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# EXPERIMENTAL INVESTIGATION ON THERMAL PERFORMANCE OF REINFORCED CONCRETE SLAB

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## CHAPTER 1

## INTRODUCTION

### 1.1 GENERAL:

The thermal performance of a slab refers to its ability to resist heat transfer. By improving the insulation properties of the slab, we can reduce heat loss, which can lead to energy savings and increased comfort. By incorporating GGBS (Ground Granulated Blast Furnace Slag) and pumice stone into the concrete mix of the hollow slab, we can significantly improve its thermal performance. GGBS is a byproduct of the iron and steel industry and is known for its high thermal resistance and low thermal conductivity. Pumice stone, on the other hand, is a lightweight and porous volcanic rock that provides excellent insulation properties. The combination of GGBS and pumice stone helps to reduce heat transfer through the slab, making it more energy-efficient. This can lead to lower energy consumption for heating and provide higher cooling purposes in buildings.

A hollow slab is a type of concrete slab that contains voids or hollow spaces within its cross-section. It is filled with a cavity refers to a type of construction where the slab has voids or hollow spaces within its cross-section. These cavities can be created using various methods, such as using precast hollow blocks or forming voids during the casting process. This design helps reduce the weight of the slab while maintaining its structural integrity. It's often used in buildings to achieve longer spans and decrease material usage. Thermocouple testing in concrete slabs is a great way to identify temperature variations. By placing thermocouples at different points on the slab, you can measure and monitor the temperature changes over time. This helps in evaluating the thermal performance and identifying any potential areas of concern. It's an effective method to ensure the desired temperature control and optimize energy efficiency. By monitoring temperature changes using thermocouples will provide valuable data to assess the success of your experiment and optimize thermal performance. It's an exciting project that combines energy efficiency, sustainability, and improved comfort in building design. This data will provide valuable insights into the thermal performance of the slab and the effectiveness of using GGBS and pumice stone in enhancing insulation properties. It's an essential step in evaluating the success and achieving energy-efficient and sustainable building practices.

### 1.2 MECHANISM OF GGBS AND PUMICE STONE:

GGBS and pumice stone work together to improve the thermal performance of slabs. GGBS reduces heat transfer, while pumice stone traps air within its pores for enhanced insulation. This combination helps create energy-efficient and sustainable buildings. By monitoring temperature changes using thermocouples and analyzing heat flow within the slab, we can assess the effectiveness of these materials and their impact on energy efficiency.

#### 1.2.1 GGBS:

Ground granulated blast furnace slag (GGBS) is a byproduct of the iron and steel industry, and it is used as a supplementary cementitious material in the production of concrete and cement-based materials. GGBS has several important mechanical properties that make it a valuable additive in construction and infrastructure projects.

**Fig 1.1 GGBS**

Some of the key mechanical properties of GGBS include:

- **Strength Enhancement**: GGBS can enhance the compressive and flexural strength of concrete when used as a partial replacement for Portland cement. It reacts with calcium hydroxide in the presence of water to form additional calcium silicate hydrate (C-S-H) gel, which contributes to the strength of the concrete.
- **Tensile Strength:** GGBS can improve the tensile strength of concrete, making it more durable and resistant to cracking.
- **Durability**: GGBS can improve the durability of concrete by reducing the permeability of the material. This leads to increased resistance to chemical attack, sulfate attack, and carbonation, which can extend the service life of structures.
- **Reduced Heat of Hydration**: GGBS has a lower heat of hydration compared to Portland cement. This is advantageous in mass concrete structures where excessive heat generation during curing can cause cracking and reduced long-term durability.
- **Workability:** GGBS can improve the workability of concrete due to its fine particle size and spherical shape. It can also reduce the water demand, which helps in maintaining the desired water-cement ratio and workability.
- **Reduced Alkali-Silica Reaction (ASR):** GGBS can mitigate the risk of alkali-silica reaction, a deleterious chemical reaction that can cause cracking and deterioration of concrete in the presence of reactive aggregates.
- **Sulfate Resistance:** GGBS can enhance the resistance of concrete to sulfate attack, making it suitable for environments with high sulfate concentrations, such as marine or industrial settings.
- **Reduced Shrinkage:** GGBS can reduce the drying shrinkage of concrete, which helps in minimizing cracks and improving long-term durability.
- **Improved Corrosion Resistance:** GGBS can enhance the resistance of concrete to corrosion of embedded reinforcement, which is crucial for the long-term structural integrity of reinforced concrete.

**1.2.2 PUMICE STONE:**

Pumice is a highly porous, lightweight, and volcanic rock with unique mechanical properties that make it valuable for various industrial and commercial applications. The mechanical properties of pumice stone can vary somewhat depending on its specific source and processing.

**Fig 1.2 PUMICE STONE**

Some common mechanical properties of pumice stone include:

- **Low Density:** Pumice stone is known for its low density, which makes it exceptionally lightweight. Its low density is due to the numerous air-filled cavities in its structure. This property makes it buoyant in water and useful for applications such as lightweight concrete or as an abrasive in products where density is a consideration.
- **Lightweight:** Its low density contributes to its lightweight nature, making it easy to handle and transport
- **High Porosity:** Pumice stone has a very high porosity, with a significant portion of its volume composed of interconnected voids or pores. This porosity is a result of gas bubbles trapped during its formation. It can absorb and retain a considerable amount of water or other liquids, making it useful for water filtration.
- **Abrasive Properties:** Pumice is often used as an abrasive material due to its hardness and abrasive nature. It can be used in various forms, such as pumice powder or pumice stones, for scrubbing and exfoliating applications in personal care products, industrial cleaning, and polishing.
- **Hardness:** Pumice typically has a low Mohs hardness, which makes it relatively soft compared to many other natural minerals and rocks. This characteristic is advantageous for its use in personal care and polishing products where a gentler abrasive action is desired.
- **Insulating Properties:** Pumice has good insulating properties due to its low thermal conductivity. It is often used in lightweight concrete mixes for insulating purposes in construction.

- **Chemical Inertness:** Pumice is chemically inert, meaning it does not react with most chemicals. This makes it suitable for applications where a non-reactive, stable material is needed, such as in water treatment processes.
- **High Compressive Strength:** Pumice has reasonable compressive strength for its lightweight nature. This property can be beneficial in lightweight concrete, where it provides structural stability without the added weight of traditional aggregates.
- **Fire Resistance:** Due to its low thermal conductivity and insulating properties, pumice can provide fire-resistant qualities in certain applications. It is used in fire-resistant materials like lightweight fire bricks.

**1.3 SLAB:**

In building construction, a slab refers to a flat, horizontal structural element that provides a building's floors and roofs. Slabs are essential components in constructing multi-story buildings and other structures, offering a stable and load-bearing surface for occupants, furniture, equipment, and other loads. The design and construction of slabs involve considerations such as load-bearing capacity, span, materials used (commonly reinforced concrete), and adherence to building codes and standards.

**1.3.1. TYPES OF SLAB:**

There are different types of slabs, and the choice depends on factors such as the building design, loads, and architectural requirements. Common types include:

- **One-Way Slab:** Designed to span in one direction, usually supported by beams.
- **Two-Way Slab:** Designed to span in both directions, distributing loads in two perpendicular directions. Reinforcement is typically provided in both directions.
- **Flat Slab:** A type of two-way slab without beams, providing a flat soffit and simpler formwork.
- **Ribbed Slab:** Contains voids or ribs between the floor and the soffit, reducing the amount of concrete used and providing a lighter structure.
- **Waffle Slab:** Similar to a ribbed slab but with a waffle-like pattern of voids.
- **Post-Tensioned Slab:** Involves tensioning high-strength steel tendons after the concrete has set, enhancing the slab's performance.

### 1.3.2. SELECTION OF SLAB:

The one-way slab has reinforcements which help resisting bending moments from bending along the slab's long direction. One-way slabs deforms under load into a cylindrical surfaces. The direction that is normal to support on opposite sides of the rectangle is the structural action present in the one-way slab. Two-way slabs are selected for their structural efficiency and load-carrying capacity. They distribute the load in both directions, making them suitable for larger spans and heavy loads. They can also provide better resistance against deflection and cracking compared to one-way slabs.

### 1.3.3 ONE WAY SLAB:

One-way slabs are designed to span in one direction, typically supported by beams or walls on two opposite sides. They are commonly used in buildings where the spans are longer in one direction than the other.

These methods take into account factors such as the slab thickness, reinforcement layout, and the properties of the concrete and reinforcement materials. Overall, two-way slabs are a versatile and effective structural solution for various building applications.

Here are some key details about two-way slabs:

- **Load Distribution:** Two-way slabs are designed to distribute loads uniformly in both the longitudinal and transverse directions, which is why they are called "two-way." This means that they can support loads effectively over a larger area without excessive deflection.
- **Reinforcement:** Two-way slabs are typically reinforced with steel bars to enhance their load-carrying capacity. The reinforcement is placed in both directions, creating a grid-like pattern.
- **Design Methods:**

  **i)** Direct Design Method: In this method, you directly calculate the required reinforcement based on the loads and dimensions of the slab.

  **ii)** Equivalent Frame Method: This method simplifies the analysis of the slab by modeling it as a series of one-way slabs supported by frames. It's a more complex but accurate approach.

- **Shear and Moment Distribution:** Two-way slabs can experience bending moments and shearing forces. Designers need to consider these forces when determining the size and placement of reinforcement.
- **Materials:** Two-way slabs are often made of reinforced concrete. The quality of the concrete and steel used, as well as proper curing and construction techniques, are crucial for their durability and strength.
- **Supporting Elements:** Two-way slabs are usually supported by beams or walls at their edges. The way they are supported affects their design and structural analysis.
- **Span-to-Depth Ratio:** The ratio of the span (the distance between supports) to the depth of the slab is an important factor in design. A lower span-to-depth ratio results in a stiffer and stronger slab.
- **Deflection:** Two-way slabs are designed to limit deflection, ensuring that they don't sag excessively under load.
- **Building Codes and Standards**: Design and construction of two-way slabs should adhere to local building codes and standards to ensure safety and structural integrity.

**1.4 TESTS TO BE TAKEN:**

That's a comprehensive list of tests for evaluating the properties of GGBS and pumice stone, Preliminary tests like specific gravity, sieve analysis, water absorption, and setting time provide important baseline information. And for thermal performance, thermocouple testing will help monitor temperature changes and evaluate the insulation properties.

**1.4.1 PRELIMIARY TESTS:**

- For the preliminary tests, you can start by determining the specific gravity of the materials.
- Conduct a sieve analysis to assess the particle size distribution. Measure the water absorption capacity to understand how the materials interact with moisture.
- Finally, evaluate the setting time to determine the appropriate handling and curing time for your experiment. These tests will provide valuable insights into the characteristics of GGBS and pumice stone.

**1.4.1.1 SPECIFIC GRAVITY:**

The specific gravity test, also known as the relative density test, is a fundamental procedure in materials science and geotechnical engineering used to determine the density or mass of a material relative to the density of water. It is commonly employed for various purposes, including assessing the quality and composition of materials. Here's how the test is typically conducted:

- **Sample Preparation:** A representative sample of the material in question is collected. This material can be a solid, liquid, or powder.
- **Weighing:** The initial mass (weight) of the sample is measured accurately using a balance or scale. This weight is typically recorded in grams or another appropriate unit.
- **Submersion in Water:** The sample is then submerged in a container of water. The water used should be at a specified temperature, often 20 degrees Celsius (68 degrees Fahrenheit). The sample is left in the water for a sufficient period to ensure that it reaches the same temperature as the water.
- **Determining Apparent Mass:** After the sample has reached the water temperature, it is weighed while submerged in water. This weight is known as the "apparent mass" because it accounts for the buoyancy effect of the water.
- **Calculation:** The specific gravity is calculated by dividing the initial mass of the sample by the difference between the initial mass and the apparent mass (mass in water). This formula is expressed as:
- **Formula:**

$$\text{Specific Gravity} = \frac{\text{Initial Mass of Sample}}{\text{Initial Mass - Mass in Water}}$$

### 1.4.1.2 SEIVE ANALYSIS:

Sieve analysis is a laboratory test used to determine the particle size distribution of a granular material. It is commonly performed on materials like soil, sand, gravel, aggregates, and powdered substances like flour or cement. The primary purpose of this test is to evaluate the distribution of particle sizes within a sample, which can be crucial in fields such as construction, geology, agriculture, and materials science.

Here's how the sieve analysis test is typically conducted:

- **Sample Collection:** A representative sample of the material in question is collected. The sample should be sufficiently large to provide accurate results and should be dry if moisture content isn't a specific parameter of interest.

- **Selection of Sieves:** A set of standard sieves with varying mesh sizes is chosen. These sieves have a specific arrangement of openings (usually square or round) that allow particles of different sizes to pass through.
- **Stacking Sieves:** The sieves are stacked in descending order of mesh size, with the sieve with the largest openings at the top and the finest at the bottom. A collection pan is placed beneath the finest sieve.
- **Sieving Process:** The material sample is placed on the top sieve, and the stack of sieves is subjected to mechanical shaking or vibrational motion. This causes the particles to be sorted by size, with smaller particles passing through the finer sieves and larger particles retained on the coarser sieves.
- **Data Analysis:** The weight of material retained on each sieve is then used to calculate the percentage of material that falls within specific size ranges. This data is represented as a particle size distribution curve.
- **Formula:**

$$\text{Percent Finer} = \frac{\text{Total Mass of Sample}}{\text{Mass of Aggregate Retained on Sieve}} \times 100$$

### 1.4.1.3 WATER ABSORPTION

The water absorption test, also known as the water absorption capacity test, is a common laboratory procedure used to determine the ability of a material to absorb water. This test is important for various materials, including construction materials, ceramics, and porous substances.

The water absorption test is conducted as follows:

- **Sample Preparation:** A representative sample of the material is collected, and its initial weight (W1) is measured and recorded.
- **Immersion in Water:** The sample is completely immersed in water for a specified period of time, typically 24 hours. The water should be at a standard temperature, often room temperature (about 20°C or 68°F).
- **Removal from Water:** After the specified soaking period, the sample is removed from the water,

and its surface is gently dried with a clean, dry cloth to remove any excess surface water.

- **Weighing After Immersion:** The sample is weighed again (W2) immediately after removal from the water.
- **Calculation:** The water absorption capacity is calculated as:

$$\textbf{Water Absorption} = [(W2 - W1) / W1] \times 100$$

This formula expresses the percentage increase in weight due to water absorption. It indicates how much water the material has absorbed relative to its initial weight.

### 1.4.1.4 SETTING TIME:

The setting time test is a common laboratory test used to determine the time it takes for a cementitious material, such as cement or concrete, to change from a plastic, workable state to a rigid, hardened state. It is an important test to assess the behavior of construction materials and is often used to ensure that the material has the desired workability and strength characteristics. The setting time is typically divided into two main categories:

- **Initial Setting Time:** This is the time taken for the material to transition from a plastic state to a state where it can no longer be molded or worked with. It marks the beginning of the setting process.
- **Final Setting Time:** This is the time taken for the material to reach a state of hardness and strength that it can be considered fully set and suitable for use in construction or other applications.

### 1.4.2 THERMAL PERFORMANCE:

Thermocouple testing is a valuable method to assess the thermal performance of slabs. By monitoring temperature changes using thermocouples, you can analyze heat flow and evaluate the insulation properties of GGBS and pumice stone. It's an important step in your study to understand the impact of these materials on energy efficiency.

### 1.4.2.1 THERMOCOUPLE TESTING:

A thermocouple test refers to the measurement and evaluation of temperature using a thermocouple, which is a temperature sensor consisting of two different conductive metal wires joined at one end. The principle behind thermocouples is that they generate a voltage (electromotive force or EMF) when there is a temperature difference between the two ends of the wires. This voltage is proportional to the temperature difference, allowing for accurate temperature measurement.

Here's how a thermocouple test is typically conducted:

- **Selection of Thermocouple:** The appropriate type of thermocouple is selected based on the temperature range and environmental conditions of the application. There are various types of thermocouples, such as Type K, Type J, Type T, and many others, each with specific temperature ranges and characteristics.
- **Installation:** The thermocouple is installed in the location where temperature measurement is required. It can be attached to a surface, immersed in a fluid, or inserted into a gas or material.
- **Connection:** The free ends of the thermocouple wires are connected to a temperature measuring device, often a thermometer, temperature controller, or data acquisition system. The device measures the voltage generated by the thermocouple and converts it into a temperature reading.
- **Temperature Measurement:** As the temperature at the measurement point changes, the thermocouple generates a voltage proportional to that temperature difference. The measuring device displays or records the temperature based on the voltage reading and the specific calibration of the thermocouple type.

## 1.5 NEED OF THE PROJECT:

- Evaluating the thermal performance of slabs using GGBS and pumice stone and Testing the effectiveness of these materials in enhancing insulation properties.
- Monitoring temperature changes on the slab using thermocouples and Analyzing heat flow and thermal transfer within the slab.
- Assessing the impact of the experiment on energy efficiency and Considering the use of a hollow two-way slab with a cavity for improved insulation.
- Exploring the benefits of cooling slabs in achieving energy-efficient building practices.
- GGBS and pumice stone are used to reduce industrial waste and $CO_2$ emissions
- Hollow core slab not only reduces building costs it also reduces the overall weight of the structure.

## 1.6 OBJECTIVE OF THE PROJECT:

- To investigate how the incorporation of GGBS and pumice stone in the concrete mix can enhance the thermal performance and efficiency of the slab.
- To measure the Mechanical Performance of Concrete by using GGBS and pumice Stone.

- To make light weight concrete slab and to improve its insulation properties

## 1.7 SCOPE OF THE PROJECT:

- To study the effect of mixing GGBS (ground-granulated blast furnace slag) and pumice stone and how it improves the thermal performance and insulation properties of reinforced concrete slabs.
- To determine the mechanical properties of GGBS and pumice stone in various stages such as 7days, 14 days and 28 days
- To ensure that the data collected from the thermocouple testing will provide valuable insights into the heat flow and thermal transfer within the slab.

## 1.8 ADVANTAGES:

- **Improved Energy Efficiency:** By incorporating GGBS and pumice stone into the slab, you can enhance its insulation properties. This means less heat loss or gain, resulting in reduced energy consumption for heating and cooling. It's a win-win for both your wallet and the environment.
- **Sustainable Construction:** GGBS is a byproduct of the steel industry, and using it reduces the demand for traditional cement production, which is a significant source of carbon emissions. Pumice stone, being a natural volcanic material, is also an eco-friendly choice. By opting for these materials, you're promoting sustainable building practices and contributing to a greener future.
- **Enhanced Comfort:** The improved thermal performance of the slab means better temperature regulation indoors. You can say goodbye to uncomfortable drafts and temperature fluctuations. Whether it's a hot summer or a chilly winter, your building will provide a cozy and comfortable environment for its occupants.
- **Longevity and Durability:** GGBS and pumice stone can enhance the durability of the slab, making it more resistant to cracking and other structural issues. This means your building will stand strong for years to come, saving you maintenance costs in the long run.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1. LITERATURE STUDIES BASED ON

Over the last decade much research has been conducted to compare the various characteristics and mechanical properties of ggbs and pumice stone. Various literature studies have been made to know how the thermal performance of various slab have been tested and how its improved according to insulation of various materials.

**1. Thermal performance of different construction materials used in New Zealand dwellings comparatively to international practice – 2023 by Yazeed Al Radhi, Krishan U Roy, Hao Liang, Kushal Ghosh , G. Charles Clifton , James B.P. Lim, et.al.,**

The majority of small to medium residential dwellings in New Zealand are constructed using timber, which makes up over 90% of the market share of structural materials in construction. Over the last decade, attention has been scoped to new construction techniques such as cold-formed steel homes, concrete masonry with insulating fillers, and, more recently, precast concrete homes. The materials reviewed include timber, cold-formed steel, concrete, bricks, phase change materials, and novel systems. The review of over 190 journal papers has indicated that New Zealand has yet to adopt recent technologies, such as concrete for typical construction materials, phase change material for new materials, and thermally activated building systems for new systems. Composite materials are also the subject of ongoing research, showing great potential for thermal performance when used in insulation products. The paper summarizes conclusive points in the reviewed literature and their applicability to the New Zealand construction industry.

**2.The flexural behavior of hollow core concrete slabs with different shape – 2023 by Samer Saeed, Sura Alkhafaji, Jasim Al-kaabi, et.al.,**

Hollow slabs are slabs of reinforced concrete in which voids allow the concrete to be reduced in size. This type of slab results in reduced raw materials Consumption and increased insulating properties to achieve sustainability goals. This paper reported an experimental research program focused on the study of the bending behaviour of the elements of hollow slabs of normal-strength concrete. Three models of the one-way concrete slab were cast, It had dimensions of 1020 mm length, 420 mm width, and 100 mm thickness. The results showed that the bearing capacity of the circular hollow core slab is higher by 12% compared to the square hollow core slab according to the type of voids and both of holes made the hollow core slab with a decrease in load capacity of 11% to 25% when compared to the solid slab. The solid slab has lower deflection value compared to the two hollow slabs whose weight is reduced by 23% compared to the solid slab.

**3. Structural Performance of ferrocement beams incorporating longitudinal filled with lightweight concrete – 2023 by Yousry B. Shaheen, Boshra A. Eltaly, Shaimaa G. Yousef & Sabry Fayed, et.al.,**

In this study, 10 ferroconcrete concrete (FC) beams with lightweight cores reinforced with welded steel mesh as a shear reinforcement were evaluated under three-point bending tests along with two conventionally normal-weight concrete (NWC) beams. Expanded polystyrene and lightweight aerated autoclaved brick wastes were used to create lightweight core concrete. This study was done on the tested beams' ductility index, failure modes, first cracking loads and associated deflections, and ultimate loads besides corresponding deflections. Experimental results showed that the use of FC, various filling materials, and welded steel meshes in place of traditional stirrups enhanced the ultimate load by 36.6–107.3%, the ultimate deflection by 6–272%, and the ductility by 89–1155% when referenced to a control NWC beam. When the holing ratio increased from 10 to 20%, the ductility of FC beams was enhanced by 307.7%. Proposed equations were developed to predict the ultimate load and bending moment capacity of FC beams while taking into account the compressive strength of the beam body and filling material, the holing ratio, the tensile reinforcement ratio, and the volume fraction of the steel mesh.

**4. Comparative Study of the Strength Properties of the Concrete with Partial Replacement of the Coarse Aggregate with Pumice and Over Burnt Bricks – 2023 by K Sumanth Kumar, Manoj Kumar, K Sri Vishnu, S Venka Reddy, et.al.,**

Concrete is the universally accepted material for its adverse properties with high usage of the concrete for all type of the works in the world, it leads to depletion of natural resources like river sand, and granite. Which are the components of the concrete as fine aggregate and coarse aggregate in this project M30 grade concrete is taken in which 10%, 20%, & 30% of coarse aggregate is replaced with over burnt bricks and 10%, 20% and 30% of coarse aggregate replaced with pumice by volume. And the compressive, flexural and split tensile strength properties at 7, 28 & 56 days and the unit weights of the concrete compared. In order to safe guard the natural resources, alternate material like over burnt bricks, pumice considered in the present project.

**5. Installation of Concrete with GGBS as a Substitute for Cement – 2023 by Ashish Dhaka, Er. Abhishek Arya.et.al.,**

In this study, it is believed that the high cost of concrete is due to the scarcity and high cost of its elements, which has led to the production of concrete being done using materials that are economically feasible alternatives. As a result, the price of concrete has increased significantly. This particular technical study's major purpose is to evaluate the qualities of concrete that has had a portion of its cement replaced with ground granulated blast furnace slag (GGBS). This is the abbreviated form of the material's full name: ground granulated blast furnace slag. This conversation will focus on the application of GGBS in concrete, as well as the positives and negatives associated with using it as a component. It is proposed that a new technique be created for the construction of a self-compacting concrete (SCC) mix that includes large volumes of ground granulated blast furnace slag (ggbs) as a material that may substitute cement. This would be done in order to fulfill the requirements of the American Concrete Institute (ACI). The investigation that was carried out to plan and validate this strategy concentrated primarily on three distinct facets. This allows the model to be used to determine the plastic viscosity of SCC, which was the focus of this particular investigation.

**6. An experimental study of thermal performance of 3D printed concrete slabs 2023 by Dhrutiman Dey, Biranchi Panda, et.al.,**

This work presents the most important advances in 3D printing, specifically the thermal performance of 3D printed concrete slabs with potential use as walls elements. One of the principal factors restricting widespread adoption of 3D printed concrete is the lack of thermal insulation, which needs an immediate attention. It is with this backdrop that this paper conducts a preliminary investigation on the thermal performance of 3D printed slabs containing two different cavity patterns with and without insulation material. The 3D printed solid slab has shown slight reduction in inside surface temperature (1°C) than casted slab owing to the cold joints between the printed layers. Compared to solid printed slab, 3D printed hollow slab with two and three identical cavities have shown 6°C and 4 °C higher inside surface temperature respectively. However, with added insulation, the inside temperature of printed hollow slabs was found to be similar to the solid slab due to increased insulation capacity. The delayed heat transfer resulted in higher outside surface temperature for the 3D printed hollow insulated slabs.

**7. Experimental Study on the Mechanics and Impact Resistance of Multiphase Lightweight Aggregate Concrete – 2022 by Jian Meng, Ziling Xu, Zeli Liu, Song Chen, Chen Wang, Ben Zhao, An Zhou.et.al.,**

Multiphase lightweight aggregate concrete (MLAC) is a green composite building material prepared by replacing part of the crushed stone in concrete with other coarse aggregates to save construction ore resources. The results of a comprehensive performance evaluation of four multiphase light aggregate concretes are coal gangue ceramsite concrete (CGC) > fly ash ceramsite concrete (FAC) > coral aggregate concrete (CC) > pumice aggregate concrete (PC). The compressive, flexural and splitting tensile strength and the impact energy consumption increased by 29.25%, 19.93%, 13.89% and 8.2%, respectively, it also compared with the reference concrete. The impact test results of MLAC obeyed the distribution law of the two-parameter Weibull distribution model, which can be used to predict and describe the impact life of multi-phase lightweight aggregate concrete under different failure probabilities. The impact resistance of MLAC under multiple factors was analyzed in depth. The analysis showed that the influence of the aggregate replacement rate on the impact resistance of multi-phase lightweight aggregate concrete was higher than the probability of failure or the failure of the concrete specimens.

**8. A Comprehensive Review on the Ground Granulated Blast Furnace Slag (GGBS) in Concrete Production - 2022 by Jawad Ahmad, Karolos J. Kontoleon, Ali Majdi, Muhammad Tayyab Naqash, Ahmed Farouk Deifalla, Nabil Ben Kahla, Haytham F. Isleem and Shaker M. A. Qaidi.et.al.,**

With respect to the mechanical properties, durability and thermal behaviour ground-granulated blast-furnace slag (GGBS) delineates a rational way to develop sustainable cement and concrete. In addition of Ordinary Portland Cement (OPC), the durability of concrete containing GGBS cement is shown to be superior. Previous studies have suggested different optimum percentages of GGBS varying from 10 to 20%, depending on the source of GGBS. concrete mix design and particle size of GGBS. Physical assets of GGBS, such as specific gravity and bulk density of concrete. are approximately equal to the cement. Furthermore, the SEM of GGBS shows the angular and rough surface texture of GGBS particles. The chemical composition of GGBS shows that it can be used as a cement replacement up to a certain extent. The heat of hydration decreased with the substitution of GGBS as the pozzolanie reaction proceeds slowly as compared to the hydration of cement. The workability of concrete is reduced by replacing OPC with GGBS due to the larger surface area and rough surface texture of GGBS particles. Therefore. plasticizer was recommended particularly for the higher dose of GGBS. The optimum dose is important for better mechanical and durability aspects of concrete. Different researchers reported different values of optimum quantity of GGBS due to varying sources of GGBS.

**9. Analysis of thermal-induced spalling tests on high to ultra-high performance concrete subjected to standard fire – 2021 by Hadjira Bensalem, Samira Djaknoun, Evariste Ouedraogo, Ramane Amrouche.et.al.,**

Thermal instability of high-performance concretes is a topical subject. Research in this area uses experimental and modelling approaches which have two main aims: understanding the mechanisms of thermal instabilities and attempting to predict their occurrence. This study falls into the first category. It examines the spalling behaviour of instrumented slab specimens of high-performance concrete and ultra-high-performance concrete which are equipped with thermocouples and subjected to standard fire thermal cycles on their undersides. During testing, all of the specimens suffered explosive thermal-induced spalling. The bursts were generally accompanied by audible sound production, and often manifested as sudden variations in the measured temperature-time curves, meaning that their occurrence and progression could be traced. Some of the thermocouples embedded in the concrete displayed temperature curves with a plateau at 100 °C; this reflects the presence of liquid and water vapour, and suggests a water saturation front in the concrete.

**10. Computational assessment of thermal performance of 3D printed concrete wall structures with cavities structures 2021 by Hannelie Marais, Heidi Christen, Seung Cho, Wibke De Villiers, Gideon Van Zijl.et.al.,**

This paper investigates the thermal performance of two candidate 3D printed cement-based façade construction materials, i.e. lightweight foam concrete and high-performance concrete, distinguished by density (1400 versus 2100 kg/m$^3$) and thermal conductivity (0.37 versus 1.1 W/mK). For the element considered here, a 6.6% lower internal temperature is calculated when cavity radiation and convection are not considered. Neglecting cavity radiation and to a lesser extent cavity convection may significantly under-estimate heat transfer through a 3D concrete printed walling system. Investigation of the number and size of cavities in the lightweight foam concrete element reveals that a solid lightweight foam concrete wall performs better thermally than a 3D printed lightweight foam wall section with large, wide cavities for economic material use, however, the introduction of reduced cavity widths leads to improved thermal insulation.

## 2.2. SUMMARY OF LITERATURE REVIEW

- It is proposed that a new technique be created for the construction of a self-compacting concrete (SCC) mix that includes large volumes of ground granulated blast furnace slag (ggbs) as a material that may substitute cement.
- With respect to the mechanical properties, durability and thermal behavior. ground-granulated blast-furnace slag (GGBS) delineates a rational way to develop sustainable cement and concrete.
- They also considered several indicators such as the interior maximum temperature reduction (MTR), decrement factor (DF) and time lag (TL) to compared among tested bricks in addition to the thermal behaviour during melting and solidification of PCM.
- They reduced over 90% of the market share of structural materials in construction. And Despite progress made in recent times, New Zealand homes are still classified as being cold and inefficient in terms of thermal performance when compared to other countries experiencing similar climate.
- The finite element computational strategy is validated by reasonably accurate simulation of published heat flow experimental results, incorporating potentially dominating cavity radiation and convection.

# CHAPTER 3
# METHODOLOGY

## 3.1. GENERAL

Materials used in this study were chosen according to the specifications that meets the requirement of appropriate standards as well as the objective of this research. The study on ggbs and pumice stone focuses on the improvement of the strength and thermal performance of slab that relates with microstructural behavior of specimen.

## 3.2. METHODOLOGY FOR THESIS WORK

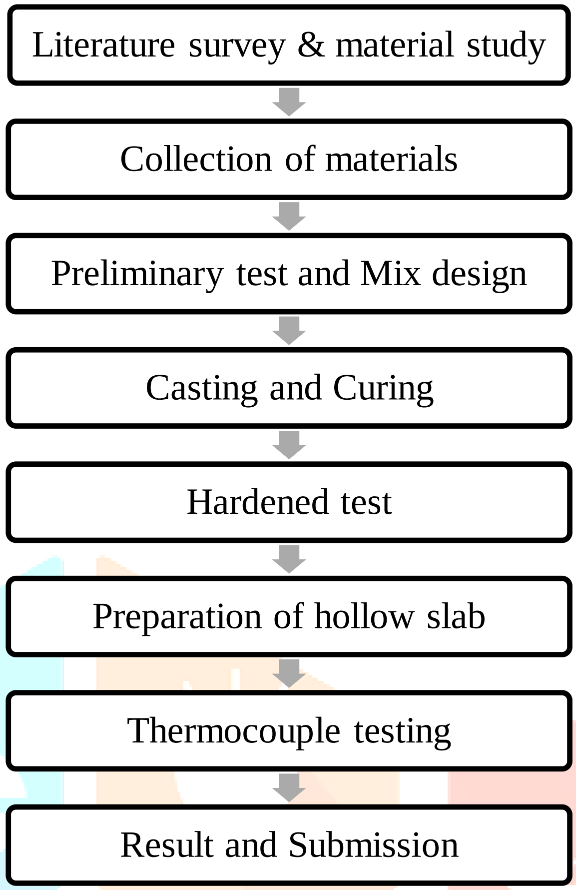


**Fig. 3.1. Flow Chart of Work Methodology**

# CHAPTER 4

# MATERIALS COLLECTION

## 4.1 CEMENT:

A cement is a binder, a substance used for construction that sets, hardens, andadheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete

**Fig 4.1 CEMENT**

### 4.1.1 Fineness of Cement:

The size of the particles of the cement is its fineness. The required fineness of good cement is achieved through grinding the clinker in the last step of cement production process. As hydration rate of cement is directly related to the cement particle size, fineness of cement is very important.

### 4.1.2 Soundness of Cement:

Soundness refers to the ability of cement to not shrink upon hardening. Good quality cement retains its volume after setting without delayed expansion, which is caused by excessive free lime and magnesia.

### 4.1.3 Strength of Cement:

Three types of strength of cement are measured compressive, tensile and flexural. Various factors affect the strength such as water-cement ratio, cement-fine aggregate ratio, curing conditions, size and shape of a specimen, the manner of molding and mixing, loading conditions and age.

### 4.1.4 Setting Time of Cement:

Cement sets and hardens when water is added. This setting time can vary depending on multiple factors, such as fineness of cement, cement-water ratio, chemical content, and admixtures. Cement used in construction should have an initial setting time that is not too low and a final setting time not too high. Hence, two setting times are measured:

- Initial set: When the paste begins to stiffen noticeably (typically occurs within 30-45 minutes)

- Final set: When the cement hardens, being able to sustain some load (occurs below 10 hours)

### 4.1.5 Heat of Hydration:

When water is added to cement, the reaction that takes place is called hydration. Hydration generates heat, which can affect the quality of the cement and also be beneficial in maintaining curing temperature during cold weather. On the other hand, when heat generation is high, especially in large structures, it may cause undesired stress.

### 4.1.6 Bulk Density:

When cement is mixed with water, the water replaces areas where there would normally be air. Because of that, the bulk density of cement is not very important. Cement has a varying range of density depending on the cement composition percentage. The density of cement may be anywhere from 62 to 78 pounds per cubic foot.

### 4.1.7 Specific Gravity (relative density):

Specific gravity is generally used in mixture proportioning calculations. Portland cement has a specific gravity of 3.15, but other types of cement (for example, portland-blast-furnace-slag and portland-pozzolan cement) may have specific gravities of about 2.90.

### 4.1.8 Compressive Strength:

It is the most common strength test. A test specimen (50mm) is taken and subjected to a compressive load until failure. The loading sequence must be within 20 seconds and 80 seconds.

## 4.2 COARSE AGGREGATE:

Coarse aggregates are a construction component made of rock quarried from ground deposits. Examples of these kinds of ground deposits include river gravel, crushed stone from rock quarries, and previously used concrete

**Fig 4.2 COARSE AGGREGATE**

### 4.2.1 Composition:

Aggregate consisting of such materials that can chemically react with alkalis in cement and cause excessive expansion, cracking, and deterioration of concrete mix should never be used. Therefore it is necessary to test aggregates to ensure whether there is the presence of any such constituents in aggregate or not.

### 4.2.2 Size and Shape:

The size and shape of the aggregate particles greatly influence the quantity of cement required in concrete mix and hence ultimately the economy of concrete. IS: 456 recommended the below choose the maximum size of coarse aggregate to be used in PCC and RCC mix. The maximum size of coarse aggregate in concrete making should be less than,

- 1/4th of the minimum dimension of the RCC member
- 1/5th of the minimum dimension of the RCC member.

### 4.2.3 Surface Texture:

The development of hard bond strength between coarse aggregate and cement paste depends upon the surface roughness, surface texture, and porosity of coarse aggregate. In case the surface is but porous, the maximum bond strength will develop in concrete. In porous surface aggregates, the bond strength of aggregate increase as cement paste start setting.

### 4.2.4 Specific Gravity:

The ratio of the weight of oven-dried aggregate which is kept for 24 hours at a temperature of 100 to 100°C, to the weight of an equal volume of water displaced by saturated dry surface aggregate is called the specific gravity of aggregates. Specific gravity is mainly oh two types:

- Apparent specific gravity
- Bulk specific gravity

The specific gravity of major aggregates falls within the range of 2.6 to 2.9.

**4.2.5 Bulk Density:**

Bulk density of aggregate can be defined as the weight of coarse aggregate required to fill the unit volume of the container. It is generally expressed in kg/liter. Bulk density of aggregates particles depends upon the following 3 factors which are:

- Degree of compaction
- Grading of aggregates
- The shape of aggregate particles

**4.2.6 Voids:**

The empty spaces left between coarse aggregate particles are known as voids. The volume of voids equals the difference between the total volume of the aggregate mass & the volume occupied by the particles alone.

**4.2.7 Porosity and Absorption:**

The holes produced in the rocks at the time of the solidification of the molten magma, due to air bubbles, are known as pores. Water absorption may be defined as the difference between the weight of very dry aggregates and the weight of the saturate aggregates with the surface dry condition.

**4.2.8 Bulking of Sand:**

It can be defined as an increase in the bulk volume of the quantity of sand in a moist condition over the volume of the same quantity of dry or completely saturated sand. The proportion/ratio of the volume of moist sand due to the volume of sand when dry is called a bulking factor

### 4.3 FINE AGGREGATES :

When the aggregate is sieved through 4.75mm sieve, the aggregate passed through it is called as fine aggregate. Nature sand is generally used as fine aggregate, silt and clay also come under this category. The soft deposit consisting of sand, silt and clay is termed as loam. The purpose of fine aggregate is to fill the voids, on coarse aggregate and to act as workability agent.

**Fig 4.3 FINE AGGREGATE**

#### 4.3.1 Size:

The size of fine aggregate should be equal to or less than 4.75 mm.

#### 4.3.2 Shape:

Sand of irregular nodular shape is preferable to completely round grained sand. Shape of the aggregate plays a more important role in coarse aggregate rather than fine aggregate.

#### 4.3.3 Specific Gravity:

It is the ratio of density of aggregate to the density to water.

#### 4.3.4 Bulk Density:

It is the ratio of weight of aggregate (including voids) to its unit volume. The phenomenon of increase in sand volume due to the increase of moisture content

#### 4.3.5 Moisture Content (% water absorption):

It is the ratio of weight of water absorbed to weight of dry aggregate; measured in percentage.

### 4.3.6 Bulking:

Bulking of sand means increase in volume of sand due to surface moisture.

### 4.3.7 Surface Texture:

Surface texture is the property which defines whether a particular surface is polished, dull, smooth or rough. Generally rough surface aggregate is preferable to smooth aggregates.

### 4.3.8 Soundness:

Soundness means the ability of aggregates to resist excessive change in volume as a result of change in physical condition.

### 4.3.9 Durability:

Some of the aggregate contain reactive silica, which reacts with alkalies present in cement and hence reduce the durability. Durability is the ability to resist against the weathering actions, chemical attack, etc.

### 4.3.10 Silt Content:

It is defined as the total quantity of fine particles of deleterious materials having particle from 0.06 mm to 0.002 mm present in sand.

## 4.4 GGBS:

Ground Granulated Blast Furnace Slag (GGBS) is a cement substitute that improves durability. GGBS, used in a concrete mix, offers a good alternative to traditional Portland Cement. Ground Granulated Blast Furnace Slag (GGBS) offers great durability, reducing the likelihood of concrete thermal cracking, and it improves concrete’s resistance to damage from alkali-silica reaction, sulphates and chlorides.

**Fig 4.4 GGBS**

### 4.4.1 Hydraulic Property:

GGBS exhibits hydraulic properties, meaning that it can react with water and calcium hydroxide to form compounds with cementitious properties. It contributes to the strength and durability of concrete.

### 4.4.2 Fineness:

GGBS is finely ground, typically having a similar particle size distribution to that of Portland cement. The fine particles contribute to the material's pozzolanic and cementitious properties.

### 4.4.3 Pozzolanic Activity:

GGBS is pozzolanic, meaning it can react with calcium hydroxide in the presence of water to form additional cementitious compounds. This contributes to the strength and durability of concrete by reducing permeability.

### 4.4.4 Sustainability:

The use of GGBS in concrete is considered environmentally friendly as it utilizes a byproduct of industrial processes, reducing the need for landfill disposal and the consumption of natural resources.

### 4.4.5 Color:

GGBS often imparts a lighter color to concrete compared to traditional Portland cement, which can be aesthetically desirable in architectural applications.

## 4.5 PUMICE STONE:

Pumice is a volcanic rock that consists of highly vesicular rough textural rock glass. It generally light colored. It is created when gas-saturated liquid magma erupts like a carbonated drink and cools so rapidly that the resulting foam solidifies into a glass full of gas bubbles. Pumices from silica-rich lavas are white, those from lavas with intermediate silica content are often yellow or brown, and rarer silica-poor that are black.

**Fig 4.5 PUMICE STONE**

### 4.5.1 Name origin:

The names derived from the Latin word "pumex" which means foam and through history has been given many names because its formation was unclear.

### 4.5.2 Neutral pH:

Pumice stone typically has a neutral pH, making it non-acidic. This property is advantageous when used in skincare products, as it is less likely to cause irritation.

### 4.5.3 Availability:

Pumice deposits are found in several volcanic regions around the world, contributing to its widespread availability.

### 4.5.4 Natural Appearance:

Pumice stones often have a distinctive light color, and their natural appearance makes them aesthetically pleasing for decorative uses.

### 4.5.5 Thermal Stability:

Pumice stone exhibits good thermal stability, making it suitable for use in high-temperature applications, such as lightweight aggregates in refractory materials.

# CHAPTER 5

# PRELIMINARY TESTS

## 5.1 GENERAL:

The experimental investigation consists of collection of materials, testing of material to know its characteristics and properties, whether the materials has its optimum values to use in concrete mixing, casting of specimens is done to determine its mechanical properties.

## 5.2 TEST ON CEMENT:

The major test Specific gravity of cement is taken, more formally known as relative density, is a measure of the density of a substance in comparison to the density of water.

| TEST CONDUCTED | VALUES OBTAINED |
|---|---|
| Specific Gravity | 3.14 |

**Table 5.1 SPECIFIC GRAVITY OF CEMENT**


**Fig 5.1 SPECIFIC GRAVITY OF CEMENT**

## 5.3 TEST ON GGBS:

The major test Specific gravity of GGBS (Ground Granulated Blast Furnace Slag) is taken, more formally known as relative density, is a measure of the density of a substance in comparison to the density of water.

| TEST CONDUCTED | VALUES OBTAINED |
|---|---|
| Specific Gravity | 2.86 |

**Table 5.2 SPECIFIC GRAVITY OF GGBS**



**Fig 5.2 SPECIFIC GRAVITY OF GGBS**

## 5.4 TEST ON FINE AGGREGATE:

River sand was used as fine aggregate in the experimental investigation. The specific gravity (G) of soil grains or solids usually called soil is the ratio of the weight in air of the given volume of dry soil solids at a states temperature to the weight in air of an equal volume of distilled water at a stated temperature.

Properties of fine aggregate determine by the following tests:

- Specific gravity test
- Sieve analysis test

### 5.4.1 SPECIFIC GRAVITY OF FA:

In concrete technology, specific gravity of aggregates is made use of in design calculation of concrete mixes with the specific gravity of each constituent known, its weight can be converted into solid volume and hence a theoretical yield of concrete per unit volume can be calculated.

**Specific gravity of fine aggregate = 2.66**



**Fig 5.3 SPECIFIC GRAVITY OF FINE AGGREGATE**

### 5.4.2 SEIVE ANALYSIS OF FA:

Good grading implies that a sample of aggregate contains all standard fractions of aggregate in required proportion such that the sample contains minimum voids. The apparatus used to conduct a sieve analysis on fine aggregate are set off required IS Sieves, a receiver, fine brush and balance.

**Seive analysis or gradation of Fine aggregate = 3.60**


**Fig 5.4 SEIVE ANALYSIS OF FA**

## 5.5 TEST ON PUMICE STONE:

The major test Specific gravity of Pumice stone is taken, more formally known as relative density, is a measure of the density of a substance in comparison to the density of water.

| TEST CONDUCTED | VALUES OBTAINED |
|---|---|
| Specific Gravity | 2.52 |

**Table 5.2 SPECIFIC GRAVITY OF PUMICE STONE**

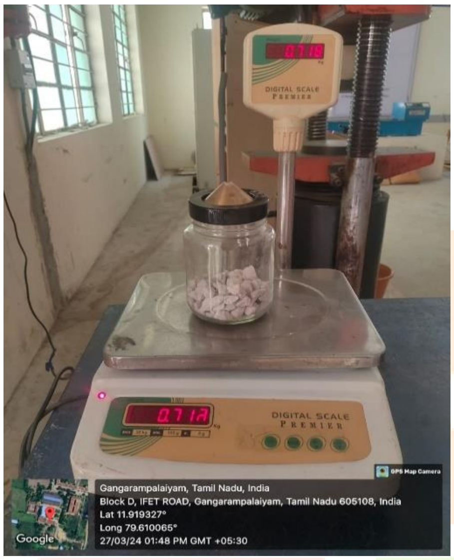



**Fig 5.5 SPECIFIC GRAVITY OF PUMICE STONE**

## 5.6 TEST ON COARSE AGGREGATE:

Two sizes of coarse aggregate were used in this project i.e. 20mm graded aggregate as per IS: 383 and 10mm graded aggregate as per IS: 383 was used. The major tests taken in this material:

- Gradation of coarse aggregate
- Specific gravity
- Moisture content

### 5.6.1 SPECIFIC GRAVITY OF CA:

To determine the specific gravity of coarse aggregates, the apparatus used are pycnometer, standard ramming rod and weighing balance.

**Specific Gravity of Coarse aggregate = 2.68**



**Fig 5.6 SPECIFIC GRAVITY OF COARSE AGGREGATE**

## 5.6.2 GRADATION OF COARSE AGGREGATE:

Good grading implies that a sample of aggregate contains all standard fractions of aggregate in required proportion such that the sample contains minimum voids. A sample of the well graded aggregate containing minimum voids will require minimum paste to fill up the voids in the aggregates.

The apparatus used to conduct a sieve analysis on fine aggregate are set of required IS Sieves, a receiver, fine brush and balance.

**Gradation of Coarse aggregate = 5.43**

**Fig 5.7 SEIVE ANALYSIS OF CA**

### 5.6.3 MOISTURE CONTENT:

Water absorption gives an idea of strength of aggregate. Aggregates having more water absorption are more porous in nature and are generally considered unsuitable unless they are found to be acceptable based on strength, impact and hardness tests.

**Water Absorption on Coarse aggregate = 0.5%**

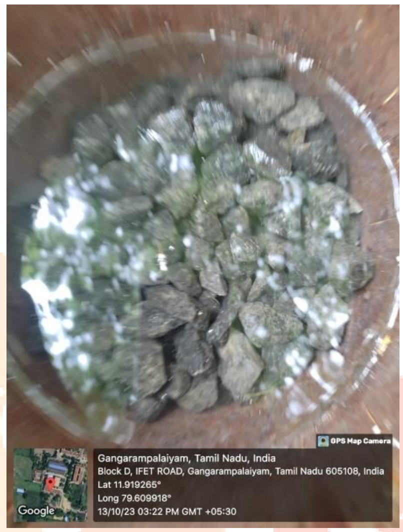


**Fig 5.8 WATER ABSORPTION ON CA**

# CHAPTER 6

# MIX DESIGN

### 6.1 GENERAL:

Mix design is the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible.

### 6.2 DESIGN STIPULATIONS:

Characteristics strength required= 35 N/mm$^2$

Grade of concrete = M35

Max nominal size of aggregate= 20mm

Min cement content = 300kg/m$^3$

Max Water cement ratio = 0.45

Max cement content = 450 kg/m$^3$

Workability (slump) - 80mm

Degree of supervision= good

Exposure condition = mild

### 6.3 TEST DATA FOR MATERIAL:

Type of cement = OPC – 43 grade

Type of aggregate – Crushed angular aggregate

Specific gravity of coarse aggregate = 2.68

Specific gravity of fine aggregate = 2.66

Specific gravity of cement = 3.14

Specific gravity of GGBS = 2.86

Specific gravity of pumice stone = 2.52

Water absorption of coarse aggregate= 0.5%

Water absorption of fine aggregate= 1%

### 6.4 TARGET MEAN STRENGTH:

Mean target strength = fck + ks

= 35+1.65(4)

= 41.6 N/mm$^2$

### 6.5 WATER CEMENT RATIO:

Cement = 43 grade

As per Is 456-2000,

Max water cement ratio = 0.55 (mild exposure)

Hence adopt = 0.4

Therefore, Water cement ratio = 0.45

### 6.6 DETERMINATION OF WATER CONTENT:

For 20 mm nominal size coarse aggregate, and sand zone II

Max Water content per m of concrete = 186 kg

Adjustment of w/c ratio for 80 mm slump, compaction factor and sand belonging to zone II

Required water content = 186 + [(6/100) x (186)]

= 197 kg /m$^3$

### 6.7 DETERMINATION OF CEMENT CONTENT:

Water cement ratio =0.45,

Weight of cement = water content / water cement ratio

= 197/0.45

= 438 kg

## 6.8 MIX PROPORTION OF FINE AND COARSE AGGREGATE:

Proportion of volume of CA corresponding to 20 mm size aggregate and FA zone II cement ratio of 0.45 to 0.60

Volume of Coarse Aggregate = 0.62 kg/$m^3$

Hence, for w/c ratio of 0.45,

Corrected proportion of volume of Coarse Aggregate = 0.56 kg/$m^3$

Volume of Fine Aggregate = 1 – Volume of Coarse Aggregate

= 1- 0.56

= 0.44 kg/$m^3$

## 6.9 MIX CALCULATION:

The mix calculation per unit volume of concrete shall be as follow :

1) Volume of concrete =1$m^3$

2) Volume of cement = (mass of cement/specific of cement)x1/1000

= (438/3.14)x1/1000

= 0.139 $m^3$

3) Volume of water = (mass of water/specific of water)x1/1000

=(197/1)x1/1000

= 0.197 $m^3$

Volume of all in aggregate = 1-(0.139+0.197)

=0.664 $m^3$

4) Mass of coarse aggregate = 0.664 x0.56x2.68x1000

= 996.5 kg

5) Mass of fine aggregate = 0.664x0.44x2.66x1000

= 777.15 kg

## 6.10 MIX PROPORTION:

Mix ratio of M35 grade concrete = 1:2.4

| Cement (kg/ $m^3$) | FA (kg/ $m^3$) | CA (kg/ $m^3$) | WATER (l/$m^3$) |
|---|---|---|---|
| 438 | 876 | 1752 | 0.45 |

**Table 6.1 MIX PROPORTION**

### 6.11 PARTIAL REPLACEMENT:

Incorporating GGBS (30%, 40%, 50%) for the replacement of cement and pumice stone (15%, 20%, 25%) for the replacement of coarse aggregate

| Cement (kg/ $m^3$) | GGBS 40% (kg/ $m^3$) | FA (kg/ $m^3$) | CA (kg/ $m^3$) | Pumice stone 20% (kg/ $m^3$) | WATER (litre/$m^3$) |
|---|---|---|---|---|---|
| 262.8 | 175.2 | 876 | 1402 | 350 | 0.45 |

**Table 6.2 MIX DESIGN**

# CHAPTER 7

# CASTING AND CURING

### 7.1 GENERAL:

The formwork is prepared to create the shape of the slab, reinforcement bars are placed to provide strength, concrete is poured into the formwork and levelled and the concrete needs time to cure and gain strength. Curing involves keeping the concrete moist and protected from drying out too quickly.

### 7.2 REINFORCEMENT:

- Reinforcement is produced in slabs to enhance their strength and durability
- It helps to distribute the local evenly and prevent cracking or failure
- It adds structural integrity to the slab

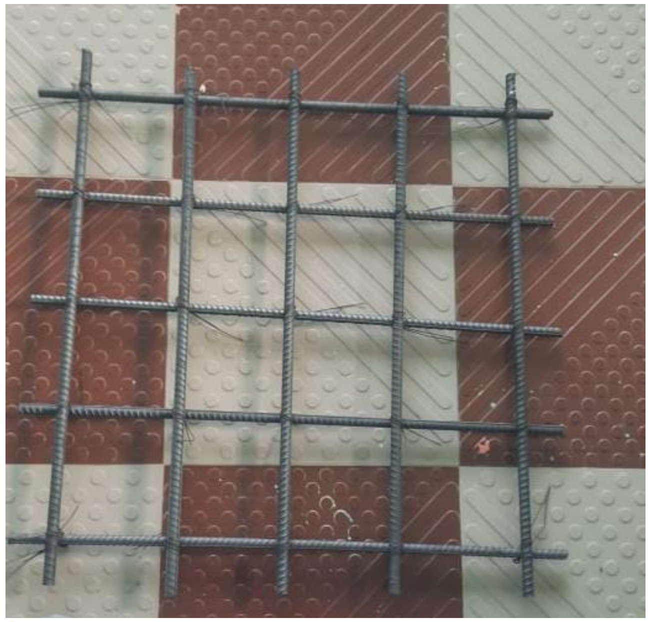

**FIG 7.1 REINFORCEMENT**

## 7.3 MIXING OF CONCRETE:

The mixing refers to mixing of cement, fine aggregate, coarse aggregate, partial replacement of 40% of GGBS and 20% of Pumice stone and water.


**FIG 7.2 MIXING**

## 7.4 CASTING:


FIG 7.3 CASTING

## 7.5 FINISHING:


FIG 7.4 FINISHING

## 7.6 CURING:


**FIG 7.5 CURING**

# CHAPTER 8

# CONCLUSION

## 8.1 CONCLUSION:

The study presented in this paper aimed to investigate the thermal energy behaviour in building a slab and reducing the weight of the slab and increasing the performance of the slab using cost effective materials with varying insulation properties. A comprehensive numerical investigation was conducted which involved the development and validation of heat transfer in the slab from the literature review study. We have developing the cost effective a highly performance and heat resistance slab for residential house building, for which the preliminary tests like specific gravity test, sieve analysis, etc are completed for using these materials.

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