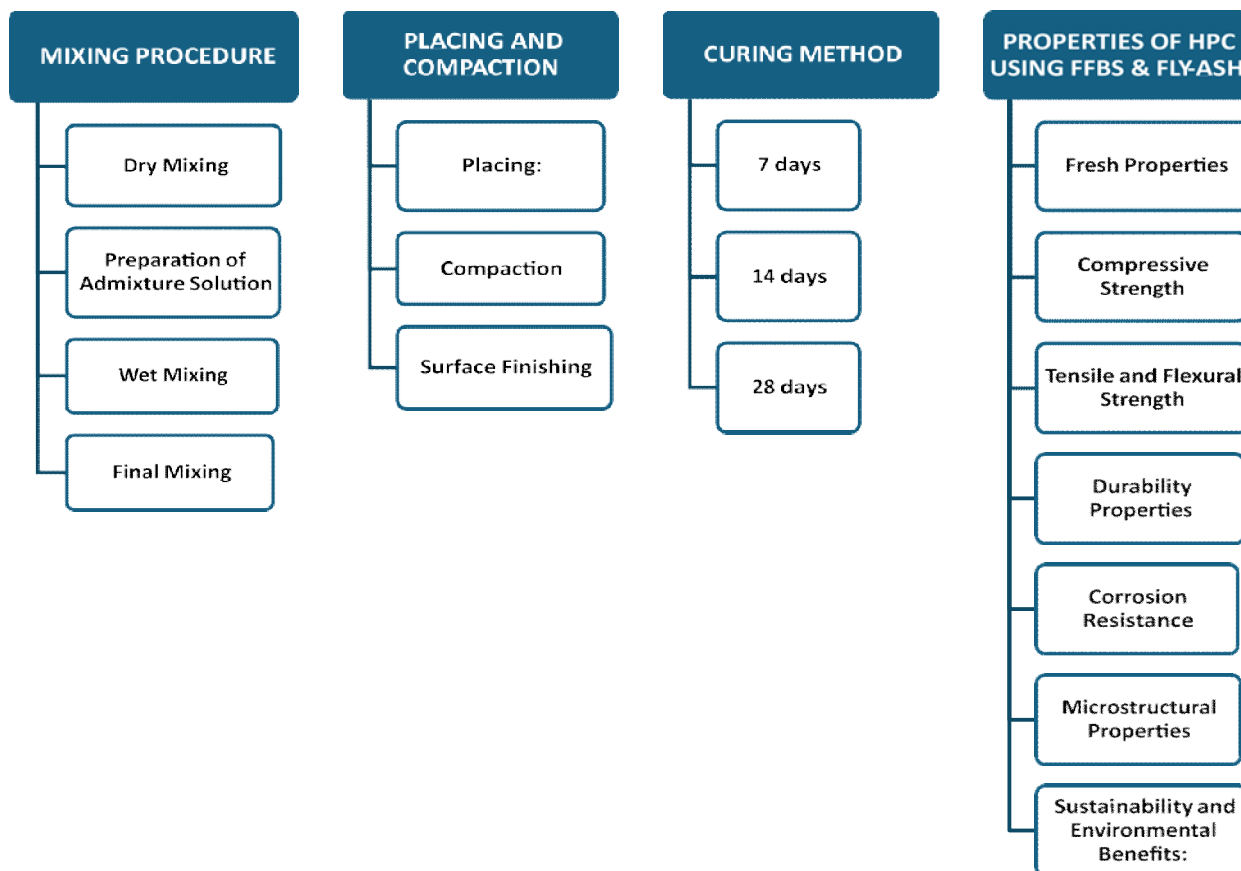
Binder: Fine Agg: Coarse Agg =

1 : 1.42 : 2.16

Expected Performance

- 7 Days Strength: 45–50 MPa
- 28 Days Strength: 68–75 MPa

V. METHODOLOGY



A. MIXING PROCEDURE

1) DRY MIXING

In this stage cement, GGBS fly ash, aggregate and coarse aggregate are mixed together in a big container or drum. They are blended for 2 to 3 minutes. The goal of mixing is to spread out the extra cement material evenly with the aggregates. When we mix them properly the particles fit together better. This also makes sure that slag, fly ash are well mixed, with cement before we add water. This way everything is combined uniformly.

2) PREPARATION OF ADMIXTURE SOLUTION

To make the Admixture Solution we need to mix an amount of superplasticizer, which is a high-range water-reducing admixture with some of the water that will be used for mixing. This is important for High Performance Concrete because it usually has little water in it. By doing this we can make sure the concrete is workable, without adding water. The Admixture Solution is made separately so that it can be spread out evenly when we add it to the mix.

3) WET MIXING

During mixing, water and a special admixture are added slowly to the dry mix while the mixer is running. Wet mixing is continued for 3 to 5 minutes until a uniform and consistent mixture is obtained. This step is important as it ensures proper hydration of cement and initiates the reaction of fly ash and slag with the cement.

4) FINAL MIXING

During concrete mixing, the remaining water is added gradually as required. Mixing is continued until the concrete attains a uniform colour and consistency. The mixture should be smooth and cohesive, with good binding properties. It should not contain any segregation or dry patches.

B. PLACING AND COMPACTION

1) PLACING

Freshly prepared High-Performance Concrete should be placed immediately after mixing to prevent loss of workability.

The moulds used must be clean and lightly oiled before casting. The concrete should be placed in layers to ensure uniform distribution and to avoid segregation. Proper handling and care are essential to achieve the desired quality and performance of the High-Performance Concrete.

2) *COMPACTION*

Each layer is compacted using a table vibrator or a needle vibrator to remove the entrapped air. Proper compaction improves the density of the concrete and ensures good bonding between the paste and aggregates. Care should be taken to avoid over-vibration, as it may lead to bleeding and segregation.

3) *SURFACE FINISHING*

The top surface is levelled after compaction. It is then finished with a trowel. This helps to get a smooth and even finish. The finish is suitable, for testing and curing the surface.

4) *CURING METHOD*

Curing is really important for making HPC strong and durable especially since it has a water-binder ratio. We keep the specimens in moulds for 24 hours, at room temperature. We cover them so they do not lose moisture. After we take them out of the moulds we put them in water that is around 27 degrees. The HPC specimens are cured for 7 days or 14 days or 28 days it depends on when we're going to test them. Proper curing of the HPC is necessary for the cement to keep getting hydrated and for the slag and fly ash to be activated which makes the HPC perform better over time.

C. PROPERTIES OF HPC USING GGBS AND FLYASH

1) *FRESH PROPERTIES*

High Performance Concrete (HPC) containing GGBS and fly ash generally exhibits better cohesiveness and reduced water loss. The spherical shape of fly ash particles improves workability, while GGBS helps in achieving a denser particle packing. Since HPC has a low water content, a superplasticizer is added to ensure proper flowability. This is essential for the effective utilization of GGBS and fly ash in HPC.

2) *COMPRESSIVE STRENGTH*

The use of GGBS and fly ash helps to increase the strength over time. GGBS makes the strength better on, through a process that happens after the initial hydration. Fly ash combines with calcium hydroxide to create more of a kind of gel which makes the material denser and stronger. This results in a long-term compressive strength.

3) *TENSILE AND FLEXURAL STRENGTH*

When the cement pastes and aggregates bond well, the tensile and flexural strength of the concrete improve. This is due to the refinement of the microstructure, which reduces crack formation and enhances the load-carrying capacity. Therefore, improved microstructure plays a significant role in increasing the tensile and flexural strength of concrete.

4) *DURABILITY PROPERTIES*

High Performance Concrete with Ground Granulated Blast Furnace Slag and fly ash has a few things going for it. For one thing it is not very easy for water to get through. It also does not absorb a lot of water. This is because the tiny structure of the High-Performance Concrete is very dense. This keeps things like chlorides and sulphates from getting in and damaging the High-Performance Concrete. As a result, the High-Performance Concrete can stand up to chemicals better. It will last longer. The dense structure of the High-Performance Concrete is very good, at keeping substances out which means the High-Performance Concrete will have a longer service life.

5) *CORROSION RESISTANCE*

The concrete is good, at keeping water and bad stuff out. It is dense. Has very small holes. This helps stop the metal from getting rusty. So, bridges made with this concrete last longer. The concrete's ability to resist corrosion is important. It helps prevent metal damage. This makes reinforced concrete structures stronger and longer-lasting. The corrosion resistance of the concrete really helps. It keeps the metal inside safe from getting damaged.

6) *MICROSTRUCTURAL PROPERTIES*

When you mix slag and fly ash together it makes a strong and uniform structure inside. The special reaction that happens with the fly ash makes the tiny holes smaller. Gets rid of small cracks, which means the Microstructural Properties of the material are better and it will last longer. The Microstructural Properties are improved because the material becomes stronger and more durable.

7) *SUSTAINABILITY AND ENVIRONMENTAL BENEFITS*

Using GGBS and fly ash of some of the cement helps reduce the amount of cement used and lowers carbon dioxide emissions. These are waste materials, from industries. Using them helps save resources. It also supports eco- building practices without affecting how well it works.

VI. APPLICATION

High Performance Concrete that has GGBS and fly ash in it is used a lot in buildings. This is because High Performance Concrete is very strong and lasts a time. People use High Performance Concrete to build buildings and bridges. They also use it to make flyovers and floors in factories.

High Performance Concrete is a choice for buildings near these because it does not let water in easily. It is also good for buildings that hold water, like dams and for sewage treatment plants. High Performance Concrete is used for projects like roads and special parts that are made in factories. It is also used for structures that need to be strong.

The good thing about High Performance Concrete with GGBS and fly ash is that it is good, for the earth. This is because we use cement and that helps our environment.

VII. LIMITATION

High Performance Concrete with GGBS and fly ash is a thing but it also has some problems. One big issue with High Performance Concrete with GGBS and fly ash is that you have to be very careful when you mix it because if you do not get it right it can affect how well it works and how strong it is. When you use materials like fly ash in High Performance Concrete with GGBS and fly ash it can take longer for it to get strong especially if you use a lot of fly ash or slag.

High Performance Concrete with GGBS and fly ash also needs helpers like superplasticizers, which can make the cost of the materials higher at first.

To get the results from High Performance Concrete, with GGBS and fly ash you need to take good care of it while it is hardening and make sure the people working with it know what they are doing. If you do not take care of High-Performance Concrete with GGBS and fly ash while it is hardening it may not be as strong and durable as you want it to be.

VIII. CONCLUSION

High performance concrete made with GGBS and fly ash gets stronger. Lasts longer. It performs better too. These materials make the concrete's internal structure finer. This means it is less prone to water seepage and more resistant to damage and rust. To get the results you need to plan the mix carefully and cure it properly. The advantages of high-performance concrete are clear. It has structural performance and is more environmentally friendly. This makes high performance concrete a good choice for construction today. When you replace some cement with GGBS and fly ash you get concrete that is stronger and lasts longer. It is also kind to the environment. This is why high-performance concrete is a material for building infrastructure in the future. High performance concrete that uses GGBS and fly ash is better in ways. It is stronger and more durable. It also performs better in the term. The GGBS and fly ash refine the concrete's microstructure. They reduce permeability. Make it more resistant to chemical attacks and corrosion. You do need to design the mix and cure it properly. The benefits are worth it. High performance concrete performs better. Is more environmentally friendly. This makes it a great solution for construction. By using GGBS and fly ash of some cement you can make concrete that is stronger and more durable. It is also better for the environment. This is why high-performance concrete is so important, for building infrastructure in the future.

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