Sustainable Concrete Innovation: Enhancing Strength With GGBS And EPS Beads

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ABSTRACT

In today's rapidly evolving construction landscape, concrete remains the backbone of infrastructure, from modest homes to towering skyscrapers. Traditionally, concrete consists of cement, fine aggregate (river sand), coarse aggregate, water, and various admixtures tailored to specific needs. However, the excessive extraction of river sand has led to alarming environmental consequences, including ecosystem disruption, increased flood risks, and depletion of natural resources. To address these challenges, this study explores an eco-friendly alternative by partially replacing cement with Ground Granulated Blast Furnace Slag (GGBS) and fine aggregate with Expanded Polystyrene (EPS) beads. We examine the impact of these substitutions on M25-grade concrete, with GGBS replacing cement at 25% and 35%, while EPS beads replace fine aggregate at 0.4%, 0.6%, and 0.8%. Experimental findings reveal a remarkable improvement in compressive strength, increasing from 28.4 N/mm² to 35.6 N/mm² with 25% GGBS and 0.6% EPS beads, and from 28.4 N/mm² to 34.1 N/mm² with 35% GGBS and 0.6% EPS beads.

The results demonstrate that sustainable concrete formulations can not only mitigate environmental impact but also enhance structural performance, paving the way for greener, more resilient construction practices.

Keywords: Sustainable Concrete, Alternative Fine Aggregate, Lightweight Concrete, Partial Replacement.

1. INTRODUCTION

Concrete has long been the foundation of modern construction, shaping everything from simple homes to soaring skyscrapers. Its adaptability, durability, and strength make it indispensable, yet traditional concrete production poses significant environmental challenges. One of the most pressing concerns is the high carbon footprint of cement, a key ingredient in concrete. Cement manufacturing releases substantial amounts of CO_2, contributing to climate change. As the construction industry expands, finding sustainable alternatives to conventional concrete has become more crucial than ever. To tackle the issue, researchers are turning to Supplementary Cementing Materials (SCMs) like Ground Granulated Blast Furnace Slag (GGBS) and lightweight aggregates such as Expanded Polystyrene (EPS) beads. These innovative materials not only reduce environmental impact but also enhance the performance of concrete. GGBS, an industrial by-product, effectively replaces a portion of cement, leading to lower CO_2 emissions and improved durability. Meanwhile, EPS beads, a lightweight plastic material, serve as an alternative to coarse aggregate, significantly reducing the overall weight of concrete. This weight reduction is particularly beneficial for structural efficiency, seismic resistance, and construction cost savings. Lightweight concrete (LWC) has revolutionized modern construction by offering advantages such as dead load reduction, improved thermal insulation, better seismic response, and enhanced fire resistance. It is already being widely adopted in countries like the USA, UK, and Sweden for precast and prestressed structural components. The key to achieving lightweight concrete lies in replacing traditional aggregates with lighter materials or introducing controlled air content through foaming agents. In this study, GGBS and EPS beads are incorporated into M25-grade concrete to explore their combined impact on compressive strength, durability, and sustainability. By leveraging industrial by-products and lightweight materials, this research aims to bridge the gap between structural efficiency and environmental responsibility. The results will contribute to a more eco-friendly, cost-effective, and high-performance alternative to conventional concrete, paving the way for the future of sustainable construction.

2. LITERATURE SURVEY

In the modern trends, the cement plays a vital role for the preparation of concrete in the construction industries. Therefore, the requirement of cement is important in the construction of civil engineering structures, like, industries, houses, bridges, water retaining structures, earth retaining walls, landing strips and road pavements. Hence, the production of cement is increased in the cement industry to meet such a demand in the construction industries. Carbon dioxide (CO_2) is emitted from cement industries during the process of calcinations of lime stone in dry process, combustion of fuels in the kiln and power generation. It contributes about 5% of global anthropogenic CO_2emission (Mikulicz et al. 2013). Approximately, 1.25tonnes of CO_2 is emitted per tonne of cement production in the industries (Habeeb et al. 2009). Cement industries are one of the largest CO_2 producers when compared to other industries (Saunois et al. 2016). The emission of CO_2 leads to environmental trouble for greenhouse effect, and it also increase the earth temperature to cause global warming (Patel & Balakrishna 2014). On the other side, the poor people are struggling to construct their own buildings in their locality due to the continuously increasing the cost of cement (Alabadan et al. 2005 and Aho & Utsev 2008). These two bigger issues, such as Global warming and continuous raising the cost of cement have induced many scientists and researchers to identify the most appropriate alternative supplementary cementing materials for the replacement of cement. By considering these issues, our present research work was proposed to identify the effective way for the replacement of cement with waste materials disposed from agricultural and industries. Arivalagan et al. (2014) studied the sustainability of concrete with GGBS as a replacement for cement. The research work was carried out for M35 grade concrete with GGBS level of 20%, 30% and 40% for the replacement of cement at different age of curing. In the study, the workability, compressive strength, splitting tensile strength and flexural strength of concrete replaced with GGBS were examined. The optimum GGBS level was considered by high compressive strength, low heat of hydration, resistance to chemical attack, better workability, good durability and cost-effectiveness. It was observed that due to filler effect of GGBS, the strength of concrete increased for 20% replacement of cement at the age of 28 days. The degree of workability of concrete was similar to that of ordinary concrete with the addition of GGBS up to 40% replacement level. It was concluded that the strength at the early age is low when compared to normal concrete, but in the later age strength of GGBS blended concrete is better than normal concrete, because the grain size of GGBS is lesser than OPC. Binici et al. (2007) performed the experimental work to analyses the effect of the fineness on the compressive strength, sodium sulfate resistance and the heat of hydration of the both GGBS & Ground Basaltic Pumice (GBP) and Plain Portland Cement (PPC). The pulverizing time of both clinker and additives were also examined. The result showed that GBP and clinker had lesser grindability compared to GGBS. Blended cement had higher strength values, especially at later ages, compared to PPC for the same Blaine values. It was concluded that the finer ground blended cement specimens had higher compressive strength and sodium sulfate resistance compared to the coarser blended cement and PPC. The heat of the hydration of blended cement was lesser than that of PPC.

Karri et al. (2015) executed the strength and durability study on GGBS concrete. In this research work, the performance of M20 and M40 grade concrete using GGBS by replacing cement with replacement level of 30%, 40% and 50% was investigated. Several numbers of cubes, cylinders and prisms are tested for compressive strength, split tensile strength and flexural strength respectively. Durability characteristics of concrete containing GGBS with hydrochloric and sulphuric acid were also examined. It was noticed that the workability of fresh concrete increases as increasing the percentage of GGBS content. It was observed that the compressive, splitting tensile and flexural strength of hardened concrete were increased for both M20 and M40 grade of concrete when the cement is replaced with GGBS. The maximum compressive, splitting tensile and flexural strength of concrete were obtained at 40% replacement of cement by GGBS for both grades of concrete. It was also observed that the compressive strength characteristics of concrete was decreased when the concrete is exposed to hydrochloric and sulphuric acid as compared to 29 normal concretes, but the influence of acid on concrete was decreased as increasing the percentage of GGBS. The concrete has more resistance against acid attack, when the OPC was replaced with 40% of GGBS.

Duan et al. (2013) utilized the industrial wastes and by-products for preparation of concrete to reduce the cost for treatment of waste before to disposal and ultimately preserve natural resources and energy. In this work, the pore structure and Interfacial Transition Zone (ITZ) of concrete together with GGBS and metakaolin (MK) were investigated. The pore structure, morphology of ITZ and microhardness of GGBS and MK incorporated concrete were examined at the age of 28 days by employing the new methods, such as, Mercury Intrusion Porosimetry (MIP), Scanning Electronic Microscopy (SEM) and microhardness tester respectively. In this study, the mechanical property such as compressive strength and durability performance including carbonation resistance, chloride penetration resistance and freeze-thaw resistance were experimentally assessed in relation to their pore structure characteristics and ITZ. The result showed that the utilization of GGBS and MK in concrete was helpful to enhance the performance of pore structure and the ITZ of concrete. It was concluded that the compressive strength and durability of GGBS and MK blended concrete was increased, due to enhancement on the pore structure and ITZ. Zhou et al. (2012) studied the effect of Pulverized Fuel Ash (PFA) and GGBS for making concrete. In this study it was noticed that the setting time of both PFA and GGBS blended paste delayed than OPC, but the initial and final setting time of paste containing PFA and GGBS were similar to that of OPC with the replacement level up to 30%. The PFA and GGBS incorporated concrete showed better workability than ordinary concrete. The compressive and splitting tensile strength of concrete containing PFA has lower strength than ordinary concrete and GGBS blended concrete and it was enhanced by adding 30 short discrete fibres in PFA concrete. It was noticed that the compressive and splitting tensile strength of concrete at the age of 28 days curing were maximum at 30% replacement of cement with GGBS and it decreased when the replacement level exceeded 30%. Oner & Akyuz (2007) conducted the experimental study to predict the optimum percentage of GGBS for compressive strength of concrete. The GGBS blended concrete showed positive effects on the workability. The early age strength of GGBS concretes was lesser than that of control concretes with the same binder content. On the other hand, the strength of GGBS concrete increased as increasing the curing period due to slow pozzolanic reaction and delayed for calcium hydroxide formation. It was concluded that the compressive strengths of concrete were maximum when the cement replaced by 55 - 59% of GGBS, after that the compressive strengths were decreased. Rughooputh & Rana (2014) investigated the mechanical performance of concrete by partially replacing the cement with GGBS. The work was carried out to investigate the effects on the mechanical properties of concrete including compressive strength, splitting tensile strength, flexural strength, modulus of elasticity, drying shrinkage and initial surface absorption by partially replacing the OPC with GGBS. The result demonstrated that the compressive and splitting tensile strengths, flexure and modulus of elastic were increased as increasing the percentage of GGBS. The percentage of drying shrinkage slightly increased with the partial replacement of OPC with GGBS. Pathan et al. (2012) examined the properties of concrete using GGBS. The GGBS is an excellent replacement of cement than various other alternatives. The rate of strength improvement in GGBS replaced concrete was low in early stages but with proper curing the later strength was increased extremely. It was noticed that the strength obtained at 30% replacement of cement with GGBS is 31 lower than that of normal Concrete. Concrete mix with 40% replacement produced higher compressive strength, but it decreased when the cement replacement is greater than 50%. It was observed that the setting time of concrete containing GGBS increased as increasing the percentage of GGBS content and it has better workability for all the percentage of replacement. It was concluded that 45% replacement of cement by GGBS attained the maximum compressive strength.

Suresh & Nagaraju (2015) reviewed the performance of the concrete containing GGBS. The presence of pores in the concrete is responsible for the penetration of moisture in the concrete. The GGBS replaced concrete has high resistance against attacks of aggressive environments such as silage pits; it is almost due to the solid and strong microstructure of the internal bond between aggregate and binder transition zone. The chemical compositions of GGBS cement paste most likely responsible to this resistance. It was suggested that the GGBS is a good replacement to cement in various cases and serves efficiently but it could not replace the cement completely. However, the cement replaced partially using GGBS, provides excellent performance to the concrete. It was advised that 20% to 40% of replacement of cement with GGBS may be excellent to attribute high early strength.

Tamilarasan et al. (2012) studied the workability performance of concrete with GGBS for the replacement of cement with and without the addition of superplasticiser. In this experimental works, M20 and M25 concrete mixes were adopted with GGBS replacement level of 0% to 100% at an interval of 5%. In this study, the workability performance of GGBS incorporating concrete was examined by conducting the slump test, compaction factor test, Vee-Bee consistometer test and flow test. It was observed that the degree of workability of GGBS concrete was better than control concrete for M20 grade 32 concrete with the replacement level up to 45% and for M25 grade concrete it was up to 50%. Patel & Balakrishna (2014) investigated the flexural behavior of reinforced concrete beam replacing with GGBS for cement and slag sand for fine aggregate. In this work, M40 grade of concrete was adopted with the GGBS replacement level of 0%, 30%, 40% and 50% and slag sand content was fixed as 40%. It was observed that the slump value of fresh concrete improved as increasing the GGBS replacement level. Based on the results, it was concluded that the mechanical properties of hardened concrete, such as, compressive strength, splitting tensile strength and flexural strength of concrete containing 40% of GGBS content and 40% of slag sand was optimum and it was equal to the control concrete at 28 days curing period. However, the strengths of concrete containing 50% of GGBS and 40% of slag cement were lower than that of control mix. Awasara & Nagendra (2014) analysed the strength characteristics of GGBS concrete. This research work was focused on the analyses of strength properties of M20 grade concrete with replacement of cement at 20%, 30%, 40% and 50% using GGBS along with natural and crushed sand. The maximum compressive strength of concrete containing natural sand at 28 days curing period was 32.59N/mm2 for the replacement of cement with 30% of

GGBS and those achieved for 0%, 20%, 40%, and 50% of GGBS replacement were 29.11N/mm2, 31.11N/mm2, 30.7N/mm2 and 27.74N/mm2 respectively. Also, it was 29.78N/mm2 for the replacement of cement with 30% of GGBS along with crushed sand and those obtained for 0%, 20%, 40%, and 50% of GGBS replacement were 25.61N/mm2, 27.11N/mm2, 26.37N/mm2 and 22.22N/mm2respectively. The flexural strength of concrete containing natural sand and 0%, 20%, 30%, 40%, and 50% of GGBS content were 3.17N/mm2, 3.62N/mm2, 3.87N/mm2, 3.55N/mm2 and 3.41N/mm2 respectively and when crushed sand 33 used, they were 3.01N/mm2, 3.45N/mm2, 3.58N/mm2, 3.44N/mm2 and 3.12N/mm2 . This result showed that the flexural strength offered good performance than normal plain concrete for 20%, 30 % and 40% replacement level. Rami et al. (2017) examined the performance of reinforced concrete beams cast with different percentages of GGBS replacement to cement. In this study, totally eight RCC beams were prepared with various percentages of GGBS replacement of 0%, 50%, 70%, and 90%, respectively. The performance of the tested specimens was examined and compared to that of a control beam without GGBS (0%). Additionally, the compressive and tensile strength of concrete for various mixes were examined and compared. The test results indicated that the compressive and tensile strength of the different mixtures were relatively similar. As well, the performance of RCC beams with GGBS replacement up to 70% is similar to that of control specimen. Though, the stiffness and strength of the RCC beam specimens with 90% GGBS were lower than that of control specimen by 16% and 6%, respectively. In this study, it was concluded that the use of GGBS up to 70% for the replacement to cement is realistic and will not comprise the performance of RC Beams.

Abdulkar kan , et al(2009) This paper reports the results of an investigation study on the effects of using expanded polystyrene beads (EPS) in a lightweight concrete as a potential aggregates. In this project eps beads are used in the form of aggregate. In this study, we get to know that in Aggregate the foam which is used is a thermally modified waste EPS foam. By heat treatment method we had get modified waste expanded polystyrene aggregates (MEPS)by a hot air oven at 125°C for 20 min and keeping EPS foams in that oven. By introducing the weight concrete can be produced:(1) gas-sing material like-aluminium powder or we can use fibre, (2) plastic granules like aggregates, e.g., expanding urethanes foam(EPS),urethane or different polymer materials. Monali Patil, et al(2016) This paper presents the outcomes of an exploratory examination into the engineering properties like, the compressive property and splitting property of polystyrene aggregates concrete different in thickness. In Germany 1950 an unyielding cellular plastic is unusual explore which had named EPS or expanded polystyrene. Since 1958the expanded polystyrene has been came into force and work in wrapping things. In this it is made up of 98% of gas but the remaining is of small, global EPS beads-which itself create of co2andhydrogen.Withthe quickly evolution and technology growth, the use of replacement for aggregates in concrete has been grow a lot. In concrete building like enlarged glass and EPS beads etc.. gradually different and new substance are being made and work as renewal of aggregate in concrete raising.

Abdulkadir kan ,et al(2007)in this paper to determine the effect of cement and expanded polystyrene ratio, M25 mix design by volume were used. In this experiment EPS beads taken for the mixture were constant at 0.02 to 1. The examination of the final result leads to a final decision that with the grow of cement to EPS beads ratio in that the mixes, the final thickness, compressions , splitting Ness rise when it has been compared to the control sample. Abhijit's Parmar et al (2015) Research Report, he observed the Activates and Progress of Light Weight Concrete. In his research report he was focusing on performance of EPS light weight Concrete's

Compressive Strength Test, density and supplementary test and also compared with other types of Light weight Concrete. In his report he says that the increase in usage of Lightweight concrete in green buildings and sea structures all over the world shows the success of this concrete . Further he says " The freedom to tinker with the properties of the concrete by altering the making process and components gives greater flexibility to creative minds while emphasizing the fundamentals of concrete design."

Linchang Miao et al(2016) In his research report, observe that EPS volume ratio of 0 %, 20 %, 30 %, and 40 % by replacing matrix or coarse aggregate, Shows that the two design styles had nearly the same compressive strength. He applied Frequency of 5 Hz, 50000 or 100000 times and cyclic loading of 40 KN, 50KN, and 60 KN, The results of this research had practical significance on using EPS beads concrete in some long-term recyclic dynamic load engineering . Further he says The L.W.C. (Light Weight Concrete) has no pollution effect to the environment because manufactured EPS particle consumes little energy, and the particle has no poison and harm. Bengin M A Herki, et al (2020) Volcanic materials such as pumice are used in the production of concrete as partial replacement of natural aggregate concrete(LWAC)utilizing a locally available lightweight aggregate (LWA) called pumice aggregate (PA).This novel LWAC is made by partial replacement of coarse aggregate with different replacement levels of 10%, 20%, 30%, 40% and 50% of PA by volume. The study id focused to determine the mechanical and durability properties of LWAC to find the optimum replacement level of PA. The properties of PA were reported by conducting comprehensive series of tests on workability, compressive strength, density, and total water absorption and ultrasonic plus velocity (UPV). It is concluded that the LWAC has sufficient strength and adequate density. Anil Pratap Singh,et al (2018),A Study on Light Weight Concrete It is use for minimizing the dead load of structure.so it is very essential to reducing the overall cost of project. The main purpose are EPS beads is used in engineering. Since at least the 1950s. The polystyrene aggregate to produce light weight concrete with the unit weight varying from 1200 to 2000 kg/m3.The properties are good thermal insulation, the lower the thermal conductivity. Aggregate, both in concrete and mortar. EPS beads can be conventional concrete making material. Jaydeep Singh et al (2017),studied the light weight concrete - Expanded Polystyrene (EPS) is a light weight material. Expanded Polystyrene waste in a granular form is used as light weight aggregate to produce light weight non - structural concrete with the unit weight varying from 950 kg /m3 to 1350 kg/m3.It is considered to be one of the best sensor materials available and used widely since the 1950s.It is properties are such as compressive strength, modulus of elasticity, drying shrinkage and creep of polystyrene aggregate concrete varying in density.

Vandale Amar Diliprao, et al(2019) deals with the study of polystyrene foam are thermoplastic material obtain by Polymerization of styrene. In construction has lot of advantages by using of expanded polystyrene as compare use of conventional material which result in sustainable future. EPS is versatile durable material that offers excellent insulation property. As the structure of consist of 98% air its initial thermal properties are maintain throw out it's working life. It can be manufacture in a wide range of shape & sizes. The use expanded polystyrene in construction has lot of advantage compare with use of conventional material which result in sustainable future. EPS is use as lightweight aggregate to produced light weight concrete with unit weight less than 1000kg/m3 which make it as lightweight concrete coarse aggregate is measure contributor for heavy weight of concrete as replacing it with EPS beads result reduction of the density of concrete. Daneti Saradhi Babua et al (2003) Investigated the influence of the EPS beads or polystyrene aggregate size content, on strength and moisture migration characteristics of light weight concrete. from the study's itis cover that the expanded polystyrene beads and unexpanded beads we're use as light weight aggregate in concrete. which contain fly ash and aluminium powder as supplementary cementitious materials. Light weight concrete with heavy rang of concrete densities (1000-1900 kg/m3)were studies, mainly because of to know the compressive strength, split tensile strength, moment of moisture and absorption. And from, there result indicated that for aggregate size and concrete density, concrete along with UEPS aggregate shows 70% higher compressive strength as compared to EPS aggregate. EPS aggregate concrete with small size of polystyrene beads exhibited higher compressive strength was noticeable in low density concrete when it was compared with higher density concrete. Bharath V B et.al 2020, They concluded that Experimental investigation has been carried out to determine utilization of the sugarcane bagasse ash and glass powder as cement replacement materials by making the cement concrete.

Nagaswaram Roopa et. al 2017, they concluded that the workability of concrete in terms of slump cone and compaction factor shows that Compaction factor changes slightly with increasing fly ash, Thermocol replacement and the slump cone also changes with the % increase in the replacement of fly ash, Thermocol content and the values falls within the value for normal range of concrete. By conducting the compressive strength of concrete cubes compressive strength is increased by partial replacement of cement with fly ash and fine aggregate with Thermocol. For 3 days of curing period ,it is observed that the strength of concrete at partial replacement of fly ash and Thermocol is increased when compared to the normal compressive strength of concrete. For 7 days of curing period ,it is observed that the strength of concrete at partial replacement of fly ash and Thermocol is increased when Compared to thermocol compressive strength of concrete. For 28 days of curing period , it is observed that the strength of Concrete at partial replacement of fly ash and Thermocol is increased compared to normal cubes. It is for the proportion of 35%fly ash and 0.2% Thermocol. In the same manner the compressive strength of concrete is increased Compared to the normal mix and partial replacement of 35% fly ash and0.2% Thermocol. Dr. G. Elangovan 2015, he concludes that Based on the test results obtained from the experimental programme of this work, the following major conclusions are arrived from workability, compressive strength test, durability test and cost analysis. From the workability test results, slump cone value increases for concrete mix containing fly ash and thermocol when compared with reference concrete mix (R). From the experimental test results, the compressive strength of concrete mix after 7 days curing having 60% fly ash and 0.3% thermocol (FT3) has the highest strength of 23.55 N/mm2 , and its percentage improvement is 47.28 N/mm2 over reference mix. From the test results, the compressive strength of concrete mix after 28days curing having 60% fly ash and 0.3% thermocol 60% fly ash replacing with cement has the highest compressive strength of 25.62 N/mm^2 and its percentage improvement is 22.70 N/mm ^{2} over reference mix. Consequently, it is concluded that concrete mix having 60% fly ash and 0.3 % thermocol 60% fly ash replacing with cement is better mix and has the highest compressive strength for both 7 days and 28 days test result. By analyzing its cost and strength parameters, concrete mix having 60% fly ash replacing with cement is comparatively more economical.

3. PROPOSED SYSTEM

The proposed system focuses on developing an eco-friendly and high-performance lightweight concrete (LWC) by incorporating Ground Granulated Blast Furnace Slag (GGBS) as a partial replacement for cement and Expanded Polystyrene (EPS) beads as a partial replacement for fine aggregate. This approach aims to reduce cement-related CO_2 emissions, decrease the excessive use of river sand, and improve the overall sustainability of concrete structures.

The system will involve:

- **Material selection and characterization** to ensure the quality and compatibility of GGBS and EPS beads.
- **Mix proportioning and optimization** to achieve the desired mechanical properties.
- **Experimental analysis** including strength, durability, thermal conductivity, and workability assessments.
- **Comparative study with conventional concrete** to evaluate the advantages and limitations of the modified concrete.

2. Materials Used in the System

1. **Cement** – Ordinary Portland Cement (OPC 53 Grade) will be used as the primary binder. A portion of it will be replaced with GGBS.
2. **Fine Aggregate** – Natural river sand will be partially replaced with EPS beads to reduce the overall weight and improve insulation properties.
3. **Coarse Aggregate** – Standard crushed stone aggregate will be used as per M25-grade concrete requirements.
4. **Water** – Portable clean water will be used to maintain hydration and proper workability.
5. **GGBS (Ground Granulated Blast Furnace Slag)** – An industrial by-product of steel manufacturing, used as a **sustainable substitute** for cement.
6. **EPS (Expanded Polystyrene) Beads** – Lightweight, thermally insulating polymer beads used as a **partial replacement for fine aggregate**.
7. **Superplasticizers** – Chemical admixtures to improve workability and reduce water content.

3. Mix Proportions and Design

The concrete mix will be prepared with different replacement levels of **GGBS (25%, 35%)** and **EPS beads (0.4%, 0.6%, 0.8%)**. The standard M25 mix will be used as a reference for comparison.

- **Control Mix (M25 Concrete)** – Conventional concrete mix without replacements.
- **Modified Mixes**:
  - **M1:** 25% GGBS + 0.4% EPS beads
  - **M2:** 25% GGBS + 0.6% EPS beads
  - **M3:** 25% GGBS + 0.8% EPS beads
  - **M4:** 35% GGBS + 0.4% EPS beads
  - **M5:** 35% GGBS + 0.6% EPS beads
  - **M6:** 35% GGBS + 0.8% EPS beads

The ideal mix will be selected based on its compressive strength, density, workability, and durability performance.

4. Experimental Methodology

A. Workability Test

- **Slump Test** – Determines the ease of placement and flowability of concrete.
- **Compaction Factor Test** – Measures the compactibility of concrete mixtures.

B. Mechanical Strength Tests

- **Compressive Strength Test (28-day curing period)** – Evaluates load-bearing capacity.
- **Split Tensile Strength Test** – Determines resistance to tensile forces.
- **Flexural Strength Test** – Assesses resistance to bending and cracking.

C. Durability Tests

- **Water Absorption Test** – Evaluates the porosity and resistance to moisture penetration.
- **Chloride Penetration Test** – Measures concrete's ability to resist chloride ion infiltration.
- **Acid Resistance Test** – Determines how well the concrete withstands acidic environments.

D. Thermal and Density Analysis

- **Thermal Conductivity Test** – Checks heat insulation properties.
- **Dry Density Test** – Determines weight reduction benefits compared to conventional concrete.

5. Expected Outcomes of the Proposed System

1. **Improved Strength Characteristics** – Higher compressive and flexural strength due to the pozzolanic reaction of GGBS.
2. **Reduction in Cement Usage** – Leading to lower CO_2 emissions and enhanced sustainability.
3. **Weight Reduction** – EPS beads contribute to lightweight concrete, reducing dead loads.
4. **Better Thermal Insulation** – Due to the air-filled structure of EPS beads, reducing heat conductivity.
5. **Cost-Effective Construction** – Reduced material costs by using industrial by-products and lightweight aggregates.
6. **Improved Workability** – Superplasticizers and EPS beads enhance the concrete's fluidity.
7. **Eco-Friendly Approach** – Sustainable use of industrial by-products reduces environmental degradation.

4. RESULTS AND DISCUSSIONS

The results of the experimental investigation for the various tests are discussed in this chapter.

4.1 Fresh properties of concrete (Slump cone test)

The slump Values of the concrete for replacement of sand with EPS beads by 0, 0.4, 0.6, 0.8% and cement with GGBS 25, 35% are shown in table 6.1 and graphically represented in Fig 4.1.

Table 4.1: Slump Values (mm) for different mixes

MIX	GGBS% – EPS %	Slump (mm)
M0	0-0	120
M1	25 – 0.4	124
M2	25 – 0.6	127
M3	25 – 0.8	132
M4	35 – 0.4	134
M5	35 – 0.6	140
M6	35 – 0.8	142

It is observed that there is increase in the workability of the concrete the sand replacing with EPS beads and cement replacing with GGBS. Based on the observations, all of the slump values are in the medium workability range.

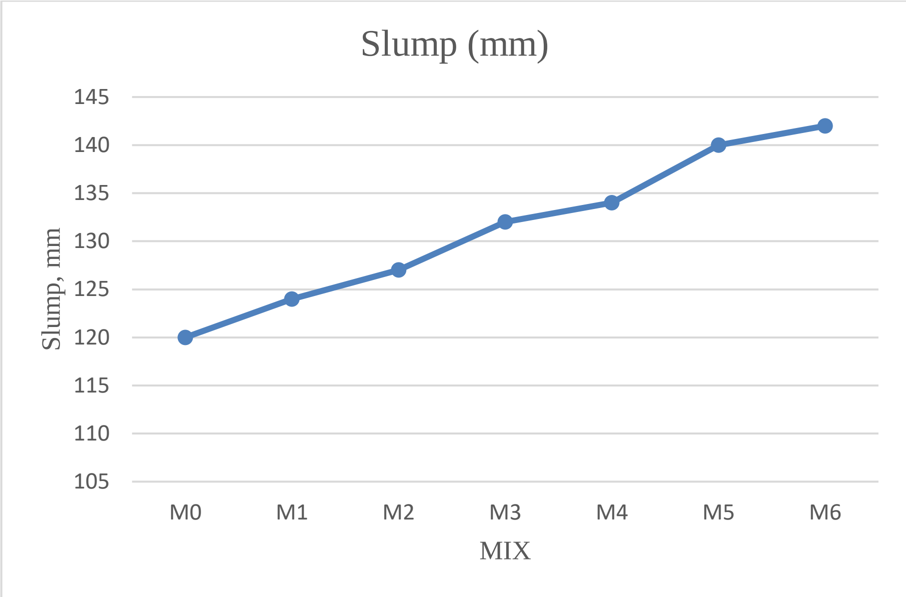

Fig 4.1 Slump Values Vs % MIX

4.2 Compressive strength test

The compressive strength values of the concrete for replacement of fine aggregate with EPS beads by 0, 0.4, 0.6, 0.8% and cement with GGBS 25, 35% are shown in table 6.2 and graphically represented in Fig 4.2 (a & b).

It is observed that there is increase in the compressive strength of the concrete when the fine aggregate with EPS beads by 0, 0.4, 0.6, 0.8% and cement with GGBS 25, 35%. The percentage increase of compressive strength (28days) values for M1, M2, M3, M4, M5, M6 replacement of Fine aggregate with EPS beads – cement with GGBS is 7.04%, 25.35%, 10.56%, 5.28%, 20.07%, 0.7% respectively. Based on the observations, all of the compressive strength values are higher for EPS & GGBS replacement in the concrete. The optimum dosage of GGBS replacement in cement and EPS beads replacement in natural fine aggregates is 25% & 0.6% (M2 mix).

Table 4.2: Compressive strength (Mpa) for different mixes

MIX	GGBS% – EPS %	7days	14 days	28 days
M0	0-0	17.04	25.561	28.4
M1	25 – 0.4	18.24	27.36	30.4
M2	25 – 0.6	21.36	32.04	35.6
M3	25 – 0.8	18.84	28.26	31.4
M4	35 – 0.4	16.87	25.9	29.9
M5	35 – 0.6	19.65	29.67	34.1
M6	35 – 0.8	16.6	24.7	28.6

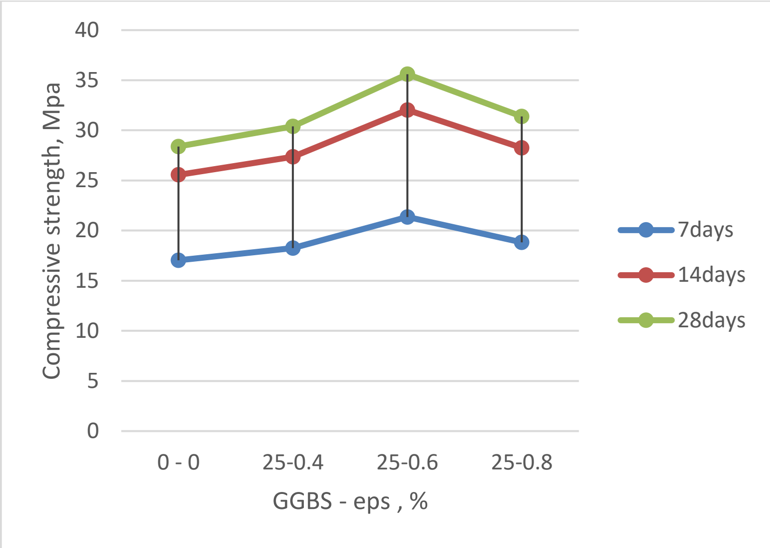

Fig 4.2(a) Compressive strength Vs % (GGBS – EPS %)

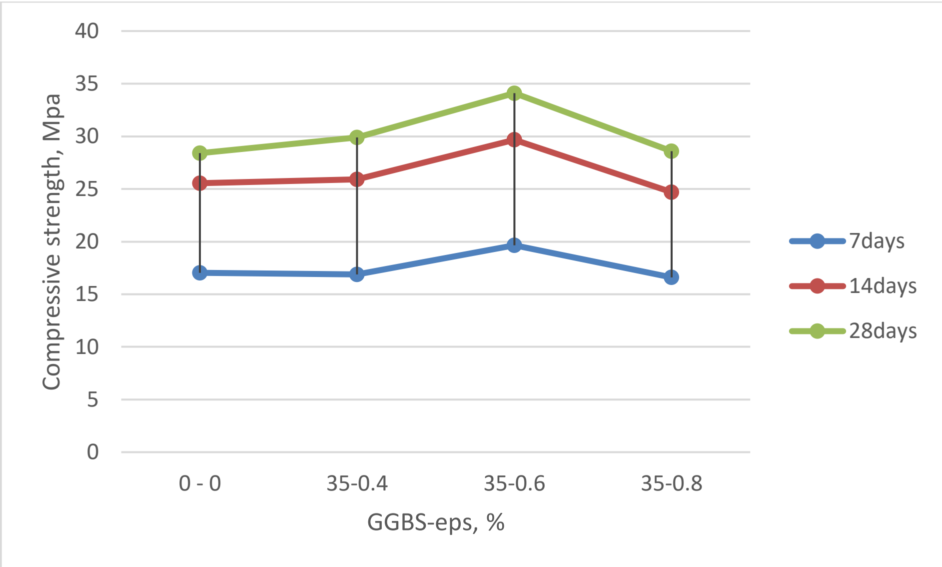

Fig 4.2(b) Compressive strength Vs % (GGBS – EPS %)

4.3 Split tensile strength test

The Split strength values of the concrete for replacement of fine aggregate with EPS beads by 0, 0.4, 0.6, 0.8% and cement with GGBS 25, 35% are shown in table 6.3 and graphically represented in Fig 6.3 (a & b).

It is observed that there is increase in the tensile strength of the concrete when the fine aggregate with EPS beads by 0, 0.4, 0.6, 0.8% and cement with GGBS 25, 35%. The percentage increase of tensile strength (28days) values for M1, M2, M3, M4, M5, M6 replacement of Fine aggregate with EPS beads – cement with GGBS is 7.1%, 26.76%, 8.27%, 4.75%, 18.83%, 0.058% respectively. Based on the observations, all of the tensile strength values are higher for EPS & GGBS replacement in the concrete. The optimum dosage of GGBS replacement in cement and EPS beads replacement in natural fine aggregates is 25% & 0.6% (M2 mix).

Table 4.3: Split tensile strength (Mpa) for different mixes

MIX	GGBS% – EPS %	28 days

M0	0-0	3.408
M1	25 – 0.4	3.65
M2	25 – 0.6	4.32
M3	25 – 0.8	3.69
M4	35 – 0.4	3.57
M5	35 – 0.6	4.05
M6	35 – 0.8	3.41

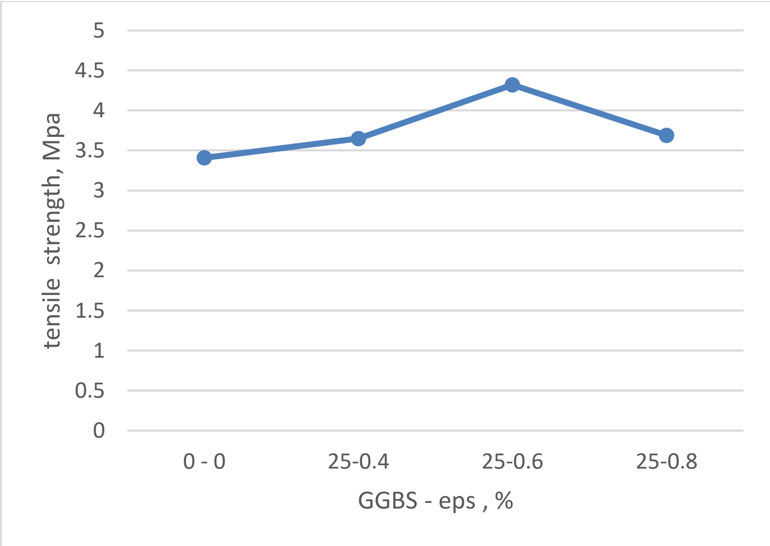

Fig 4.3(a) Tensile strength Vs % (GGBS – EPS %)

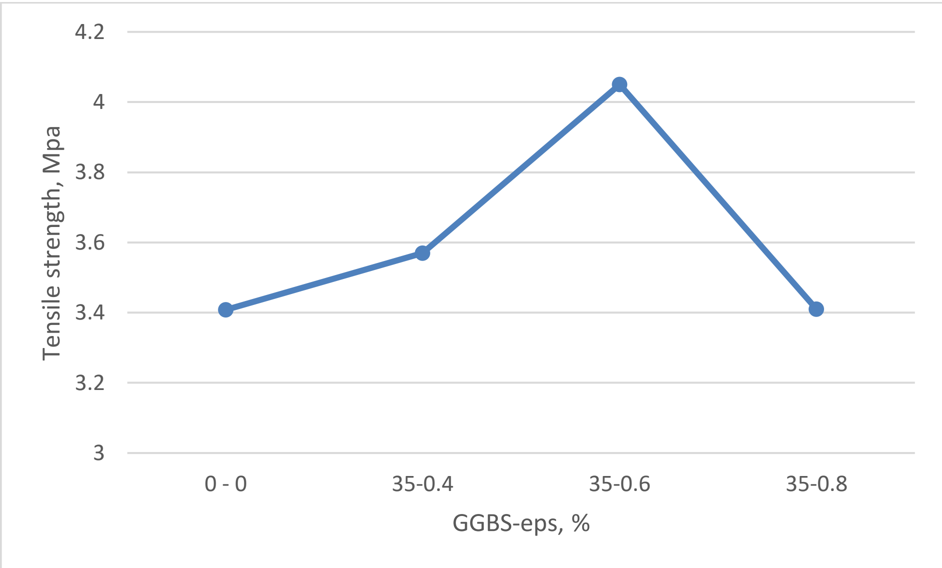

Fig 4.3(b) Tensile strength Vs % (GGBS – EPS %)

4.4 Water absorption test

The water absorption values of the concrete for replacement of fine aggregate with EPS beads by 0, 0.4, 0.6, 0.8% and cement with GGBS 25, 35% are shown in table 6.3 and graphically represented in Fig 6.4.

It is observed that there is increase in the water absorption of the concrete when the fine aggregate with EPS beads by 0, 0.4, 0.6, 0.8% and cement with GGBS 25, 35%. The percentage decrease of water absorption values for M1, M2, M3, M4, M5, M6 mixes replacement of Fine aggregate with EPS beads – cement with GGBS is 23%, 28.2%, 35.89%, 48.7%, 53.84%, 56.4% respectively. Based on the observations, all of the water absorption values are lesser for EPS & GGBS replacement in the concrete. The least water absorption of GGBS replacement in cement and EPS beads replacement in natural fine aggregates is 35% & 0.8% (M6 mix).

Table 4.4: water absorption (%) for different mixes

MIX	GGBS% – EPS %	Water absorption (%)
M0	0-0	3.9
M1	25 – 0.4	3.0
M2	25 – 0.6	2.8
M3	25 – 0.8	2.5
M4	35 – 0.4	2.0
M5	35 – 0.6	1.8
M6	35 – 0.8	1.7

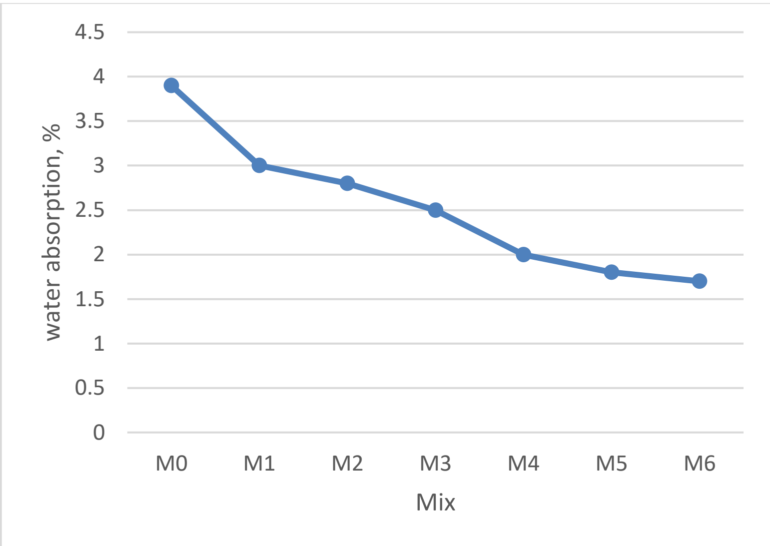

Fig 4.4 Water absorption Vs % Mix

5. CONCLUSIONS

The study demonstrates the potential of sustainable and lightweight concrete through the partial replacement of cement with Ground Granulated Blast Furnace Slag (GGBS) and fine aggregate with Expanded Polystyrene (EPS) beads. The experimental results reveal that incorporating 25% GGBS and 0.6% EPS beads significantly enhances compressive and tensile strength, with improvements of 25.35% and 26.76%, respectively, compared to conventional concrete. The workability of the mix increased due to the presence of EPS beads, making the concrete more fluid and lightweight, while the reduced water absorption ensured improved durability and resistance to moisture penetration. Furthermore, this approach not only reduces cement dependency, thereby minimizing CO_2 emissions, but also promotes waste utilization, addressing environmental concerns such as river sand depletion and industrial waste disposal. The use of

GGBS as an SCM fosters sustainable construction practices, ensuring eco-friendly, cost-effective, and structurally efficient alternatives for modern infrastructure. By embracing such innovative materials, we pave the way for a greener, more resilient, and economically viable future in construction.

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