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Study of Flexural Behaviour of Lightweight Sandwich Slabs

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Abstract - Affordable quality building is vital in developing countries to meet their needs. The need to accommodate more people in one place has accelerated the importance of housing in urban and rural areas. A novel technique was urgently required to match these demands. Emphasis given to the construction and improvement of housing systems paved the way for sandwich panels which is a lightweight structural element.

The goal of this study is to develop an innovative sandwich panel using a strong outer with concrete and a low-strength thermally insulating material Expanded polystyrene as the inner core. This panel could be utilized for the construction of wall and floor elements. This study deals with the experimental investigation and methodology carried out for the fabrication of the sandwich panel. The mix proportions of the concrete used the development of sandwich panels are also discussed. The panels' casting process is also described

Key Words: (Affordable housing,Sandwich panels ,Lightweight,structural element,Expanded polystyrene (EPS) Concrete, Thermally insulating material,Wall and floor element,Experimental-investigation, Mix proportions,Casting process,Yield strengh,Load-carrying capacity,Deflection characteristics ,Static flexural test, Axial compression test)…

1.INTRODUCTION

The study of the flexural behavior of lightweight sandwich slabs is an essential area of research in structural engineering, particularly in applications requiring both strength and reduced dead weight. Sandwich slabs consist of two outer layers, known as the facesheets, typically made from high-strength materials such as reinforced concrete or steel, and an inner core, which is often lightweight and provides thermal insulation and reduced density. The primary focus of this study is to understand how these slabs perform under bending or flexural loads, including how the material properties of the facesheets and core, as well as their interaction, influence the slab's overall performance. Lightweight sandwich slabs are widely used in construction, such as in floors, roofs, and walls, due to their ability to reduce the overall weight of a structure while maintaining high load-bearing capacity. The research typically involves evaluating the load distribution, deflection behaviour, stress-strain characteristics, and failure modes of these slabs under different loading conditions. With the increasing demand for energy-efficient and cost-effective building materials, investigating the flexural behaviour of such slabs is crucial for optimizing their design and ensuring their safety and durability in various structural applications.

1.1 SANDWICH PANELS

Sandwich panels are an excellent way to obtain extremely lightweight panels with very high bending stiffness, high strength and high buckling resistance. Sandwich wall system is an innovative prefabricated wall panel which consists of an integrated core insulation allowing very low energy design and retrofit of buildings Sandwich panel is a three-layer element which consists of two thin flat facing plates of relatively higher strength material and in between a thick core of relatively lower strength and density is encased or it could consists of thin skin box of relatively higher strength material in-filled with relatively weaker an d lower density material known as core, When the inner core is made of an insulating material like Expanded polystyrene, thermal comfort of the building can be drastically improved leading to energy efficiency.

Sandwich construction form has distinct advantages over conventional solid structural sections as it provides high strength-to-weight ratio and high stiffness when compared to a solid panel, Sandwich

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composite panel possesses excellent flexural and sheat properties. Their inherent lightweight characteristics make them ideal structural components where weight reduction is desirable. Thus structural sandwich panels are becoming important elements in modern lightweight construction. Thus the sandwich panels have a very good potential to withstand seismic as well as impulsive loads. In sandwich panels transfer of shear between the wythes is achieved by providing shear connectors. The various types of sandwich panels are (1) Non-composite system (ii) Composite system and (iii) Semi-composite system. The insulation core within sandwich panels varies. The core material used generally falls into one of the following categories are (i) Non-combustible mineral wool or fiberglass (ii) Polyisocyanurate Foam (PIR) (iii) Polyurethane Foam (PUR) and (iv) Expanded or Extruded Polystyrene (EPS and EXPS).

1.2 OBJECTIVE OF THE STUDY

The objective of the study is to develop innovative precast sandwich panels which can be used for the construction of walls and floors for all types of structures and also for constructions in earthquake prone areas. The materials and technology used for the manufacture of the panels should lead to structural efficiency, ductility, light weight, energy efficient, resource efficient and speed in construction.

1.3 SCOPE OF THE STUDY

The scope of the study includes the following:

Evolve an innovative precast sandwich type panel with the outer wythes made of Geopolymer concrete and inner core made of Expanded polystyrene.

Development of M40 Geopolymer concrete for the outer wythe of the panel. Provide appropriate reinforcement for load carrying capacity and ductility. Reinforcement will consist of welded wire mesh at the outer surface of the panel and cold form infilled box section at the periphery of the panel.Casting of two panels of size 2.825m x 1.225m x 0.13m.Testing the panels in static flexure and axial compression.

2. RESEARCH METHODOLOGY

Sandwich slab is the modern method slab construction used to construct in a peculiar way. Inthis sandwich construction we made it as in lightweight slab. To overview of themethodology for designing and analyzing lightweight sandwich slabs we must considerdesign and analysis

Define Design Requirements: Identify the intended application, loadings, and performancecriteria (e.g., strength, stiffness, weight, and durability).

Select Materials: Choose suitable materials for the concrete layers, core, and bondingagents, considering factors like strength, stiffness, density, and compatibility.

Determine Layer Thicknesses: Optimize the thicknesses of the concrete layers and core toachieve the desired structural performance while minimizing weight.

Analyze Structural Behavior: Use numerical models (e.g., finite element analysis) oranalytical methods to simulate the slab's response to various loads and conditions.

5. Optimize Design Parameters: Refine the design by adjusting layer thicknesses, materialproperties, and bonding conditions to achieve the optimal balance of performance and weight.

3.MATERIALS

3.1 CEMENT:

Cement is a fundamental material in construction, known for its binding properties

that contribute to the strength and durability of structures. Its key properties include

fineness, which enhances hydration and strength development, and consistency, whichaffects the workability of cement mixtures. The setting time of cement is crucial, as itdetermines how quickly the material transitions from a fluid state to a hardened form,influencing construction timelines. Compressive strength is one of the most importantproperties, as it dictates the load-bearing capacity of the cement once it has hardened.Soundness ensures that the cement does not expand excessively after setting, whichcould lead to cracking or failure. Additionally, the heat of hydration, or the heatreleased during the chemical reaction with water, must be managed to prevent thermalcracks in large structures. Other important properties include specific gravity, whichhelps in mix proportioning, and bulk density, which affects storage and transportation.These material properties collectively ensure that cement performs effectively,providing durability, strength, and reliability in construction projects.

3.2. COARSE AGGREGATE:

Coarse aggregate is a key component of concrete and other construction materials, contributing to the overall strength, stability, and durability of the final product. It consists of naturally occurring or crushed stone, gravel, or rock fragments, typically larger than 4.75 mm. The physical properties of coarse aggregate play a significant role in concrete performance. Its size and gradation affect the workability, strength, and density of the concrete mix. A well-graded aggregate with a range of particle sizes leads to better packing, reducing voids and the need for excess cement paste. The hardness and toughness of the aggregate influence the wear resistance and durability of the concrete, especially in load-bearing or high-traffic applications. Additionally, the shape and surface texture of the aggregate affect the bond between the aggregate and cement paste, which can impact the strength and stability of the concrete. Porosity and absorption are also important, as highly porous aggregates may absorb water, potentially affecting the water-cement ratio and weakening the mix. Overall, the quality and characteristics of coarse aggregate directly influence the performance, longevity, and structural integrity of concrete.

3.3. FINE AGGREGATE:

High Fine aggregate, typically consisting of natural sand or crushed stone particles smaller than 4.75 mm, is an essential component in concrete and mortar mixes. Its material properties significantly impact the workability, strength, and durability of the final product. The gradation or particle size distribution of fine aggregate affects the compactness of the mix, with well-graded particles leading to better packing and fewer voids, which enhances the strength and reduces the need for excess cement paste. The texture and shape of the particles influence the workability of the mix; smoother, rounder particles improve workability, while angular particles provide better bonding with the cement paste. Fine aggregate should also be clean and free from impurities like silt, clay, or organic matter, as these can weaken the mix and reduce durability. Its moisture content and absorption capacity are crucial, as they affect the water-cement ratio, which is key to achieving the desired strength. Overall, the properties of fine aggregate play a crucial role in the performance, consistency, and quality of concrete and mortar.

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3.4. VERMICULATE:

Vermiculite is a naturally occurring mineral with unique properties that make it valuable in various industrial and construction applications. It is a hydrated magnesium-aluminum-iron silicate that expands significantly when heated, a process known as exfoliation. This expansion creates lightweight, porous particles that offer excellent insulation, both thermal and acoustic. Vermiculite low density and high water absorption capacity make it ideal for use in lightweight concrete, plasters, and as a packing material for fireproofing. It is also chemically inert, non-combustible, and resistant to mold and rot, making it suitable for moisture control and fireproofing applications. In agriculture and horticulture, vermiculite is valued for its ability to retain water and nutrients, promoting healthy plant growth. Additionally, its non-toxic and environmentally friendly nature makes it a safe material for use in a wide range of products. Overall, vermiculite's combination of lightweight, insulation, water retention, and fire-resistant properties makes it a versatile and effective material in construction, agriculture, and industrial uses.

3.5. EPS BEATS:

- EPS (Expanded Polystyrene) beads are lightweight, versatile material widely used in construction, packaging, and insulation due to their unique properties. Made from expanded polystyrene, a type of thermoplastic, EPS beads have a low density and are composed of 95-98% air, making them extremely lightweight and efficient as insulation material. Their excellent thermal insulation properties help reduce heat transfer, making them ideal for use in insulating walls, roofs, and floors in construction. EPS beads also have good shock-absorbing qualities, which makes them suitable for protective packaging and cushioning in various products.

3.6. METAL MESH:

Metal mess, often referred to in discussions about metal fatigue and structural integrity, describes a state where the material exhibits disordered, chaotic structural characteristics due to various stressors like heat, corrosion, or mechanical strain. This degradation can lead to compromised mechanical properties, such as reduced tensile strength and increased brittleness. Over time, the microstructure of the metal may become irregular, resulting in a lower resistance to fatigue and failure. Understanding these changes is crucial for engineers and materials scientists to ensure the reliability and safety of metal components in applications ranging from aerospace to construction. Proper maintenance and material selection can help mitigate the effects of metal mess, prolonging the lifespan and functionality of metal structures.

4. METHODOLOGY:

4.1 WOODEN MOULD:

Preparing a wooden mold involves several key steps to ensure it is sturdy and functional for casting. The dimensions of the mold (30x20x10)cm. And selecting the appropriate type of wood, such as plywood. Assemble the mold by attaching the sides to a bottom piece using screws, nails, or wood glue. If needed, reinforce the corners with dowels or brackets for added strength. Seal any gaps in the joints with wood filler and sand the interior surfaces smooth to prevent imperfections on the cast material. Once the mold is fully assembled, test it with a small amount of casting material to check for any issues before proceeding with the final casting.

4.2 CASTING:

Casting a lightweight sandwich slab involves creating a composite structure with multiple layers, typically consisting of two outer concrete skins and a core material that provides insulation and reduces weight. The process begins by preparing a mould, which is designed to hold the outer concrete layers and the lightweight core material. The core is usually made from materials like expanded polystyrene (EPS), foam, or other lightweight aggregates, which offer thermal and sound insulation while keeping the overall weight of the slab low. Once the mould is prepared, the first layer of concrete is poured to form the bottom skin of the slab, followed by placing the core material into the mould. The core is carefully positioned and secured, ensuring it maintains the correct shape and thickness. After the core is in place, the second layer of concrete is poured over the core to form the top skin. The concrete layers are typically vibrated to ensure proper compaction and to eliminate air pockets. After curing, the sandwich slab is removed from the mould, ready for installation or further processing. The result is a strong, insulated, and lightweight slab that is ideal for use in construction where thermal insulation, reduced weight, and structural integrity are important.

5. RESULTS:

5.1. COMPRESSIVE TEST:

Prepare the concrete mix according to the M20 grade proportions. Ensure thorough mixing to achieve uniform consistency. Pour the mixed concrete into the cube Molds, ensuring no air pockets remain. Use a vibrator if necessary to eliminate air bubbles. Allow the cubes to cure for a specified period (commonly 7, 14, or 28 days) in a controlled environment, keeping them moist to prevent drying. After curing Place, the cube centrally on the testing machine's loading platens. Ensure the platens are clean and aligned properly. Gradually apply the load to the cube at a controlled rate (typically 0.5 to 1.0 MPa per second). Continuously monitor the load and record the maximum load applied before failure occurs. Note the mode of failure (e.g., crushing, diagonal cracking) once the cube fails.

The Compressive Strength value is around – 2900 psi or 20MPa

Period		Specimens			Average
		1	2	3	
3 Days	Strength(N/mm2)	6	7	7.5	6.83
7 Days	Strength(N/mm2)	13.5	14	13	13.5
14 Days	Strength(N/mm2)	17	18.5	18	17.83
28 Days	Strength(N/mm2)	20	18	19	19

5.2. TENSILE STRENGTH TEST

Prepare a concrete mix as per M20 grade. Cast the specimen in a mould. Common shapes include: Cylindrical specimens (typically 150 mm in diameter and 300 mm in height). Ensure proper vibration and compaction to eliminate air pockets. Cure the specimens for a standard period (e.g., 7, 14, or 28 days) to achieve desired strength. Maintain moisture to prevent drying. For cylindrical specimens, the most common method is a split-cylinder test (using a compressive testing machine Place the specimen in the testing machine, ensuring proper alignment. For a split-cylinder test: Apply a compressive load vertically until the specimen fails, typically using two loading platens that apply pressure on the sides of the cylinder. Record the load at which the specimen fails and observe the failure mode (e.g., cracking, splitting).

The tensile strength of M20 grade concrete is around - 2-3 N/mm2.

Period		Specimens		Average
		1	2	
3 Days	Strength(N/mm2)	1.036	1.090	1.063
7 Days	Strength(N/mm2)	2.06	2.03	2.045
14 Days	Strength(N/mm2)	2.75	2.36	2.555
28 Days	Strength(N/mm2)	3.02	3.105	3.06

5.3. FLEXURAL TEST ON CONCRETE

Prepare a concrete mix as per M20 grade proportions and standards. Pour the concrete into beam moulds, ensuring proper compaction to eliminate air pockets. Ensure the beams have smooth and even surfaces .Cure the specimens for a standard period (commonly 7, 14, or 28 days) in a controlled environment to achieve desired strength. Maintain moisture to prevent drying. Place the beam specimen on the supports of the testing machine, ensuring it is centred and properly aligned. For a three-point bending test, position the supports at equal distances from the ends of the beam. Apply the load gradually at the midpoint (for three-point testing) or at two points (for four-point testing) until failure occurs. The load should be applied at a controlled rate (typically 0.5 to 1.0 MPa per second).Record the load at which the specimen fails and note the failure mode (e.g., cracking, crushing).

The flexural strength of M20 grade concrete around - 3.13 MP.

5.4. THREE-POINT OR FOUR-POINT BENDING TEST

Lightweight sandwich slabs involves several key components to ensure accurate and reliable results. Initially, a universal testing machine (UTM) is used for applying controlled loads, utilizing load cells for precise measurement and displacement gauges to monitor deflection at critical points.Theslabs, prepared with consistent dimensions (1000mm*300mm*100mm)and materials, are positioned on support spans for either a three-point or four-point bending test, depending on the design specifications. During testing, the load is applied gradually, typically at a rate of 1-2 mm/min, while continuously recording both the load and deflection until failure occurs. Safety measures, such as protective barriers and personal protective equipment, are implemented to safeguard personnel. Following the test, the slabs are inspected to document failure modes, and the collected data is analyzed to generate load-deflection curves and assess mechanical performance. This structured approach facilitates a comprehensive understanding of the flexural behaviour of lightweight sandwich.

SLUMP CONE TEST

5.5. COMPARISON BETWEEN CONVENTIONAL SLAB AND LIGHT WEIGHT SANDWICH SLAB:

Parameter	**Conventional slab**	**Lightweight sandwich slab**
Core Material	Dense materials like concrete or brick	Lightweight materials such as expanded polystyrene (EPS), foam concrete, or honeycomb cores
Weight	Heavier due to denser core and facesheets	Lighter due to the use of lightweight core materials
Thermal Insulation	Moderate insulation, depending on the core	Superior thermal insulation due to the lightweight, insulating core material
Load-Bearing Capacity	Generally higher, as it uses denser materials	Moderate load-bearing capacity, but optimized for reduced weight
Cost	Typically more expensive due to the use of denser, high-strength materials	More cost-effective, especially when using low-cost lightweight core materials
Flexural Strength	Higher flexural strength due to stronger materials	Lower flexural strength but optimized for efficient load distribution
Applications	Used in heavy-duty structures, bridges, and high-load-bearing systems	Common in residential, commercial buildings, and roofs requiring light weight and insulation
Construction Time	Longer construction time due to heavier materials	Faster construction time due to ease of handling and lighter materials
Environmental Impact	Higher environmental footprint due to denser, heavier materials	Lower environmental impact due to the use of sustainable and lightweight materials
Sound Insulation	Generally good sound insulation due to dense materials	Better sound insulation due to the porous and insulating nature of the lightweight core

6. CONCLUSION:

6. 1 GENERAL

In conclusion, the lightweight sandwich slabs have emerged as a compelling solution for modern construction, offering a compelling blend of structural efficiency, thermal performance, and acoustic insulation. By strategically combining high- strength face sheets with a lightweight core material, these slabs deliver exceptional performance while minimizing overall weight.

6.2 CONCLUSION

Reduced Structural Load : The lightweight idea of sandwich chunks altogether decreases the general burden on the structure's establishment and primary components, prompting cost investment funds and plan adaptability.

Enhanced Thermal Performance: The sandwich board's layered design actually lessens sound transmission, establishing calmer and more agreeable indoor conditions.

Rapid Construction: Prefabricated sandwich panels can be quickly assembled on-site, accelerating construction timelines and minimizing labor costs.

Fire Resistance: Many sandwich slabs are designed to meet stringent fire safety standards, offering protection against fire spread and structural collapse.

Versatility: These slabs can be customized to suit various applications, including floors, roofs, and walls, making them adaptable to diverse construction projects.

6.3 SUGGESTION

Exploration of Different Lightweight Materials
Further research should investigate a variety of lightweight materials, such as EPS beats, Vermiculate, or advanced chemical admixtures, to optimize the bond strength and durability of sandwich slab.

Such effective and eco-friendly materials could be explored to make the process even more natural.

Optimization of Precoating Processes

The method and duration of precoating application (spraying, immersion, or mixing) and its impact on the microstructure of RCA need to be optimized. Each precoating method may influence how well RCA bonds with cement paste.

The thickness of the precoating layer should be investigated to find a balance between cost-effectiveness and performance enhancement.

Long-Term Durability Testing

Long-term tests of lightweight sandwich slab under different environmental conditions (freeze-thaw cycles, sulphate attack, and chloride penetration) should be conducted to assess durability.

Shrinkage and creep behaviour of sandwich slab should also be studied to prevent cracking in large concrete structures

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Application in High-Strength Concrete

The use of sandwich slab in high-performance or ultra-high-performance concrete (UHPC) could be a viable option. Exploring how lightweight influences the mechanical properties of sandwich slab in high-strength concrete mixtures may broaden its applicability.

Standardization and Guidelines

The development of standardized guidelines for the use of precoated RCA in structural concrete applications is necessary. Currently, many specifications for RCA focus on natural aggregates, and tailored standards for precoating treatments would ensure consistency and quality in practice.

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