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Expanded Polystyrene Fly Ash Geopolymer Concrete Structure

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Abstract*: The objective of the project is to study the Strength characteristics of Fly ash-based Geo polymer concrete using Sodium hydroxide and Sodium silicate. Sodium hydroxide gives more advantage using in geo polymer concrete. Fly ash is one of the larger overdoing materials vacant from thermal power plants. Its treatment and disposal were a problem in the prime stages. Investigator commence out a useful method of replacing fly ash for cement in calculated quantities. Presently the percentage of replacement has been increasing. Here an experiment has been conducted to Study the performance of concrete using fly ash as the larger required material without addition of cement. Low calcium fly ash (class F) is preferred as a source material than high calcium fly ash (class C) alkaline liquid Sodium hydroxide and Sodium silicate are used in this project as binders and expanded polystyrene (EPS) used in this project. Given the fact that fly ash is considered as the waste material, fly ash-based Geo polymer concrete using Sodium hydroxide and Sodium silicate. Therefore, cheaper than the Portland cement concrete. The special properties of geo polymer concrete can further enhance the economic benefits.*

Keywords: Expanded Polysterene, Geopolymerization, Potassium Silicate, Normal Mix Design, Wet Density of Geopolymer Concrete

I. INTRODUCTION

The increasing global demand for sustainable construction materials has driven significant interest in eco-friendly alternatives to traditional Portland cement concrete. One such innovation is geopolymer concrete, which eliminates the need for cement by utilizing industrial by-products like fly ash, activated through alkaline solutions. This approach not only reduces carbon emissions associated with cement production but also addresses the disposal challenges of fly ash, a prevalent waste from coal-based thermal power plants. Integrating expanded polystyrene (EPS) beads further enhances the material's lightweight properties, making it suitable for structural applications where reduced dead load is crucial. EPS contributes to superior thermal insulation and energy absorption while maintaining adequate compressive strength. The synergy between fly ash and EPS in geopolymer matrices presents a promising solution to environmental concerns, resource conservation, and performance efficiency. This research investigates the mechanical behaviour, durability, and feasibility of fly ash-based lightweight geopolymer concrete with EPS, aiming to optimize its mix design for practical construction applications while promoting sustainable development.

II. SIGNIFICANCE OF GEOPOLYMER CONCRETE

The construction industry is a major contributor to global carbon emissions, primarily due to the extensive use of ordinary Portland cement (OPC), which releases approximately one ton of CO_2 for every ton produced. This environmental concern has catalyzed the exploration of sustainable alternatives, with geopolymer concrete emerging as a promising solution. Unlike OPC, geopolymer concrete utilizes industrial by-products such as fly ash, reducing greenhouse gas emissions and promoting waste recycling. Fly ash, abundant from thermal power plants, poses significant environmental hazards when improperly disposed of, occupying large landfills and causing air pollution. Incorporating fly ash into geopolymer concrete not only mitigates these issues but also enhances the concrete's mechanical properties, including high compressive strength, low shrinkage, and superior resistance to chemical attacks.

This sustainable approach supports the global push towards green construction practices, aligning with environmental conservation goals while maintaining structural performance.

III. ROLE OF EXPANDED POLYSTYRENE (EPS) IN CONCRETE

Expanded Polystyrene (EPS) plays a critical role in developing lightweight concrete, offering significant advantages in structural efficiency and thermal performance. EPS is a lightweight, closed-cell foam material with exceptional insulating properties, commonly used to reduce the density of concrete without compromising its essential strength characteristics. When integrated into geopolymer concrete, EPS enhances workability, reduces dead load, and improves thermal insulation, making it ideal for applications in precast panels, non-load-bearing walls, and insulation layers in high-rise buildings. Additionally, EPS contributes to energy efficiency by minimizing thermal conductivity, thereby reducing heating and cooling costs in buildings. The material's resistance to moisture absorption and biological degradation further improves the durability of concrete in harsh environmental conditions. This study investigates optimal EPS proportions in flyash-based geopolymer concrete to balance lightweight characteristics with mechanical performance, aiming to expand its applicability in sustainable construction.

IV. METHODOLOGY

The methodology for developing flyash-based lightweight geopolymer concrete using expanded polystyrene (EPS) involves a systematic approach encompassing material selection, mix proportioning, sample preparation, curing, and testing. The process begins with the selection and preliminary testing of raw materials, including fly ash, fine and coarse aggregates, sodium hydroxide (NaOH), sodium silicate (Na_2SiO_3), and EPS beads. The fly ash used is Class F, rich in silica and alumina, sourced from thermal power plants. Its physical and chemical properties, such as fineness, specific gravity, and chemical composition, were determined to ensure suitability for geopolymerization. The fine and coarse aggregates, obtained locally, were tested for specific gravity, fineness modulus, water absorption, and impact value following IS standards. EPS beads, known for their lightweight and insulating properties, were characterized based on density, compressive strength

The mix design was formulated considering the desired

compressive strength, workability, and density. The proportioning of materials was guided by previous research, with fly ash constituting the primary binder activated using a combination of sodium hydroxide and sodium silicate solutions in a fixed ratio. The alkaline solution-to-fly ash ratio was maintained at 0.4 by mass, with the sodium silicate-to-sodium hydroxide ratio set at 2. EPS beads were introduced as partial replacements for fine aggregates in varying proportions—5%, 10%, 15%, and 20% by volume—to investigate their impact on the concrete's properties. Additional water and superplasticizers were added to improve workability.

For mixing, the dry materials—fly ash, fine aggregates, coarse aggregates, and EPS—were thoroughly blended in a pan mixer for uniform distribution. The alkaline solution, prepared 24 hours prior to mixing to ensure complete dissolution of NaOH pellets, was gradually added to the dry mix, followed by additional water and superplasticizer. The fresh concrete was then cast into standard cube molds of 150 mm × 150 mm × 150 mm, compacted using a vibrating table to eliminate air voids. After casting, specimens were covered with plastic sheets to prevent moisture loss and left undisturbed for 24 hours (rest period) before demolding. Curing was carried out using two methods: oven curing at temperatures of 60°C, 90°C, and 120°C for 24 and 48 hours, and ambient curing at room temperature for comparison. The oven-cured specimens were gradually cooled to room temperature to prevent thermal cracking.

Compression testing machine (CTM) following IS 516 standards. Non-destructive tests, including the Schmidt Rebound Hammer test and Ultrasonic Pulse Velocity (UPV) test, were performed to evaluate surface hardness and internal defects. The experimental data were analyzed to assess the influence of EPS content on compressive strength, density, and durability, providing insights into the optimal mix design for lightweight geopolymer concrete applications.

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Fig. 1 Specimen at time of testing and after testing

Fig. 2 Split tensile test

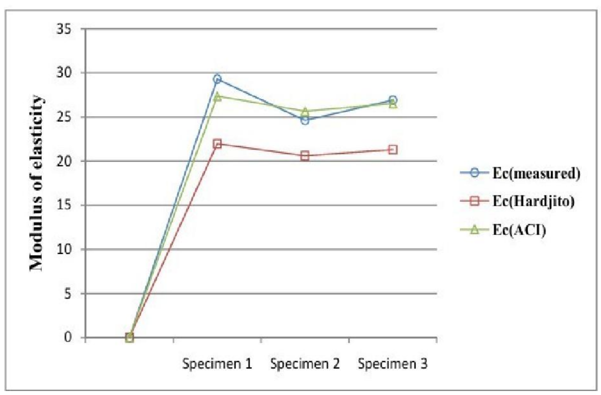

Fig. 3 Correlation between Ec (measured), Ec (Hardjito) and Ec(ACI) for ambient curing having 15% EPS

V. DISCUSSION

Expanded Polystyrene (EPS) Fly Ash Geopolymer Concrete represents a promising advancement in sustainable construction materials, combining the benefits of geopolymer technology with lightweight EPS aggregates. The integration of fly ash as a binder, activated by alkali solutions, provides an eco-friendly alternative to conventional cement, significantly reducing carbon emissions. The inclusion of EPS beads enhances thermal insulation and weight reduction, making the material ideal for non-load-bearing structures, precast panels, and energy-efficient buildings. However, challenges such as poor bonding between EPS and the geopolymer matrix, low compressive strength, and thermal degradation of EPS at high temperatures have been areas of ongoing research. Surface modifications of EPS, incorporation of fibers, and optimized mix designs have shown improvements in structural performance, addressing some of these limitations. Additionally, durability studies indicate that geopolymer concrete with EPS can exhibit good resistance to chemical attacks and moisture absorption, further supporting its potential in sustainable infrastructure. Despite these advantages, large-scale adoption is still limited due to cost considerations, lack of standardized guidelines, and the need for specialized curing techniques.

VI. CONCLUSION

The development of flyash-based lightweight geopolymer concrete using expanded polystyrene (EPS) marks a significant stride towards sustainable and eco-friendly construction materials. This research highlights the dual environmental benefits of utilizing industrial by-products such as fly ash, a waste material from thermal power plants, and EPS, a lightweight polymer with excellent insulating properties. By replacing ordinary Portland cement with geopolymeric binders, the concrete significantly reduces carbon dioxide emissions, addressing the urgent need to mitigate the environmental impact of traditional cement production. The inclusion of EPS not only reduces the overall density of the concrete, making it ideal for lightweight structural applications, but also enhances thermal insulation, contributing to energy-efficient building designs.

Experimental results indicate that while the incorporation of EPS leads to a reduction in compressive strength compared to conventional geopolymer concrete, the optimized mix proportions can achieve an effective balance between lightweight characteristics and structural performance. The concrete exhibits satisfactory mechanical properties, good workability, and improved resistance to thermal fluctuations, making it suitable for applications in precast elements, non- load-bearing walls, and insulation layers in multi-story buildings. Additionally, the reduction in dead load due to EPS integration can lead to cost savings in foundation design and structural support systems.

However, challenges such as the potential for reduced bonding strength between EPS beads and the geopolymer matrix were observed, suggesting the need for further studies focused on surface treatment of EPS or the use of additives to enhance interfacial bonding.

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