Journal of Science and Technology
ISSN: 2456-5660 Volume 7, Issue 09 (November 2022)
www.jst.org.in *DOI:https://doi.org/10.46243/jst.2022.v7.i09.pp12-23*

Application of Ground Granulated Blast Furnace Slag (GGBS) In High Performance Concrete

Vishakha N. Surati, Dr. Nisha P. Soni, Mr. Keyur P. Shah

PG Scholar, Civil Engineering Department, S.N. Patel Institute of Technology and Research Centre, Umrakh, Bardoli, Gujarat, India

Head of the Department, Civil Engineering Department, S.N. Patel Institute of Technology and Research Centre, Umrakh, Bardoli, Gujarat, India

Assistant professor, Civil Engineering Department, S.N. Patel Institute of Technology and Research Centre, Umrakh, Bardoli, Gujarat, India

To Cite this Article
Vishakha N. Surati, Dr. Nisha P. Soni, Mr. Keyur P. Shah, **Application of Ground Granulated Blast Furnace Slag (GGBS) In High Performance Concrete"**",*Journal of Science and Technology, Vol. 07, Issue 09,-November 2022, pp*12-23

Article Info
Received: 29-09-2022 *Revised: 18-09-2022* *Accepted: 28-10-2022* *Published: q13-11-2022*

Abstract:

Application of Ground Granulated Blast Furnace Slag (GGBS) for high-performance concrete is the demand of the decade as a supplementary cementitious material for making concrete more environmentally friendly and economical. In this research, the properties of High-performance concrete have been evaluated by incorporating (GGBS) as a replacement for cement, the production of which increases the amount of CO_2 generated in the environment. This research focuses on making an M70 grade concrete mix with minimum use of cement and increasing the potential application of GGBS in various percentages. The properties evaluated during the experimental study were compressive strength, flexural strength, and split tensile strength of concrete. The result of the study concludes that the GGBS as a mineral admixture helps to control the quality of concrete and the workability of the mix is also increased. The result of the study also showed positive insights. The maximum compressive strength achieved with the use of mineral admixture is 77.4 Mpa and maximum tensile strength is 5.1 Mpa and flexural strength after 28 days of testing is 9.1 Mpa.

1. INTRODUCTION:

Cement-based composites are the most used construction materials in the world. It is a visible component of concrete, which consists of three components: cement, coarse aggregate (sand and crushed rocks), and water. There is now a need for infrastructure, which has increased concrete consumption significantly. Due to the obvious high demand for concrete, numerous research has been conducted in order to improve High Performance Concrete (HPC) by enhancing its two major characteristic features: strength and durability.

Higher strength concrete usually requires a higher cement content (600 kg/m3 to 700 kg/m3), which the IS code restricts since that improves the hydration rate, leading to the formation of thermal cracks and lowering structural performance. The increased OPC level increases the carbon footprint, which is detrimental to the environment. With respect to the environment, the current work employs Ground Granulated Blast Furnace Slag (GGBS), a waste by-product of the steel industry, as the Supplementary Cementitious Material (SCM). In this investigation, three grades of concrete were crafted with powder contents of 25%, 30%, and 35% OPC overtaken by GGBS to produce sustainable and cost-effective high-performance concrete.

Concrete is used for a number of purposes, along with resistance to various atmospheric conditions. In such cases, Portland cement may not require the standard quality performance and durability. Concrete properties the same as high strength and performance necessarily involve the use of other cementitious materials. However, it is well acknowledged that, in order to reduce the carbon impact of concrete on the planet and in compliance with IS–456:2000, the optimum concrete mixture must be limited to 450 kg/cum. Furthermore, increasing the cement content will raise not only the total cost of the project per m3, but also the heat produced throughout hydration and the initial deformation cracks. These concerns can be addressed by using supplementary cementitious materials (SCMs) besides fly ash, ground granulated blast furnace slag (GGBS), silica fume (SF), rice husk ash (RHA), and others to substitute OPC in a compressive manner and generate ecologically responsible concrete. As a result, much focus has been given on trying to produce HPC at a cheaper price and reducing emissions while providing similar characteristics.

The concept of high-strength concrete (HSC) started in the 1970s as an outcome of the need for rapid construction. Due to the high heat of hydration and shrinkage cracks, HSC has a high cement content in many cases. The strength factor alone is insufficient for establishing concrete quality; durability must be considered. When evaluating the concept of high-performance concrete, this has been the most significant consideration. Even though natural resources for both HSC and HPC are the same, expertise in the components, their properties, and interactions is critical in distinguishing HPC from HSC. Researchers have attempted to eliminate the problem of high cement content and a high carbon footprint by using industrial by-products (which are pozzolanic or cementitious in nature) in concrete.

ISSN: 2456-5660 Volume 7, Issue 09 (November 2022)
www.jst.org.in *DOI:https://doi.org/10.46243/jst.2022.v7.i09.pp12-23*

GGBS is a good potential cementitious material which can be combined with Portland cement to create durable concrete while also enriching it. The addition of GGBS to Portland cement improves not only the concrete's early strength but also forms a calcium silicate hydrate (CSH) gel around the cement particles, making the concrete denser and less porous. This may make the concrete more resistant to cracking.

HPC applications

HPC has a wide spectrum of uses in infrastructure, building services, and many non-structural architectures and design merchandise. Over the last two decades, extensive testing developments have been carried out all over the world to develop and expand HPC innovation as a present and future production input. HPC has been used in the building projects of approximately 200 roads in either one of their components. Other building components that can be used include sunshades, cladding, and roof components. Precasting is favored in the precast sector because it generates structures that are gentle, skinny, long-lasting, as well as aesthetically pleasing. This is also commonly used as an intermediate layer to structural materials, improving their workability and compressive strength while requiring less maintenance. Because of its high resistance to aggressive agents, it is also used in marine construction. In many areas where conventional concrete has proven ineffective, UHPC has emerged as an innovative and cost-effective solution.

2. LITERATURE REVIEW:

(Prem et al. 2020) It is critical to extract the maximum performance from all materials used in the production of concrete. When attempting to manufacture HPC, any material incompatible with the process could be hazardous to the completed project High-performance concrete be used include super plasticizer sand supplementary cementing materials in addition to Portland cement, aggregates, and water. The desired details of the material properties for HPC production are provided here.(Al Saffar, Al Saad, and Tayeh 2019) This study investigates research findings on the development of a high-performance inner curing process (HPC). Object parts were used to create the inbuilt curing necessary to eliminate subconscious in the concrete mixture, reducing the risk of cracking in hardened concrete. This study will concentrate on HPC behavior, such as density, strength (compressive, splitting tensile, and flexural), shrinkage (autogenously and drying), and the nanostructure of hydration products. According to the findings, internal curing is more effective at splitting tensile and flexural strength than compressive strength at a later age. Internal curing has compacted and deseeded the interfacial transition zone, increasing strength. (Prasanna, Srinivasu, and Ramachandra Murthy 2021)The use of GGBS as a mineral admixture requires only grinding, which saves a significant amount of energy when compared to the production of OPC. Because of its engineering benefits, GGBS is gaining popularity, owing to the reduction of negative environmental effects. The lower cement content required for concrete preparation results in a reduction in CO2 emissions. The use of mineral admixtures containing bottom ash was shown to improve the concrete physical and mechanical properties. In comparison to the OPC and GGBS manufacturing emits fewer greenhouse gases and requires less energy. GGBS is a by-product of the pig iron industry; it has a higher less lime and further alumina and silica content than Portland cement. The ashes are typically when contrasted to concrete mixtures, GGBS-blended material is much more environmentally sustainable because it contains a mixture of chemical formations such as aluminium, silicon, calcium, magnesium, and oxygen. It also improves workability and reduces concrete bleeding.(Smarzewski 2019) The main objective of this study is to establish the modulus of rupture of concrete products (HPC) containing silica fume (SF). The article shows the results of an investigation into changes in material properties such as compressive strength, splitting tensile strength, modulus of elasticity, fracture energy, and characteristic length of six HPC due to the addition of SF. The percentages of SF added to the HPC were 0%, 5%, 10%, 15%, 20%, and 25% by weight of cement content. The water/binder ratio was set at 0.25. The use of SF improves all of the mechanical properties of concrete that have been tested. The study found that replacing cement in concrete with SF improved the mechanical properties of HPC significantly after 28 days.(Journal et al. 2018)Concrete is made up of natural, inexpensive, and easily accessible ingredients such as cement, sand, aggregate, and water. Cement is the world's second most commonly used material, after water. However, the rapid production of cement creates two major environmental issues for which we must devise civil engineering solutions. We are all aware that CO2 emissions are seriously toxic and cause a variety of climatic factors. Ground Granulated Blast Furnace Slag (GGBS) is a natural outcome of pig steel making that is produced by rapidly heating molten slag with moisture or softening molten material. Melted slag is produced here, which is immediately tapped and quenched by water. This rapid cooling of molten slag contributes to the structure of "granulated slag." Granulated Slag (GGBS) is created from Blast Furnace Slag. One of the byproducts of burning fuel in coal-fired power plants is fly ash. Fine particles rise with flue gases and are collected by particle

Journal of Science and Technology
ISSN: 2456-5660 Volume 7, Issue 09 (November 2022)
www.jst.org.in DOI:https://doi.org/10.46243/jst.2022.v7.i09.pp12-23

mineral admixture, which comes in both provision of goods and services and portable forms. This ultra-fine material will create an effective gap among cement grains, producing a very dense concrete with greater compressive strengths and incredibly low penetrability. (Nagendra 2018) In the current study, Ground Granulated Blast Furnace Slag (GGBS) has been used as a mass substitute for cement. GGBS is used as a partial replacement for cement in concrete mixes with particle sizes ranging from 125-250 μ m, 90-125Vm, 45-90 μ m, 20-45 μ m, and 20 μ m. The dosage of GGBS is varied from 10% to 40% with 10% increments to evaluate the compressive strength of concrete as well as the micro structural analysis of concrete. Scanning electron microscopy (SEM) and an energy dispersive spectrometer are used to investigate the microstructure (EDS). Silica and calcium were found to be the two most abundant compounds in the study, with consumption occurring both before and after the pozzolonic reactions. The optimum compressive strength is observed for 20 m size particles at a 20% replacement level, and it is also observed that the consumption of calcium is greater for the aforementioned replacement. (Dhanya R 1, Arasan G.V 2017) Steel slag is an inorganic material composed of silicates and alumina. -calcium silicates produced during steelmaking iron production from coal via water-jetting and water-immersion of burning hot blast-furnace slag for crystallization. A 55-59 percent replacement of cement by GGBS was discovered to produce the best concrete strength. GGBS improves the corrosion resistance (due primarily to chlorine), durability, and binding power of concrete. It changes the pore structure of concrete, resulting in harder concrete and greater abrasion resistance. Chloride ion permeability and penetration in concrete are reduced. The addition of GGBS to concrete can also influence the electrochemical pore solution in the cement system. The addition of GGBS to concrete can also reduce the resistance of concrete to sulphate attack in both moderate and severe environments.(Prajapati, Prajapati, and Qureshi 2017) The effect of mineral admixture on HPC performance, Fly ash and GGBS, specifically, with M-grade IS cube object was investigated. By weight of the binder, Cement substitution with Portland. The percentage of fly ash and GGBS substitute extend between 10% and 30%. Conplast SP430-Sulphonated Naphthalene Polymers were used as a super plasticizer to improve workability for high temperatures. Concrete performance super plasticizer dosage the same as the other ratios of the mixture. Furthermore, we searched for compressive strength, split tensile strength, and flexural strength by displacing fine aggregate of different ratios of foundry sand. Each case is unique. The HPC mix, grade M60concrete is designed in accordance with Indian standards. To obtain the desired strengths and properties, concrete elements were tested besides GGBS and fly ash. Finally, participants prepared concrete using various proportions of fly ash and ground granulated blast furnace slag as a replacement for cement. They casted mortar cubes and prisms are kept for 28 days to cure. Finally, compressive and flexural tests are performed. (Ramakrishnan et al. 2017) This study describes a workshop study that looked at the mechanical and durability properties of concrete using a combination of crushed waste glass powder (GP) and ground granulated blast furnace slag (GGBS) as a partial substitution in cement. Mechanical characteristics are analyzed employing compressive strength, flexural strength, bond strength, and split tensile strength experiments. Water absorption and sorptivity, two aspects of durability, are investigated. Cement replacement by glass powder ranged from 5% to 45 % in 5% increments, and GGBS replacement ranged from 45 % to 5% in 5% increments, respectively. In total, ten different mix combinations are investigated at three dissimilar concrete periods, namely 3, 7, and 28 days.(George et al. 2016): Geopolymer is an inorganic member that aims to replace OPC in the production of concrete. As a trend toward more sustainable development, pozzolanic advancements as a concrete structure are becoming more popular. A French Professor named Joseph Davidovits pioneered geo-polymer technology. This technology primarily employs alkaline activator solutions such as potassium or sodium silicates and potassium or sodium hydroxides, as well as industrial by-products such as ground granulated blast furnace slag (GGBS), fly ash, and so on. The alkaline activator solution primarily undergoes geo-polymerization before reacting with industrial by-products to produce a obligatory property that holds the aggregates. Alccofine and GGBS were used as cementitious composites. Alkaline stimulators including sodium hydroxide flakes and sodium silicate, slag sand as fine aggregates, 12.5mm coarse aggregates, fresh water, and fibers like AR glass and steel fibers have been used to create fiber reinforced geopolymer concrete in this research. The characteristics of fresh and hardened fiber reinforced concrete mix are explored, and sample treating is performed at atmospheric temperatures.

3. MATERIALS AND PROPORTION

HPC typically contains supplementary cementitious materials, aggregates, gravel, admixtures, such as super plasticizers, and water. Cement, fine aggregate, coarse aggregate, GGBS and super plasticiser were used in present investigation. As a supplementary cementitious material, GGBS, a by-product of the steel plant, is utilized. An inorganic additive that aids in the approach to minimizing the water content of the concrete while achieving the necessary flow ability of HPC. Under this task, the HPC is established using a different proportion of GGBS, and the strength is calculated using compressive, split tensile, and flexural modulus.

PROPERTIES OF MATERIALS USED:

Cement	
Specific gravity	3.14
Initial setting time (minutes)	127 min
Final setting time (minutes)	215 min
Standard consistency	30%
Compressive strength at 28 days	53.466 N/mm^2
GGBS	
Specific gravity	2.9
Bulk density	1200 kg/m^3
Fineness	>350 m2/kg
colour	Off-white
Fine aggregate	
Specific gravity	2.662
Water absorption	0.847%
Bulk density: loose	1.211 kg/lt
Bulk density: compacted	1.456 kg/lt
Coarse aggregate 10mm	
Specific gravity	2.73
Water absorption	0.50
Bulk density	1556 kg/m^3
Fineness modulus	2.42
Coarse aggregate 20 mm	
Specific gravity	2.76
Water absorption	0.33
Bulk density	1612 kg/m^3
Fineness modulus	3.08

3. MIX DESIGN:

The concrete mix is designed for M70 grade. In this study 25%, 30%, and 35% of the GGBS were replaced with cement with water cement ratio of 0.26.

SR. NO.	MATERIALS	QUANTITIES
1	Cement	428 kg/m^3
2	Water	149 kg/m^3
3	w/c ratio	0.26355
4	GGBS	134 kg/m^3
5	Super-plasticizer	2.675 kg/m^3
6	CA	1226 kg/m^3
7	FA	680 kg/m^3

MIX PROPORTION OF CONCRETE

Mix name	Mix description	Cement (kg/m^3)	GGBS (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Water (kg/m^3)	Super plasticizer (kg/m^3)
HPC	Control mix	562	0	680	1226	149	7.03
Mix 1	25% GGBS	422	140	680	1226	149	7.03
Mix 2	30% GGBS	393	169	680	1226	149	7.03
Mix 3	35% GGBS	365	197	680	1226	149	7.03

4. LABORATORY INVESTIGATION:

For the purpose of making concrete, the materials mentioned above were combined in the proper proportions. The materials were mixed dry, then water and admixture were added and thoroughly mixed. Cubes (150x150x150mm) were cast to test their strength. Specimens were kept in water for curing before being tested.

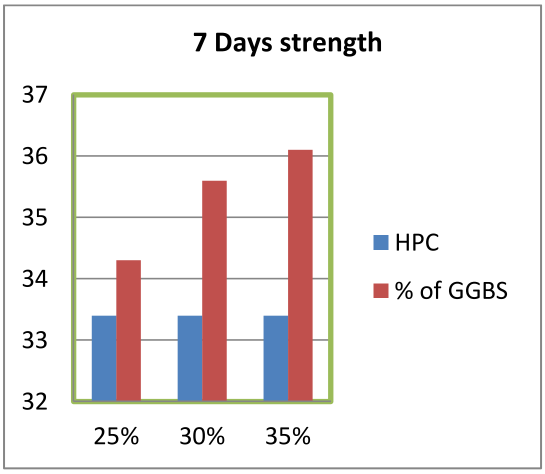
The specimens were dehydrated after being removed from the humidity chamber. The sample has been compressed strength tested for 7 and 28 days, with the results recorded based on three trials.

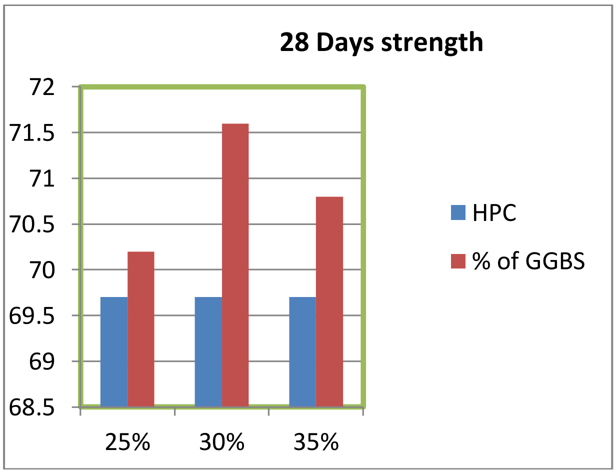
A. Compressive strength:

Cubes were tested using a compressive testing machine. Specimens kept for 7 days and 28 days for curing were tested.

PROPORTION	7 Days strength			28 Days strength		
	Sr.	Strength (Mpa)	Average (Mpa)	Sr.	Strength (Mpa)	Average (Mpa)
HPC	1	34.2	33.4	1	74.6	74.8
	2	33.6		2	75.8	
	3	32.5		3	73.9	
Mix 1 (25% GGBS)	1	35.2	34.3	1	75.8	74.6
	2	33.3		2	73.6	
	3	34.5		3	74.3	
Mix 2 (30% GGBS)	1	35.6	35.6	1	78.2	77.4
	2	34.5		2	76.9	
	3	36.7		3	77.2	

Mix 3 (35% GGBS)	1	34.5	35.2	1	76.5	75.5
	2	36.6		2	74.9	
	3	34.4		3	75.2	

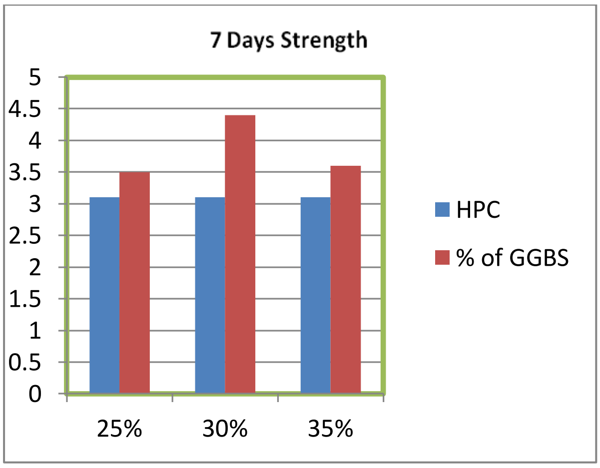


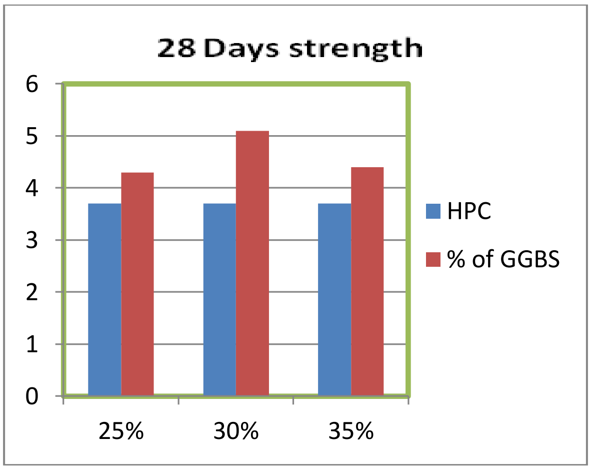


B. SPLIT TENSILE STRENGTH TEST:

Cylinders were tested using a Compact compression testing machine. Specimens kept for 7 days and 21 days for curing were tested.

PROPORTION	7 Days Strength			28 Days Strength		
	Sr.	Strength (Mpa)	Average (Mpa)	Sr.	Strength (Mpa)	Average (Mpa)
HPC	1	3.2	3.1	1	3.7	3.7
	2	3.1		2	3.5	
	3	2.9		3	3.8	
Mix 1 (25% GGBS)	1	3.5	3.5	1	4.2	4.3
	2	3.3		2	4.5	
	3	3.6		3	4.3	
Mix 2 (30% GGBS)	1	4.2	4.4	1	5.3	5.1
	2	4.6		2	4.9	
	3	4.4		3	5.2	
Mix 3 (35% GGBS)	1	3.6	3.6	1	4.4	4.4
	2	3.5		2	4.3	
	3	3.8		3	4.6	



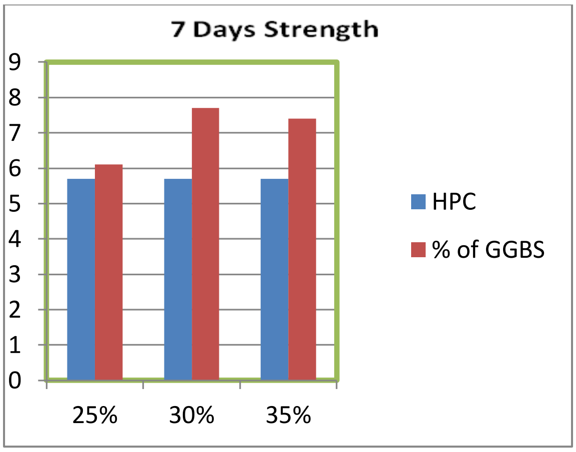


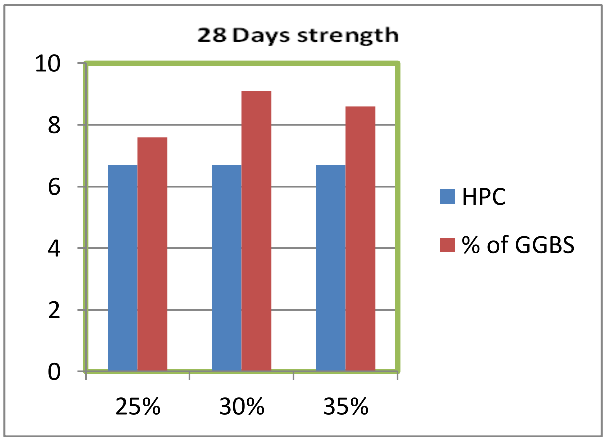
Journal of Science and Technology
ISSN: 2456-5660 Volume 7, Issue 09 (November 2022)
www.jst.org.in DOI:https://doi.org/10.46243/jst.2022.v7.i09.pp12-23

C. FLEXURAL STRENGTH TEST:

Beams were tested using a universal testing machine. Specimens kept for 7 days and 21 days for curing were tested.

PROPORTION	7 Days Strength			28 Days Strength		
	Sr.	Strength (Mpa)	Average (Mpa)	Sr.	Strength (Mpa)	Average (Mpa)
HPC	1	5.5	5.7	1	6.9	6.7
	2	5.9		2	6.7	
	3	5.7		3	6.6	
Mix 1 (25% GGBS)	1	5.9	6.1	1	7.8	7.6
	2	6.2		2	7.5	
	3	6.3		3	7.7	
Mix 2 (30% GGBS)	1	7.6	7.7	1	9.3	9.1
	2	7.9		2	9.2	
	3	7.5		3	8.9	
Mix 3 (35% GGBS)	1	7.3	7.4	1	8.6	8.6
	2	7.5		2	8.4	
	3	7.6		3	8.7	





6. CONCLUSION:

- As the proportion of GGBS rises, the slump value of fresh concrete grows up to a 30 percent replacement, then decreases significantly. The greater the auditory stimulation of wind in the composite, and thus the greater the quantity of mixture, the easier and thinner the slag.
- The water absorption of concrete is observed to decrease as the percentage of GGBS increases. As a result of this finding, it is concluded that the GGBS can be used to improve the structure's water impermeability. As a result, the corrosion of

reinforcement may be delayed, and the durability of the R.C.C. structure may be increased.

- Cement replacement with ground granulated blast furnace slag increases compressive strength by up to 30% GGBS for M70 grade concrete. Compressive strength decreased after 30% replacement of ground granulated blast furnace slag.
- The highest proportion of GGBS in concrete production should be 30% when using OPC. Based on our observations, we concluded that strength and higher ordinary for 4 weeks while trying to compare to conventional concrete.
- After testing the compressive strength of cubes, it can be concluded that the mix of 30% GGBS achieves the maximum compressive strength of 77.4 MPa. Compressive strength decreased after a 30% replacement of ground granulated blast furnace slag.
- When the GGBS was increased by 30%, the split tensile strength and flexural strength increased by 5.1 MPa and 9.1 MPa, respectively, at the end of 28 days.
- Based on the data presented above, we can conclude that a 30% GGBS replacement works best for all tests. The use of GGBS in concrete saves money when compared to traditional cement concrete. This is a significant financial saving. As a result, GGBS concrete is more cost-effective.

7. SCOPE FOR FURTHER STUDY:

- The same study can be expanded to include various types of industrial waste, such as fly ash, silica fumes, rice husks, and so on.
- Waste from the steel industry can be used to further this research.
- The same research can be expanded by substituting recycled aggregate for the original aggregate.
- The same study can be expanded to include criteria for durability.

REFERENCES:

1 George, Reethu, Aneena Thomas, P. B. Amala Mary, and Niya Eldhose. 2016. "An Experimental Study on Glass Fibre Reinforced Concrete." *International Research Journal of Engineering and Technology* 4(13):1–5.

2 Journal, International, O. F. Engineering, Economical Analysis, O. F. Concrete, Steel Fiber, Ggbs As, Partial Replacement, and O. F. Cement. 2018. "*1 1 , 2 & 3." 7(2):24–30.

3 Nagendra, V. 2018. "Ground Granulated Blast Furnace Slag (GGBS): Effect of Particle Size and Dosage on Compressive Strength with Microstructural Analysis of Concrete." *International Journal for Research in Applied Science and Engineering Technology* 6(5):2467–74. doi: 10.22214/ijraset.2018.5404.

4 Prajapati, Anjali, Piyush Prajapati, and Mohammed Qureshi. 2017. "An Experimental Study on High Performance Concrete Using Mineral Admixtures." 5(2):2080–86.

5 Prasanna, P. K., K. Srinivasu, and A. Ramachandra Murthy. 2021. "Strength and Durability of Fiber Reinforced Concrete with Partial Replacement of Cement by Ground Granulated Blast Furnace Slag." *Materials Today: Proceedings* 47(xxxx):5416–25. doi: 10.1016/j.matpr.2021.06.267.

6 Prem, Prabhat Ranjan, Parukutty Sanker Ambily, Bhashya Vankudothu, and Bhajantri H. Bharatkumar. 2020. "Sustainable Production of High Performance Concrete." *Encyclopedia of Renewable and Sustainable Materials* (January):527–36. doi: 10.1016/b978-0-12-803581-8.11501-2.

7 Ramakrishnan, K., G. Pugazhmani, R. Sripragadeesh, D. Muthu, and C. Venkatasubramanian. 2017. "Experimental Study on the Mechanical and Durability Properties of Concrete with Waste Glass Powder and Ground Granulated Blast Furnace Slag as Supplementary Cementitious Materials." *Construction and Building Materials* 156:739–49. doi: 10.1016/j.conbuildmat.2017.08.183.

8 Al Saffar, Doha M., Aymen J. K. Al Saad, and Bassam A. Tayeh. 2019. "Effect of Internal Curing on Behavior of High Performance Concrete: An Overview." *Case Studies in Construction Materials* 10:e00229. doi: 10.1016/j.cscm.2019.e00229.

9 Smarzewski, Piotr. 2019. "Influence of Silica Fume on Mechanical and Fracture Properties of High Performance Concrete." *Procedia Structural Integrity* 17:5–12. doi: 10.1016/j.prostr.2019.08.002.