EXPERIMENTAL INVESTIGATIONS ON FOAMED CONCRETE

A

PROJECT REPORT

Submitted in partial fulfilment of the requirements for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

of

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to

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WAKNAGHAT, SOLAN – 173234
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May– 2023

STUDENT'S DECLARATION

We hereby declare that the work presented in the project report entitled **"Experimental investigations on foamed concrete"** submitted for partial fulfilment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of our work carried out under the supervision of **Dr. Tanmay Gupta**.This work has not been submitted elsewhere for the reward of any other degree/diploma. We are fully responsible for the contents of this project report.

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CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"Experimental investigations on foamed concrete"**in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat**is an authentic record of work carried out by **Arjun Verma (191616) and AstikPrashar (191617)**during a period from August, 2022 to May, 2023under the supervision of **Dr. Tanmay Gupta, Assistant Professor (SG)**, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

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ABSTRACT

This study's objective was to assess the mechanical properties of pervious concrete, normal concrete, and foamed concrete, and examine the effects of various fibre kinds on the mechanical characteristics of foamed concrete, to identify the most effective types of fibers and optimal fiber percentages to use in foamed concrete mixtures. The study used a mix design approach to create different concrete samples, including foamed concrete, pervious concrete, and normal concrete with varying compressive strengths. The samples then underwent a series of tests to measure their density, compressive strength, tensile strength, and flexural strength. The study used various types of fibers, including brass-coated and crimped steel fibers and polypropylene fibers, at different percentages by volume and lengths to create different samples of foamed concrete. The samples then underwent various mechanical tests, including compressive, flexural, and split-tensile strength tests, to assess the effect of fibre addition on the foamed concrete's mechanical characteristics.

The most widely used construction material is concrete, but making it requires a lot of energy and produces a lot of greenhouse gas emissions. As a result, scientists have looked into concrete alternatives that have less of an impact on the environment, like foamed concrete and pervious concrete. The purpose of this study was to evaluate the mechanical characteristics of pervious concrete, normal concrete, and foamed concrete in order to identify which was best for construction purposes.

In this study, it is concluded that normal concrete has the highest compressive, split tensile, and flexural strength but is the most expensive. Pervious concrete has higher compressive and split tensile strength compared to foam concrete, while foam concrete has higher flexural strength. Adding fiber improves the mechanical strength of foam concrete, with CSF resulting in the highest compressive and flexural strength, followed by BSF and PPF. BSF has the highest flexural strength followed by CSF and then PPF.

Key words: Foamed Concrete, Pervious Concrete, Mechanical Properties, Fibers, Compressive Strength, Tensile Strength, Flexural Strength, Mix Design, Construction Materials, Sustainability

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LIST OF ABBREVIATIONS

ABBREVIATIONS	Full form
BSF	Brass coated steel fiber
CSF	Crimped steel fiber
CTM	Compression testing machine
FC	Foamed Concrete
FRC	Fiber reinforced concrete
FFC	Fibrous foamed concrete
GGBS	Ground granulated blast furnace slag
OC	Ordinary Concrete
OPC	Ordinary Portland Cement
PPC	Portland pozzolana Cement
PPF	Polypropylene Fiber
w/c	Water to cement ratio

CHAPTER 1

INTRODUCTION

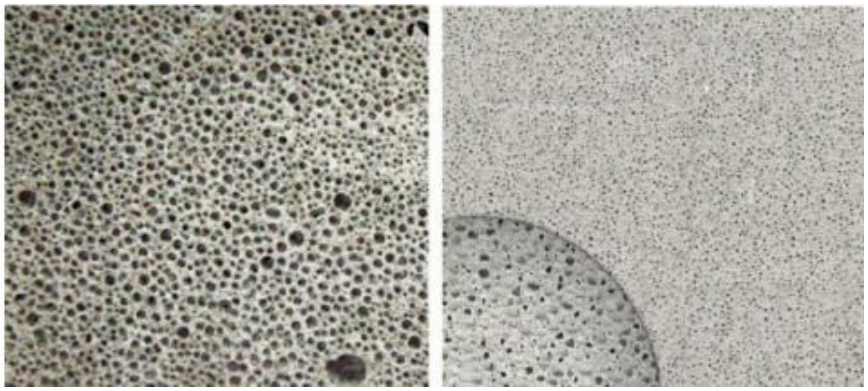
1.1 General

Foamed concrete, also known as Light weight Cellular Concrete (LCC), is characterized by its low density (400-1850 Kg/m3) attributed to the presence of random air voids. It differentiates itself from highly air-entrained materials as it generally contains an air content exceeding 25%. Foamed concrete is highly regarded for its exceptional thermal insulation properties, excellent workability and flowability, reduced cement content, and minimal use of aggregate. The production of substantial lightweight building materials and components, such as structural elements, partitions, filling grades, and road embankment infills, is made possible by this material because to its affordability. The simplicity of production, from the manufacturing facility through the final application, further adds to its advantages. Furthermore, foamed concrete incorporates fewer chemicals, thereby meeting the demands of sustainability and the environment. In recent years, the construction of numerous eco-friendly buildings utilizing foamed concrete has been on the rise. This construction practice is commonly employed in various nations, including Germany, the United States, Brazil, the United Kingdom, and Canada.

Despite its excellent qualities as a building material, foam concrete has limited global exposure. Consequently, the construction industry's understanding and recognition of foam concrete's contribution are hindered by insufficient knowledge about the material, lack of confidence in its capabilities, and inadequate technological advancements.

1.2 History and recent development

Foamed concretes have experienced faster growth than any other specialized concrete product in the past decade, despite not being a new material.The Romans were producing crude concrete 2,000 years ago using hot lime water, tiny stones, and coarse sand. They found that adding animal blood to the mixture and stirring it produced tiny air bubbles that made the mixture easier to work with and more durable. They even added horse hair to the mixtures to reduce shrinking, just as we do today with fibres. Additionally, there is proof that this technology was developed by the Egyptians over 5000 years ago, with comparable outcomes. However, Axel Eriksson received the first patent for foamed concrete using Portland cement in 1923. According to studies done so far, foamed concrete has exceptional qualities such a low density that reduces foundation size, labour, operating expenses, and structural dead loads. Furthermore, due to its microstructural cells and textural surface, it improves sound absorption, thermal conductivity, and fire resistance.



(a) (b)

Fig 1.1 Porous structure of (a) Foamed Concrete (b) Autoclaved aerated concrete. [18]

1.3 Material Constituents

Foam concrete consists of fine aggregate sand, cement, water, foam, admixtures (fly ash, plasticizers and fibres etc.) for mortar and coarse aggregates for concrete. The majority of components are cement and fine aggregate.

Fig 1.2 Constituents of foamed concrete [1]

1.4 Material Properties

A cement-based slurry and a stable, homogeneous foam are combined to form foam concrete, either through mixing or injection. The proportions of cement, fly ash, aggregates, fillers, and entrained foam volume in the mix designs for cement mortar determine its physical properties. However, there are still existing weaknesses and poor durability in foam concrete. The production process and performance level have an impact on the unique qualities that each foam concrete property possesses. While the hardened stage of foam concrete incorporates physical, functional, and mechanical features, the fresh state focuses on mixture consistency, rheology, and stability.

1.5Applications

Foamed concrete possesses unique attributes, including reduced density, high flowability, low thermal conductivity, and self-compacting properties. These qualities, combined with its ease of production and cost-effectiveness, have led to its application in various fields of civil and structural engineering. Additionally, foamed concrete is environmentally friendly and offers cost-saving benefits. Some of its applications are shown in the figure below.

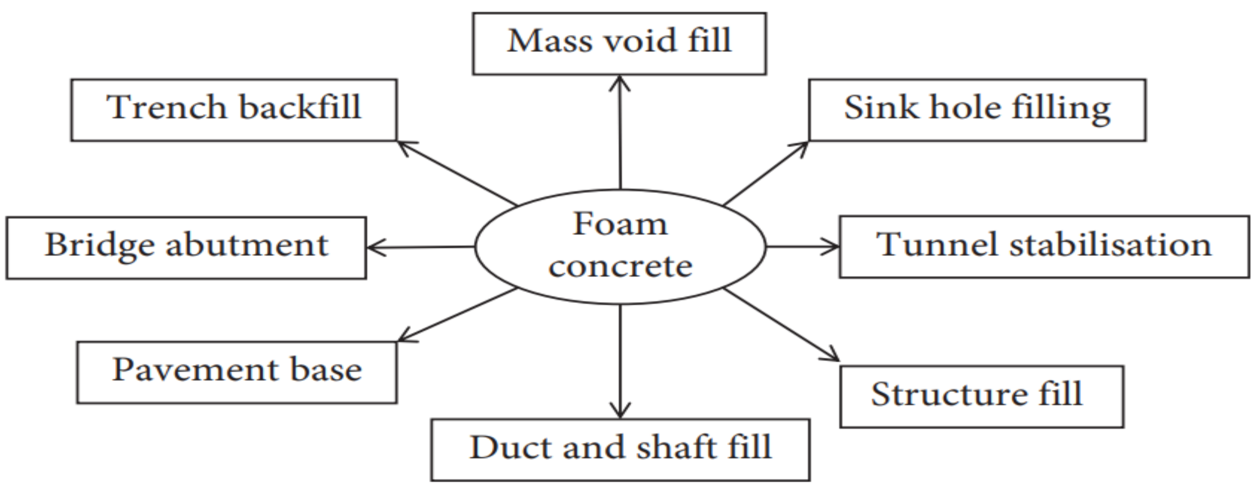


Fig 1.3 Applications of foamed concrete [4]

1.6 Organisation of report

This report presents a comparison of the properties of foamed, pervious, and normal concrete. The thesis is organized as follows.

Chapter 2 discusses various research paper studies related to our investigation. It is focusing on reviewing other related studies.

Chapter 3 provides a description of various materials and method used to complete this report. This includes basic test on material and samples.

Chapter 4 shows the result and analysis of various tests with the help of graphs. The variation with different percentages of material is shown.

Chapter 5 presents the conclusion of the study, by examining the mechanical properties of foamed, pervious, and normal concrete. It also discusses potential areas for future research in this domain.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The construction industry is actively exploring alternatives to traditional concrete because of its heavy nature and strong thermal conductivity, which contribute to global warming. Among the potential alternatives being researched is foam concrete (FC), which has the capability to replace traditional concrete by lowering the dead load on buildings and foundations, conserving energy, and lowering production and labor costs during construction and transportation. Additionally, the presence of numerous pores in foam concrete provides effective thermal insulation, making it suitable for various weather conditions. However, despite its numerous benefits, the adoption of foam concrete in structural projects has been limited due to a lack of technical and engineering expertise, as well as concerns about achieving adequate strength.

This project entails an investigation into the characteristics of foamed, pervious, and conventional concrete. at a specific compressive strength range. Additionally, it involves an analysis of the properties of fibrous foamed concrete at a specific density range.

2.2 Reviews

Helmut Weigler Sieghart Karl [1980] [10]

This paper explores the various options available for the production of lightweight concretes, as well as the key properties associated with lightweight-aggregate foamed concrete. The results of this study show that lightweight-aggregate foamed concrete can be used to build heat-insulating walls with loads bearing on them or stiffening them.

Yang, Jing, and Guoliang Jiang. [2003] [25]

This paper provides an introductory overview of a specialized pervious concrete pavement material specifically engineered for use on roadways.. Traditional methods and materials used in pervious concrete result in low strength.However, smaller aggregate sizes, silica fume, and superplasticizer can all significantly boost the pervious concrete's strength.

M. R. Jones, and A. McCarthy [2005] [9]

This report details a laboratory investigation into construction with foamed concrete that uses two distinct kinds of fly ash, so thatit could be utilised in structural applications. Coarse fly ash was used to replace sand fine aggregate, whereas fine fly ash was used to partially replace Portland cement. Furthermore, the potential for polypropylene fibers to improve plasticity and tensile strength in foamed concrete was explored. Various engineering properties, including early age and durability characteristics, were evaluated to determine the viability of foamed concrete for structural purposes. The results indicate that foamed concrete is indeed feasible for such applications. It cannot, however, be substituted for regular weight concrete due to its special qualities, which include high drying shrinkage strain and relatively low tensile strength and stiffness performance.

D Aldridge Ravindra K. Dhir , Moray D. Newlands , and Aikaterini McCarthy [2005] [3]

This report provides a comprehensive overview of the historical background, evolution, and practical applications of foamed materials, including a detailed definition and analysis of their physical properties such as density, strength, and thermal characteristics. The report also presents a comprehensive overview of various methods of production, ranging from traditional techniques to innovative and emerging approaches. Additionally, the report includes an analysis of mix designs and the impact of various foaming chemicals and foam types on the overall characteristics of the material.

E.K. Kunhanandan Nambiar, K. Ramamurthy [2006] [11]

This report presents the outcomes of an extensive study that aimed to assess the effects of different filler types, such as sand and fly ash, as on the characteristics of foam concrete, as well as sand particle size during moist curing. The research findings indicate that the choice of filler significantly influences the consistency of the mixture required to achieve the desired density in pre-formed foam concrete. Additionally, the flow behavior of foam concrete is primarily determined by the foam volume. The study observed that reducing the particle size of sand resulted in increased strength of the foam concrete. Furthermore, substituting sand with fly ash led to higher strength at a given density, and finer filler materials exhibited an improved strength-to-density ratio.

K.Ramamurthy, E.K. Kunhanandan Nambiar, G. Indu Siva Ranjani [2009] [5]

The objective of this paper was to categorize the literature related to foam concrete based on the constituent materials, mix design, production techniques, and fresh and hardened properties of the foam concrete. The study concluded that most of the research conducted on foamed concrete has been focused on assessing its properties rather than its foam characteristics, which play a significant role in calculating the strength of the material. There is no standardised mix proportioning method available for foam concrete, despite the fact that a number of mix proportioning methods and guidelines have been presented for reaching the appropriate density and strength.Since the consistency of the mix diminishes with an increase in foam volume, which in turn affects the stability of the mix, the water-to-solid ratio utilised for the mix must satisfy both the stability and consistency criteria of the mix.

Josef Hadipramana, Abdul Aziz Abdul Samad, Ahmad Mujahid Ahmad Zaidi[2013] [27]

In order to increase the compressive and splitting tensile strength of foamed concrete, polypropylene fibre (PF) was added in this study. Mechanical studies showed that PF considerably increased the concrete's strength. The matrix's microcracks were decreased and the growth of cracks was stopped by the PF and matrix's fibrillation and interfacial bonding.Although the porous characteristic of foamed concrete was taken into account, and the curing process indicated that interfacial adhesion widens during cement hydration. The microstructure of the foamed concrete was altered by the addition of PF, as shown by Scanning Electron Microscope (SEM) analysis.

Y.H. Mugahed Amran, Nima Farzadnia, A.A. Abang Ali [2015] [2]

This paper's goal was to demonstrate a thorough analysis of the constituents, manufacturing methods and properties of foamed concrete, as well as its potential applications in the construction industry. The study has reviewed various literature sources, which revealed that most of the research conducted so far has primarily focused on evaluating the properties of foamed concrete and paid less attention to the foam's characteristics and its impact on the strength of the concrete structure.

E P Kearsley, H F Mostert [2016] [13]

The purpose of this study was to incorporate more fly ash than usual into a foamed concrete mix. Fly ash was chosen as a replacement for cement in the mix. In normal concrete, the water/cement ratio is typically determined by the desired compressive strength, while the workability indicates the amount of water required. For foamed concrete, the ratios of water/cement and sand/cement are determined once the target casting density is established. The casting densities achieved in the study were very close to the targeted densities, indicating that the approach used to determine the water requirements of the materials in the foamed concrete was effective.

Chandrappa, Anush K., and Krishna Prapoorna Biligiri. [2016] [24]

Pervious concrete has gained significance as an environmentally-friendly pavement material. This paper reviews its developments, mechanical-hydrological-durability properties, storm water purification efficiency, field investigations, rehabilitation techniques, and life cycle cost analysis.To better understand it and establish it as a sustainable highway material, more research is required.

Kamarul Aini Mohd Sari and Abdul Rahim Mohammed Sani [2017] [6]

The aim of this paper is to examine the use of basic raw materials, their characteristics, methods of manufacturing, and application in lightweight foamed concrete with densities ranging from 300 Kg/m^3 to 1800 Kg/m^3. Moreover, the paper explores the various factors that affect the strengths and limitations of foamed concrete, which were identified through previously conducted research studies.

Jingwen Zhang, Ningshan Jiang, Hui Li, and Chengyou Wu [2018] [14]

The purpose of this study was to examine the effects of four crucial parameters on the compressive strength of cement-based foam concrete. These factors consist of the quantity of the foaming agent, the water-cement ratio, the foam stabiliser, and the water reduction agent. The study aimed to determine the relative influence of each of these factors on the compressive strength of the foam concrete.The findings indicate that the primary factors influencing the 7-day compressive strength of cement-based foam concrete are the water-cement ratio, foam agent content, water reducer content, and foam stabilizer content.

D.Kavitha , K.V.N Mallikarjunrao [2018] [7]

In this project to achieve the maximum strength of 1900 kg/m3, foam concrete blocks were manufactured for this project in accordance with the planned proportions.Cubes were made using a special mix, and the results of tests on their density and compressive strength were reported.

Aphai Chapirom, Teerawat Sinsiri, Chai Jaturapitakkul, Prinya Chindaprasirt [2019] [16]

The objective of this study was to investigate the influence of horizontal mixer speed rotation on the compressive strength of cellular lightweight concrete. The research examined the correlation between the mixer speed and the compressive strength, water absorption, and drying density of the cellular concrete. The evaluated cellular concrete had a wet density of 1,000 Kg/m^3, density of foam is 49 Kg/m^3, w/c is 0.5 and the ratio of sand to cement is 0.95. at the age of 28 days.

The experiment revealed that the cellular concrete's characteristics are influenced by the rate of rotation. The concrete mixer's compressive strength and water absorption are increased when the speed is set to 45 rpm, and the foam size and spread in the concrete is more uniform than at any other speed.

Amritha Raj, Dhanya Sathyan, K.M. Mini [2019] [1]

This study's objective was to perform a thorough evaluation of foamed concrete by looking at its component parts, physical features, and mechanical attributes, such as compressive strength, flexural strength, and elastic modulus.The study also included a review of different types of foams used in foam concrete and their impact on the properties of the material. Additionally covered were topics like thermal conductivity, acoustic qualities ,fire resistance and resilience to hostile environments. Furthermore, the paper outlines various applications of foam concrete.Additionally, the study provides an overview of the different production methods and mix designs for foamed concrete, including the effects of different variables such as particle size and type of filler. Overall, The primary objective of this paper is to offer a comprehensive insight into the properties and applications of foamed concrete within the construction industry.

Yanbin Fu, Xiuling Wang, Lixin Wang, and Yunpeng Li [2020] [4]

This paper presents an extensive review of the constituents, manufacturing processes, and material characteristics of foam concrete, including its compressive strength, drying shrinkage, stability, and pore structure. Additionally, The usage of foam concrete in tunnel and underground engineering is covered, along with some technological restrictions and new directions for improving foam concrete's performance. The study highlights the importance of investigating the long-term performance and related properties of foam concrete for its sustained use in engineering applications.

Manan Hashim, Manzoor Tantray [2021] [15]

In this study, the effectiveness of synthetic and protein-based foaming agents in foamed concrete was compared. The aim was to investigate the impact of these foaming agents on the characteristics of the concrete, including microstructure, drying shrinkage, compressive strength, and foam stability. The results showed that the protein-based foam exhibited superior foam stability and strength in comparison to the synthetic foaming agent. The microstructure analysis revealed that the smaller, circular, well-defined pores that weren't connected to one another could be found in protein-based foamed concrete.

XinyuCong, Tairui Qiu, Jiquan Xu , Xinqing Liu , Liqing Wang [2022] [26]

This study investigated the effects of different fibers on the mechanical properties, workability, and pore structures of foamed concrete. The connection of digital images and X-ray computed tomography techniques were used to analyze the cementitious matrix and strain field distributions, respectively. Results showed that fiber properties and their bond performance with the cement matrix were significant determinants of mechanical characteristics of the reinforced foamed concrete. The fresh slurry's rheological characteristics and workability were both impacted by the fibres. Carbon and polyacrylonitrile fibers were found to distribute strain field homogeneously and effectivelydelay crack spreading after peak loads.

2.3 Summary of Literature review

Foam concrete is a kind of concrete that only has small sand and no huge aggregates, together with very light ingredients like foam, cement and water.Since it lacks a phase of coarse aggregate, it can be compared to regular concrete and is hence homogeneous. Foamed concrete is appealing for many construction applications because of its low self-weight (400 to 1850 Kg/m^3), good workability (flowing and self-compacting), and excellent thermal insulating qualities (< 0.50 W/mK).To achieve desired qualities in foamed concrete, there is no precise mix proportion procedure.Trial and mix error method are used to calculate net water content, foam content, binder content. FC water absorption andcompressive strength are increased when the concrete mixer's speed is set to 45 rpm.The protein-based foam performed better in the foam stability and strength test than the synthetic foaming agent.

Its use in structural applications has been constrained by both a perceived difficulty in achieving sufficiently high strength (>25 N/mm^2) and a lack of technical and engineering knowledge. However, there is still a need for further research to understand the long-term performance and enhancement of foamed concrete.

2.4 Gaps in Existing Literature

Based on the literature review conducted, it was observed that the majority ofstudies evaluated the properties of foam concrete rather than the foam's own characteristics, itself or how they affect the foamed concrete matrix's strength. Although various criteria, such as material proportioning methods, guidelines, and trial and error methods, influence the desired density and strength, Currently, there are no established techniques for precisely determining the appropriate material mix proportions for designing foamed concrete..There are various review papers comparing properties of foam and normal concrete, but there are few papers comparing their properties experimentally.

2.5 OBJECTIVES

Based on the Literature review, following objectives were determined

1. This study aims to compare strength properties of foamed concrete with normal and pervious concrete
2. Conduct a cost analysis of foamed concrete in comparison to normal and pervious concrete.
3. To examine the impact of different types of fiber inclusions on the foamed concrete's mechanical characteristics.

CHAPTER 3

METHODS AND MATERIALS

3.1 General

This chapter will explore the methodologies employed to compare the characteristics of foamed concrete, pervious concrete, and conventional concrete. The flow chart of work plan is given below:

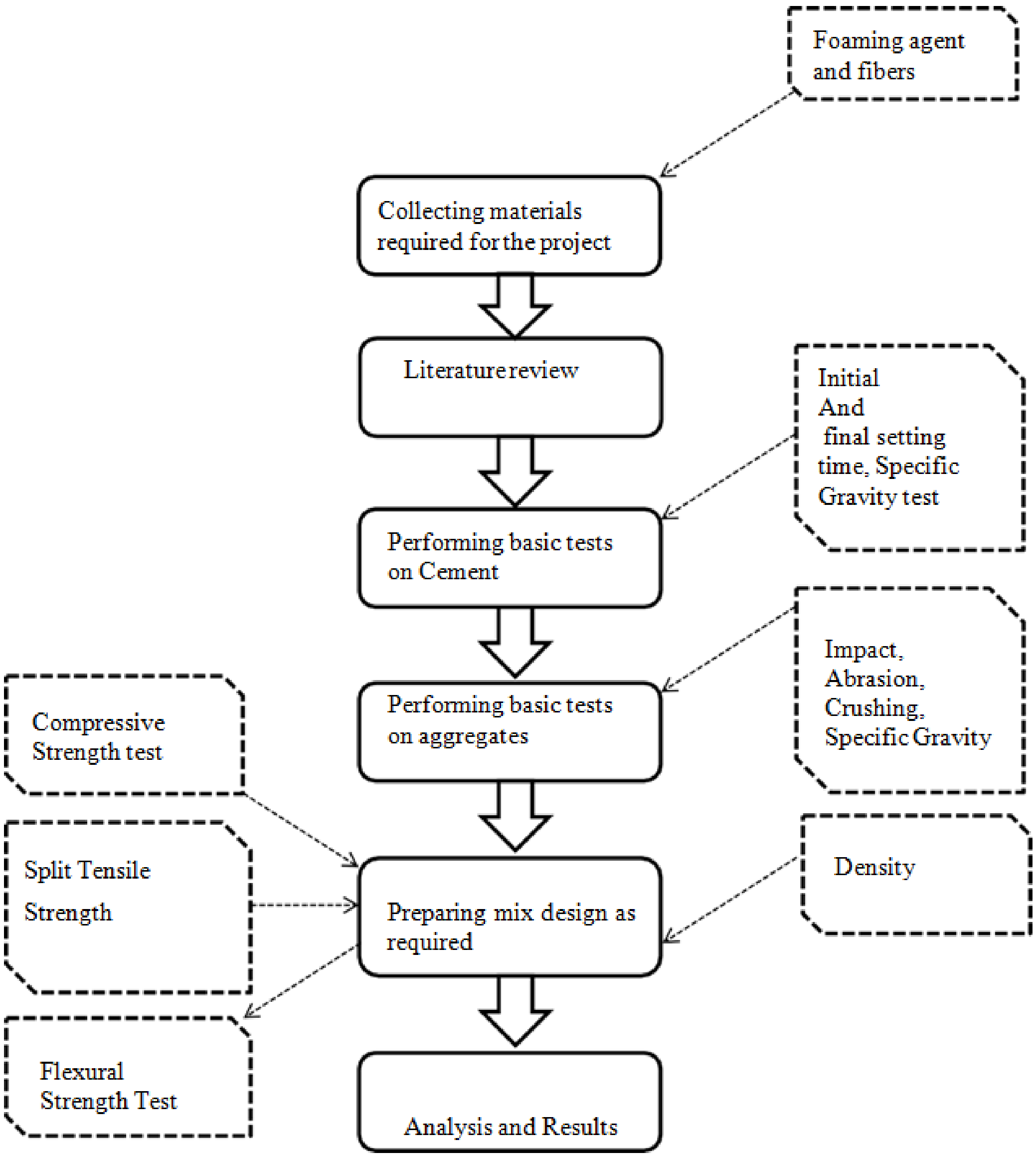


Fig 3.1 Flow chart of work plan

3.2 Materials Used

The various materials required for this study is listed in the table below.

Table 3.1 Materials required

S.No	Material
1	Cement (PPC 43)
2	Coarse Aggregate
3	Fine Aggregate
4.	Foam
5	Fibers

3.3 Material Properties

3.3.1 Cement (PPC 43)

A variety of ingredients, including gypsum, OPC clinker, fly ash, volcanic ash, calcined clay, and silica fumes, are used to create Portland Pozzolana Cement (PPC). Pozzolana is used as a crucial component in the creation of PPC and contains reactive silica.

When normal sand (IS: 650) is used to make cement mortar in a 1:3 ratio, it is tested under standard laboratory circumstances, and if the cement mortar achieves a minimum compressive strength of 43 MPa after 28 days, it is categorised as 43 Grade Pozzolana Portland Cement.

Table 3.2 Properties of cement

Properties	Values
Bulk density	1400Kg/m^3
Soundness	2.5mm
Fineness	330 m^2
Final Setting time	500min
Specific Gravity	3.12

3.3.2 Aggregates

- **Coarse Aggregate:-**

  Coarse aggregate is defined as stone that has broken into small fragments and has an irregular shape. Aggregates including limestone, granite, and river aggregate are used in construction projects. Aggregate having a size bigger than 4.75 mm or that holds on a 4.75 mm IS Sieve is referred to as coarse aggregate. 10 mm and 20 mm coarse aggregate were employed in this investigation.

- **Fine Aggregate:-**

  The typical type of sand particles that are obtained by land mining is what is essentially meant by "fine aggregate." Fine aggregate is defined as aggregate that passes the 4.75 mm IS Sieve the majority of the time, and the grading and content of coarser material for various grading zones must be within the bounds of Table 9 of IS 383-2016.Unlike natural sources, manufactured fine aggregates are created by processing raw materials using thermal or other methods such separation, washing, crushing, and scouring. Recycled concrete aggregate (RCA) may be used in manufactured fine aggregate.

3.3.3 Foam

By introducing air bubbles into the cement paste mixture, foam agents are used to control the density of foamed concrete. Synthetic detergents, adhesive resins, hydrolyzed proteins, resin soaps, and saponin are among the common foaming agents. Among them, resin-based foam agents were among the first to be employed in foamed concrete. Protein-based foam agents generate a more robust and closed-cell bubble structure that permits the incorporation of up to 12 additional air units, leading to a more steady network of air voids. Conversely, synthetic foam agents have a higher expansion capacity and, as a result, they become less dense.

Foaming agent with the formula R_x $(OCH_2CH_2)yOS0_3M$ and made of a combination of alkyl sulphates and alkyl ether sulphates is disclosed in U.S. Patent No. 5,240,639 (Diez et al.),R_x stand for linear or branched chain hydrocarbons with an average of x carbon atoms, where at least approximately 80% of x is between 8 and 10; y stands for the typical amount of ethylene oxide per mole of hydrocarbon R_x , which is between 0.4 and 1.3;

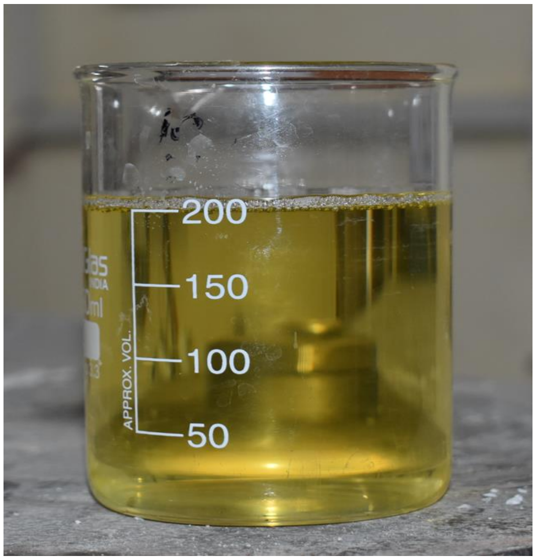


Fig 3.2 Foaming agent

M denotes a cation that can generate asurfactant that is water soluble;and Surfactant makes up between about 44 and 85 weight percent of the foaming agent in the mixture with y = 0 plus y = 1 (the sum of the alkyl sulphate and the alkyl mono-ether sulphate), and alkyl sulphate surfactant makes up between 25 and 85 weight percent of the foaming agent with y = 0 (alkyl sulphate). This mixture of surfactants is said to have better foaming capabilities.

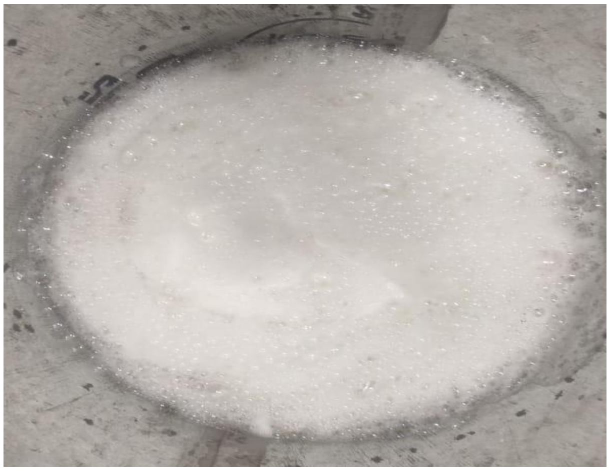


Fig 3.3 Foam

The foaming agent utilised in this investigation was synthetic-based. The properties of foaming agent is given in the Table 3.3

Table 3.3 Properties of foaming agent

Properties	Values
Type	Synthetic
Specific gravity	1.0 to 1.05
pH	>7.5
Density of foam	50-60gm
Dose	1 liter for 25-30 liter of water

3.3.4 Fibers

The use of fibers in concrete is becoming increasingly common due to their ability to increase the mechanical characteristics strength and durability of concrete. Fibres can be made from a variety of materials, such as steel, glass, polypropylene, nylon, and natural fibres, and they can be sparingly added to concrete. These fibres improve the tensile strength, ductility, toughness, and resistance to impact, cracking, and shrinking of the concrete.

Fiber-reinforced concrete (FRC) is adaptable and can be utilised for a variety of projects, including overlays, precast concrete elements, tunnels, slabs, and bridge decks. Depending on the intended use, design requirements, and environmental considerations, fibres will be added to concrete in a specific type and quantity.

In this study, three types of fibers were employed: brass coated steel fiber, crimped steel fiber, and polypropylene fiber

3.3.4.1 Brass Coated steel fiber

Brass coated steel fiber is a type of fiber that is used as reinforcement in concrete to improve its mechanical properties. It is made by coating steel fibers with a layer of brass through a process called electroplating.

Fig 3.4 Brass Coated steel fiber

The fiber used in this research was having following properties as shown in the table.

Table 3.4 Properties of Brass coated steel fiber

Length	8mm
Diameter	0.25mm
Appearance	Brass Coated
Cross Section	Round
Tensile Strength	2000mm^2
Aspect Ratio	32

3.3.4.2 Crimped Steel Fiber

Crimped steel fiber is a category of fiber utilized in concrete to enhance its mechanical characteristics. These fibers are manufactured from high-strength steel wire that has been crimped or bent into a wavy or hook-shaped configuration. The crimped shape permits the fibers to interlock more efficiently with the concrete matrix, boosting its tensile strength, ductility, and toughness.

Fig3.5 Crimped Steel fiber

The Crimped Steel fiber used in this research was having following properties as shown in the table.

Table 3.5 Properties of Crimped Steel fiber

Length	50mm
Diameter	1mm
Appearance	Bright and clean
Shape	Hook like
Tensile Strength	1400Mpa
Aspect Ratio	50

3.3.4.3 Polypropylene fiber

A synthetic substance made from polypropylene polymer called polypropylene fibre is frequently used in the construction industry to improve the mechanical qualities of concrete. These fibres aid to strengthen the toughness, ductility, impact resistance, and durability of concrete while also reducing cracking and shrinkage. They are typically added to concrete in small amounts, frequently less than 1% by volume. They are frequently small, with lengths between a few millimeters and a few centimetres, and have a high aspect ratio, which means that their length is significantly bigger than their diameter. Polypropylene fibres are simple to work with, integrate nicely with concrete, and have minimal effects on the workability of the concrete.

Fig 3.6 Polypropylene fiber

The Polypropylene fiber used in this research was having following properties as shown in the table.

Table 3.6 Properties of Polypropylene fiber

Length	8mm
Diameter	0.3mm
Appearance	White
Tensile Strength	700Mpa
Aspect Ratio	27

3.4 Tests on Cement

3.4.1 Normal consistency of cement

According to IS 4031(Part 4), the cement consistency test was conducted.

The consistency of cement is used to determine the amount of water that should be added to cement to obtain a normal or natural consistency, stated as a percentage of cement weight.

Fig 3.7 Normal Consistency test

The table below presents the outcomes of the normal consistency test.

Table 3.7 Consistency test

S. No	Cement's weight	% of water to be added to the sample(ml)	Water weight to be added to the sample (ml)	Penetration Value
1	300	32	96	35
2	300	30	90	30
3	300	29	86	30

Normal Consistency of cement came out be 32%

3.4.2 Fineness Test –

According to IS 4031(Part 1), the cement fineness test was conducted. A standard IS sieve was used to filter the cement sample. The weight of cement particles larger than 90 microns was used to measure the percentage of cement retained on the sieve.

The results of fineness test are shown in the table given below.

Table 3.8 Fineness Test

S. No	Weight of cement sample in g (W1)	Weight of cement retained on 90 µm sieve in g (W2)	Cement's fineness (W2/W1) *100
1	100	8.8	8.8%
2	100	6.7	6.7%
3	100	7.42	7.42%

Fineness value of cement = 7.64%

3.4.3 Specific gravity test

According to IS 4031(Part 1), the cement specific gravity test was conducted. A cement sample's specific gravity is determined by, weight of specific gravity bottle is measured (W1). Than fill half the bottle with cement paste and record the weight (W2). Fill the remaining bottle with kerosene, avoiding air bubbles, weight it (W3), then clean and dry the bottle. Refill with kerosene, weight with stopper (W4), remove kerosene, fill with water, and measure the weight(W5).

Table 3.9 Specific gravity Test

Description of item	**Result**
Bottle's empty weight (w1)	125.3
Bottle’s weight + Cement (W2)	189.8
Bottle’s weight + Cement + Kerosene(W3)	396.1
Bottle’s weight + Kerosene(W4)	347.7
Bottle’s weight + Full water (W5)	64.5

Formula: (W2-W1)* Specific gravity of kerosene/[(W4-W1)-(W3-W1)]

Specific gravity of cement = 3.12

3.5 Tests on Aggregates

3.5.1 Abrasion Test

Aggregate toughness and abrasion resistance, such as crushing, degradation, and disintegration, are measured using the Los Angeles abrasion test. With each revolution, the charge and sample are raised and lowered by an internal shelf in the drum, creating impact pressures.The appropriate rpm is reached by the machine, the contents are taken out, and the percent loss is calculated.

Table 3.10 Abrasion Value of Coarse aggregate

Aggregate's weight in g(W1)	Aggregate's weight retain on 1.70mm sieve in g(W2)	Abrasion Value
5000	2900	42

Abrasion Value= 42%

Fig 3.8 Los Angeles Abrasion apparatus

3.5.2 Impact test

Coarse aggregates' impact test was done according to the procedure described in IS 2386.

his test is done to evaluate the toughness of aggregates. When they come in contact with flaws, cracks, or notches, many materials degrade rapidly.

Table 3.11 Impact Value of Aggregate

Cylinder weight with aggregates W2(g)	Aggregate's weight after passing through a 2.36 mm sieve W1(g)
400	62.5

Impact test value = (W1/W2) *100

= 15.6 %

3.5.3 Crushing test

Crushing test was done according to the IS 2386 to determine their crushing test values. The strength of the aggregate in concrete is not perfectly reflected in the compressive strength of the parent rock. The test conducted to know the compressive strength of aggregate.

Table 3.12 Aggregate Crushing Value of Aggregates

Cylinder weight with aggregates W1 (g)	Aggregates' weight passing through a 2.36mm sieve(g)	Aggregate crushing value (%) = (W2/W1) *100
2376	550	20.1

Aggregate crushing value = 20.1%

3.6 Mix Proportions

3.6.1 Normal Concrete

Normal concrete design mix in this project was designed according to two Indian standards: IS 10262:2019 and IS 456:2000. This report investigates the properties of three types of normal concrete - M10, M15, and M20.In this investigation, ordinary Portland cement of grade 43 was utilized along with a coarse aggregate size of 20 mm for the preparation of conventional concrete. Additionally, sand that could pass through a sieve with a mesh size of 4.75 mm was employed. The quantity estimation of each type is shown in the table below.

Table 3.13 Quantity estimation for normal concrete

Grade Designation:	**Cement** (Kg/m^3)	**Sand** (Kg/m^3)	**Coarse aggregate**	**Water** (Kg/m^3)
M10	222	739	1663	111
M15	316.8	704	1571	158.4
M20	395	656.6	1112.6	197.5

3.6.2 Pervious Concrete

Pervious concrete is a distinct form of concrete that has a porous composition that permits the free flow of air and water. It has a void ratio of 15-35% and a compressive strength of 5 MPa to 25 MPa, making it possible for water to seep into the earth instead of draining into stormwater systems. Pervious concrete is frequently utilized in locations like parking lots and sidewalks where water run-off can be a significant issue.

In this study, pervious concrete mix was designed following the guidelines of IRC-44.In this investigation, ordinary Portland cement of grade 43 was utilized along with a coarse aggregate size of 10 mm for the preparation of pervious concrete and no fine aggregate was used.This report investigates the properties of three types of pervious concrete - M10, M15, and M20. The quantity estimation of each type is shown in the table below.

Table 3.14 Quantity estimation for pervious concrete

Grade Designation:	**Cement** (Kg/m^3)	**Coarse aggregate** (Kg/m^3)	**Water** (Kg/m^3)
M10	251	1520	100.4
M15	286.7	1520	114.68
M20	307.69	1520	123.08

3.6.3 Foamed Concrete

The foamed concrete mix was designed following the guidelines of ACI 523.3R-14, which provides recommendations for cellular concretes with densities exceeding 50 lb/ft^3 (800 kg/m^3).In this study, a synthetic-based foaming agent was used, andsand that could pass through a sieve with a mesh size of 4.75 mm was employed.This report investigates the properties of three types of foamed concrete - M10, M15, and M20. The quantity estimation of each type is shown in the tables below.

Table 3.15 Quantity estimation for foamed concrete.

Grade Designation:	Cement (Kg/m^3)	Sand (Kg/m^3)	Water (Kg/m^3)	Foam (Kg/m^3)
M10	383.5	977.12	173.215	18.535
M15	379.5	1176.8	152.57	14.178
M20	376.83	1314.53	151.1	11.55

3.6.4 Fibrous Foamed Concrete

Fibrous foamed concrete is a lightweight building material that utilizes the advantages of both fiber reinforcement and foamed concrete. By blending cement, water, foam, and fibers (such as steel or polypropylene), a durable and robust material is created that remains lightweight. The fibers are added to improve the tensile strength, toughness, and crack resistance of the concrete, while the foam helps to maintain a high porosity and low density.

In this study, a synthetic-based foaming agent and sand that passed through a 4.75 mm sieve were used to create fibrous foamed concrete.This fibrous foam concrete was casted for density 1540 Kg/m^{3}with three types of fibers, including brass-coated steel fiber (BSF), crimped steel fiber (CSF), and polypropylene fiber (PPF), were added at varying percentages to create foamed concrete with the same density but different fiber content. Fiber is used as sand replacement in this project.The quantity of fibers incorporated into concrete is typically measured using the volume fraction, which represents the proportion of fibers added to the overall volume of the concrete mixture. Volume fraction values commonly fall within the range of 0.1% to 2%

Fiber content of 0.5% and 1% by volume of the total concrete mixture was utilized.The quantity estimation for both percentages is shown in the tables below.

Table 3.16 Quantity estimation for 0.5 % FFC.

Fiber		**Cement** (Kg/m^3)	**Sand** (Kg/m^3)	**Water** (Kg/m^3)	**Foam** (Kg/m^3)
Name	**Qty**(Kg/m^3)				
CSF	1.23	383.5	975.89	173.215	18.535
BSF	1.23	383.5	975.89	173.215	18.535
PPF	1.23	383.5	977.12	173.215	18.535

Table 3.17 Quantity estimation for 1 % FFC.

Fiber		**Cement** (Kg/m^3)	**Sand** (Kg/m^3)	**Water** (Kg/m^3)	**Foam** (Kg/m^3)
Name	**Qty** (Kg/m^3)				
CSF	2.5	383.5	974.62	173.215	18.535
BSF	2.5	383.5	974.6	173.215	18.535
PPF	2.5	383.5	977.12	173.215	18.535

3.7 Casting of Samples

The process of creating concrete test specimens used to measure the concrete's compressive strength, flexural strength, split tensile strength and other qualities is known as casting of concrete samples. During the casting process, the components of the concrete (cement, aggregates, water, and admixtures) are combined in the correct proportions and placed into molds of specified dimensions.

After the concrete is placed in the molds, it is consolidated to remove any voids. The consolidation can be done using a vibrating table or a vibrating poker, depending on the type of concrete and the dimensions of the molds.

Once the concrete is compacted, it is left to cure under controlled conditions, generally in a damp environment, for a length of time that depends on the type of concrete and the properties that need to be tested.

During the curing period, the concrete is left undisturbed and is protected from external factors that can affect the curing process, such as temperature changes, drying winds, and direct sunlight. After the curing period is complete, the test specimens are carefully removed from the molds and are taken to a laboratory for testing.

In this study, For each batch of concrete, nine cubes, nine cylinders, and nine beams were cast and these specimens were kept submerged in clean water for the required number of days for curing. Three samples were evaluated on each testing day after the specimens had been cured for 3, 7, and 28 days.

Specimens with varying percentage of fibers were designated by CSF1, CSF2, BSF1, BSF2, PPF1, PPF2.

Table 3.18 Different nomenclature of specimen used.

Designation	**Type of fiber**	**% of fiber**
CSF1	Crimped steel fiber	0.5%
CSF2	Crimped steel fiber	1%
BSF1	Brass coated steel fiber	0.5%
BSF2	Brass coated steel fiber	1%
PPF1	Polypropylene fiber	0.5%
PPF2	Polypropylene fiber	1%

3.7.1 Dimensions

- Cubes: 150mm*150mm*150mm
- Cylinder: 150*300mm
- Beam : 100mm*100mm*500mm

Fig 3.9 Foamed concrete blocks

Fig 3.10 Pervious Concrete blocks

3.7.2 Casting procedure

i. The moulds were properly cleaned and boulted tightly.

ii. Grease or oil was applied to the mould so that it becomes easier to demould.

(Grease and oil are not applied to foam concrete molds, as oil can interfere with the chemical reaction that takes place during the curing process of foam concrete)

iii. Concrete was added in Mold in 3 equal layers.

iv. Each layer was compacted with a vibrating table and was demoulded after 24 hours. (A vibrating table was not used for foamed concrete in the experiment, as it had self-leveling properties. Similarly, it was not used for pervious concrete, as excessive vibration could have reduced its ability to allow water to pass through it)

v. Casted cubes were kept inside the water for the required number of days.

Fig 3.11 Casting of foamed concrete blocks

3.8 Testing of Samples

Testing of the specimens typically involves the application of loads to the specimens until they fail, various measurements are made to ascertain the concrete's strength and other characteristics. The results of the tests are used to evaluate the quality of the concrete and to determine whether it meets the required specifications.

For each batch of concrete, nine cubes, nine cylinders, and nine beams were cast and these specimens were kept submerged in clean water for the required number of days for curing.Using a compression testing machine (CTM), the cubes and cylinders were evaluated for compressive strength and split tensile strength, while the beams were tested for flexural strength using a flexure testing machine.These tests' main goal was to figure out the concrete mix's compressive strength, split tensile strength, and flexural strength.

Fig 3.12 Testing of samples in CTM

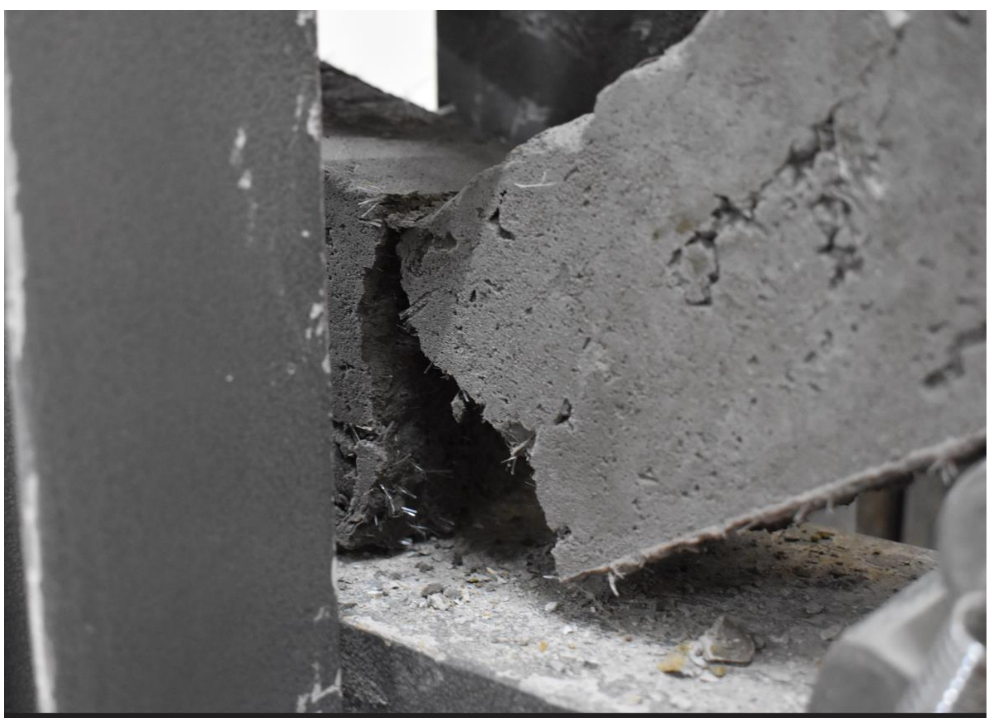


Fig 3.13 Testing of beam in flexure testing machine

CHAPTER 4

RESULTS AND DISCUSSION

4.1 General

Basic tests were performed on normal concrete, pervious and foamed concrete in laboratory. The results of these tests performed on foamed, pervious concrete and normal concrete are shown in this chapter.

4.2 Results

Different experiments were conducted on cement, aggregate and foam prior the casting of concrete blocks. Results of these tests are given in the Table 5.1

Table 4.1 Result values for various testsconducted

S.no	Experiment	Result
1	Specific gravity of Cement	3.12
2	Specific gravity of Fine Aggregate	2.59
3	Specific gravity of Coarse Aggregate	2.69
4	Initial setting time of Cement	45min
5	Final setting time of Cement	450 min
6	Normal consistency of Cement	32%
3	Water absorption on Coarse aggregate	0.98

Following the completion of these testing, concrete block casting began. Cubes and beams were casted according to the IS code 516:2 and cylinders were casted according to the IS: 5816: 1999. Cubes,beamand cylinders were demoulded after approximately 24 hours and were kept in tank for curing.

4.2.1 Compressive Strength

In this research, the compressive strength was measured by making cubes of dimensions 150mm x 150mm x 150mm . These cubes were cured for the required number of days, and then they were tested under a CTM to determine their compressive strength.

The results for various types of grade of concrete are shown in the tables given below.

Grade: M10

Compressive strength of M10 normal, foam and pervious concrete at various days of curing is shown in the table below.

Table 4.2 Compressive strength of M10

No. of days	Normal Concrete	Foamed Concrete	Pervious Concrete
3	4.5	2.9	5.4
7	7.3	3.5	8.9
28	11.4	9.8	13.2

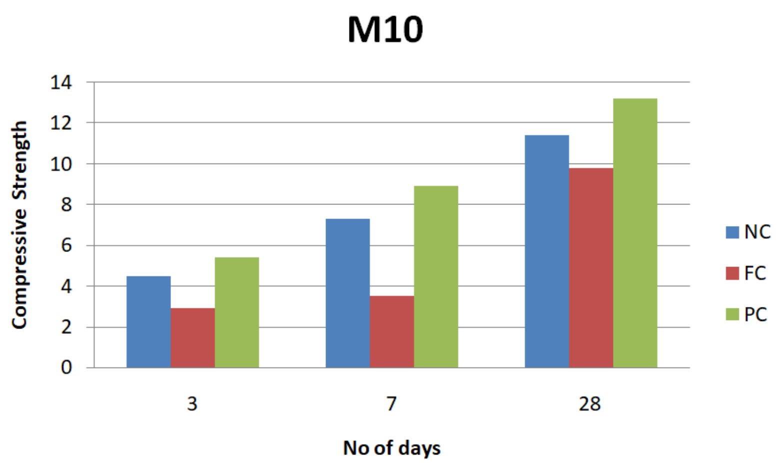


Fig 4.1 Compressive strength graph for M10

Fig 4.2 Compression testing of normal concrete.

Grade: M15

Compressive strength of M15 normal, foam and pervious concrete at different days of curing is shown in the table below.

Table 4.3 Compressive strength for M15.

No. of days	Normal Concrete	Foamed Concrete	Pervious Concrete
3	7.2	5.7	6.7
7	12.1	7.3	11.9
28	18	14.8	17.5

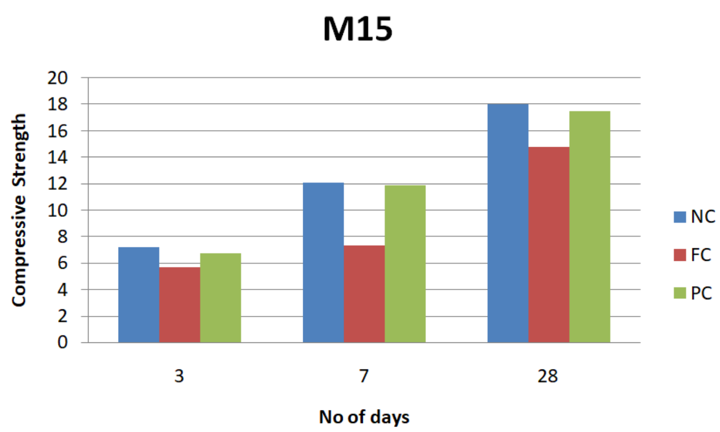


Fig 4.3 Compressive strength graph for M15

Grade: M20

Compressive strength of M20 normal, foam and pervious concrete at different days of curing is shown in the table below.

Table 4.4 Compressive strength of M20.

No. of days	Normal Concrete	Foamed Concrete	Pervious Concrete
3	11	7.8	8.2
7	15.3	9.2	14.1
28	23	18	21

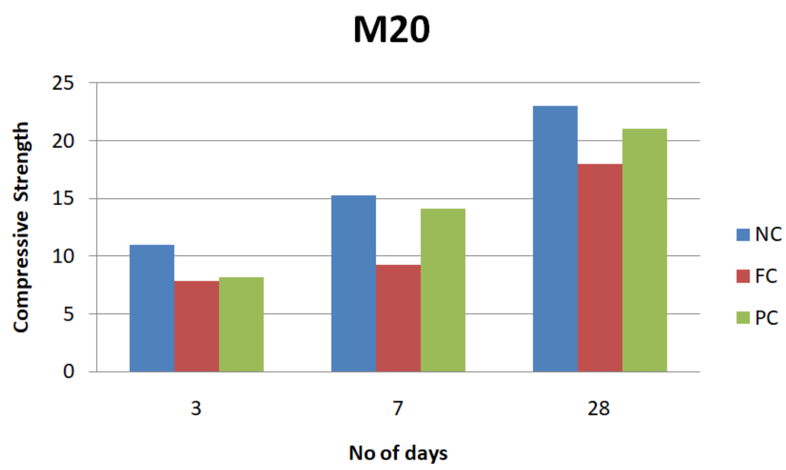


Fig 4.4 Compressive strength graph for M20

Grade: Fibrous Foamed concrete

Compressive strength of foamed concrete with varying percentage of fiber is shown in the tables given below.

Table 4.5 Compressive strength for 0.5% fiber replacement

No. ofDays	FC	CSF1	BSF1	PPF1
3	2.9	5.8	4.6	4.4
7	3.5	6.7	5.4	5.2
28	9.8	11.6	11.3	10.3

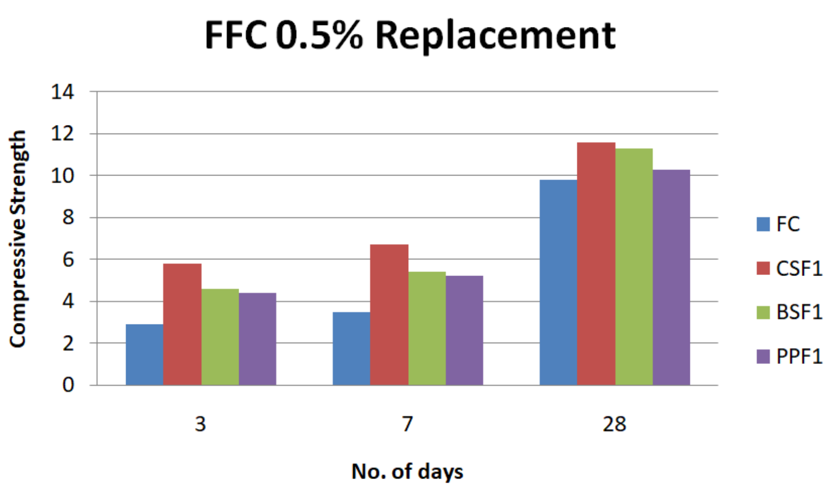


Fig 4.5 Compressive strength for 0.5% fiber replacement

Table 4.6 Compressive strength for 1% fiber replacement

No. ofDays	FC	CSF1	BSF1	PPF1
3	2.9	6.1	5.8	5.4
7	3.5	7.33	6.9	6.5
28	9.8	13.4	12.9	12.3

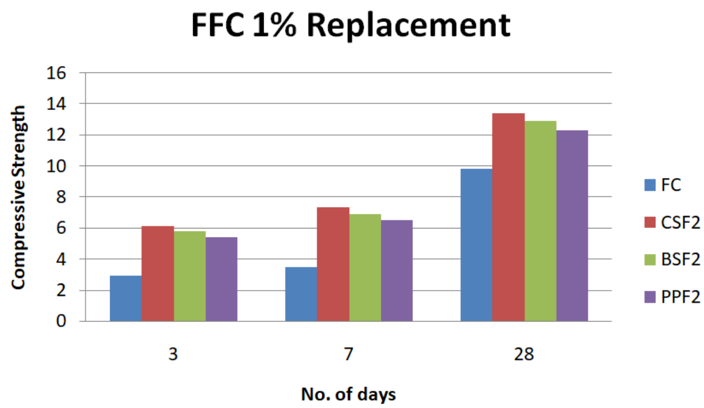


Fig 4.6 Compressive strength for 1% fiber replacement

4.2.2 Split tensile strength

In this report, the Split tensile strength was measured by making cylindersof dimensions 150mm x 300mm. These cylinders were cured for the required number of days, and then they were tested under a CTM to determine their Split tensile strength.

Fig 4.7 Split tensile test

Split tensile strength results for various grades of concrete are shown in the tables given below, and their comparison is shown in the figures below.

Grade: M10

Table 4.7 Split tensile strength test for M10

No. of days	Normal Concrete	Foamed Concrete	Pervious Concrete
3	0.45	0.42	0.65
7	0.85	0.53	1.06
28	1.13	1.06	1.5

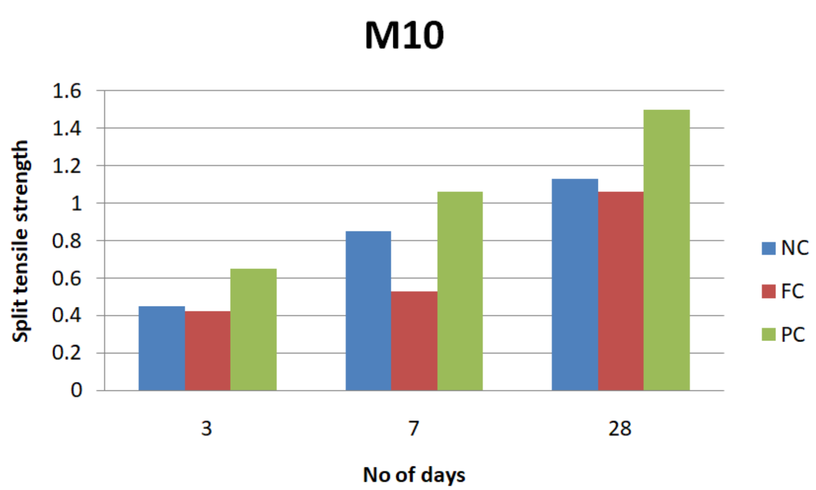


Fig 4.8 Split tensile strength graph for M10

Grade: M15

Table 4.8 Split tensile strength test for M15

No. of days	Normal Concrete	Foamed Concrete	Pervious Concrete
3	0.73	0.71	0.75
7	1.27	0.87	1.33
28	1.89	1.39	1.96

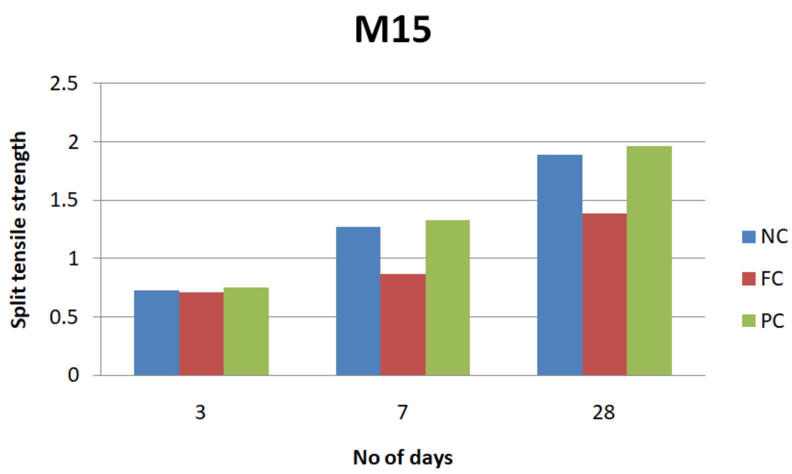


Fig 4.9 Split tensile strength graph for M15

Grade: M20

Table 4.9 Split tensile strength test for M20

No. of days	Normal Concrete	Foamed Concrete	Pervious Concrete
3	1.09	0.87	0.94
7	1.82	1.02	1.62
28	2.4	1.59	2.41

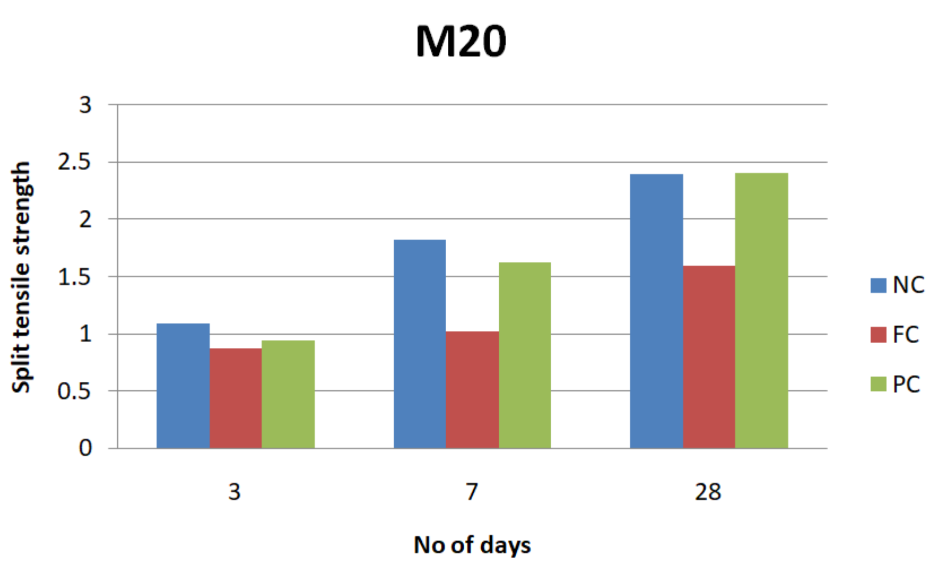


Fig 4.10 Split tensile strength graph for M20

Grade: Fibrous Foamed concrete

Table 4.10 Split tensile strength test for 0.5% fiber

No. of days	FC	CSF1	BSF1	PPF1
3	0.42	0.92	0.95	0.87
7	0.53	1.13	1.12	0.95
28	1.06	1.37	1.43	1.33

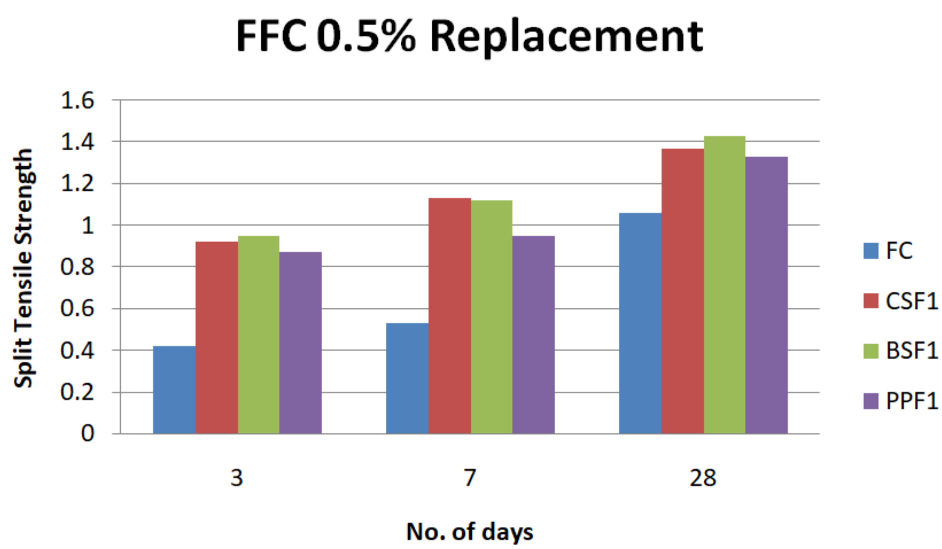


Fig 4.11 Split tensile strength graph for 0.5% fiber

Table 4.11 Split tensile strength test for 1% fiber

No. of days	FC	CSF2	BSF2	PPF2
3	0.42	0.99	1.09	0.95
7	0.53	1.18	1.23	1.13
28	1.06	1.50	1.54	1.46

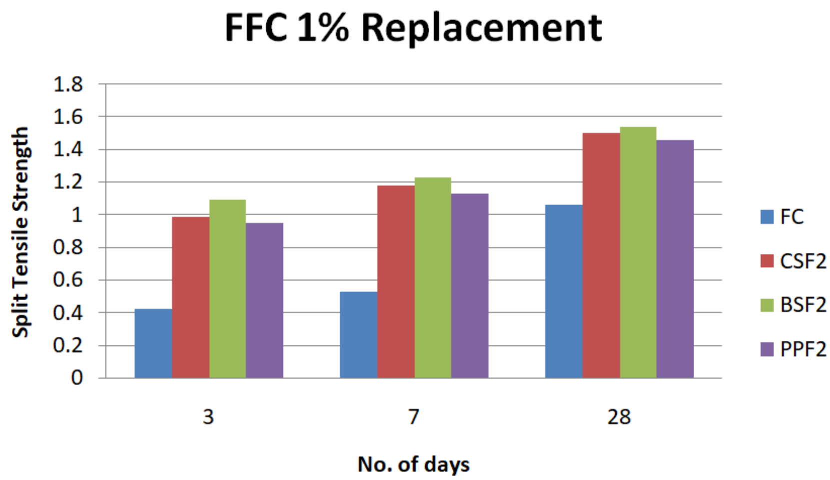


Fig 4.12 Split tensile strength graph for 1% fiber

4.2.3 Flexural strength of beams

In this research, the flexural strength was measured by making beams of dimensions 100mm *100mm*500mm. These beams were cured for the required number of days, and then they were tested under a Flexural Testing Machine to determine their flexural strength.The results for flexural strength for various grades of concrete are shown in the tables given below, and their comparison is shown in the figures below.

Grade: M10

Table 4.12 Flexure strength for M10

No. of days	Normal Concrete	Foamed Concrete	Pervious Concrete
3	1.2	0.75	0.39
7	1.66	0.88	0.97
28	2.23	2.06	1.7

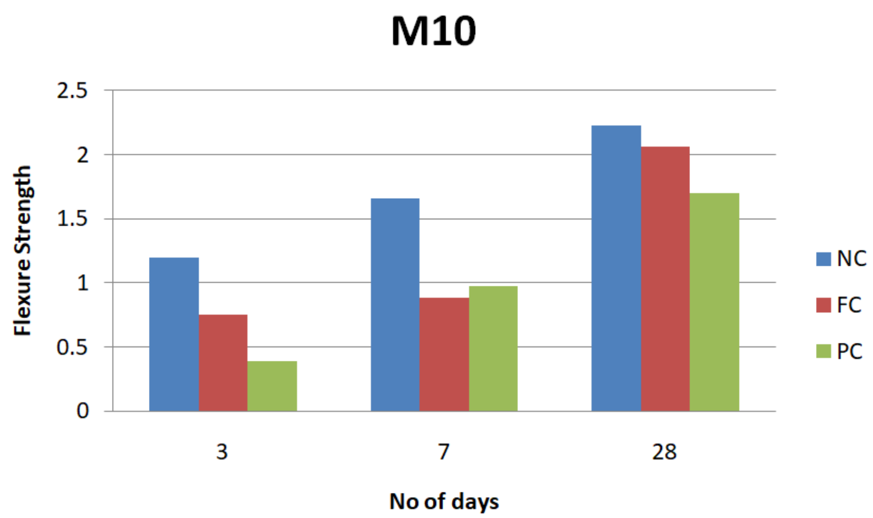


Fig 4.13 Flexure strength graph for M10

Grade: M15

Table 4.13 Flexure strength for M15

No. of days	Normal Concrete	Foamed Concrete	Pervious Concrete
3	1.64	1.3	0.6
7	2.33	1.62	1.46
28	3.04	2.9	2.4

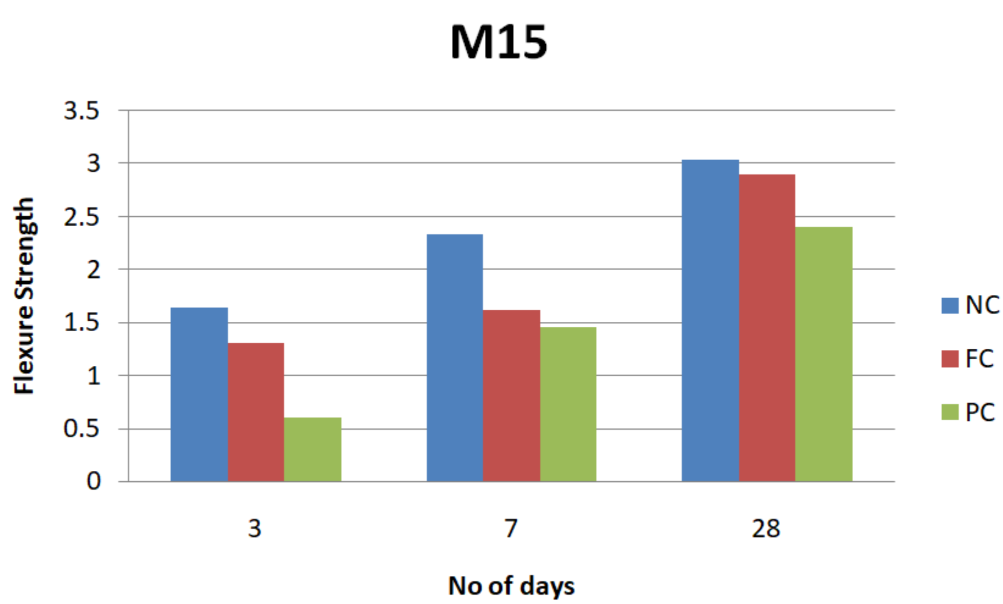


Fig 4.14 Flexure strength graph for M15

Grade: M20

Table 4.14 Flexure strength test for M20

No. of days	Normal Concrete	Foamed Concrete	Pervious Concrete
3	2.18	1.7	0.85
7	2.73	1.96	1.84
28	3.6	3.4	2.99

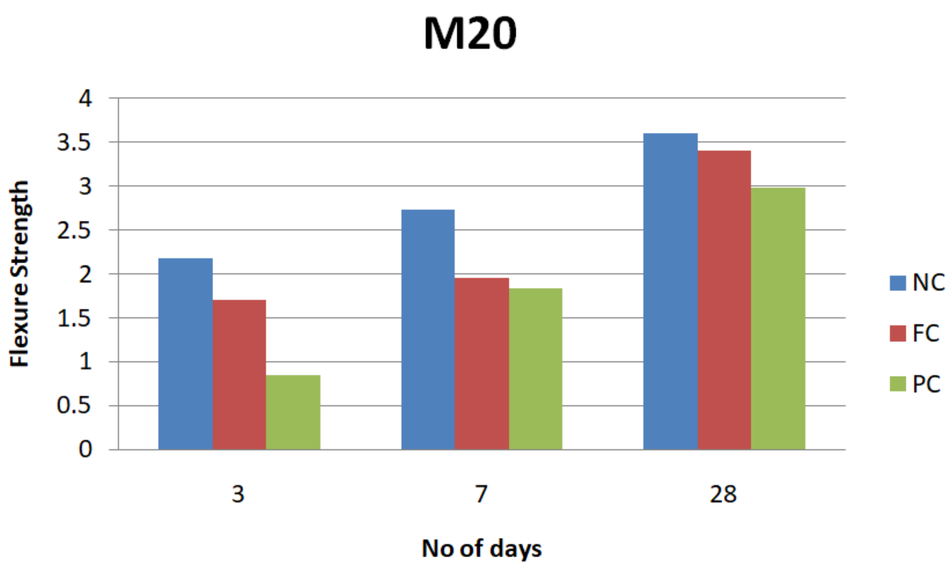


Fig 4.15 Flexure strength graph for M20

Grade: Fibrous Foamed concrete

Table 4.15 Flexure strength test for 0.5% fiber replacement

No. of days	FC	CSF1	BSF1	PPF1
3	0.75	0.92	0.87	0.83
7	0.88	1.01	0.98	0.94
28	2.06	2.30	2.25	2.17

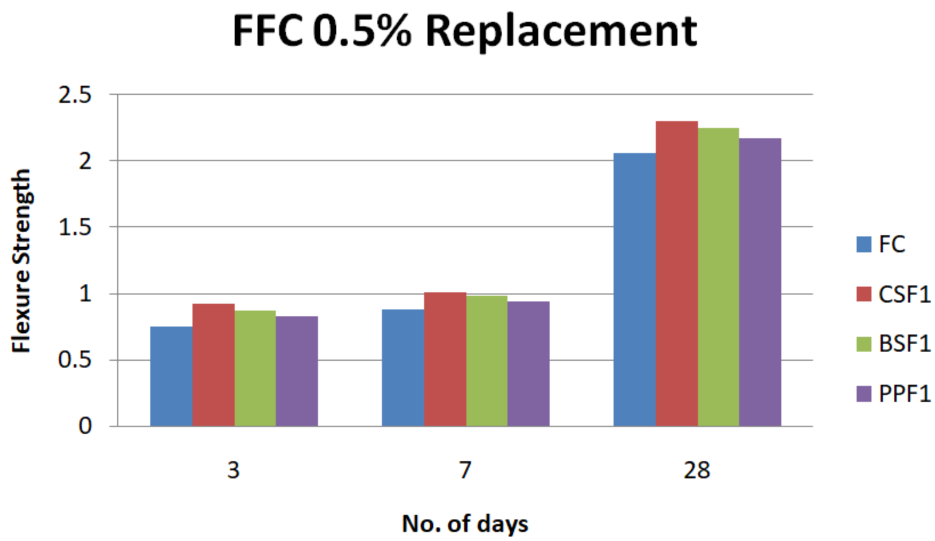


Fig 4.16 Flexure strength graph for 0.5% replacement

(a) Before testing

(b) After testing

Fig 4.17 Flexure testing of PPF beam

Table 4.16 Flexure strength test for 1% fiber replacement

No. ofDays	FC	CSF2	BSF2	PPF2
3	0.75	1.01	0.95	0.91
7	0.88	1.34	1.27	0.94
28	2.06	2.35	2.32	2.27

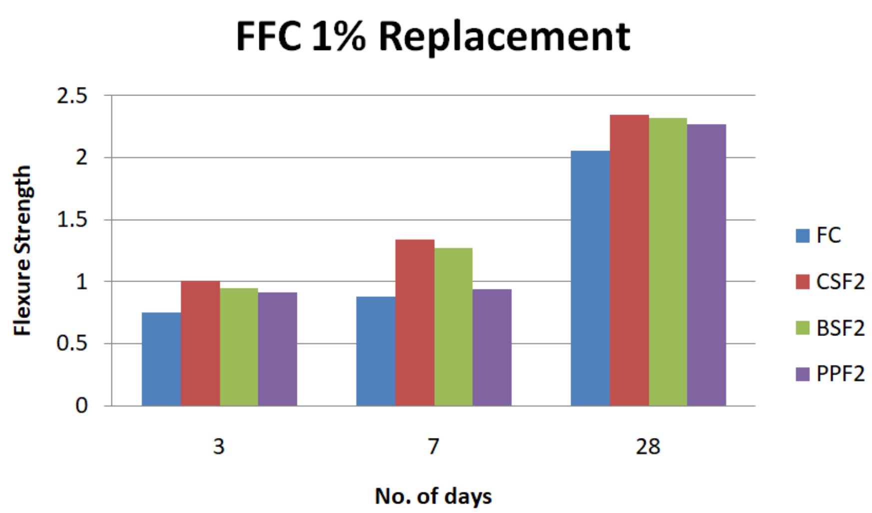


Fig 4.18 Flexure strength graph for 1% fiber replacement

4.2.3 Density

In this study, the density of different concrete grades was measured by creating cubes with measurements of 150mm *150mm*150 mm. The weight of these cubes was then accurately measured after demoulding, allowing for the determination of their respective densities.

Grade: M10

Table 4.17 Density for different type of concrete M10

Type of concrete	Weight (Kg)	Density (Kg/m^3)
Normal	9.08	2690
Foam	5.19	1540
Pervious	6.32	1873

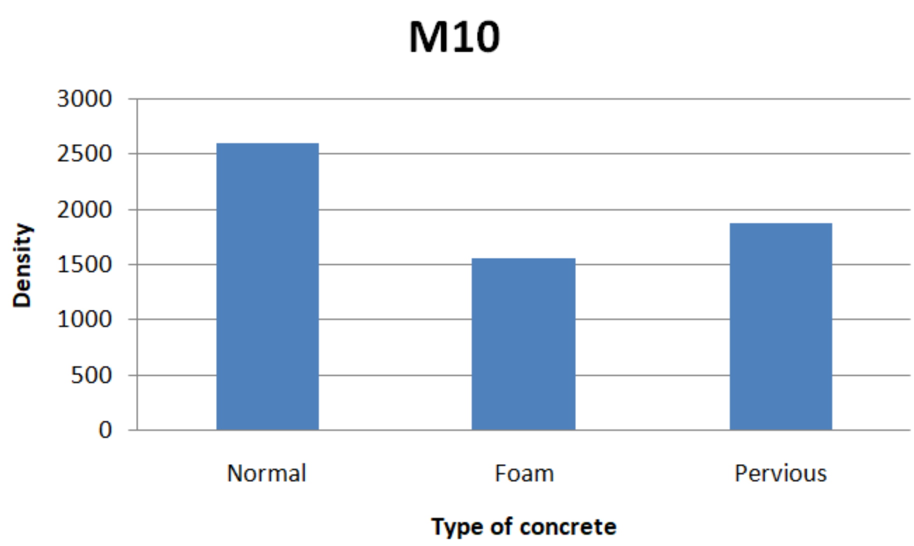


Fig 4.19 Density for different type of concrete M10

Grade: M15

Table 4.18 Density for different type of concrete M15

Type of concrete	Weight	Density
Normal	9.03	2676
Foam	5.83	1727
Pervious	6.49	1923

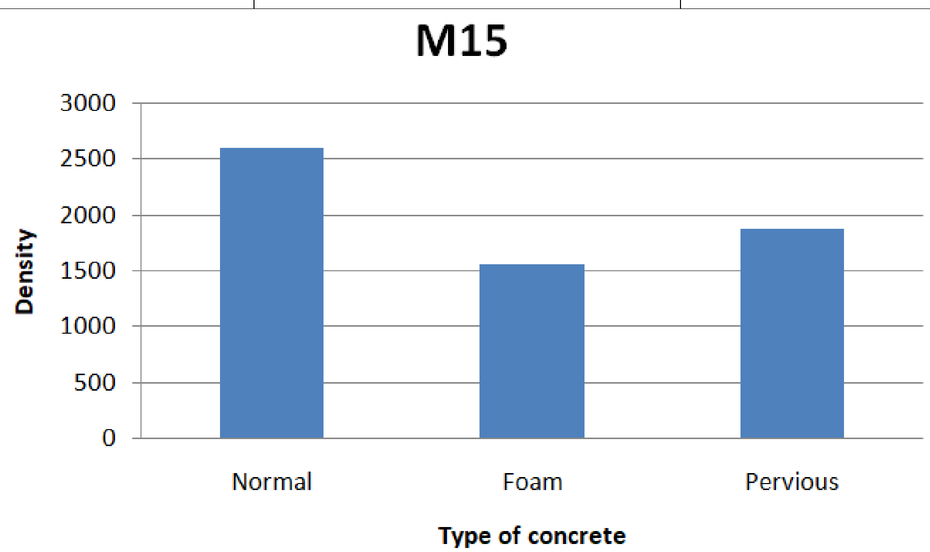


Fig 4.20 Density for different type of concrete M15

Grade: M20

Table 4.19 Density for different type of concrete M20

Type of concrete	Weight	Density
Normal	8.01	2373
Foam	6.27	1858
Pervious	6.59	1953

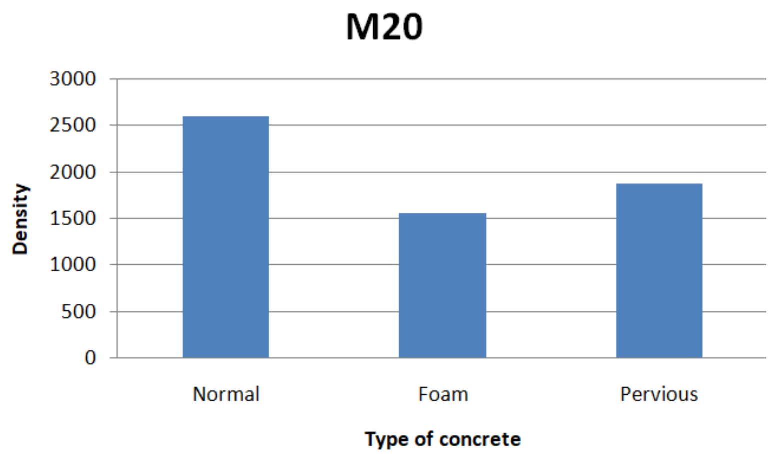


Fig 4.21 Density for different type of concrete M20

4.3 Cost analysis

The cost analysis of different types of concrete was conducted to compare the expenses associated with the construction of foam, pervious, and normal concrete. For this cost analysis, the rates of products from the nearby locality were taken. The prices of these concrete constituents are shown in the table below.

Table 4.20 Cost of different constituents

Constituent	Price(₹)
Cement	370 per bag
Coarse Aggregate	32 per cubic feet
Fine Aggregate	35 per cubic feet
Foaming Agent	82 per Liter

Cost of water for this analysis was taken zero.

The results for cost analysis for various grades of concrete are shown in the tables given below, and their comparison is shown in the figures below.

Grade: M10

Table 4.21 Cost analysis of M10

Constituent	Normal Concrete	Pervious Concrete	Foam concrete
Cement	1665	1883	2876
Fine Aggregate	569	-	752
Coarse Aggregate	1048	958	-
Foaming Agent	-	-	61
Total Cost (₹)	3282	2840	3690

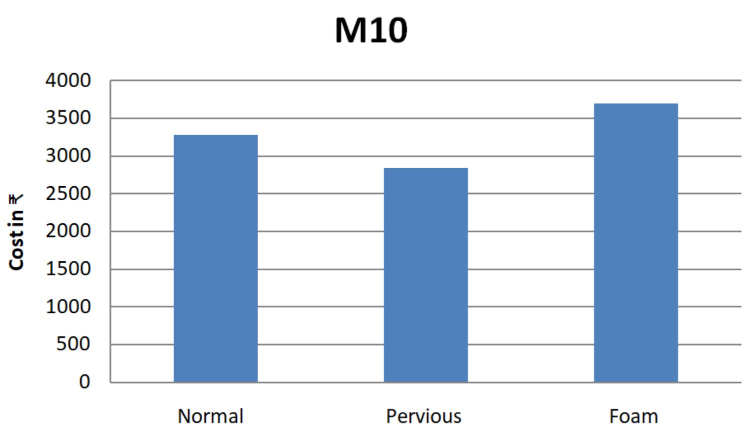


Fig 4.22 Cost analysis graph M10

Grade: M15

Table 4.21 Cost analysis of M15

Constituent	Normal Concrete	Pervious Concrete	Foam concrete
Cement	2376	2150	2846
Fine Aggregate	542	-	906
Coarse Aggregate	990	958	-
Foaming Agent	-	-	47
Total Cost (₹)	3908	3108	3799

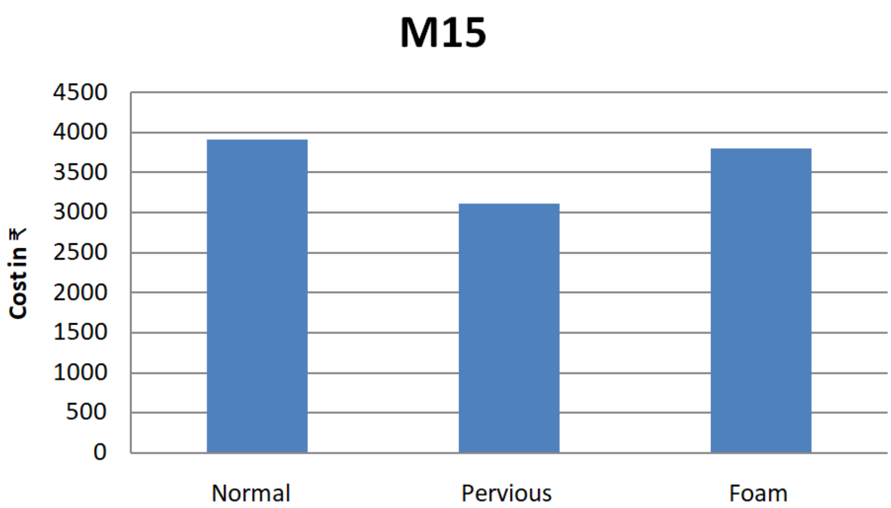


Fig 4.23 Cost analysis graph M15

Grade: M20

Table 4.22 Cost analysis of M20

Constituent	Normal Concrete	Pervious Concrete	Foam concrete
Cement	2963	2308	2846
Fine Aggregate	506	-	1012
Coarse Aggregate	701	958	-
Foaming Agent	-	-	38
Total Cost (₹)	4169	3265	3877

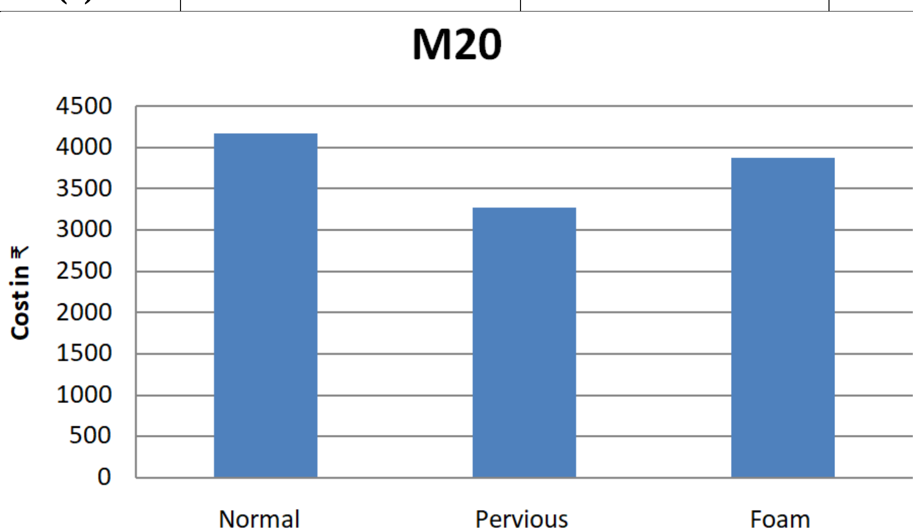


Fig 4.24 Cost analysis graph M20

CHAPTER 5

CONCLUSION

5.1 Conclusion

On the basis of the experiments conducted it was concluded that foamed concrete takes time to gain its strength. The rate of strength gain in foamed concrete is very little at the beginning but this rate of strength gain of foamed concrete increases very rapidly with time.

Normal Concrete consistently demonstrates the highest compressive strength values at all time intervals (3 days, 7 days, and 28 days). It exhibits superior strength development over time compared to Foamed Concrete and Pervious Concrete.Pervious Concrete generally displays the second highest strength, while Foamed Concrete demonstrates the lowest compressive strength values.Foam concrete of the same density, with different percentages of fiber, exhibits the highest compressive strength when incorporating crimped steel fiber. It is followed by brass-coated steel fiber, then polypropylene fiber, and finally foam concrete without fiber.

Normal Concrete shows the highest split tensile strength at all time intervals (3 days, 7 days, and 28 days), followed closely by Pervious Concrete. Foamed Concrete demonstrates the lowest split tensile strength among the three types.Foam concrete of the same density, with different percentages of fiber, exhibits the highest split tensile strength when incorporating BSF. It is followed by CSF, then polypropylene fiber, and finally foam concrete without fiber.

Normal Concrete exhibits the highest flexural strength among the three types at all time intervals (3 days, 7 days, and 28 days). Foamed Concrete generally demonstrates moderate flexural strength, while Pervious Concrete displays the lowest flexural strength values.Foam concrete of the same density, with different percentages of fiber, exhibits the highest compressive strength when incorporating CSF. It is followed by BSF, then PPF, and finally foam concrete without fiber.

Foam concrete demonstrates the lowest density among the three types, followed by Pervious Concrete and Normal Concrete. This characteristic implies that incorporating foam concrete in the structure can significantly reduce the dead load.

Foam concrete is most expensive for M10 due to the higher usage of foaming agent to achieve lightweight properties. It is followed by Normal Concrete and then Pervious Concrete. For M15 and M20 grade of concrete, Normal Concrete is the most expensive, followed by Foam Concrete, and then Pervious Concrete. It can be concluded that pervious concrete is the most cost-effective, followed by foam concrete, and then fiber concrete. But the use of pervious concrete is limited due to its very low workability.

5.2 Future study

There is considerable potential for future research in investigating the impact of foam on the properties of foamed concrete. The following areas offer opportunities for further study:

1. A more detailed examination of the engineering characteristics of foamed concrete, including Poisson's ratio, elastic modulus, shrinkage, and creep.
2. Investigation of the factors influencing foam stability to enhance understanding and control of foam quality.
3. Clarification of the mechanisms responsible for Foamed concrete has better fire resistance than regular concrete.
4. Development of standardized design methods for foam concrete to ensure consistent performance and structural integrity.
5. Evaluation of the characteristics of foamed concrete reinforced with different types of fibers to enhance its strength and durability.
6. Development of suitable superplasticizers that can increase the density of foamed concrete without negatively impacting foam stability and mix segregation.
7. Investigation into low-density, high-strength concrete formulas to develop a highly energy-efficient material for numerous applications.

By addressing these research areas, further advancements can be made in understanding and optimizing foamed concrete for enhanced performance and wider applications.

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