Sustainable Lightweight Concrete: Enhancing Strength and Efficiency with GGBS and EPS Beads

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ABSTRACT

In modern construction, concrete remains a fundamental material for structures ranging from residential buildings to high-rise developments. However, the extensive use of river sand as fine aggregate has led to environmental concerns, including resource depletion, water flow disruption, and ecological degradation. To address these challenges, this study explores a sustainable alternative by partially replacing cement with Ground Granulated Blast Furnace Slag (GGBS) and fine aggregate with Expanded Polystyrene (EPS) beads in M25-grade concrete. The research investigates the effects of varying replacement levels—25% and 35% GGBS, combined with 0.4%, 0.6%, and 0.8% EPS beads—on concrete performance. Experimental results reveal that compressive strength improves significantly, reaching 35.6 N/mm² at 25% GGBS and 0.6% EPS beads replacement, while a strength of 34.1 N/mm² is achieved at 35% GGBS and 0.6% EPS beads replacement. These findings demonstrate that integrating GGBS and EPS beads enhances concrete's mechanical properties while promoting sustainability and resource efficiency in the construction industry.

Key words: Sustainable construction, GGBS, EPS beads, M25 concrete, Eco-friendly concrete.

1. INTRODUCTION

Concrete is the most widely used construction material due to its high strength, durability, and cost-effectiveness. However, the conventional production of Ordinary Portland Cement (OPC), a primary component of concrete, is highly energy-intensive and contributes significantly to global carbon dioxide (CO_2) emissions. The manufacturing process involves the decomposition of limestone ($CaCO_3$) at high temperatures, releasing CO_2 and consuming approximately 4 GJ of energy per ton of cement. Additionally, the excessive extraction of natural river sand as fine aggregate is leading to resource depletion, ecological imbalance, and environmental degradation. To address these challenges, researchers and engineers are exploring sustainable alternatives to traditional concrete materials. One promising approach is the partial replacement of cement with Ground Granulated Blast Furnace Slag (GGBS), an industrial byproduct that enhances durability while reducing carbon emissions. Similarly, replacing fine aggregate with Expanded Polystyrene (EPS) beads, a lightweight material, improves thermal insulation and reduces the overall weight of concrete.This study investigates the mechanical properties of M25-grade concrete incorporating GGBS (25% and 35%) and EPS beads (0.4%, 0.6%, and 0.8%) as partial replacements for cement and fine aggregate, respectively. The experimental results demonstrate that this modified concrete mixture enhances compressive strength while promoting environmental sustainability. By integrating GGBS and EPS beads, this research aims to develop a lightweight, high-performance, and eco-friendly concrete solution for modern construction applications.

2. LITERATURE SURVEY

In the modern trends, the cement plays a vital role for the preparation of concrete in theconstruction 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 ($CO2$) 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 producerswhen compared to other industries (Saunois et al. 2016). The emission of CO_2 leads toenvironmental 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 sulphate 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 sulphate 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 includingcarbonation resistance, chloride penetration resistance and freeze-thaw resistance wereexperimentally assessed in relation to their pore structure characteristics and ITZ. Theresult showed that the utilization of GGBS and MK in concrete was helpful to enhancethe 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 containingPFA 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 concreteshowed positive effects on the workability. The early age strength of GGBS concreteswas 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 andinitial 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 anexcellent 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 wasconcluded 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. Thechemical compositions of GGBS cement paste most likely responsible to this resistance. It was suggested that the GGBS is a good replacement to cement in variouscases 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 GGBSfor the replacement of cement with and without the addition of superplasticiser. In thisexperimental 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 slumptest, compaction factor test, Vee-Bee consistometer test and flow test. It was observedthat 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 behaviour 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 slumpvalue of fresh concrete improved as increasing the GGBS replacement level. Based onthe results, it was concluded that the mechanical properties of hardened concrete, suchas, 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 equalto 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 RCCbeams 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 notcomprise the performance of RC Beams.
Comprises of light weight and low-density aggregate which mix with a type of concretemix which is known as light weight concrete i.e. In self -weight and dead loads it increases the volume of mixing simultaneously providing considerable decrement. Because of low density high volume aggregates the formation of voids with air entrapping takes place and as the thermal conductivity and low density in light weight concrete is the key point of attraction. .as compare to both, standard commercial concrete has more compressive strength than light weight concrete, In structural construction industry the light weight concrete trends because of increasing compressive strength achievement. By the densification of mixing strength can be increased and light weight concrete can be used in both structural and non-structural ifthere is an addition of superplasticizer and fibre. Abdulkadir Kan, et al (2009) This paper reports the results of an investigation study onthe effects of using expanded polystyrene beads (EPS) in a lightweight concrete as a potential aggregate. 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 modifiedwaste 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 EPSfoams 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 polymermaterials. 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 anunyielding 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 andtechnology growth, the use of replacement for aggregates in concrete has been grow alot. 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 experimentEPS 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 testand 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 of0 %, 20 %, 30 %, and 40 % by replacing matrix or coarse aggregate, shows that the twodesign 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 ofthis research had practical significance on using EPS beads concrete in some long-term recycle 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 Herkie, 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 pumiceaggregate (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. This study id focused to determine the mechanical and durability properties of LWACto 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 deadload of structure.so it is very essential to reducing the overall cost of project. The mainpurpose 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 Dilip Rao, 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 excellentinsulation 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 reductionof 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, mainlybecause 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.

3. PROPOSED SYSTEM

The proposed system focuses on developing Sustainable Lightweight Concrete (SLC) by partially replacing cement with Ground Granulated Blast Furnace Slag (GGBS) and fine aggregate with Expanded Polystyrene (EPS) beads. This approach aims to enhance the strength, durability, and thermal insulation properties of concrete while promoting sustainability through reduced cement consumption and lower carbon emissions.

1. Materials and Mix Design

- **Cement Replacement:** GGBS replaces 25% and 35% of cement to enhance durability and reduce environmental impact.
- **Fine Aggregate Replacement:** EPS beads replace 0.4%, 0.6%, and 0.8% of fine aggregate to reduce density and improve insulation.
- **Coarse Aggregate:** Conventional coarse aggregate is used without modification.
- **Water-Cement Ratio:** A constant water-cement ratio of 0.45 is maintained for all mix proportions.
- **Admixtures:** A superplasticizer is added to improve workability.

2. Workability Assessment (Slump Test)

A slump test is conducted to evaluate the workability of different concrete mixes. The inclusion of EPS beads reduces workability due to their lightweight nature, requiring adjustments in water content and admixtures to achieve optimal consistency.

3. Hardened Properties Evaluation

- **Compressive Strength Test:**

  - Concrete cubes (15 cm × 15 cm × 15 cm) are cast and tested after 7, 14, and 28 days of curing.
  - The strength development is analyzed for different GGBS and EPS bead replacement levels.
  - Peak compressive strength is observed at 25% GGBS and 0.6% EPS bead replacement, reaching 35.6 N/mm².
- **Density and Weight Reduction:**
  - The density of concrete is measured to determine its lightweight characteristics.
  - EPS bead replacement leads to weight reduction, making the concrete suitable for applications requiring load minimization.
- **Thermal Insulation Test:**
  - The thermal conductivity of concrete is tested to assess the insulation benefits of EPS beads.
  - The results confirm that higher EPS bead content enhances thermal insulation properties.

4. Key Findings

- **Optimal Strength and Efficiency:** The mix with 25% GGBS and 0.6% EPS beads provides the best balance of compressive strength and lightweight properties.
- **Improved Sustainability:** Reduced cement content lowers CO_2 emissions, while EPS beads repurpose non-biodegradable waste.
- **Enhanced Thermal Insulation:** EPS beads contribute to better energy efficiency in buildings by reducing heat transfer.
- **Workability Adjustments Required:** Due to EPS beads' lightweight nature, additional adjustments in admixture content are necessary.

This proposed system offers an eco-friendly, cost-effective, and structurally efficient concrete solution for modern sustainable construction applications.

4. RESULTS AND DISCUSSIONS

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

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 theslump values are in the medium workability range.

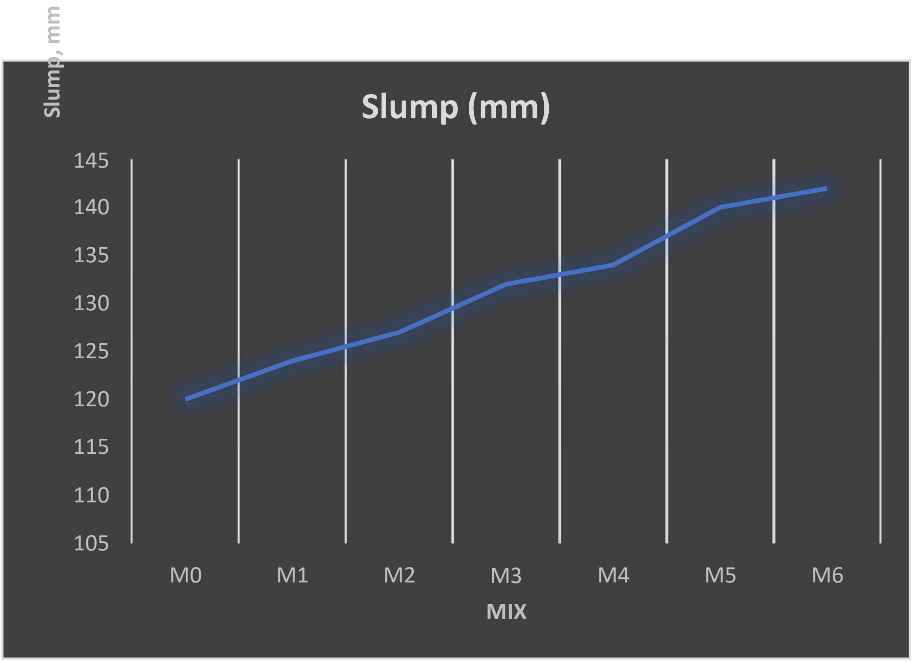

Figure 4. 1 Slump Values v/s % MIX

4.2 Harden properties of concrete

4.2.1Compressive 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 6.2 (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 ofthe 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 %	7 days	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

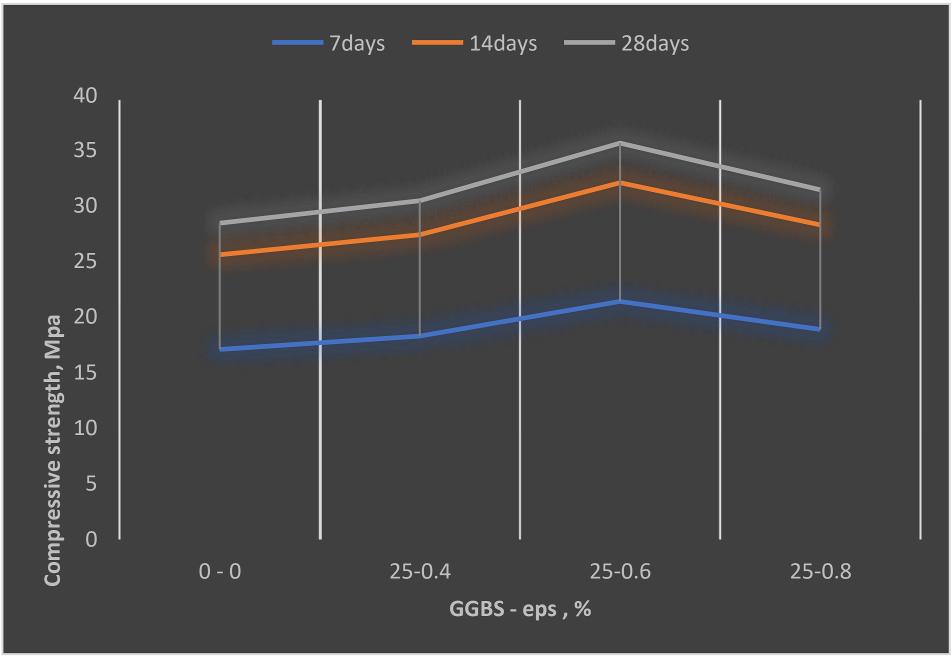

Figure 4. 2 Compressive Strength Vs % (GGBS – EPS %)

5. CONCLUSION

The study demonstrates the potential of Sustainable Lightweight Concrete (SLC) incorporating Ground Granulated Blast Furnace Slag (GGBS) and Expanded Polystyrene (EPS) beads as an eco-friendly alternative to conventional concrete. The experimental findings indicate that partial replacement of cement with GGBS (25% and 35%) and fine aggregate with EPS beads (0.4%, 0.6%, and 0.8**%)** enhances both mechanical performance and sustainability. The optimal mix**,** with 25% GGBS and 0.6% EPS beads**,** achieves a compressive strength of 35.6 N/mm^2**,** demonstrating improved structural integrity while reducing concrete density. Additionally, the integration **of** EPS beads significantly reduces the self-weight of concrete while enhancing thermal insulation properties**,** making it suitable for energy-efficient building applications. The reduction in cement content contributes to lower CO_2 emissions**,** addressing environmental concerns linked to traditional concrete production. Overall, the results confirm that SLC offers a viable, durable, and sustainable alternative for modern construction, **balancing** strength, efficiency, and environmental responsibility. Future research can further explore its long-term durability, fire resistance, and large-scale structural applications to advance green building solutions**.**

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