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Experimental Study of Fibre Reinforced Concrete using GGBS and Steel Fibre

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Abstract*: High-performance concrete is defined as concrete that meets special combinations of special Performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practices. Ever since the term high-performance concrete was introduced into the industry, it had widely used in large-scale concrete construction that demands high strength, high flowability, and high durability. A high-strength concrete is always a high-performance concrete, but a high-performance concrete is not always a high-strength concrete. Durable concrete Specifying a high-strength concrete does not ensure that a durable concrete will be achieved. It is very difficult to get a product which simultaneously fulfills all of the properties. So the different pozzolanic materials like Ground Granulated Blast furnace Slag (GGBS), Steel Fibres, are some of the pozzolanic materials which can be used in concrete as partial replacement of cement, which are very essential ingredients to produce high performance concrete. So we have performed CTM tests of these above mentioned materials to know the variation of different constituent within it. Also it is very important to maintain the water cement ratio within the minimal range, for that we have to use the water reducing admixture i.e superplasticizer, which plays an important role for the production of high performance concrete. So we herein the project have tested on different materials like Ground granulated blast furnace slag, Steel Fibers to obtain the desired needs. We used steel fiber in different percentage i.e 0.0%, 0.05%, 0.1%, to that of total weight of concrete and casting was done. Finally we used different percentage of steel fibers & GGBS with the replacement of cement keeping constant fiber content and concrete was casted. In our study it was used two types of cement, Portland slag cement and ordinary Portland cement. We prepared mortar, cubes, cylinder, prism and finally compressive test, splitting test, flexural test are conducted. Finally porosity and permeability test conducted. Also to obtain such performances that cannot be obtained from conventional concrete and by the current method, a small number of trial mixes are required to select the desired combination of materials that meets special performance.
Keywords: Concrete, fibre reinforce, steel fibre, Compressive, split tensile & flexural strengths

I. INTRODUCTION

Concrete is the most widely used man-made construction material in the world. It is obtained by mixing cementitious materials, water, aggregate and sometimes admixtures in required proportions. Fresh concrete or plastic concrete is freshly mixed material which can be moulded 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 Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for green house effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact.

A. Characteristics That May Be Considered Critical For An Application Are

1) Ease of placement
2) Compaction without segregation
3) Early age strength
4) Long-term mechanical properties
5) Permeability

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6) Density
7) Heat of hydration
8) Toughness
9) Volume stability
10) Long life in severe environments

B. Salient Features of HPC

1) High Compressive strength
2) Low water-binder ratio
3) Reduced flocculation of cement grains
4) Wide range of grain sizes
5) Densified cement paste
6) No bleeding homogeneous mix
7) Less capillary porosity
8) Discontinuous pores

C. Stronger Transition Zone At The Interface Between Cement Paste And Aggregate

1) Low free lime content
2) Endogenous shrinkage
3) Powerful confinement of aggregates
4) Little micro-cracking until about 65-70% of fck
5) Smooth fracture surface

D. There Are Special Method Of Making High Strength Concrete Such That

1) Seeding
2) Revibration
3) High speed slurry mixing
4) Use of admixtures
5) Inhibition of cracks
6) Sulphur impregnation
7) Use of cementitious aggregate

II. MATERIALS & PROPERTIES

A. Ground Granulated Blast Furnace Slag

Ground Granulated Blastfurnace 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 effectively be 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 GGBS in the form of Portland slag cement is not uncommon in India, experience of using GGBS as partial replacement of cement in concrete in India is scanty. 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 composition of oxides in GGBS is similar to that of Portland cement but the proportions varies.

The four major factors, which influence the hydraulic activity of slag, are glass content, chemical composition, mineralogical composition and fineness. The glass content of GGBS affects the hydraulic property, chemical composition determines the alkalinity of the slag and the structure of glass.

The compressive strength of concrete varies with the fineness of GGBS.

Ground granulated blast furnace slag now a days mostly used in India. Recently for marine out fall work at Bandra, Mumbai. It has used to replace cement to about 70%. So it has become more popular now a day.

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Table.1 Chemical composition (%) of GGBS:

SiO2	39.18
Al2O3	10.18
Fe2O3	2.02
CaO	32.82
MgO	8.52
Na2O	1.14
K2O	0.30

B. Performance of Ground Granulated Blast Furnace Slag in Concrete

The replacement of cement with GGBS will reduce the unit water content necessary to obtain the same slump. This reduction of water content is more pronounced with increase in slag content and also on the fineness of slag. This is because of the surface configuration and particle shape of slag being different than cement particles. Surface hydration of slag is Slightly slower than that of cement. Reduction of bleeding is not significant with slag of 4000 cm2/g fineness but significant when slag fineness of 6000 cm2/g and above.

Product of hydration of OPC

OPC (C3S/C2S) + H2O ——————————> C-S-H + CH

Product of hydration of GGBS

GGBS (C2AS/C2MS) + H2O ——————————> C-S-H + SiO2

The generation of secondary gel results in formation of additional C-S-H, a principal binding material. This is the main attribute of GGBS, which contributes to the strength and durability of the structure. The diagrammatic representation of secondary gel formation is shown below.

C. Advantages of Using GGBS

1) Reduce heat of hydration
2) Refinement of pore structures
3) Reduce permeability to the external agencies
4) Increase resistance to chemical attack.

D. An Overview on Fibre

In recent years, several studies have been conducted to investigate the flexural strengthening of fibre reinforced composite fabrics. Recently, the use of high strength fibre-reinforced concrete (FRC) materials has gained acceptance as structural reinforcement for concrete.

In this composite material, short discrete fibres are randomly distributed throughout the concrete mass. The behavioral efficiency of this composite material is far superior to that of plain concrete and many other construction materials of same cost. Due to this benefit, the use of FRC has steadily increased during the last two decades and its current field of application includes airport and highway pavements, earthquake resistant and explosive resistant structures, mines and tunnel linings, bridge deck overlays, hydraulic structures, rock slope stabilization. Extensive research work on FRC has established that the addition of various types of fibres such as steel, glass, synthetic and carbon, in plain concrete improves strength, toughness, ductility, and post cracking resistance etc. The major advantages of fibre reinforced concrete are resistance to microcracking, impact resistance, resistance to fatigue, reduced permeability, improved strength in shear, tension, flexure and compression.

The character and performance of FRC changes with varying concrete binder formulation as well as the fibre material type, fibre geometry, fibre distribution, fibre orientation and fibre concentration.

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E. Fibre Materials

According to the terminology adopted by the American Concrete Institute (ACI) Committee 544, Fibre Reinforced Concrete, there are four categories of FRC based on fibre material type. These are Steel Fibre Reinforced Concrete, Glass Fibre Reinforced Concrete, Synthetic Fibre Reinforced Concrete, including carbon fibres; and Natural Fibre Reinforced Concrete.

F. Fibre Geometry

Individual fibres are produced in an almost limitless variety of geometric forms including,

G. Prismatic

Rounded or polygon cross-section with smooth surface or deformed throughout or only at the ends.

H. Irregular Cross-section

Cross-section varies along the length of the fibre.

I. Collated

Multifilament (alternatively termed branching or fibrillated) or monofilament networks (or bundles) that are usually designed to separate during FRC production (mixing).

J. Equivalent Diameter

For fibres that are not circular and prismatic in cross-section, it is useful to determine what would be the diameter of an individual fibre if its actual cross-section were formed as a prismatic circular cross- section. The equivalent diameter of a fibre is the diameter of the circle having the same area as that of the average cross-sectional area of an actual fibre.

Relatively small equivalent diameter fibres have correspondingly low flexural stiffness and thus have a certain ability to conform to the shape of the space they occupy in the paste phase of the concrete mixture in between aggregate particles. Relatively large equivalent diameter fibres have greater flexural stiffness and will have a correspondingly greater effect on the consolidation of aggregates during the process of mixing and placement.

K. Fibre Aspect Ratio

The fibre aspect ratio is a measure of the slenderness of individual fibres. It is computed as fibre length divided by the equivalent fibre diameter for an individual fibre. Fibres for FRCcan have an aspect ratio varying from approximately 40 to 1000 but typically less than 300. This parameter is also a measure of fibre stiffness and will affect mixing and placing.

L. Fibre Denier

Principally when discussing about Synthetic fibre reinforced concrete, the term fibre denier is often used. This is terminology that evolved from the textile industry. The denier of a fibre is defined as the weight, in grams, of 9000 metres of fibre.

M. Fibre Content

The concentration of fibre within a given unit volume of fibre reinforced concrete ranges from high to low relative to the total volume of concrete produced. It is useful to classify FRC on the basis of fibre concentration (volume percentage) as this one factor is seen to significantly affect mixing, placing, and hardened concrete performance, as much as any other single factor. Volume percentage may be considered high if in the range 3 to 12%, moderate if in the range 1 to 3%, and low if in the range 0.1 to l.0%, based on the total volume of the concrete produced. The different ranges of fibres that can be used are given below in the fibre. The synthetic fibre is ranging from 0.1% to 2% by volume percent of the matrix.

N. Fibre Count and Specific Surface

Fibre count (FC) and fibre specific surface (FSS) are the number of fibres in a unit volume of FRC and the surface area of fibre in a unit volume of FRC, respectively. Consider the mass of an FRC composite based on volume basis. The total volume of fibre in any given unit of volume of composite, i.e. the volume fraction (or percentage if multiplied by 100), may consist of only one single (large) fibre or it may be any number of smaller individual fibres. Recently developed a new type of fibre manufactured by Reliance company come in to picture i.e., steel Fibre. This is a synthetic fibre.

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III. EXPERIMENTAL PROGRAMMES

A. Outline of Present Work

GGBS is a product confirming to engineering requirements in terms of Physical and chemical properties. So in our present study we are going to put our great diligence in study of Steel Fibres which can be made as a partial cement replacement material simultaneously achieving required strength testing on mortar cubes. GGBS is a non-metallic product essentially consists of silicates and aluminosilicates of calcium and other bases. The four major factors, which influence the hydraulic activity of slag, are glass content, chemical composition, mineralogical composition and fineness. The granular material when further ground to less then 45 micron will have specific surface of about 400-600 m2/kg (Blaine). But here in our present study we have delved into the use of GGBS in different percentages in mortar testing, where we have used GGBS passing through 75 micron sieve. Here the specific surface of about275-550 m2/kg. We are going to use of GGBS as partial replacement of cement because of its advantages like lower energy cost, higher abrasion resistance, lower hydration heat evolution, higher later strength development.

We are going to use Steel fibre in different percentage i.e, 0%, 0.05%, 0.1% to the weight of concrete and study the 7 days and 28 days compressive strength, splitting tensile and flexural strength of concrete to that of normal concrete with maintaining the water cement ratio in the range of 0.35-0.41. Then with different percentages of cubes, cylinders and prisms were cast and tested to analyse the change in compressive, splitting tensile and flexural strength. We used two types of cement for our study i.e Portland slag cement and ordinary Portland cement (53 grade). Finally Porosity and Capillary absorption test was conducted on different specimens to analyse the effect of steel fibres on concrete.

Different material used in this study are given below for the strength evaluation of concrete using different pozzolanic material , fibre.

B. Cement

For the experiment following one type of cement were used,

(a) Ordinary Portland cement (53 grade)

The chemical composition and different properties are shown below.

1) Fineness – 340 m2/kg
2) Specific gravity- 2.96
3) Initial setting time - 120 min
4) Final setting time – 240 min

Table-2 Properties of Portland slag cement

Specific gravity	2.96
Initial setting time (min)	125
Final setting time (min)	235

Table-3 Properties of Ordinary Portland cement

Specific gravity	3.1
Initial setting time (min)	90
Final setting time (min)	190

5) *Fibre:* In this project work it was used Steel fibre. It is a type of synthetic fibre. In different weight fraction (0.0%, 0.1%, 0.2%, 0.3%) to concrete it was used.

C. Ground Granulated Blast Furnace Slag (GGBS)

As pozzolanic activity greatly depends on fineness, so GGBS passing through 75 micron whose fineness of order of 275-550 m2/kg was used. Specific gravity test was conducted using Le-Chatelier apparatus and found to be 2.77. X-Ray diffraction test was conducted

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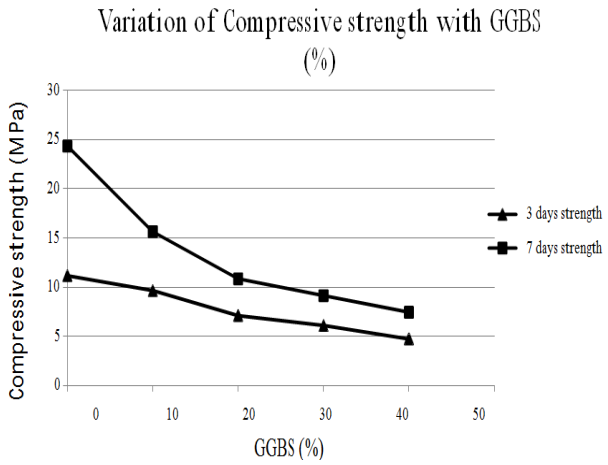
D. Test Result

Table - 4 Effect of GGBS in normal consistency of cement:

% of cement replaced by GGBS (%)	Consistency (%)
0	31.0
10	32.0
20	33.5

Table- 5 effect of GGBS on Compressive strength of cement:

% of GGBS with cement replacement	3 days strength (MPa)	7 days strength (MPa)
0	11.176	24.31
10	9.66	15.63
20	7.117	10.85



IV. DISCUSSION

It is observed here that the consistency percentage is increasing as the percentage of GGBS increases as a cement replacement, but the change is not so abrupt. But found that as we go on increasing the percentage of Rice husk ash the consistency percentage increases rapidly.

The variation of compressive strength of mortar mix with different proportions of GGBS partial replacement of cement is shown in fig. It was observed that 3 days and 7 days compressive strength reduces about 10% and 20% that is from 11.176 MPa to 9.66 MPa and 24.31 to 15.63 respectively, as GGBS percentage increases from 0 to 10%. If percentage of GGBS was further increased the compressive strength reduces greatly. Finally when the GGBS percentage increased to 40% the strength reduces by about 60% and 70% in 3 days and 7 days respectively of its initial values. So it was concluded that the use of GGBS specially in Portland slag cement leading to adverse effect on the strength of mortar.

Firstly with Portland slag cement the effect of fibre and SF on strength of concrete are shown below Figure then using OPC.

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Table 6 Effect of Steel fibre on Compressive strength using slag cement:

Fibre content (%)	7 days compressive strength (N/mm^2)	28 days compressive strength (N/mm^2)
0.0	29.036	37.77
0.05	24.63	27.4067
0.1	26.43	32.148

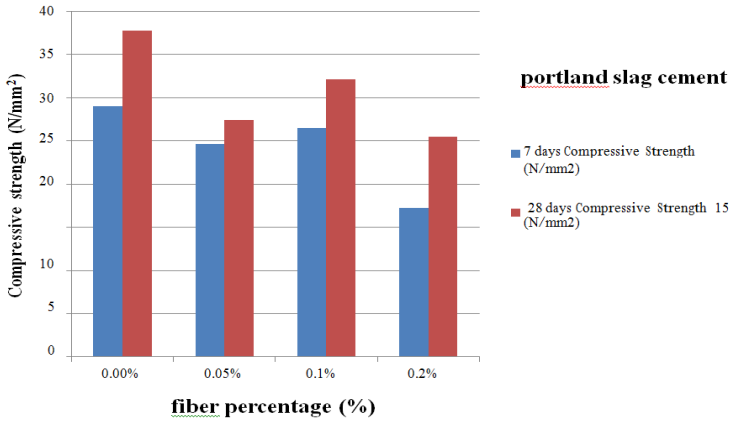


Figure 1 Effect of Steel fibre on compressive strength

Effect of Steel fibre on Splitting Tensile Strength using slag cement:

Fibre content (%)	7 days splitting tensile strength (N/mm^2)	28 days splitting tensile strength (N/mm^2)
0.0	2.523	2.873
0.05	2.12	2.452
0.1	2.569	3.018

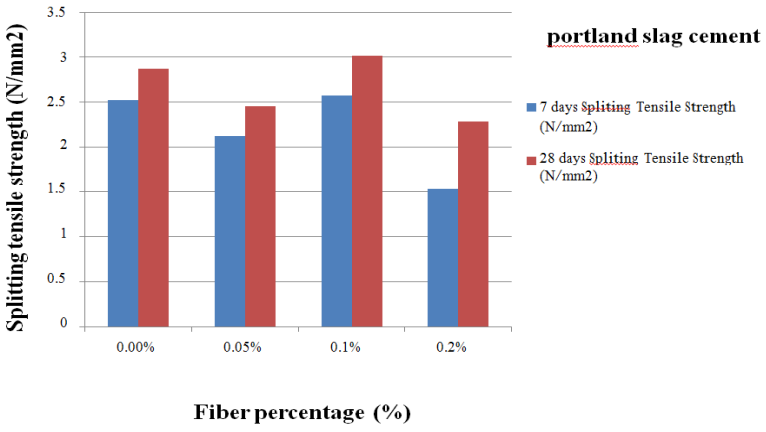


Figure 2 Effect of steel fibre on tensile strength

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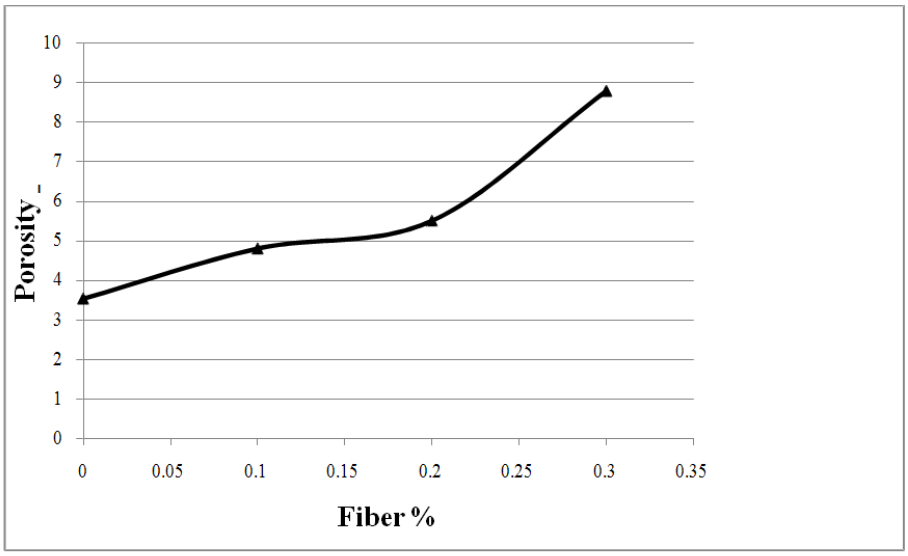


Figure 3 Porosity of different fibre content

The capillary absorption coefficient is greatly influenced by the addition of silica fume in Recron fibre reinforced concrete. With 10% SF the capillary decreases by two times and at 20% SF the capillary decreases about 70% to capillary with 0.2% fibre only. Then at 30% SF it is increased slightly again.

The porosity of concrete decreases with silica fume. As the percentage of silica fume increases from 0 to 30% porosity of concrete goes on decreasing. It was reduced by about 12% that of fibre reinforced with 0.2% fibre.

V. CONCLUSION

In this present study with the stipulated time and laboratory set up an effort has been taken to enlighten the use of so called pozzolanic material like ground granulated blast furnace slag, fibre reinforced concrete in accordance to their proficiency. It was concluded that,

1) Use of GGBS as cement replacement increases consistency. Although fineness greatly influenced on proper pozzolanic reaction still GGBS passing 75 micron sieve not giving good strength of mortar. Using GGBS more than 10% in Portland slag cement the strength reducing rapidly.

2) With the use of superplasticizer it possible to get a mix with low water to cement ratio to get the desired strength.

3) In case of Portland slag cement with the use of steel fibre, the 28 days compressive strength at 0.2% fibre content the result obtained is maximum. The 28 days splitting tensile and flexural strength also increases about 5% at 0.2% fibre content to that of normal concrete. Further if fibre percentage increases then it was seen a great loss in the strength.

4) With Portland slag cement keeping 0.2% Recron fibre constant and varying silica fume percentage the compressive, splitting tensile, flexural strength affected remarkably. Using 20% silica fume with 0.2% fibre percentage the 28 days compressive strength increases 7% more than concrete with 0.2% fibre only. 28days split tensile and flexural strength increases further, about 12% and 10% that of normal concrete.

5) The tensile strength increases about 15% at 10% SF and constant 0.2%fibre, then decreases with increasing the SF percentage. Flexural strength is not giving good indication and goes on decreasing and it is about 40% decrement as the SF percentage increases to 30%.

6) Ordinary Portland cement gives good compressive strength result as compared to Portland slag cement in case of mix with SF and 0.2%.

7) The capillary absorption coefficient (k) with decreases great sign as SF percentage increases at constant fibre percentage i.e 0.2%. At 20% SF content the k value decreases progressively with 70% reduction that to without SF content concrete.

8) The porosity value also decreases as the SF value increases from 0-30% in fibre reinforced concrete.

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A. Scope of Further Work

1) The research work on pozzolanic materials and fibre along with pozzolanas is still limited. But it promises a great scope for future studies. Following aspects are considered for future study and investigation;

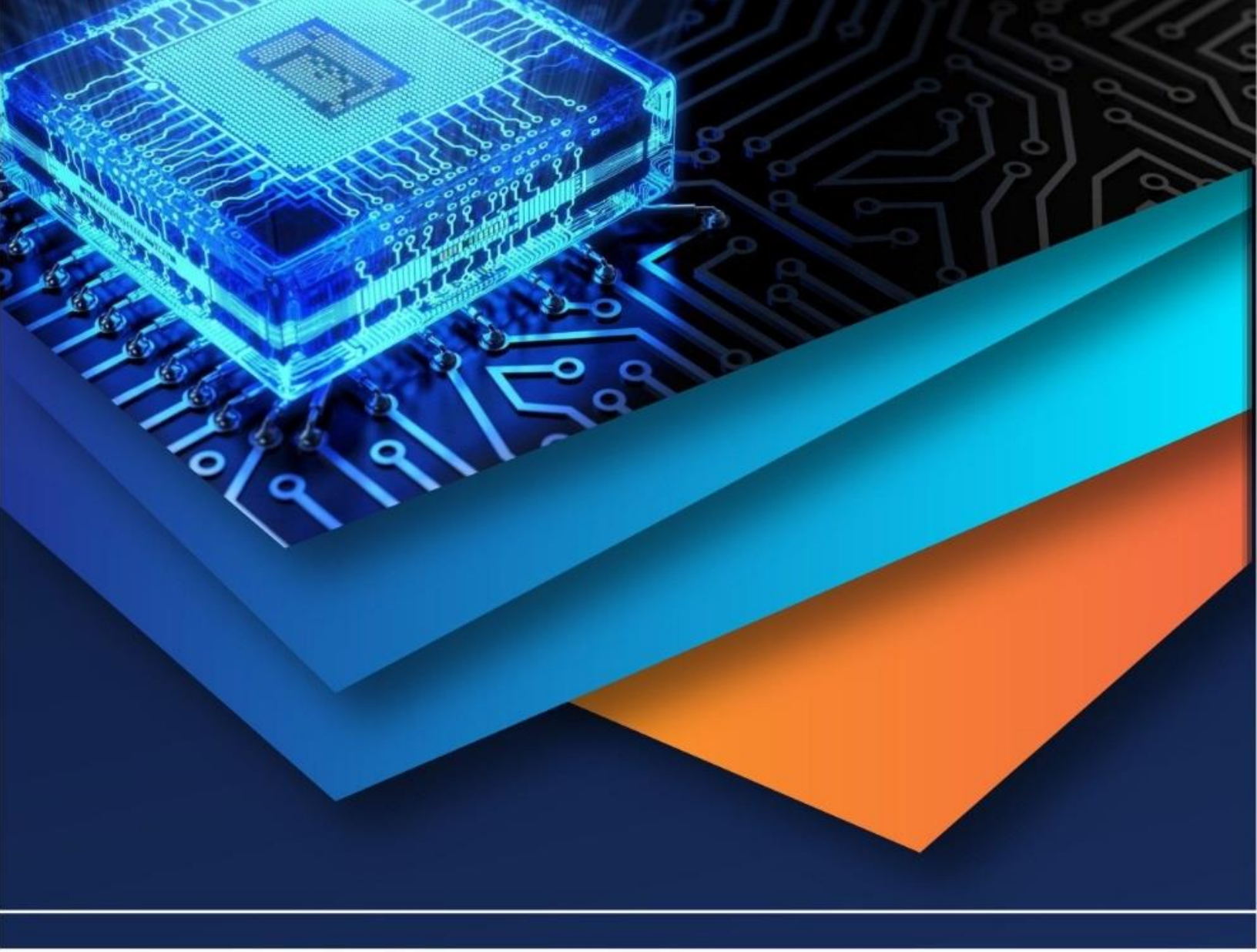
2) Percentage and actual fineness of GGBS require as partial cement replacement for good strength development.

It requires a proper mixing proportions for the development of high strength, high performance concrete which may not be possible manually. So it needs some global optimisation techniques to develop the desired result with greater accuracy and time saving.

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