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Lightweight Foam Blocks With Natural Fibre

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Abstract

The development of technology is a widely accepted one for those who are eager to create changes in the environment. Emerging technology leads to furnishing more materials and equipment's to the construction industry, but it has paved the way for overrun cost. There is lot of chances to pollute the environment by using these advanced materials, so the utilization of eco-friendly materials will develop a better world to live in. Natural fibres possess the highest tensile strength, especially kenaf fibre. Incorporation of these fibres in light weight foamed concrete intensifies its mechanical properties. This project explains the manufacture of light weight foam blocks with natural fibres. The cement, fly ash, Slaked Lime, Foaming Agent and water is mixed in ratio 1:0.67:0.042:0.024:0.55 with different percentages of kenaf fibres (0%, 0.4%, 0.5% by volume of fraction of concrete). Foamed concrete can be produced with dry densities of 400 to 1600 kg/m^3. Kenaf fibres possess greater tensile property, flexural strength and impact strength. The use of natural fibres as composites are light weight, possess lower density, reasonably strong, ecofriendly and free from health hazards, easy availability and cost effective. The use of light weight foam blocks with natural fibres has several benefits such as it limits the number of blocks needed for the construction as the size of the lightweight blocks is 600 x 200mm and so it consumes less time compared to brick and the construction time is 20 times faster than bricks. The expected results will be light weight foam blocks with kenaf fibres of percentage ranges of 0%, 0.4%, 0.5% shows higher strength characteristics than control mix of normal light weight foamed concrete.

Keywords: Lightweight foam concrete, Lightweight foam blocks, Natural fibre, Kenaf fibre.

1. Introduction

1.1 General

Lightweight foam blocks are an innovative construction material designed to provide superior thermal insulation, sound absorption, and reduced structural load compared to traditional concrete blocks. These blocks are produced by incorporating a foaming agent into a cementitious slurry, creating a highly aerated structure with a uniform distribution of air voids. The key ingredients used in the production of lightweight foam blocks include cement, fly ash, slaked lime, a synthetic-based foaming agent, and water. Among these, cement acts as the primary binder, while fly ash, particularly Class F fly ash, enhances workability, durability, and sustainability by partially replacing cement, reducing carbon emissions. Slaked lime contributes to improved setting characteristics and overall stability of the matrix.

Incorporating natural fibres such as Kenaf fibre further enhances the mechanical and physical properties of lightweight foam blocks. Kenaf fibre, derived from the Hibiscus cannabinus plant, is known for its excellent tensile strength, durability, and biodegradability. When integrated into the mix, Kenaf fibre improves crack resistance, enhances flexural strength, and reduces shrinkage by acting as a reinforcing agent within the cellular structure. Additionally, the presence of fibres enhances the block's energy absorption capacity, making it more resistant to impact and thermal variations. The use of a foaming agent generates a uniform pore structure, reducing density while maintaining adequate compressive strength, making the blocks ideal for non-load-bearing walls, partitions, and insulation applications.

Lightweight foam blocks reinforced with Kenaf fibre present a sustainable and cost-effective alternative to conventional building materials. Their reduced weight leads to lower transportation and handling costs, while their enhanced durability extends the lifespan of structures. With growing emphasis on green building solutions, the integration of natural fibres into lightweight foam blocks aligns with environmental and sustainability goals, reducing reliance on traditional construction materials while offering superior performance.

1.2. Foamed Concrete

1.2.1 History of Foamed Concrete

Foamed concrete has a long history, with its first recorded use dating back to 1923, primarily as an insulating material. Extensive research on its composition, physical properties, and production methods was conducted in the 1950s and 1960s. This research led to the development of new admixtures in the late 1970s and early 1980s, which enabled the commercial application of foamed concrete in construction. Initially, it was widely used in the Netherlands for filling voids and ground stabilization. Further studies in the Netherlands contributed to its broader adoption as a reliable building material. In recent years, advancements in technology have led to the development of continuous foam generators, where a foaming agent is agitated with compressed air to produce "aircrete" or "foamcrete." This material is highly versatile, offering fire resistance, insect resistance, and waterproofing properties. Additionally, foamed concrete provides excellent thermal and acoustic insulation while being easy to cut, carve, drill, and shape using conventional woodworking tools. It is widely used in construction for applications such as foundations, subfloors, building blocks, walls, domes, and arches, which can be reinforced with construction fabric. Over the past two decades, improvements in production equipment and high-quality foaming agents have facilitated the large-scale use of foamed concrete in modern construction.

1.2.2 Properties of Foamed Concrete

The foam concrete properties in its fresh and hardened state are explained as follows.

1.2.2.1 Fresh Properties of Foamed Concrete

Foamed concrete exhibits excellent workability, characterized by a high slump value of approximately 150 mm, often leading to collapse. This high workability is attributed to the strong plasticizing effect of the foaming agent, making foamed concrete highly desirable for various applications. However, once the flow of the mix remains static for an extended period, it becomes challenging to restore its original state. In its fresh state, foamed concrete exhibits thixotropic behavior, allowing it to maintain its shape while reducing the likelihood of bleeding due to its high air content. An increase in mix temperature enhances the filling ability and contact efficiency due to the expansion of air. However, an excessive amount of sand or the use of coarse aggregates beyond standard specifications can lead to segregation, potentially causing bubble collapse, which reduces the overall volume and affects the foam structure. Proper handling is essential when pumping fresh foamed concrete, as uncontrolled free fall or turbulence at the discharge point may result in structural collapse of the foam.

1.2.2.2 Hardened Properties of Foamed Concrete

Foamed concrete exhibits a thermal conductivity ranging from 0.1 W/mk to 0.7 W/mk , depending on its density. The material undergoes drying shrinkage between 0.3% and 0.07% for densities of 400 kg/m³ and 1600 kg/m³, respectively. However, foamed concrete does not achieve the same strength as autoclaved aerated concrete of similar density. Under loading conditions, internal hydraulic pressure develops within the structure, leading to deformation. Despite this, hardened foamed concrete demonstrates excellent resistance to freeze-thaw cycles. Observations indicate that foamed concrete used in environments with temperatures ranging from -18°C to +25°C does not exhibit significant damage, further proving its durability in varying climatic conditions.

The physical properties of the foam concrete are clearly related to the dry density. The variation is seen in the tabulation given below.

TABLE.1.1 TYPICAL PROPERTIES OF FOAMED CONCRETE IN ITS HARDENED STATE

Dry Density Kg/m^3	Compressive Strength N/mm^2	Tensile Strength N/mm^2	Water Absorption Kg/m^2
400	0.5 – 1	0.05-0.1	75
600	1-1.5	0.2-0.3	33
800	1.5 -2	0.3-0.4	15
1000	2.5 -3	0.4-0.6	7
1200	4.5-5.5	0.6-1.1	5
1400	6-8	0.8-1.2	5
1600	7.5-10	1-1.6	5

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1.2.3 ADVANTAGES OF FOAMED CONCRETE

1. Foamed concrete is lightweight, reducing structural load and making handling easier. This makes it suitable for high-rise buildings and prefabricated structures.
2. It has good thermal insulation, helping maintain indoor temperatures. This reduces the need for heating and cooling, improving energy efficiency.
3. The high air content provides excellent sound insulation by absorbing noise. This makes it ideal for partitions, walls, and flooring in buildings.
4. It is easily pumpable and self-levelling, requiring minimal compaction. This simplifies construction, reducing labour costs and speeding up the process.
5. It is highly durable and resistant to freeze-thaw cycles, ensuring longevity. It does not degrade over time, even in harsh weather conditions.
6. The material is cost-effective as it requires less cement and no aggregates. This leads to significant savings in material and transportation costs.
7. It provides excellent fire resistance due to its porous structure. This enhances safety in buildings, especially in fire-prone areas.
8. Foamed concrete is eco-friendly and can incorporate industrial by-products like fly ash. This helps reduce waste and promotes sustainable construction.
9. It is versatile and can be moulded into various shapes and densities. This makes it suitable for a wide range of construction applications.

1.2.4 APPLICATIONS OF FOAMED CONCRETE

1. Enhanced Strength: Improves tensile and flexural strength, suitable for structural applications.
2. Thermal and Acoustic Insulation: Provides excellent thermal insulation and sound absorption.
3. Sustainable Construction: Eco-friendly, renewable, and biodegradable, reducing carbon footprint.
4. Lightweight Building Blocks: Ideal for easy-to-handle, lightweight blocks for non-load-bearing walls.
5. Fire Resistance: Offers improved fire resistance for safer construction.
6. Soil Stabilization: Useful in stabilizing soils with reduced load on underlying structures.
7. Precast Elements: Suitable for lightweight precast panels and beams.
8. Green Roof Systems: Supports plant growth in green roofs while minimizing structural loads.
9. Infrastructure Applications: Effective for lightweight filling in embankments and road construction.

"LWFC with kenaf fibres enhances mechanical properties and promotes sustainable practices, making it versatile for various engineering applications"

1.3 NEED FOR THE STUDY

The need for the study of this project is driven by the increasing demand for sustainable construction materials that minimize environmental impact. By developing eco-friendly lightweight foam concrete (LWC) with natural fibres, such as kenaf, the project aims to optimize material efficiency and reduce waste in construction practices. Incorporating natural fibres is expected to enhance the mechanical properties of the foam concrete, leading to improved performance in various applications. Additionally, utilizing locally available materials can lower construction costs, making it a more viable option for builders. Overall, this research contributes to ongoing innovations in the construction industry, promoting the use of advanced materials and methods that align with contemporary sustainability goals.

Furthermore, the construction industry faces significant challenges, including high carbon dioxide emissions during the production of traditional materials like Portland cement. The study highlights the potential of kenaf fibres, which can absorb carbon dioxide, thus offering a dual benefit of enhancing concrete properties while also contributing to environmental remediation. This aligns with global efforts to reduce greenhouse gas emissions and promote greener building practices. By exploring the integration of natural fibres into lightweight foam concrete, the project not only addresses material performance but also supports broader environmental objectives, making it a timely and relevant area of research.

1.4 SIGNIFICANCE OF THE PROJECT

The project solution focuses on developing lightweight foam concrete (LWC) by incorporating kenaf fibres as a natural reinforcement. This approach aims to enhance the mechanical properties of the concrete while maintaining a lightweight structure. The mix design will be optimized with varying proportions of kenaf fibres (0%,0.4% & 0.5%) by volume) alongside a base mix of cement, fly ash, and water.

The resulting lightweight foam blocks will facilitate faster construction and easier handling. Comprehensive testing will ensure the material meets structural requirements, while the use of kenaf fibres will highlight environmental benefits, such as carbon sequestration and sustainability. Overall, this project aims to present LWFC as a cost-effective and eco-friendly alternative to traditional concrete in various construction applications.

1.5 OBJECTIVES OF THE PROJECT

1. To examine the properties of fibre such as density, tensile strength, water absorption, elongation percentage and young's modulus.
2. To arrive mix ratio for foamed concrete through literature review.
3. To cast three different mixes of light weight foam blocks with kenaf fibre. (0%, 0.4% & 0.5% by volume fraction of concrete)
4. To develop a lightweight foam block with natural fibres and to examine the engineering properties and physical requirements as per IS 2185 (PART 4): 2008.
5. To carry out the experimental study on the mechanical behavior with various kenaf mix percentages.

2. LITERATURE REVIEW

2.1 LITERATURE REVIEW ON FOAMED CONCRETE AND NATURAL FIBRE

(LaibiPoullain, Leklou, Gomina, Sohounhloue, 2018) has evaluated that the mechanical and thermal properties of compressed earthen blocks (CEB) has been influenced by kenaf fibre length. It was observed that the CEB has higher tensile strength and bonding with kenaf fibre intrusion. There is positive effect on compressive strength of CEB with optimum fibre length 50mm. Addition to this immersion of kenaf fibre till its saturation before adding to its matrix adversely affects the mechanical properties of CEB.

(Mahzabin, Hock, Kang. & Jarghouyeh, 2017) investigated the mechanical properties of lightweight foamed composite (LFC) with the inclusion of kenaf fibres and super plasticizer. NaOH treated kenaf fibre contents of 0.4%, 0.45% and 0.5% (by weight of cement) with 5cm length were used in composite. The density of 1000kg/m^3 to 2000 kg/m^3 foamed concrete was used for all the tested specimens. The ratio of cement, sand and water used was 1:1.5:0.45. In reference to the results and discussion, the different percentages of fibre used were proven to have a lesser contribution towards compressive strength or might even have reduced the result. The results also showed that water absorption and density of the composite mortar increased as the volume of fibre increased from 0.4% to 0.5%. However, a higher percentage of fibre inclusions had been recorded to have a positive contribution towards flexural and tensile splitting properties of composites. Concrete with fibre resulted in a better tensile splitting strength compared to control specimens.

(Jones & McCarthy, 2005) Low self-weight (800 to 1600 kg/m3), high workability (flowing and self-compacting) and excellent thermal insulating properties (0.50 W/mk) make foamed concrete attractive for many construction applications. Indeed, it is now a well-established material in void filling and highway reinstatement uses. This paper describes a laboratory study of the development of foamed concrete, utilizing two types of fly ash with the potential for use in structural applications. ‘Fine’ fly ash (i.e.to BS EN450) was used to partially replace Portland cement and a ‘coarse’ fly ash (i.e.to BS 3892-2) to replace sand fine aggregate. In addition, the potential of polypropylene fibres in foamed concrete to enhance plasticity and tensile strength was examined. However, the characteristics of foamed concrete, particularly high drying shrinkage strain and relatively low tensile strength and stiffness performance, mean that straight substitution for normal weight concrete is not possible and more innovative structural forms will need to be developed.

(JitChaiyaphum, Sinsiri, &Chindaprasirt, 2011) has examined various properties of compressive strength, water absorption, and the porosity of cellular lightweight concrete or CLC, which is pre-formed foam method made from Portland cement blended with foaming agent and pozzolan materials. Uses of fly ash replace cement in the proportions 10, 20 and 30 percent by weight of binder. Constant water to binder ratio of 0.5 and unit weight of 800 kg/m3 compared compressive strength at curing age 3, 14, 28 and 60 days. The study result that replacing cement with fly ash is high strength on the early stage.

(Falliano, De Domenico, Ricciardi, & Gugliandolo, 2019) investigated the mechanical strength of fibre reinforced lightweight foamed concrete. The foamed concrete was prepared with VMA that increases the cohesion and consistency of the cement paste at the fresh state (extrudable foamed concrete). In this 60 small scale prism specimens were casted for testing flexural strength and 100 cubic specimens were casted for testing compressive strength in accordance with two different testing standards for comparative purpose. The effect of three curing conditions (air, cellophane, water), three dry densities (400, 600, 800 kg/m3), three fibre contents (0.7%, 2%, 5%), and the presence of an additional glass-fibre reinforced polymer (GFRP) mesh in the tensile zone of the beams were analyzed. The polymer fibres of 7 2-5% increase the flexural capacity to considerable manner. Addition of GFRP mesh obtains high mechanical strengths associated with low densities typical of ultra-light weight concrete elements.

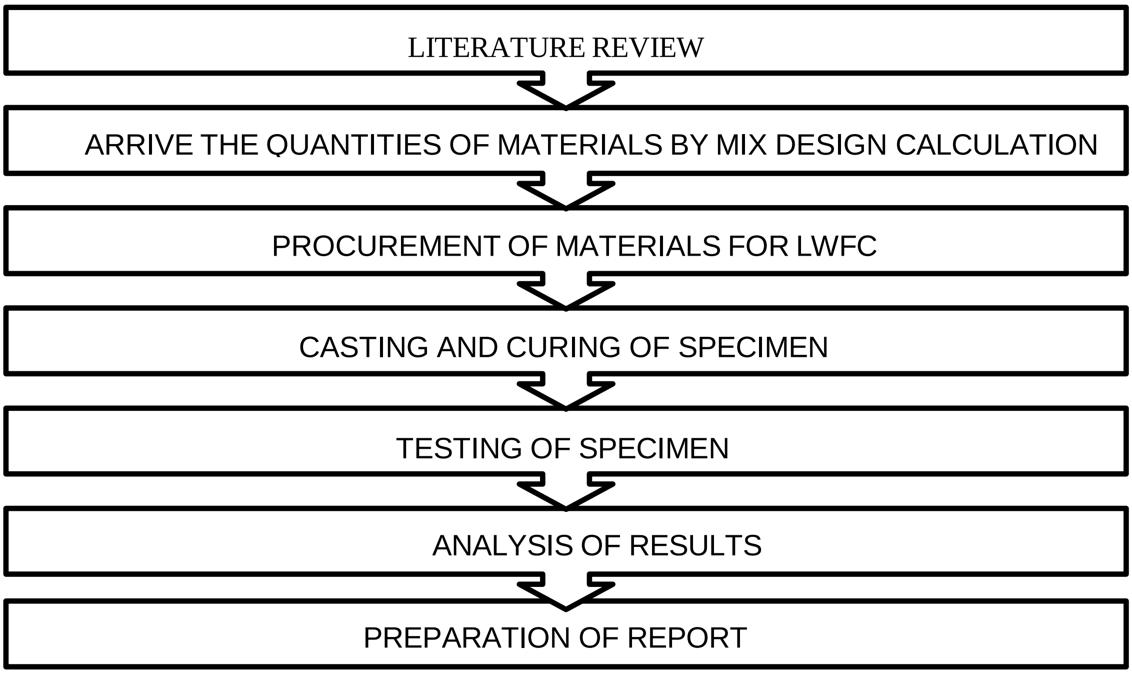
(Tian Fook Lam et al, 2015) has declared that the mechanical properties of kenaf fibre reinforced concrete are influenced by fibre volume content and fibre length. This experiment has been conducted with 5 different percentages of fibre content at 2 different fibre lengths. The Flexural strength and split tensile strength of kenaf fibre reinforced concrete is directly proportional to its fibre content and fibre length but its compressive strength is inversely proportional to its fibre content. As a result, upon inclusion of kenaf fibre with fibre length is 50mm and 0.75% of fibre volume fraction in beam, the mechanical property can be significantly improved.

(P. Balaji, N. Vengatajalapathi, N. Subramanian, 2015) has explained about Substituting composite structures for conventional metallic structures have many advantages because of higher specific stiffness and strength of composite materials. This has found its wide applications in aerospace, automotive, marine and sporting industries. There has been continuous lookout for synthesizing composites without compromising on the mechanical and physical properties. In this research, fibre reinforced composites were prepared with kenaf fibres of fibre length 5-6 mm. The resins used in this study are polyester and epoxy. The composites were synthesized at fibre-resin weight percentages. The prepared composites were tested to study the mechanical properties of the composite such as tensile strength, flexural strength, impact strength and hardness. The results show that the kenaf reinforced epoxy composite exhibited better mechanical properties than Kenaf-polyester composite.

(Lim, Putra, Nor,&Yaakob, 2018) evaluated the sound absorption of kenaf fibre specimens both under normal and random sound incidence. The normal- incidence sound absorption coefficient measurement was conducted using the impedance tube method. The effect of thickness involving full fibre and air-fibre specimen and the effect of bulk density were discussed. For the random-incidence sound absorption coefficient, the test was conducted in reverberation chamber. The absorption and level of absorption coefficient improve significantly when bulk density and thickness are increased. Additional air gap improves the absorption toward lower frequency.

(M.A. Othuman Mydin, Zamzani, and Ghani, 2019) collates a database of elevated temperature axial compressive and flexural strengths of coir fibre reinforced foamed concrete exposed to heating temperatures of 105°C, 200°C, 300°C, 400°C, 500°C, 600°C, 700°C and 800°C. There were four densities of foamed concrete 700, 1100, 1500 and 1900 kg/m3 were prepared and tested. The untreated coir fibre were added in foamed concrete in percentages of 0.1%, 0.2%, 0.3%, 0.4%, 0.5% and 0.6% by mix volume fraction. This paper helps in prediction of elevated temperature strengths of fibre reinforced foamed concrete which can be exploited to assist manufacturers to develop their products.

3. METHODOLOGY



4. MATERIALS

The basic components of the mix composition of LWFC were cement, Fly ash, Slaked lime, foaming agent, foam, natural fibre and water.

4.1 CEMENT (IS 1489 PART I 1991)

Portland cement is a crucial binding material in construction, known for its ability to set, harden, and adhere to other substances, forming a strong matrix. Ordinary Portland Cement (OPC) is a fundamental component of concrete and is primarily composed of calcium oxide (CaO), silica (SiO_2), and alumina (Al_2O_3). These oxides are obtained from calcareous and argillaceous raw materials, with additional elements such as iron oxide (Fe_2O_3) and bauxite sometimes included to achieve the desired composition. However, the production of OPC generates a significant amount of carbon dioxide (CO_2), contributing to global warming. To address this environmental concern, researchers have explored the incorporation of pozzolanic materials, which help reduce OPC consumption while maintaining concrete performance. Pozzolanic materials, including fly ash, volcanic ash, calcined clay, and silica fumes, react with calcium hydroxide to enhance strength and durability, promoting sustainable and eco-friendly construction practices.

Ordinary Portland cement of 53 grade (BS 12:1996 or BS EN 197: Part 1: 2000) is usually used as the main binder for foamed concrete. However rapid hardening Portland cement to BS 915:1983 has also been used, and there does not seem to be any evidence why sulfate resisting cement to BS 4027:1980 could not be used. Usually the total cement content will lie between 300 and 400 kg/m3, but up to 500 kg/m3 has been used to attain higher strength concrete. In this project, OPC of grade 53 is used effectively.

Fig.no: 1 Cement

4.2 FLYASH (IS 3812:2003)

Fly ash is a byproduct of burning pulverized coal in power plants, formed when mineral impurities such as clay, feldspar, quartz, and shale fuse and solidify into fine, glassy particles. In foamed concrete, fly ash can be used as a filler, replacing fine aggregates like sand, enabling high-volume utilization and providing an economical and environmentally friendly method for its disposal. Pulverized fuel ash (PFA), conforming to BS 3892: Part I 1997 or BS EN 450: 1995, is often incorporated at levels of up to 80% of the cement content to reduce costs, enhance workability, and improve long-term strength. Compared to sand, fly ash contributes to higher strength and better consistency in foamed concrete. There are two primary types of fly ash: Class F (low calcium fly ash) from Mettur and Class C (self-cementing fly ash) from Neyveli. In this study, Class F fly ash is used, replacing 40% of the cement content to improve the performance and sustainability of foamed concrete while reducing greenhouse gas emissions associated with cement hydration.

Fig.no: 2 Fly ash

4.3 SLAKED LIME

Slaked lime is used with Class F fly ash to enhance its self-cementing properties. Class F fly ash, on its own, is not cementitious, but when combined with slaked lime (calcium hydroxide), it activates a pozzolanic reaction. The calcium in the slaked lime reacts with the silica and alumina in the fly ash, forming calcium silicate hydrate (C-S-H), a compound that binds the materials together and contributes to the strength and durability of the mix. This reaction improves the mechanical properties of the material, making the fly ash behave as a supplementary binder. In lightweight foam blocks, this activation helps reduce the reliance on OPC cement, improving both performance and sustainability.

Fig.no: 3 Slaked lime

4.4 FOAMING AGENT

A foaming agent is a substance that aids in the formation of foam, typically acting as either a surfactant or a blowing agent. Surfactants reduce the surface tension of liquids, making it easier to create foam, and they can also enhance the foam's stability by preventing the bubbles from merging. On the other hand, blowing agents are gases that create the gaseous phase in the foam, helping to form the bubbles.

There are two primary types of foaming agents:

1. **Protein-based foaming agents:** These are made from natural sources, such as soybean extracts, and are primarily used to produce lightweight concrete and other concrete materials. Protein-based foaming agents do not chemically react with the concrete but instead serve to trap air within the mix, forming a stable foam structure. The foam helps to reduce the overall density of the concrete without producing harmful fumes or toxins. However, these agents require more energy to generate foam compared to synthetic alternatives. To improve their stability and enhance foam formation, protein-based foaming agents are typically prepared in the presence of calcium hydroxide ($Ca(OH)_2$) and a small amount of sodium bisulfide ($NaHSO_3$). Furthermore, various gels and surfactants are added to these agents to improve their performance and workability, such as alkyl benzene sulfonates, which help optimize the foam structure.

2. **Synthetic foaming agents:** These are chemical compounds commonly used in the production of concrete, blocks, bricks, and Cellular Lightweight Concrete (CLC), where a higher density foam is required. Synthetic foaming agents are effective at reducing the surface tension of liquids, making them highly efficient in generating foam. They require less energy for foam production compared to protein-based agents. These agents are globally recommended in construction, especially as the demand for lightweight concrete continues to grow. Synthetic foaming agents play a crucial role in improving the mechanical properties of concrete, such as strength and resistance, by promoting the formation of a cellular structure within the material. This enhances the overall performance of the concrete in various applications.

In this project, a synthetic foaming agent has been selected for producing lightweight foam blocks due to its effectiveness in foam formation, energy efficiency, and suitability for the required lightweight concrete characteristics.

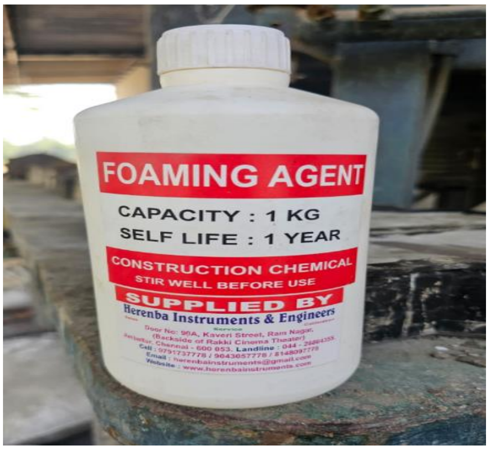


Fig.no: 4 Foaming agent

4.5 FOAM

The surfactant solution typically consists of one part surfactant mixed with between 5 and 40 parts of water. The optimal ratio depends on the type of surfactant and the production method used. The solution is then foamed to a consistency like shaving foam, with a foam density ranging between 20 and 90 kg/m³. The foam density varies depending on the application, with many cases leaning toward the upper end of this range. Foam produced with protein-based surfactants typically has a density of around 50 kg/m³, while foam made with synthetic-based surfactants can range from 60 to 90 kg/m³. The water-to-cement (w/c) ratio generally falls between 0.3 and 0.5.

For this project, the dilution ratio was determined using a trial-and-error approach. The foam density produced from the synthetic-based foaming agent was targeted to be between 60 and 90 kg/m³. Various mixing ratios of foaming agent to water were tested: 1:1, 1:2, 1:3, 2:1, 2:2, and 2:3.

Foam density and fresh concrete density were measured for each ratio. After evaluating the results, a 2:1 (foaming agent to water) ratio was selected, as it produced foam with a density of 67 kg/m³ and fresh concrete with a density of 890 kg/m³, which was deemed the optimal proportion for the project.

Fig.no: 5 Foam

4.6 KENAF FIBRE

Kenaf (Hibiscus cannabinus L.) is a fast-growing plant from the Malvaceae family, known for its two types of fibres: bast fibres (coarse) and core fibres (fine). These fibres are used in various industries, including construction, textiles, and automotive, due to their high cellulose content and rapid growth. Kenaf's fibres enhance the mechanical properties of concrete, improving crack resistance, energy absorption, and overall toughness. In fibre-reinforced concrete (FRC), kenaf fibres bridge cracks, providing post-cracking ductility and increasing toughness.

For this project, kenaf fibres were processed into 30–50 mm lengths after decortication, scotching, and washing. The fibres were added to the concrete mix at different percentages (0%, 0.4%, and 0.5%) by volume, with a cement-to-fly ash-to-Slaked lime-to-water ratio of 1:0.67:0.042:0.55. The inclusion of kenaf fibres aimed to improve the concrete's tensile strength, reduce the amount of steel reinforcement, and provide a sustainable, cost-effective solution for eco-friendly construction, particularly in low-cost housing projects.

Fig.no: 6 Kenaf Fibre

4.7 WATER

Water used for foamed concrete should be potable. Potable tap water available in the laboratory in Kumaraguru College of Technology, Coimbatore with pH value of 7.0 and conforming to the requirements of IS: 456-2000 was used for mixing the concrete and curing the specimens as well.

4.8 MOULD

In order to determine the size for the lightweight foam blocks, a comparison was made with Autoclaved Aerated Concrete (AAC) blocks, which are commonly used in the construction of residential buildings and apartments. The standard market sizes for AAC blocks typically have a length of 600mm, a height of 200mm, and a width ranging from 75mm to 250mm. According to IS 2185 PART I: 2008, the nominal dimensions for concrete blocks are as follows: Length: 400, 500, or 600mm; Height: 250 or 300mm; and Width: 100, 150, 200, or 250mm. Based on these references, it was decided to produce the lightweight foam blocks with dimensions of 600mm in length, 200mm in width, and 200mm in height.

For the production of these blocks, a wooden mould was used with the dimensions of 600mm x 200mm x 200mm (length x breadth x height), which allows for the creation of one specimen per mould.

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Fig.no: 7 Mould

5. MATERIAL TESTING

5.1 SPECIFIC GRAVITY TEST

Specific gravity is defined as the ratio of the weight of a given volume of material to the weight of an equal volume of water. Portland cement typically has a specific gravity value of around 3.15. For Portland pozzolan cements and Portland blast furnace cements, this value is approximately 2.90, as per the Portland Cement Association (PCA) 1988. The specific gravity of cement can be affected by its moisture content, as cement particles contain pores that may trap water. A nominal mix is typically prepared with cement having a specific gravity of 3.15. Any deviation in this value can impact the mix design, making it crucial to test the specific gravity of the cement before mixing. This is why the use of old stock cement is generally avoided, as it may be influenced by external moisture. A specific gravity greater than 3.19 may indicate that the cement was not properly ground into fine powder during production or contains excess moisture, which can be identified by the presence of lumps in the cement.

The procedure for specific gravity test is as follows.

1. The flask is allowed to dry completely and made free from liquid and moisture. The weight of the empty flask is taken as W1.
2. The bottle is filled with cement to its half (Around 50gm of cement) and closed with a stopper. The arrangement is weighed with stopper and taken as W2.
3. To this kerosene is added to the top of the bottle. The mixture is mixed thoroughly, and air bubbles are removed. The flask with kerosene, cement with stopper is weighed and taken as W3.
4. Next, the flask is emptied and filled with kerosene to the top. The arrangement is weighed and taken as W4.

$$SG = \frac{(W2 - W1)}{[(W2-W1)-(W3-W4)]} + 0.79$$

Note: The addition of 0.79 in the specific gravity formula accounts for the specific gravity of kerosene used in the test. The density of kerosene typically ranges between 0.78 to 0.82 g/cm³.

SG of kerosene = Density of water / Density of kerosene

= 1.0 g/cm^3 / 0.79 g/cm^{3} = 0.79.

TABLE 5.1 RESULT OF SPECIFIC GRAVITY OF MATERIALS

S.No	Material	Specific gravity	Limitations from code	IS code
1	Cement	3.13	3.3 – 3.25	IS 2720-part 3
2	Fly ash	2.23	2.1 - 3	IS 3812-part 1

5.2 TREATMENT OF KENAF FIBRE (Based on Alkali Treatment)

Alkali treatment (also called mercerization) is a chemical process used to improve the properties of natural fibres like Kenaf for better performance in composites or cement-based materials. This Treatment Removes lignin, wax and oil, Improving Fibre Adhesion.

➢ **MATERIALS**

1. NaOH: 5 – 10 % Solution.
2. Water: Distilled Water / Portable Water.
3. Acetic Acid: 5 % Solution.

➢ **PROCEDURE**

I. Prepare the NaOH Solution:

1. Mix 50g or 100g of NaOH in 1 Litre of Water.e.g. For 500g of kenaf requires 6 litres of water with 300g of NaOH.
2. Soak the fibre for 30 to 60 mins.
3. After that Rinse the Fibre thoroughly with water and check the pH of the Fibre and the pH of the fibre should be 7 (Neutral).
4. If it is not, Treat the Fibre Neutralization with Acetic Acid.

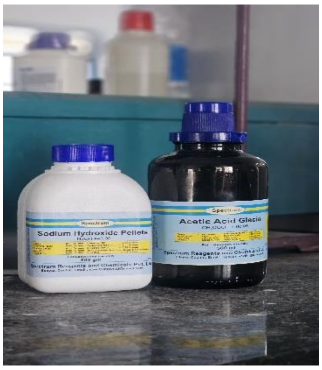

Fig no: 7
NaOH Pellets and Acetic Acid

Fig no: 8
Preparing the NaOH Solution

Fig no: 9
Soaking the Kenaf fibre in NaOH Solution

II. For Neutralize with Acetic Acid:

1. Mix 50ml of Acetic Acid with 1 litre of water e.g. For 500g of kenaf requires 6 litres of water with 300g of Acetic Acid.
2. Soak the fibre for 10 to 15 mins.
3. After that Rinse the Fibre thoroughly with water and check the pH of the Fibre and the pH of the fibre should be 7 (Neutral).

III. Oven dry:

1. Take 500g of Wet kenaf fibre for oven dry.
2. Let it dry for 6 to 12 hrs on 60^0 to 80^0 C.
3. After that let it cool down and take dry weight of it.

Fig no: 10
Soaking the Kenaf Fibre in Acetic acid Solution

Fig no: 11
Kenaf Fibre Before Drying

Fig no: 12
Kenaf Fiber After Drying

Fig no: 13 (a),(b)
To cast the blocks, kenaf fiber was chopped into
50 mm (5cm) pieces.

5.3 WATER ABSORPTION TEST ON FIBRE

The water absorption test measures how much water the fibre can absorb, helping assess its **porosity and durability.**

$$\mathbf{W} = \frac{\mathbf{(W2-W1)}}{\mathbf{(W1)}} \ \mathbf{x\ 100} = \frac{(905-730)}{(730)} \ \text{x}\ 100 = 23.97\% \sim 24\ \%$$

Where W is the percent water absorption, W1 and W2 are the wet weight of the kenaf fibre and the dry weight of the kenaf fibre after time t, respectively.

Note: According to IS 2185 Part 4:2008 For lightweight foam blocks, the water absorption percentage should be between the ranges from 10% to 30%.

TABLE 5.2 RESULT OF WATER ABSORPTION OF FIBRE

S.No	**Material**	**Wet Weight (W1)**	**Dry Weight (W2)**	**Water Absorption %**
1	Kenaf Fibre	905 g	730 g	24 %

6. MIX DESIGN

6.1 GENERAL

Mixed design of foamed concrete does not possess any codal provisions. Dry density and strength are two very important parameters of foamed concrete. The next design method of mix proportion is to determine the dry density of foamed concrete to achieve effective control of foamed concrete strength

1.Cement density is determined by dry density of foamed concrete.

2.According to the water cement ratio, the amount of foamed concrete water is determined.

3.Determine the volume of the paste according to the amount of cement and amount of water.

4.Calculate the volume of the foam according to the volume of cement paste.

5.According to the volume of foam and density of the measured foam, the quality of foam solution is calculated.

6.Calculate the quality of the foaming agent through the quality of the foam and the dilution ratio of foaming agent.

In determining the proportion of each material, we should take into account the characteristics of slow solidification of some materials. These materials may cause great changes in the early strength of foamed concrete such as slurry initial setting effect, excessive dosage will affect the stability of pouring, serious may lead to collapse, so it is necessary to control the dosage. However, there is always a certain amount of deviation between any theoretical calculation and actual production. Therefore, in the actual production and application process, the foam concrete mix proportion needs to be constantly adjusted and improved.

6.1.1 FOAM DENSITY

The density of foam can be determined, quite simply, through weighing a known volume of foam.
It is measured and calculated by using a measuring jar.
Height of measuring cylinder = 13.5 cm; Diameter =11 cm
Volume of measuring cylinder = 3.14 x 0.055×0.055× 0.135 = 0.001287 m^3
Density of foam = mass / volume = 0.086 / 0.001287 = 67 kg/m^3

6.1.2 FOAM STABILITY

Foam stability can be quantified by measuring the volume of foam which has collapsed into solution at regular time intervals.

6.2 MIX DESIGN FOR FOAMED CONCRETE

1. Design density of foamed concrete, ρd = 1000kg/m^3
2. Workability in terms of flow: 75 to 100mm
3. Degree of workability: highly workable (fluid consistency)
4. Coefficient of mass, Sa = 1.2 (for OPC)
5. Water cement ratio, B= 0.5~0.6
6. Redundancy factor, K = 1.1~1.3 (for good stability foam)
7. Density of cement, ρc = 3130 kg/m^3
8. Density of measured foam density ρf = 67 kg/m^3
9. Density of water, ρw = 1000 kg/m^3
10. Type of curing: water curing

STEP 1: Cement dosage for 1 m3 foam concrete

ρd = Sa.mc

1000 = 1.2.mc

Cement dosage for 1 m^3 foam concrete, mc = 833.33 kg

Cement is replaced by 40% fly ash

Cement dosage for 1 m^3 foam concrete = 500 kg

Fly ash dosage for 1 m^3 foam concrete = 333.33 kg

Slaked lime dosage for 1 m^3 foam concrete = 21 kg

STEP 2: Water consumption of 1 m3 foam concrete:

mw = B mc

mw = 0.55 x 500 = 275 kg

STEP 3: Total volume of slurry is composed of cement and water (m^3)

In 1 m3 foamed concrete, the grout volume and foam addition of cement and water can be calculated by the following formula

V1 = (mc /ρc) + (mw/ρd)

V1 = (500/3130) + (275/1000)

V1 = 0.4347 m^3

STEP 4: Foam addition (m^3)

V2 = K (1-v1)

V2 = 1.2(1-0.4347)

V2 = 0.6783 m^3

STEP 5: The amount of foaming agent:

my = V2 x ρf

= 0.6783 x 67 = 45.45 kg

mf = my / ((b+1) +1)

= 45.45/ ((2/1) +1)=15 kg

6.3 DENSITY OF FRESH FOAMED CONCRETE

Height of measuring cylinder =13.5cm,

Diameter = 11cm

Volume of measuring cylinder = $\pi r2$h

$= \pi \text{ x } 0.055 \times 0.055 \times 0.135 = 0.001287 \text{ m}^3$

Density of foam = mass / volume = 1.145 / 0.001287

= 890kg/m^3

6.4 MIX RATIO FOR FOAMED CONCRETE

Cement: Fly Ash: Slaked Lime: Foaming Agent: Water

500: 334: 21: 15: 275

1: 0.67: 0.042: 0.024: 0.55

7. CASTING AND CURING OF SPECIMEN

7.1 GENERATION OF FOAM

Foam is generated using paint mixer by mixing synthetic based foaming agent and water in the ratio of 2:1.

Fig.no: 14 Generation of Foam

7.2 CASTING OF LIGHT WEIGHT FOAM BLOCKS

➢ PROCEDURE:

1. Foam Preparation:

   Foam is generated using paint mixer by mixing synthetic based foaming agent and water in the ratio of 2:1.
2. Mixing Concrete:

1. Add cement, fly ash, and slaked lime into the foam.
2. Ensure no lumps and mix thoroughly until a concrete texture is achieved.

3. Pouring into Mould:

1. Pour the mixture into the mould in three layers.
2. Between each layer, spread Kenaf fibre evenly.
3. Tap the mould to release air bubbles.

4. Setting Time:

   Let the mould set for 48 hours.

5. Demoulding and Curing:

1. After 48 hours, remove the blocks from the mould.
2. Cure the blocks for 28 days before use.

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Fig no: 15 Preparation of foam

Fig no: 16 Dry mix of cement, fly ash and Slaked lime

Fig no: 17 Mixing of cement, fly ash, Slaked lime and foam

Fig no: 18 Fresh Concrete

Fig no: 19 Pouring of Fresh concrete into the Mould

Fig no: 20 Addition of Fibre

Fig no: 21 Casting of Foam Blocks

Fig no: 22 Foam Block after Demoulding

Fig no: 23 Curing of Foam Blocks

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8. Experimental Investigation:

8.1 Tests on Fresh Properties of Concrete (BS EN 12350: Part 6: 2000)

8.1.1 Plastic density:

The plastic density of the foamed concrete mix can be determined simply from the weight of the sample in a container of known volume, say 1 litre. After mixing cement and fly ash with water, the concrete mix is blended evenly in the concrete mixer. The foam is mixed for an appropriate duration and the mixing continued. Then the mixed fresh foamed concrete is filled in 1 litre jar and weight is measured.

8.2 Tests On Hardened Properties of Concrete:

8.2.1 Dimension Test:

Overall dimensions shall be measured with a steel scale graduated in 1mm divisions. Three Full sized units shall be measured for length, width and height. These specimens shall be used for other tests also. Individual measurements of dimensions of each unit shall be read to the nearest division of the scale. Length shall be measured on the longitudinal centre line of each face, width across the top and bottom bearing surfaces and height at both faces. The report shall show the average length, width and height of each specimen. The manner of measurement is pictorially depicted below.

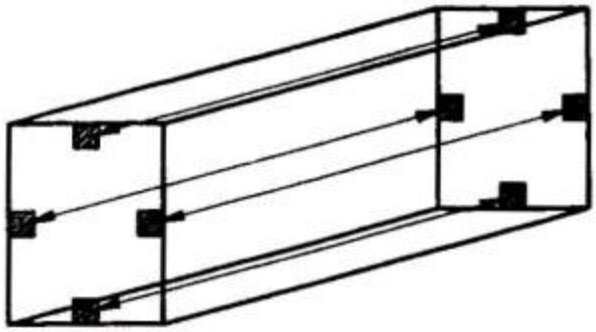

Fig 24 Four positions of checking length of whole block

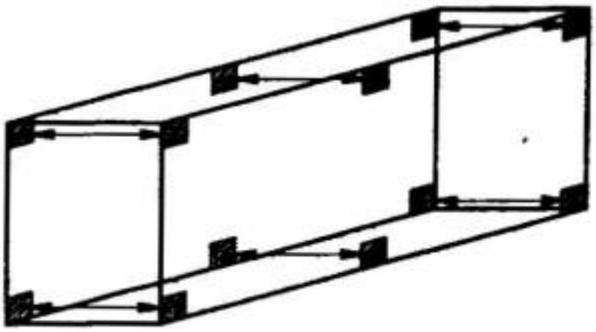

Fig 25 Six measurements of width

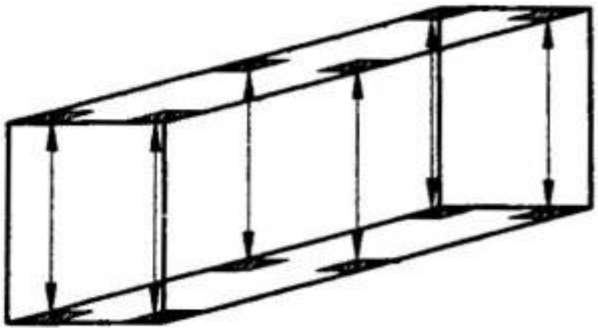

Fig 26 Six positions for checking height of whole block

8.2.2 Block Density Test:

Three blocks taken at random from the samples selected shall be dried to a constant mass in a suitable oven heated to approximately 100°C. After cooling the blocks to room temperature, the dimensions of each block shall be measured in centimetres (to the nearest millimetres) and the overall volume computed in cubic centimetres. The blocks shall then be weighed in kilograms (to the nearest 10g) and the density of each block calculated as follows:

$$density = \frac{mass\ of\ block\ in\ kg}{volume\ of\ specimen\ in\ m^3} \times 10^6\ kg/m^3$$

The average densities for the three blocks shall be taken as the average density.

8.2.3 Compressive Strength Test:

Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. A material under compression tends to reduce the size, while in tension, size elongates. A compressive strength formula for any material is the load applied at the point of failure to the cross-section area of the face on which load was applied.

Compressive Strength = Load / Cross Sectional Area.

8.2.3.1 Procedure:

The foam concrete is prepared and poured into 600 x 200 x 200 mm molds without tamping. After 24 hours, the blocks are demolded and submerged in water to cure at 27 ± 2°C for 28 days. Before testing, the loading surfaces are made smooth and even using cement paste if necessary. The block is then placed horizontally in the compression testing machine, ensuring proper alignment to avoid eccentric loading. A gradual load (2.5 – 15 MPa/min) is applied until failure, and the maximum load (P) is recorded. The compressive strength is calculated using the formula $f_n = P / A$, where $A = 200 \times 200$ mm = 40,000 mm² (0.04 m²). Finally, the results are recorded, and the average compressive strength is reported.

Fig 27 Compression testing machine

8.2.4 Water Absorption Test

Three full sized units shall be used for this test. The test specimens shall be completely immersed in water at room temperature for 24h. The specimens shall then be weighed, while suspended by a metal wire and completely submerged in water. They shall be removed from the water and allowed to drain for 1 min by placing them on a 10mm or coarser wire mesh, visible surface water being removed with a damp cloth, and immediately weighed. Subsequent to saturation, all specimens shall be dried in a ventilated oven at 100°C to 115°C for not less than 24h and until two successive weighing at intervals of

2h show an increment of loss not greater than 0.2 percent of the last previously determined mass of the specimen. Calculate water absorption as follows:

Water Absorption = [A- B/A-C] X 1000 in kg/m^3

Where,

A = wet mass of unit, in kg; B = dry mass of unit, in kg; and C = suspended immersed mass of unit, in kg. The average of the three units is calculated.

8.2.5 Flexural Strength

The flexural strength test determines the ability of a material to resist bending or failure under applied loads. It measures the maximum tensile stress that a concrete beam or block can withstand before cracking or breaking when subjected to a bending force. This test is commonly conducted using a three-point or four-point loading setup, where the specimen is supported at both ends, and the load is applied at the center (or one-third points). The result helps evaluate the durability and structural performance of concrete in real-world applications.In this project we done our testing on Universal Testing Mechine.

8.2.5.1 Procedure:

The foam concrete blocks of 600 x 200 x 200 mm are cast and cured in water at 27 ± 2°C for 7, 14, or 28 days. Before testing, the loading surfaces are checked for evenness and, if necessary, a thin layer of cement paste is applied to ensure uniform contact. The block is then placed in the flexural testing machine using a three-point or four-point loading setup, with the 600 mm length as the span and the load applied at the center (or one-third points for four-point loading). A gradual load is applied until the block fails, and the maximum load (P) at failure is recorded. The flexural strength (f_t) is calculated using the formula $f_t = (P \times L) / (b \times d^2)$, where L is the span length, b = 200 mm (width), and d = 200 mm (depth). Finally, the results are recorded, and the average flexural strength is reported.

Fig no: 28 Universal Testing Machine

9. Results and Discussion:

9.1 Density and Weight of Blocks:

1 The density of block before adding fibre is 1033.33 kg/m^3

2 Weight of the block before adding fibre is 31 kg

3 The density of block after adding 0.4% (by volume fraction of concrete) fibre is 1015 kg/m^3

4 Weight of the block after adding 0.4% (by volume fraction of concrete) fibre is 30.45 kg

5 The density of block after adding 0.45% (by volume fraction of concrete) fibre is 1006.67 kg/m^3

Weight of the block after adding 0.45% (by volume fraction of concrete) fibre is 30.2 kg

9.2 Test Results

The compressive strength is the most important physical property that identifies the possibility of using foam blocks with natural fibres in structural application. There are many factors that influence the compressive strength of LWFC blocks such as density, w/c ratio, curing method and quantity of air voids in the hardened foamed concrete varies. The compressive strength of foam blocks should be the nearest to the value as per IS 2185 part 4: 2008 as mentioned in fig 9.1. The expected results will be light weight foam blocks with kenaf fibres of percentage between 0%,0.4% and 0.5% shows higher compressive strength than control mix of normal light weight foamed concrete.

After studying many research papers, it is found that water absorption increases as density decreases. The above results will be suitable for light weight foam blocks. By adding fibres, the results will be better. The expected result should be nearer to the value as mentioned in fig 9.1.

Table 9.1 Physical properties of foam blocks.

S.No	Kenaf Fibre %	Block Density in Oven Dry Condition (kg/m^3)	Compressive Strength (N/mm^2)	Flexural Strength (N/mm^2)
1	0	1000	5.92	0.51
2	0.4	1000	6.98	0.57
3	0.5	1000	7.25	0.58

Foamed concrete be produced with densities of 400 kg/m^3 to 1600 kg/m^3 with 7 days strength of approximately 1 to 10 N/mm^2. We checked for the densities, and it came within the limit, likewise strength is also expected to be within the range and all the test results are expected to be within the limit as listed in the above table.

10. Conclusion

10.1 conclusion

This study on lightweight foam blocks with natural fibres has successfully demonstrated the structural, economic, and environmental advantages of incorporating Kenaf fibre into foamed concrete. The research findings confirm that the addition of Kenaf fibres (0.4%–0.5%) enhances tensile strength, flexural strength, and impact resistance, making foamed concrete a stronger and more durable alternative to traditional lightweight concrete. The fibres improve crack resistance, toughness, and load distribution, reducing the likelihood of early structural failures.

Furthermore, the partial replacement of cement with Class F fly ash (40%) contributes to sustainability by reducing cement consumption, thereby lowering CO_2 emissions and mitigating the environmental impact of cement production. The use of synthetic-based foaming agents ensures a controlled and uniform cellular structure, which optimizes density while maintaining workability and insulation properties.

The lightweight nature of the foam blocks reduces the overall dead load on structures, making them ideal for high-rise buildings and prefabricated construction. The ease of handling, faster installation, and lower labour costs further contribute to the economic feasibility of using these blocks over conventional bricks. Additionally, their fire resistance, moisture resistance, and excellent thermal and acoustic insulation make them suitable for diverse climatic conditions and sustainable building practices.

Overall, this research validates the effectiveness of fibre-reinforced foamed concrete and highlights its potential for widespread adoption in the construction industry. By enhancing strength, reducing weight, improving insulation, and promoting environmental sustainability, lightweight foam blocks with Kenaf fibres present a viable alternative to conventional concrete and masonry materials. Future research and large-scale implementation can further refine the technology, making it a cornerstone for modern, sustainable construction.

10.2 SCOPE OF THE FUTURE WORK

In future, light weight foam blocks with natural fibre should be properly tested and checked for its advantages. And then light weight foam concrete with inclusion of fibre can be used to manufacture wall panels.The use of lightweight foamed concrete panels using natural fibres have several benefits such as it limits the number of blocks needed for the construction so it consumes less time compared to brick and the construction time is 20 times faster than bricks. It also has several features such as fire resistance, sound absorption, heat resistance and thermal insulation.

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