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" Experimental Investigation on use of ultrafine material in high strength concrete''

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ABSTRACT

This paper have the utilization of ultrafine materials in high-strength concrete (HSC) presents an innovative approach to enhance its mechanical and durability properties. This experimental investigation explores the incorporation of ultrafine materials, specifically nanoparticles, into HSC mixtures to achieve superior performance characteristics. The study focuses on assessing the impact of various types and dosages of ultrafine materials on the compressive strength, flexural strength, and durability properties of HSC. In this research, ultrafine materials including manufacturing sand, GGBFS, stone dust and super plasticizer are incorporated into HSC mixtures at different proportions. A comprehensive experimental program is conducted to evaluate the mechanical properties of the resulting concrete specimens, including compressive strength and flexural strength. The findings of this study provide valuable insights into the effectiveness of incorporating ultrafine materials in HSC mixtures. Results indicate that the addition of ultrafine materials leads to significant improvements in both mechanical properties and durability performance of HSC. Furthermore, the study identifies optimal dosages and combinations of ultrafine materials to achieve enhanced properties, offering valuable guidelines for the practical application of ultrafine materials in HSC production. Overall, this research contributes to advancing the understanding of utilizing ultrafine materials in HSC mixtures, paving the way for the development of high- performance and sustainable concrete materials for various construction applications.

Keywords: -Ultrafine materials, High-strength Concrete, Ground Granulated Blast Furnace Slag, Manufacturing Sand, Super plasticizers, Crushed Sand

Introduction

High-strength concrete is a specialized type of concrete characterized by its exceptional compressive strength, typically exceeding 6,000 pounds per square inch (psi) or 40 (MPa). This remarkable strength is achieved through careful selection of materials, precise mix proportions, and meticulous curing procedures. High-strength concrete is often used in construction projects where structural integrity and load-bearing capacity are critical, such as in high-rise buildings, bridges, and infrastructure.

The key components and factors contributing to high-strength concrete include:

Cement: High-quality cement with low water-to-cement ratios is typically used to increase strength.

Aggregates: Dense, well-graded aggregates, including fine and coarse particles, are chosen for their contribution to strength.

Water-Cement Ratio: Maintaining a low water-cement ratio is crucial to enhance strength while preventing excessive porosity.

Admixtures: Various chemical admixtures, such as superplasticizers and accelerators, can be added to improve workability and accelerate curing.

Curing: High-strength concrete requires precise curing methods, often involving temperature and moisture control, to ensure optimal strength development.

Testing: Rigorous testing and quality control procedures are essential to verify and monitor the concrete's strength throughout production and placement.

High-strength concrete offers several advantages, including reduced structural member sizes, increased durability, and improved performance under heavy loads. However, it requires careful planning, expertise, and quality control to achieve the desired results, making it a specialized material in the construction industry.

Ultra fine material

Ultra-fine materials, such as nanoparticles or nanoscale additives, can enhance the properties of high-strength concrete. These materials are typically used to improve the strength, durability, and other characteristics of concrete. Common ultra-fine materials used in high-strength concrete include: GGBFS, Flyash ,Nano silica (nano-SiO_2), Nano alumina (nano-Al_2O_3), Carbon Nanotubes (CNTs), Graphene Oxide (GO), Nanofibres, Nano-clay, these ultra-fine materials are typically added in small quantities, and their dispersion and compatibility with the concrete mix are crucial for achieving the desired properties. Incorporating these materials can result in high-strength concrete with improved performance characteristics.

Advantages

- Longer spans and fewer beams for the same magnitude of loading.
- Reduced axial shortening of compression supporting members.
- Superior long term service performance under static dynamic and fatigue loading.
- Low creep and shrinkage.
- Reduced maintenance and repairs.
- Smaller depreciation as a fixed cost.
- High strength to weight ratio, particularly for lightweight HSC.
- Increased elastic modulus and lower creep.
- Lower column costs for concrete and steel.
- Smaller columns allow for more floor space.

Disadvantages

- Brittle when its strength is exceeded requires formwork.
- Long curing time – reaches maximum strength after 28 days.
- Low tensile strength and toughness.
- Requires a bulky structure.
- Can crack due to drying shrinkage and moisture expansion (construction joints avoid this issue.
- Structure with high self-weight, not recommended in regions with plenty of seismic activity.
- Working with cracks.

MATERIALS USED :

Ingredients in high strength concrete are: Cement, Fine aggregate, Coarse aggregate and water. Admixtures may be used to enhance some properties of the concrete like GGBS Ground Granulated Blast Furnace Slag.

1. Cement

Cement acts as a binder element in the concrete. In this research OPC 53 grade cement is used. The colour of the cement is grey. It is confirms to IS-2015. Specific gravity of the cement is 3.15. Initial setting time is 30 min and final setting time is 600min.

2. Fine aggregate

1. **River sand:** River sand is used as fine aggregate. Specific gravity of the fine aggregate is 2.16.Water absorption by fine aggregate is 1%. From sieve analysis fine aggregate is of zone II and fineness modulus of fine aggregate is 2.319.
2. **Crushed Sand:** Crushed sand is produced by crushing large rocks or gravel. It is obtained by mechanically crushing rocks, gravel, or hard stones. The particle size of crushed sand is generally finer than that of natural sand, ranging from 0.075 to 4.75mm. Crushed sand is often used as a substitute for natural sand in concrete production and other construction activities.
3. **M-Sand (Manufactured Sand)**: M-sand is manufactured by crushing hard granite rocks into fine particles. It is a processed product of rocks formed by the controlled crushing of rocks and sieving to remove fine particles. M-sand has a cubical shape and is consistent in size and gradation. It is free from impurities and has uniformity in texture. M-sand is gaining popularity as an alternative to river sand due to its consistent quality, availability, and eco-friendliness.

3. Coarse aggregate

Coarse aggregates are an essential component of high-strength concrete. They typically consist of crushed stone, gravel, or a combination of both. Coarse aggregates provide bulk and stability to the concrete mix, enhancing its strength and durability. The size and shape of coarse aggregates influence the workability and mechanical properties of the concrete. Properly graded and well-shaped coarse aggregates help to reduce voids and improve the packing of particles, resulting in higher strength and better performance of the concrete mix. Specific gravity of the fine aggregate is 2.74. Water absorption by them is 0.5% .Size of coarse aggregate is taken as 40% of 4mm to 10mm size aggregate and 60% of 10mm to 20mm.

4. Water

Water is a critical component in concrete, including high-strength concrete. It activates the cement hydration process, allowing cement particles to react and bind together with aggregates, forming a solid matrix. However, it's essential to use the right amount of water, as excess water can weaken the concrete mixture and reduce its strength. Proper water-cement ratio control is crucial for achieving high-strength concrete with optimal properties.

5. Admixture

Admixture are additives used in small quantities to modify various properties of concrete, like strength, durability, workability, to increase or decrease setting times etc. Here, GGBS is used as an admixture. It is grey in colour.

6. Super plasticizer

Superplasticizers are commonly used in high-strength concrete to improve workability without sacrificing strength. They are typically high-range water reducers that allow for a significant reduction in water content while maintaining the desired slump or flow characteristics. These additives enable the production of high-strength concrete with lower water-to-cement ratios, resulting in enhanced strength, durability, and overall performance.

7. GGBFS

In high-strength concrete, Ground Granulated Blast Furnace Slag (GGBFS) serves as a valuable addition. Its fine particles contribute to the refinement of pore structure, enhancing the density of the concrete matrix. This results in improved compressive strength, reduced permeability, and increased resistance to chemical attacks. GGBFS also mitigates heat of hydration, making it particularly beneficial in controlling temperature rise during high- strength concrete curing. Overall, its use in high-strength concrete formulations enhances both performance and sustainability.

LITERATURE REVIEW

1. "Study on compressive strength of concrete on partial replacement of cement with GGBS" Rathod Ravinder, K. Sagarika, K. Deepthi , P. Alekya Reddy , R. Spandana, S. Sruthi (2018): It is observed that, the compressive strength of concrete M30 has been increased by 5% on partial replacement of cement with GGBS (50%). The use of GGBS (50%) as partial replacement of cement helps to reduce the Energy consumption in the manufacturing of cement. It was tested at 7, 14 & 28 days.

2. "High Strength Concrete using Ground Granulated Blast Furnace Slag (GGBS)" Thavasumony D, Thanappan Subash, Sheeba D. July 2014 GGBS is used to make durable concrete structure in combination with ordinary Portland cement and other pozzolona materials. In this project, sieve analysis is done for cement, Fine aggregate and GGBS. Also For each material we can found out the result of fineness modules, uniformity coefficient, and coefficient curvature results.

3. "Effect of mineral admixture (GGBS) on concrete mix design" Khalid Shaifullah, Akshay Gada, Shreyas Galagali, Shriyash Bhondve, Tejas Ahe (June 2021) This project shows the effect of mineral admixture and compressive test results clearly shows that GGBS has increased the strength and durability of concrete and gives much more strength than the required characteristic strength of normal concrete.

4. "Experimental investigation on strength and durability characteristics of high performance concrete using GGBS and MSAND" Christina Mary V. and Kishore CH (June 2015) This research paper focuses on strength characteristics of concrete of M40 grade with replacement of cement by GGBS with 10%, 20%, 30%, 40% and 50% and replacement of natural sand by Msand with 50% and durability and compares it with conventional concrete mixes were exposed to this acid for 30 days period.

5. "Durability and mechanical properties of high strength concrete incorporating ultra-fine Ground Granulated Blast-furnace Slag" Susanto Teng, Tze Yang Darren Lim, Bahador Sabet Divsholi March2012 Ultrafine GGBS (UFGGBS) has increase surface area which increase rate apparent of hydration reactions of pozzolanic and it has filled effect better. Two concrete mixes with 450 and 520 kg/m^3 of ordinary Portland cement and two more mixes of equivalent total cementitious materials with 30% UFGGBS replacement were cast. flexural strength, Compressive strength, chloride migration, modulus of elasticity, electrical resistivity and has presented drying test result. UFGGBSin concrete has a early higher strength, improved durability even at 3 days of curing and lower permeability.

6. "Properties of high strength concrete with reduced amount of Portland cement– a case study" Raghvendra Y B, Ramalinga reddy,Nabil hossiney,Dinesh h t, Sanjay kumar shukala (15 July2021) 50% Concrete mixes proportioned with GGBS with maximum obtain 28-day compressive strength of 77 MPa. Thus, concrete mixes with 50% GGBS replaced for Portland cement are favorable for producing HSC at RMC facilities at Bangalore city.
7. "Effect of admixtures on the setting times of high-strength concrete" Megat Johari, M. Mazloom, M.A. Megat Johari (April2000) THIS paper has inclusion of GGBS at 40% replacement level and its result greater in setting times in significant retardation. In general, level of replacement the mineral admixtures were increased, in setting times there was greater retardation. However, for the concrete containing MK, this was only observed up to a replacement level of 10%.

8. “An experimental study on optimum usage of GGBS for the compressive strength of concrete” A. Oner , S. Akyuz (25Jan2007) When the water-to-binder ratios of the mixes is taken into account, it can be concluded that as the GGBS content increases, the water-to-binder ratio decreases for the same workability, and thus, the GGBS has positive effects on the workability. The GGBS concrete early age strength of was lower than the control concretes with the same binder content. However, as the period of curing is extended, the higher strength was increased for the GGBS concretes. The reason is that, the reaction of pozzolanic is slow and the formation of calcium hydroxide requires time. There are best possible results for the efficient use of GGBS content, which provides the highest strength. The maximum level of GGBS content for its maximizing strength is about 55–59% of the total binder content. After a maximum point C0 –G curves decrease, which may be due to the existence of excess GGBS in the medium, which cannot enter into reaction. This indicates that the GGBS, which behave like fine aggregate and not enter into reaction.

9. “Properties of concrete containing ground granulated blast furnace slag (GGBFS) at elevated temperatures” Rafat Siddique , Deepinder Kaur (16 April 2011) A temperature of 350 C was applied. At temperatures between 200 and 350 C, the mass loss is not very significant. The modification of the hydrates generates a degradation of the concrete microstructure. From the results it can be easily concluded that up to 20% GGBFS could be suitably used in concrete designed for nuclear structures. However, more investigations are needed on other parameters such as porosity, thermal behaviour, and permeability aspects. These results could be useful in further investigating the behaviour of concrete made with GGBFS at elevated temperatures.

10. “GGBS And Fly Ash Effects on Compressive Strength by Partial Replacement of Cement Concrete Azmat Ali Phul, Muhammad Jaffar Memon , Syed Naveed Raza Shah , Abdul Razzaque Sandhu (26 March 2019) The workability of concrete tends to increase initially with increasing replacement percentage up to an optimum limit, but then decreases partially. GGBS and Fly Ash content increases the workability reduces at the same water containing and w/c. · The optimum workability was observed at replacement percentage of 15% as compared to control one that achieved 30%.The concrete specimens with 30% replacement of cement with GGBS and Fly Ash. The partial replacement of cement with GGBS and Fly Ash in concrete gradually increases the compressive strength as percentage of replacement raised.

11. “Fast Track Construction with High-Strength Concrete Mixes Containing Ground Granulated Blast Furnace Slag” M.N. Soutsos, S.J. Barnett, J.H. Bungey, and S.G. Millard (6 Jan 2005) The early age strength development of concretes containing ground granulated blast furnace slag (GGBS) at cement replacement levels of 20, 35, 50 and 70% to give guidance have been investigated for use in fast track construction. 28- day target mean strengths for all concretes was 100 MPa. Although supplementary cementitious materials like GGBS are economical, their use has not gained popularity in fast track construction because of their slower strength development at early ages and at standard cube curing temperatures. There are however symptom that supplementary cementitious materials are heavily penalised by the standard cube curing regimes.

12. “The effects of elevated temperature on cement paste containing GGBFS” H.Y. Wang (15 January 2008) Based on the effects of elevated temperature treatments on the properties of the cement paste with 3 W/B ratios and 6 GGBFS contents, the following conclusions are drawn: Under an elevated temperature of 1050 C, cracking occurs when the GGBFS content is 10% or less for all three W/B ratios. An increase of GGBFS content to 20% or above significantly reduces cracking. At a W/B ratio of 0.23, an increasing GGBFS content greatly increases the HPC compressive strength under elevated temperatures (1050 C). Thus, the fire resistance of HPC is greatly improved when cement is replaced with GGBFS. However, at a high W/B ratio of 0.71, the addition of GGBFS does not significantly improve compressive strength. The W/B ratio of 0.23 shows a clear trend that the optimum GGBFS content for fire resistance is 50– 80%. The study found that an elevated temperature treatment can increase the absorption capacity for the low W/B ratio (0.23) specimen with a proper GGBFS percent replacement; however, further increase of GGBFS content decreases the

absorption capacity when the temperature is greater than 580 C. This indicate that adding GGBFS in cement paste increases the density. The compressive strength of concrete is more exposed than the elastic modulus to the effects of elevated temperature. For W/B ratios of 0.23 and 0.47, the inclusion of GGBFS increases the elastic modulus at elevated temperature.

13. **“**Experimental investigation on optimum usage of Micro silica and GGBS for the strength characteristics of concrete” V.B. Reddy SP. Srinivasa Raouda, (26 December 2019) In the combination of GGBS and Micro silica, concrete enhances strength, durability, and workability. The addition of Supplementary cementing Materials leads a reduction in workability, which can be compensated by little extra dosage of super plasticizer and it is clear that, the early age strength gets decreased, as the GGBS content increases. Among all the ternary mixtures, the one containing 15%MS and 20%GGBS achieved highest 7-day and the same trend was observed in all w/b ratios with increased strengths Ultimately the above discussions leads to the conclusion that, the ternary mix containing 10% Micro silica and 30% GGBS, might be considered as an optimum mix for 28-days strength to produce economical ternary blended concrete and to go to further stage of study. The split tensile strength of ternary concrete is increased as in the same line of compressive strength but, the rate of increase of tensile strength was low. However, the split tensile strength is more in ternary concrete comparatively with conventional concrete. The flexural strength of ternary concrete is enhanced over conventional concrete. It may be due to the better bonding between cement paste and aggregates in ternary concrete.

14. “Properties of concrete incorporating fly ash and ground granulated blast-furnace slag” Gengying Li , Xiaohua Zhao (27 May 2002) GGHFC can achieve adequate early-age compressive strength, while maintaining a long-term strength higher than PCC. 2. GGHFC is superior to both HFAC and PCC against H2SO4 attack, and its weight change is about 8% after 50 weeks exposure to 2% H2SO4 solution. 3. The relative strengths of GGHFC, HFAC and PCC decrease due to the decalcification and the expansive corrosion of hardened cement in H2SO4 solution.

15. “Effect of Replacement of GGBS and Fly Ash with Cement in Concrete**”** Rachita Panda,Tanmaya Kumar Sahoo (03 July 2020) in this paper efforts have been made to reduce the cost of waste management and concrete production by utilizing ground granulated blast furnace slag (GGBS) and fly ash (FA) with partial replacement of cement and also to control environmental pollution. In the present study, these by-products are used at different percentages as a partial replacement of cement have been reused in concrete. The tests were managed with partial replacement of GGBS at different percentages of 0, 10, 15, 20 and 25% and with FA at different percentage of 10, 12.5 and 15% by the dry weight of cement.

CONCLUSION

The utilization of ultrafine ground granulated blast furnace slag (GGBS) in high-strength concrete (HSC) presents a promising avenue for enhancing both mechanical properties and sustainability. Through the experimental investigations reviewed, it is evident that the addition of ultrafine GGBS contributes positively to the fresh and hardened properties of HSC. The incorporation of ultrafine GGBS in HSC results in improved workability, increased compressive and tensile strength, reduced permeability, and enhanced durability. The pozzolanic reaction of GGBS particles at the micro-level contributes to the refinement of pore structure and densification of the cementitious matrix, leading to superior mechanical performance and resistance against deleterious agents such as chloride ions and sulfate attack. Furthermore, the use of ultrafine GGBS facilitates the mitigation of greenhouse gas emissions associated with cement production, contributing to sustainability goals in the construction industry. However, the optimal dosage and particle size distribution of ultrafine GGBS need to be carefully determined to achieve the desired properties while maintaining economic feasibility. Overall, the experimental investigations reviewed highlight the potential of ultrafine GGBS as a valuable supplementary cementitious material for producing high-strength concrete with enhanced performance and reduced environmental impact. Further research and development efforts are warranted to explore its full potential and address any remaining challenges for widespread implementation in practice.

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