

Investigating Strength Characteristics of Pervious Concrete for Sustainable Construction

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering degree in
Civil Engineering

by

NASSER HUSSAIN (Register No: 40200008)

PRANAV ANAND (Register No:40200009)



DEPARTMENT OF CIVIL ENGINEERING
SCHOOL OF BUILDING AND ENVIRONMENT
SATHYABAMA
INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited with Grade “A++” by NAAC.

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

APRIL- 2024



SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with "A++" grade by NAAC

Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai – 600 119

www.sathyabama.ac.in



DEPARTMENT OF CIVIL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of Nasser Hussain (Register No: 40200008), Pranav Anand (Register No: 40200009) who carried out the project entitled **"Investigating Strength Characteristics of Pervious Concrete for Sustainable Construction"** under our supervision from June 2023 to April 2024.

Internal Guide

Dr.S.Packialakshmi

Head of the department

Submitted for Viva voice Examination held on 05/09/2024

Internal Examiner

External Examiner

DECLARATION

ACKNOWLEDGEMENT

I, Nasser Hussain (Register No: 40200008), Pranav Anand (Register No: 40200009) hereby declare that the Project Report entitled "Investigating Strength Characteristics of Pervious Concrete for Sustainable Construction" done by me under the guidance of Dr. S. Packialakshmi is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Civil Engineering.

We hereby express our thanks to Dr. S. Packialakshmi, M.E., Ph.D., Lecturer, School of Building and Construction, Anna University, Chennai, for her guidance and supervision during the project work. We also thank Dr. R. Padmanabhan, M.E., Ph.D., Lecturer, Department of Civil Engineering, Anna University, Chennai, for providing us with the necessary facilities and equipment for the project work.

We would like to express our gratitude to our project guide, Dr. S. Packialakshmi, for her valuable suggestions and constant encouragement during the project work. We also thank Dr. R. Padmanabhan, M.E., Ph.D., Lecturer, Department of Civil Engineering, Anna University, Chennai, for his valuable suggestions and constant encouragement during the project work.

1. 

2. Pranav Anand

DATE: 09/09/24

PLACE: CHENNAI

SIGNATURE OF THE CANDIDATES

ACKNOWLEDGEMENT

We are pleased to acknowledge our sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

We convey our thanks to **Dr. Devyani Gangopadhyay, B.Arch., M.T.P., Ph.D.**, Dean, School of Building and Environment and **Dr. S. Packialakshmi, M.E., Ph.D.**, and **Dr. R Padmapriya, M.E., Ph.D.**, Head of the Department, Dept. of Civil Engineering for providing us necessary support and details at the right time during the progressive reviews.

We would like to express our sincere and deep sense of gratitude to our Project Guide **Dr.S. Packialakshmi**, for her valuable guidance, suggestions and constant encouragement paved way for the successful completion of our project work. As well as we would like to thank our non-teaching staff member for their guidance to finish all the experiments which have been involved in this research.

We wish to express our thanks to all Teaching and Non-teaching staff members of the Department of Civil Engineering who were helpful in many ways for the completion of the project.

ABSTRACT

Pervious concrete, also known as permeable or porous concrete, is an innovative construction material that addresses many challenges associated with traditional concrete. Unlike conventional concrete, which is impermeable and inhibits water penetration, pervious concrete is designed to allow water to pass through it, promoting infiltration into the ground below. This unique characteristic makes pervious concrete an ideal solution for managing stormwater runoff, combating urban heat island effects, and reducing flooding in urban areas.

The composition of pervious concrete differs from conventional concrete in several key ways. It typically contains less fine aggregate and higher porosity, achieved by reducing or eliminating the sand and using larger aggregates. This results in a highly porous structure with interconnected voids ranging from 15% to 35% of the total volume, allowing water to permeate freely. To enhance its strength and durability, pervious concrete often incorporates specialized additives such as fibers, chemical admixtures, or supplementary cementitious materials.

One of the primary advantages of pervious concrete is its ability to mitigate stormwater runoff and promote groundwater recharge. By allowing rainwater to infiltrate into the soil, pervious concrete reduces the volume and velocity of runoff, minimizing the risk of flooding and erosion while replenishing groundwater supplies. This makes it an environmentally friendly alternative to traditional paving materials in parking lots, sidewalks, driveways, and other hardscape applications.

Moreover, pervious concrete contributes to sustainable urban development by helping to mitigate the urban heat island effect. Its high albedo and permeability reduce surface temperatures and heat retention compared to traditional pavements, thereby lowering ambient temperatures and improving air quality. Additionally, pervious concrete supports green infrastructure initiatives by facilitating the growth of vegetation and enhancing urban biodiversity.

Despite its numerous benefits, pervious concrete also presents some challenges, including maintenance requirements, susceptibility to clogging, and concerns regarding structural integrity. However, ongoing research and advancements in material science and engineering techniques continue to improve the performance and viability of pervious concrete for a wide range of applications.

pervious concrete represents a promising solution for sustainable urban development, offering effective stormwater management, heat island mitigation, and environmental benefits.

TABLE OF CONTENTS

CHAPTER No.	TITLE	PAGE	NO.
	ABSTRACT	V	
	LIST OF TABLES	Ix	
	LIST OF FIGURES	X	
	LIST OF ABBREVIATIONS	XI	
1	INTRODUCTION	01	
	1.1 GENERAL	01	
	1.2 GROUND GRANULATED BLAST FURNACE SLAG	02	
2	REVIEW OF LITERATURE	03	
	2.1 GENERAL	03	
	2.2 REVIEW OF LITERATURE	03	
3	AIM AND SCOPE	23	
	3.1 AIM	23	
	3.2 OBJECTIVE	23	
4	MATERIALS AND METHODS	24	
	4.1 METHODOLOGY	24	
	4.1.1 Experimental Investigation	25	
	4.2 MATERIALS AND PROPERTIES	25	
	4.2.1 Cement	26	
	4.2.2 GGBS	27	
	4.2.3 Fly Ash	28	
	4.2.4 Silica Fume	29	
	4.2.5 Fine Aggregate	29	
	4.2.6 Coarse Aggregate	30	
	4.2.7 Water	31	

	4.3 MIX DESIGN	31
	4.3.1 Mix design for M20 OPC 53	32
	4.3.2 Mix Design for GGBS concrete (25%)	36
	4.4 PREPARATION OF MATERIALS	40
	4.4.1 Preparation of Concrete molds	40
	4.4.2 Mixing Concrete	40
	4.5 TEST ON SPECIMEN	41
	4.5.1 Preparation of Specimen	41
	4.5.2 Demolding	42
	4.5.3 Curing	42
	4.6 TEST ON HARDENED CONCRETE	43
	4.6.1 Compression Strength test	43
	4.6.2 Split Tensile Strength test	44
5	RESULT AND DISCUSSION	45
	5.1 Compressive Strength	45
	5.2 Split Tensile Strength	47
6	SUMMARY AND CONCLUSION	48
	6.1 GENERAL	48
	6.1.1 Compressive strength test	48
	6.1.2 Split tensile strength test	48
	6.2 CONCLUSION	49
	REFERENCES	50

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
4.1	Properties of OPC 53 Cement	27
4.2	Properties of GGBS	28
4.3	Properties of Fine Aggregate	30
4.4	Properties of Coarse Aggregate	30
5.1	Summary of Compressive Strength	46
5.2	Summary of Split Tensile Strength	47

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO.
1.1	Conventional concrete	01
1.2	Non conventional concrete	01
4.1	Methodology chart	24
4.2	Ordinary Portland cement 53	26
4.3	Ground Granulated blast furnace slag	28
4.4	Concrete molds	40
4.5	Hand Mixing of a Fresh Concrete	41
4.6	Casting of specimen	42
4.7	Curing of Specimen	43
4.8	Split Tensile Strength	44
5.1	Compressive Strength Graph	46
5.2	Split Tensile Strength Graph	47

LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOLS

OPC
GGBS
EPA
FDPP
BMP
SUDS
W/C RATIO
PCPC
HPPC
SP
PCC
AEA
EVA
PP
SF
M-SAND
SCMs
ASTM

ABBREVIATIONS

Ordinary Portland cement
Ground granulated blast furnace slag
Environmental protection agency
Full depth permeable pavement
Best management practice
Sustainable urban drainage Systems
Water to cement ratio
Portland cement pervious Concrete
High performance porous Concrete
Super plasticizers
Portland cement concrete
Air entraining agents
Ethylene vinyl acetate
Polypropylene
Silica fume
Manufactured sand
Supplementary cementitious materials
American society for testing and materials

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Pervious concrete, also known as porous concrete, permeable concrete, or porous pavement, is a specialized type of concrete used in flatwork applications. It is designed with a high porosity that allows water from precipitation and even groundwater to pass directly through it, thereby reducing runoff from a site. This unique property makes it a valuable tool for sustainable construction and a crucial component of low impact development techniques aimed at safeguarding water quality. Pervious concrete differs from conventional concrete in that it primarily consists of large aggregates with minimal or no fine aggregates (Fig 1.1 and Fig 1.2). The concrete paste adheres to the aggregates but leaves enough space for water to permeate through the concrete slab. It is typically employed in various applications, including parking areas, locations with light traffic, residential streets, pedestrian walkways, and greenhouses.



Figure 1.1: Conventional concrete



Figure 1.2: Non-Conventional concrete

One of the significant advantages of pervious concrete is its role in managing stormwater. Recognized as a Best Management Practice by the U.S. Environmental Protection Agency (EPA), it serves as a means of first flush pollution control and stormwater management. As environmental regulations continue to restrict stormwater runoff, the cost of real estate development has risen due to the need for extensive drainage systems. Pervious concrete addresses this issue by reducing runoff, enabling the use of smaller storm sewers, and eliminating the need for separate stormwater retention ponds, making property development more cost-effective. Additionally, pervious concrete acts as a natural filter, reducing the pollutant load entering streams, ponds, and rivers. It functions as a stormwater infiltration basin, allowing water to infiltrate the soil over a wide area, facilitating the recharge of groundwater supplies. This not only conserves valuable groundwater but also leads to more efficient land use. Furthermore, pervious concrete benefits the environment by mitigating the impact of urban development on trees. Its design allows water and air to reach the root systems of trees, promoting their growth even in densely developed areas. In summary, pervious concrete is a special type of highly porous concrete designed for various flatwork applications, which plays a crucial role in managing stormwater and protecting water quality. It is recognized by the EPA as a Best Management Practice, making it a valuable tool for builders and property developers to reduce runoff, control pollution, and enhance sustainable construction practices. It also contributes to more efficient land use and supports the growth of trees in urban environments.

1.2 GROUND GRANULATED BLAST-FURNACE SLAG (GGBS)

GGBS (Ground Granulated Blast-furnace Slag) is a cementitious material whose main use is in concrete and is a by-product from the blast-furnaces used to make iron. Blast-furnaces operate at temperatures of about 1,500°C and are fed with a carefully controlled mixture of iron ore, coke, and limestone. The iron ore is reduced to iron and the remaining materials form a slag that floats on top of the iron. It can be used as an alternative material to OPC due to its inherent binding properties.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Concrete which is most widely utilized building component in the globe by up to six billion tones are manufactured every year. This makes it into one of the most versatile essential material for the purpose of construction. The main purpose of literature review is to give an idea about the research work conducted in the construction sector. This forms the bases on which one can carry out the work and techniques that can be used for conducting further experiments. The following literature review elaborates the research studies made about the strength of concrete whose cement has been replaced with GGBS, Fly ash, silica fume.

2.2 REVIEW OF LITERATURE

The present chapter elaborates the various materials and methods that were adopted by the several authors for their research especially on pervious concrete.

Gaurav Uttam Shinde & Valunjkar (2015) conducted a study on Cost and Time Control in Storm Water Management using Pervious Concrete. Their study revolves around the use of pervious concrete in metro cities as a road pavement material. This concept is relatively new in metro cities due to issues related to low groundwater levels and stormwater management in urban areas. The authors present a case study where they analyse various data points, including rainfall data, Traffic volume data, and soil and geotechnical investigation data from a residential colony. This analysis helps determine the suitability of pervious concrete for stormwater management in the given context. They also compare the costs associated with traditional stormwater management methods and stormwater management using pervious concrete pavement. The paper emphasizes that cost considerations are crucial in metro cities where maintaining expensive stormwater management systems can be challenging due to the large population. The authors

argue that pervious concrete pavement offers an irreplaceable and effective solution to address the increasing environmental and population demands in these urban areas.

Jannathul Thasni & JouharShareef (2018) developed a comprehensive summary of research pertaining to water-absorbing pavement constructed using porous concrete. The primary focus of their study is to address several critical issues, including low groundwater levels, agricultural challenges, and the effective management of stormwater runoff. The following key points and findings are elaborated upon in the paper. The paper begins by introducing the problem of declining groundwater levels, the adverse effects on agriculture, and the need for innovative solutions to manage stormwater runoff effectively. The authors delve into the concept of porous concrete as a potential solution. They explain that porous concrete is designed with a unique structure that allows it to absorb and store water, reducing runoff and recharging groundwater. The paper discusses the engineering properties of porous concrete, including its porosity, permeability, and compressive strength. These properties are vital for evaluating its suitability for various applications. The authors examine the materials used in the construction of porous pavement, including cement, aggregates, water, and admixtures. This discussion highlights the importance of selecting appropriate materials to achieve the desired properties. The study outlines the benefits and advantages of porous concrete, emphasizing its role in mitigating water-related issues. These advantages include improved groundwater recharge, reduced flooding, and enhanced sustainability. In addition to its merits, the paper also addresses the disadvantages of porous concrete, such as potential clogging over time and the need for periodic maintenance. The authors investigate the durability and strength of porous concrete, crucial factors to consider when assessing its long-term performance and suitability for various applications. A noteworthy aspect of the research is the discussion on the replacement of cement with fly ash in porous concrete. This substitution is explored to promote environmentally friendly paving solutions while ensuring safe material disposal. The paper concludes by highlighting how the incorporation of fly ash in porous concrete contributes to eco-friendliness in paving pavements. This approach aligns with sustainable practices and reduces the environmental impact of construction. In summary, the paper authored by Jannathul Thasni P. and Jouhar

Shareef in 2018 provides a comprehensive exploration of porous concrete as a solution for addressing water-related challenges, particularly low groundwater levels, agriculture problems, and stormwater management. The authors delve into the engineering properties, materials, benefits, disadvantages, durability, and strength of porous concrete, while also emphasizing the eco-friendly aspects of using fly ash as a replacement for cement.

Jayeshkumar Pitroda & Bhavsar (2013) conducted a study on pervious pavement, and they explored the use of perforated concrete as a novel concept for rural road pavement. Their research focused on the specific challenges faced by rural areas, particularly the impact of rising groundwater levels on agriculture. Traditionally, concrete had been used as the primary material for paving rural roads. One of the key findings of their study was the importance of cost considerations in rural areas. They emphasized that rural regions often have limited resources, and therefore, expensive stormwater management practices were not feasible. Instead, they proposed a solution that involved capturing rainwater and allowing it to seep into the ground through perforated concrete pavement. This innovative pavement technology served multiple purposes. Firstly, it effectively managed rainwater by allowing it to infiltrate the soil, reducing the risk of flooding and erosion. Secondly, it eliminated the need for constructing costly stormwater management features such as retention ponds and swales. This, in turn, led to more efficient land use in rural areas. In summary, Pitroda and Bhavsar's study highlighted the suitability of perforated concrete pavement for rural roads, especially in regions where cost-effective stormwater management was a priority. Their research not only addressed agricultural problems caused by rising groundwater levels but also offered a sustainable and economical solution for rural communities by promoting efficient land use and reducing the need for expensive stormwater management infrastructure.

Mosoud Kayhanine et al (2019) conducted a study, where they delved into the utilization of perforated pavements on highways as a means of managing stormwater runoff and preventing pollution. Their comprehensive research encompassed several critical aspects related to this innovative approach, including

hydraulic performance evaluation of permeable pavement, permeability measurements of porous asphalt and previous concrete paved surfaces, clogging assessment of permeable pavement surfaces, and addressing water quality and pollution control issues. One of the central findings of their collective studies highlighted the promising potential of permeable pavements, particularly Full Depth Permeable Pavement (FDPP), as integral components of sustainable transportation initiatives. The authors emphasized that, when designed correctly, FDPP can serve as an effective alternative best management practice (BMP) for managing stormwater runoff. The key to the success of FDPP lies in its specific characteristics throughout the lifespan of the pavement. Notably, the surface pavement must remain highly permeable and unclogged. This attribute ensures that the captured runoff can easily infiltrate the subgrade soil, thereby preventing adverse impacts on underground water sources. In essence, the research underscores the importance of proper design maintenance of FDPP to maximize its potential benefits in stormwater management and pollution prevention within the context of sustainable transportation programs.

Saurabh Y. Kale et al (2017) explored the topic of Permeable Pavement Systems and their various applications. The study focused on several key aspects related to this technology and its role in sustainable urban development.

The researchers investigated the concept of permeable pavement systems, which are designed to allow water to pass through them, rather than creating runoff. This type of pavement has become increasingly popular as a means of managing stormwater in urban areas. The paper delved into the concept of sustainable drainage systems (SuDS) and how permeable pavement fits into this framework. SuDS aim to mimic natural water management processes and reduce the impact of urban development on the environment. The study examined the characteristics and benefits of porous pavement, a type of permeable pavement designed to facilitate water infiltration into the ground. This helps to reduce surface water runoff and prevent flooding. The researchers discussed the role of permeable pavement in stormwater management. These systems are capable of effectively capturing and filtering rainwater, which can help mitigate the adverse effects of heavy rainfall and

improve water quality. The paper emphasized the sustainability aspects of permeable pavement systems. By reducing the need for traditional drainage infrastructure and promoting natural water filtration, these systems contribute to environmental sustainability. The study explored the filtration and drainage capabilities of permeable pavement. It described how these pavements are designed to filter pollutants from stormwater, promoting cleaner water quality. The research touched upon the potential for geothermal heating and cooling using permeable pavements. These systems can be integrated into larger sustainable urban designs to harness geothermal energy for temperature control. The paper highlighted the importance of water quality control in urban areas. Permeable pavement systems play a role in maintaining high water quality by preventing contaminants from entering water bodies. The researchers discussed the maintenance requirements of permeable pavement systems and how they need to be managed to ensure their long-term effectiveness. The study considered recent innovations in permeable pavement technology, as well as the advantages and disadvantages associated with its implementation. The focus of the paper was to demonstrate the practical application of permeable pavement within the context of a sustainable urban drainage system. This highlighted the potential benefits of incorporating this technology into urban planning and development. In summary, the research centred on the use of permeable pavement systems in sustainable urban drainage. They examined the various aspects, benefits, and challenges associated with this technology, aiming to showcase its potential application in enhancing urban water management and promoting environmental sustainability.

Vikram and Mehla (2015) investigated the effects of various combinations of materials on the properties of pervious concrete. They focused on altering the composition by replacing a portion of the cement with silica fume (6%) and adding superplasticizers (0.13-0.25%). Additionally, they varied the size of the aggregates used in the concrete mix, with sizes ranging from 4.75 to 20 millimetres. The water-to-cement (W/C) ratio was kept constant at 0.34 throughout the experiments. The researchers examined several key properties of the pervious concrete, including its workability, compressive strength, split tensile strength, flexural strength at 7, 28, and 56 days, as well as bond strength at 28 and 56 days. These properties were

assessed through experimental testing. The results of the study revealed some important findings. Firstly, it was observed that the strength of pervious concrete decreased with the addition of silica fume and superplasticizers. This suggests that these additives had a detrimental effect on the overall strength of the concrete mix. Secondly, the researchers noted that the choice of aggregate size had a significant impact on the performance of the pervious concrete. Specifically, concrete mixes with aggregate sizes in the range of 4.75 to 10 millimetres exhibited better properties compared to mixes with aggregate sizes of 10-20 millimetres or 4.75-20 millimetres. This indicates that the size of the aggregates used played a crucial role in determining the quality and performance of the pervious concrete. In summary, the study conducted by Vikram and Mehla (2015) explored the influence of silica fume, superplasticizers, and aggregate size on the properties of pervious concrete. The results emphasized the importance of carefully selecting the materials and aggregate sizes to achieve the desired characteristics and strength in pervious concrete mixes.

Admire et al(2008). have conducted a comprehensive literature review on the topic of permeable pavements. In their research, they have explored various aspects related to permeable pavements, including their types, applications, longevity, water quality considerations, and future research prospects. Permeable pavements refer to a type of pavement construction that allows water to pass through the surface and be absorbed into the ground or directed to a drainage system. These pavements have gained increasing popularity due to their potential benefits in managing stormwater runoff, reducing flooding, and improving water quality. The authors have summarized the various types of permeable pavements available in the literature. This includes pervious concrete, which is the most common type used today. Other types may include permeable asphalt, interlocking concrete pavers, and permeable pavers made from different materials. The research discusses the needs for permeable pavements, highlighting their role in mitigating stormwater runoff, preventing erosion, and improving groundwater recharge. They also describe the applications of these pavements in both residential and commercial settings, as well as in public infrastructure projects. The authors have explored the expected lifespan of permeable pavements. This involves understanding how durable and long-lasting

these pavements can be under various conditions and maintenance practices. Factors such as traffic load, climate, and maintenance play a role in determining their lifespan. The quality of water that passes through permeable pavements is a critical concern. The research discusses how these pavements can help filter and improve the quality of water that enters the groundwater or nearby bodies of water. This aspect is crucial for addressing water pollution and maintaining ecosystem health. The authors have also delved into the future scope of permeable pavements and potential areas for further research. This could include improvements in pavement materials, design, and maintenance practices, as well as a deeper understanding of their environmental and economic benefits. In summary, this provides a comprehensive overview of permeable pavements. They have covered the types, applications, lifespan, water quality considerations, and future research directions related to these innovative and environmentally friendly pavement systems.

Javier Castro (2010) conducted an experimental study that delved into the crucial role of the pore network characteristics in controlling the transport properties of concrete. The study highlighted that various factor, including total porosity, pore size, pore connectivity, and pore saturation, exert a significant influence on the transport coefficients of concrete, as previously documented by researchers such as Gardocki (1990) and Bentz et al. (1999). One noteworthy trend in contemporary research focuses on environmentally sustainable development practices. Central to this effort is the adoption of pervious concrete as a viable alternative to traditional concrete.

Pervious concrete has emerged as an effective method for mitigating and minimizing negative environmental impacts associated with conventional concrete use. This innovative material incorporates voids within its structure, enabling the passage of water through it. This feature serves a dual purpose by not only reducing the problem of waterlogging but also enhancing road surface skid resistance and elevating the water table. In the study, the performance of pervious concrete was systematically compared with the conventional materials employed in the construction of concrete road pavements. A battery of tests was conducted to assess various properties of

the concrete, including compression strength, flexural strength, and permeability. The results revealed several advantageous characteristics of pervious concrete, notably increased skid resistance and high permeability. However, it was also noted that pervious concrete requires high strength when used in highly trafficked areas. While pervious concrete may not be suitable for all road applications due to its strength requirements, it has demonstrated its compatibility for use in low-volume traffic areas. The implementation of pervious concrete pavements could yield several positive environmental outcomes. These might include improved water drainage, reduced waterlogging issues, enhanced road safety through increased skid resistance, and a rise in the water table, which can have various ecological benefits. In summary, Javier Castro's research underscores the potential of pervious concrete as a valuable solution for addressing environmental concerns and improving transportation infrastructure, albeit with certain limitations in high-traffic scenarios.

Mageswari.et.al (2016) investigated a novel approach for managing water in concrete pavements. Their research aimed to collect water that accumulates in concrete pavements and direct it to either a treatment plant or a recharge pit. The primary focus was on designing a concrete mix that would effectively facilitate this water management while maintaining structural integrity. Here are the key points from their study. The main objective of their research was to develop a concrete pavement design that could efficiently collect and manage water that accumulates within it. The collected water could then be directed for treatment or recharging into the ground. The researchers experimented with various combinations of materials, including cement, GGBS (Ground Granulated Blast Furnace Slag), water, and coarse aggregates. These combinations were tested in different proportions to determine the optimal mix for achieving M20 grade concrete. They found that an M20 grade concrete mix could be achieved with a water-to-cement ratio (w/c) of 0.36. The coarse aggregate used had a nominal size of 20 mm, passing through a sieve and retaining 10 mm. Furthermore, 30% of the cement content was replaced with GGBS. The cement-to-coarse aggregate ratio was 1:4. The researchers conducted tests and determined that the resulting concrete had a compressive strength of 20.4 kN/m³. This finding suggests that the concrete mix met the structural requirements for a pavement while still accommodating their water management goals. As part of

their design, the researchers proposed the inclusion of a perforated pipe at the center of the pavement, above the sub-base. This perforated pipe likely played a crucial role in collecting and channeling the water to the desired treatment plant or recharge pit. In summary, the study focused on the development of a concrete pavement design (M20 grade) capable of efficiently managing water accumulation within the pavement. They achieved this by experimenting with various material combinations and ratios, ultimately resulting in a concrete mix with suitable structural properties and a proposed inclusion of a perforated pipe for water collection and redirection.

Mohammed Sonebia, et.al (2016) highlights the significant role of Portland cement pervious concrete (PCPC) in sustainable urban drainage systems (SUDS) and its positive impact on environmental conditions. PCPC has emerged as a valuable tool in mitigating various urban challenges, particularly in terms of improving environmental sustainability. One of the primary advantages of PCPC is its ability to minimize flooding risks in urban areas. By allowing rainwater and snowmelt to percolate through the ground, PCPC helps in recharging the groundwater table and reducing surface runoff. This reduction in runoff also helps in mitigating peak flows during heavy rainfall events, which can be instrumental in preventing downstream flooding. Furthermore, PCPC contributes to enhancing water quality. By allowing water to pass through the porous concrete and filter contaminants, it effectively acts as a natural water purification system. This quality improvement is crucial for safeguarding the health and safety of living organisms and ecosystems. Beyond its drainage-related benefits, PCPC also plays a vital role in mitigating the urban heat island effect. PCPC surfaces reduce the absorption of solar radiation and heat storage potential in urban areas. This results in more temperate urban conditions, contributing to the overall well-being of the environment and residents. One of the key challenges in urban areas is the increase in impervious surface areas, such as roads and buildings, which hinder the percolation of precipitation into the ground. PCPC addresses this challenge by providing a permeable alternative, reducing the potential for excessive surface runoff. This, in turn, helps in preventing downstream flooding and offers an effective means to control pollution. In summary, Portland cement pervious concrete has proven to be a valuable and sustainable solution for

urban drainage systems. It aids in flood risk reduction, groundwater recharge, runoff management, water quality improvement, and mitigating urban heat, all of which contribute to healthier and more environmentally friendly urban environments. Its use can significantly enhance the overall quality of urban living while safeguarding the environment.

Aamer Rafique Bhutta et al. (2012), the primary objective of this research was to comprehensively assess various characteristics of HPPC to determine its suitability for practical applications. The study involved conducting a series of tests on the HPPC, including slump, slump-flow, void ratio, coefficient of permeability, as well as assessments of its compressive and flexural strengths and strength development rate. Moreover, the researchers introduced a test to investigate the impact of high water-reducing and thickening (cohesive) agents on the self-compaction of HPPC. The intent was to evaluate how these additives influenced the concrete's hardened properties and its practical utility. The results of the study indicated that by combining a superplasticizer (SP) with a cohesive agent, it was possible to produce HPPC with excellent workability and strength properties. The introduction of the cohesive agent into the HPPC mixture led to a reduction in the total void ratio and permeability, while it significantly increased the compressive and flexural strengths of the concrete. This effect was observed consistently across various types of porous concrete and aggregate sizes, highlighting a nearly linear relationship between compressive strength and total void ratio, as well as between the coefficient of permeability and total void ratio within the range of 15–30% total void ratio. The study also introduced a new method for assessing the properties of HPPC, known as the "freely dropping method." This method had a substantial impact on various parameters, such as the apparent density, compaction, total void ratio, coefficient of permeability, and compressive strength of HPPC. The evaluation of workability using this method was deemed successful, with the apparent density showing consistency across different positions and a compaction index exceeding 80%. Additionally, the permeability of HPPC assessed through the freely dropping method was found to be acceptable. However, it's important to note that when HPPC was created using different aggregate sizes, variations in permeability values were observed. This implies that the choice of aggregate size can influence the permeability characteristics of high-performance porous concrete. In summary, the

research by M. Aamer Rafique Bhutta, K. Tsuruta, and J. Mirza focused on evaluating the properties of high-performance porous concrete, particularly its workability, strength, and permeability. The study introduced the use of specific additives to enhance the concrete's performance and established a new method for evaluating its properties. The results shed light on the potential for producing HPPC with desirable properties for practical applications while also recognizing the influence of aggregate size on its permeability.

Aoki, et.al(2012) conducted a study in which the properties of pervious concrete containing fly ash as a cementitious agent were investigated and discussed. The research aimed to assess the impact of reducing the amount of general-purpose Portland cement in pervious concrete by introducing fly ash. Several properties of the pervious concrete samples were carefully examined, including density, porosity, compressive strength, water permeability, and drying shrinkage. Additionally, the relationships between these properties were explored. The density of pervious concrete was found to be approximately 1800 kg/m³, and it was observed that there was no significant difference in density when altering the aggregate grading or the amount of cement replaced with fly ash. The study indicated a noticeable trend: as the density of pervious concrete increased, the porosity decreased. In the density range of 1700 kg/m³ to slightly higher than 1900 kg/m³, the porosity ranged from 0.20 to 0.40. Furthermore, the compressive strength of pervious concrete exhibited an improvement with increasing density. The compressive strength increased from 8 MPa to 12 MPa when the density increased by 100 kg/m³. The study also investigated the effect of density on the water permeability coefficient of pervious concrete. It was observed that as the density increased, water permeability decreased significantly. For instance, the water permeability decreased from 20 mm/s when the density was around 1750 kg/m³ to 10 mm/s when the density was over 1900 kg/m³. It's important to note that the use of low calcium fly ash was considered in the study, and the researchers suggested that further investigation should be carried out to assess the long-term effects. Additionally, they recommended investigating the methodology of curing in the context of pervious concrete with fly ash as a cementitious agent. This research provides valuable insights into the properties and performance of pervious concrete containing fly ash,

which could have implications for sustainable construction and infrastructure projects.

Anush K. Chandrappa and Krishna Prapoorna Biligiri (2012) conducted research on pervious concrete as a sustainable pavement material, focusing on research findings and future prospects. Their paper provides a comprehensive review of the developments and the current state-of-the-art in the field of pervious concrete research and practices. They specifically investigated the mechanical, hydrological, and durability properties of pervious concrete in various studies. Pervious concrete, a porous form of concrete, has gained attention from urban developers and contractors due to its numerous advantages. It is particularly appealing for low-volume road applications. The paper also delves into rehabilitation techniques aimed at improving the hydraulic efficiency of pervious concrete pavements. The main objective of this paper is to emphasize the importance of pervious concrete and its benefits in the context of urbanization. It discusses various properties of pervious concrete, including mechanical, hydrological, durability, field performance, environmental impact, and cost-benefit aspects. The authors highlight the potential of pervious concrete as a sustainable pavement material for low-volume roads like local streets, pedestrian walkways, driveways, and possibly even arterials and highways in the future, provided that mechanistic-based design procedures are developed. The paper concludes by noting that previous studies have identified several research gaps in the field of pervious concrete. Addressing these gaps through further research and study can enhance our understanding of the material and contribute to the development and implementation of design standards for pervious concrete pavements. In summary, the research conducted by Chandrappa and Biligiri underscores the promising potential of pervious concrete as a sustainable pavement material and highlights the need for continued research to unlock its full potential in the construction of various types of roads.

Qiao Dong. et.al(2005), investigated three laboratory abrasion test methods for evaluating the abrasion and raveling resistance of Pervious Concrete (PCPC). These methods were the Cantabro test, the loaded wheel abrasion test, and the surface abrasion test. To assess the effectiveness of these test methods, the

researchers conducted tests on eight PCPC mixtures that included various sizes of coarse aggregates and additives. Cantabro Test: The Cantabro test, while showing good sensitivity and repeatability, had limitations. It provided high weight loss values, which might not accurately represent abrasion resistance since the specimens' damage was caused by impact rather than abrasion. To improve the effectiveness of this test, it was suggested to use fewer revolutions. Loaded Wheel Abrasion Test: The loaded wheel abrasion test demonstrated the best sensitivity and repeatability among the three methods. It was especially effective when studded steel wheels and high wheel loads were employed, enhancing the test's ability to evaluate abrasion resistance. This test method stood out as a reliable option for assessing PCPC. Surface Abrasion Test: The surface abrasion test was effective in distinguishing the control mix from other mixtures. However, it failed to differentiate between mixtures containing latex and/or Fiber due to unfavourably low weight loss values. The study recommended modifications, such as prolonging the test period and increasing the abraded area, to make this test more severe and effective in distinguishing between different mixtures. In summary, the investigation concluded that the loaded wheel abrasion test was the most sensitive and repeatable method for assessing abrasion resistance in PCPC. The surface abrasion test showed promise but required adjustments to enhance its effectiveness in distinguishing mixtures containing Fiber and latex. The Cantabro test, although effective, was not ideal for evaluating PCPC abrasion resistance, and using fewer revolutions might improve its performance. This study provides valuable insights into the evaluation of abrasion resistance in pervious concrete, offering guidance for researchers and practitioners in this field.

Sriravindrarajah, et.al(2000), investigates the impact of clogging on the water permeability of pervious concrete. Pervious concrete is a special type of concrete designed to allow water to pass through it, making it useful for various applications such as pavements. The study focused on understanding how pore structure clogging and compaction affect the ability of pervious concrete to allow water to permeate through it. The researchers conducted experiments to assess the water permeability of pervious concrete, using a falling head method. The results revealed that the presence of clayey materials in the water that passes through the pervious concrete significantly reduced its water permeability. In the investigation, the

researchers intentionally clogged the pores of the pervious concrete by introducing varying amounts of clayey materials in the percolating water as it passed through the concrete under the falling head method. The researchers found that compaction should be avoided during the installation of pervious concrete pavements, as it has a detrimental effect on the water permeability of the concrete. In other words, the process of compacting the concrete can seriously damage its ability to allow water to pass through. The study revealed that un-compacted pervious concrete, which had 50% of its cement content replaced with fly ash, exhibited a 7-day compressive strength of 6.9 MPa and a water permeability of 12.5 mm/s. However, the research showed that clogging of the pores in this type of concrete became a significant problem in maintaining its water permeability over time. The research suggested that high-pressure water cleaning is an effective maintenance approach for restoring the water permeability of pervious concrete. This means that when clogging occurs, cleaning the concrete with high-pressure water can help alleviate the issue and ensure that water can pass through it as intended. In summary, this study emphasizes the importance of avoiding compaction during the installation of pervious concrete pavements to maintain their water permeability. It also highlights the challenges associated with pore clogging in pervious concrete and suggests high-pressure water cleaning as a viable solution for restoring its water permeability when needed.

John T. Kevern, et.al(2009), investigated the temperature behaviour of Pervious Concrete Systems (PCPC). To assess this behaviour, they created a fully monitored parking lot at Iowa State University as part of the Iowa Pervious Concrete Stormwater Project. This parking lot consisted of two halves, one made of traditional concrete and the other of PCPC. Various sensors were strategically placed throughout the pavements and the underlying soil to gather data. Insulation Effect: The presence of air in the aggregate base beneath the PCPC acts as an insulating layer. Coupled with the higher latent heat associated with the increased soil moisture content, this insulation significantly delays or even eliminates the formation of a frost layer underneath the PCPC while still maintaining its permeability. This means that, even when the air temperature is well below freezing, the temperature within the

PCPC remains considerably warmer. This suggests that the PCPC surface could potentially be above freezing even when traditional dicers would be ineffective due to extremely low air temperatures. **Faster Thawing:** The study found that the PCPC system thaws much faster compared to traditional concrete. Thawing under the traditional Portland Cement Concrete (PCC) pavement took place approximately a month after thawing under the PCPC system. The maximum temperature differential between the pervious pavement and the air temperature occurred during warm conditions. **Temperature Differential:** The maximum temperature difference between the pervious and traditional pavements was observed during moderate conditions. The PCPC exhibited a more rapid rate of heating and cooling compared to traditional concrete. Furthermore, the daily low temperatures of the PCPC were either equal to or cooler than those of the traditional concrete, indicating that the PCPC had a lower heat storage capacity. In summary, the study demonstrated that the presence of air in the aggregate base of PCPC serves as an effective insulating layer, delaying frost formation and maintaining permeability even in extremely cold conditions. PCPC also exhibited faster thawing and more significant temperature differentials, with the pavement surface potentially remaining above freezing in colder weather. These findings have important implications for the use of PCPC in various construction and environmental application.

Muhannad T. Suleiman, et.al(2005), developed a novel method for ground improvement using pervious concrete piles. Pervious concrete piles are designed to offer increased stiffness and strength, independently of the surrounding soil confinement, while also maintaining permeability comparable to traditional granular columns. This innovative ground improvement technique has the potential to enhance the performance of structures built on weak or unstable soils. To achieve their research objectives, the authors conducted four vertical load tests, which involved one granular column and three pervious concrete piles. In their paper, they present information on the material properties of pervious concrete, the installation method they developed, and the vertical load responses of pervious concrete and aggregate piles. They also briefly discuss the variations in soil stresses and displacements during the installation of these piles. **Superior Strength: Pervious**

concrete piles exhibited a compressive strength more than ten times greater than that of granular columns while maintaining permeability like traditional granular columns. Higher Ultimate Load: The pervious concrete pile, which shared the same dimensions, aggregate type, and installation method as the granular column, demonstrated an ultimate load that was 4.4 times greater than that of the granular column. Additionally, the pervious concrete pile failed by vertically punching into the soil at the pile tip, whereas the granular column failed by bulging outward into the surrounding soil. Impact of Installation Method: The installation method had a significant impact on the response of pervious concrete piles. Comparing the response of two pervious concrete piles installed using different methods (precast pile and installed pile), the ultimate load of the installed pile was 2.6 times greater than the ultimate load of the precast pile. Increased Frictional Stress: Installation of the pervious concrete pile led to an increase in the maximum frictional stress transferred at the soil-pile interface. The ratio of the maximum frictional stress for the installed pile compared with the precast pile ranged from 2.5 to 5.3. Non-Uniform Soil Displacements: Lateral soil displacements measured at a distance of 1D from the pile center during installation were not uniform along the length of the pile. The installation of the pile also resulted in significant increases in vertical soil stress and a smaller increase in horizontal soil stress, showing trends like those reported in existing literature. In summary, this research introduces a promising ground improvement technique using pervious concrete piles that can enhance the performance of structures on weak soils. It highlights the considerable strength, effectiveness, and influence of the installation method on the behaviour of these piles. The findings contribute valuable insights for geotechnical engineering and construction practices.

Hao Wu, et.al(2016), researched where they focused on investigating the freeze-thaw durability of Portland cement pervious concrete (PCPC). They performed laboratory tests to evaluate the performance of PCPC, with particular attention given to its ability to withstand freeze-thaw cycles. The researchers considered the use of various admixtures and modifiers, including air-entraining agents (AEA), ethylene-vinyl acetate (EVA) latex, and polypropylene (PP) fibres, in different mixtures to

understand how these elements influenced PCPC's performance. To account for the differences between PCPC produced in the field and in the laboratory, they compared field specimens extracted from experimental pavement sections to laboratory-moulded specimens. The study proposed appropriate quantification indicators for this comparison.

AEA Enhancement: Even with high porosity, the addition of the right amount of AEA to the PCPC mixture significantly improved its strength and freeze-thaw durability by enhancing the interfacial bonding in the cementitious matrix.

PCPC mixtures modified with latex, specifically EVA latex, exhibited better overall mechanical performance compared to unmodified mixtures. This was due to the improvement in the bonding strength of the cementitious matrix.

The inclusion of polypropylene (PP) fibres of various lengths (ranging from 3 mm to 12 mm) resulted in observable improvements in the tensile strength and freeze-thaw durability of the PCPC mixture.

Strength-Durability Relationship: Strong relationships were identified between the strength and freeze-thaw durability of PCPC. Mixtures with higher strength generally exhibited better durability. Furthermore, the study found that tensile strength had a more direct influence on freeze-thaw durability than compressive strength.

Field vs. Laboratory Performance: PCPC specimens moulded in the laboratory under controlled conditions consistently demonstrated higher uniformity, greater strength, and superior freeze-thaw durability compared to specimens obtained from actual pavement in the field. This discrepancy highlights the need for considering these differences when designing or evaluating PCPC pavement using laboratory methods.

The study also emphasized the validity of fast freeze-thaw tests for assessing PCPC durability in cold climates, even when the material had high porosity. These findings have important implications for the design and assessment of PCPC pavements, suggesting that modifications and reinforcement techniques can improve their strength and freeze-thaw durability. Additionally, it underscores the importance of accounting for the variations between laboratory-produced and field-constructed PCPC in pavement design and evaluation.

Jing Yang and Guoliang Jiang(2003), conducted a study to explore the properties of pervious concrete pavement materials, particularly in the context of road construction. The research revealed several significant findings and advancements in the field of pavement materials:

Pervious concrete, due to its porous nature,

presents a challenge in achieving high-strength properties using traditional materials and mixture proportions. The voids in pervious concrete hinder its ability to attain high strength. To enhance the strength of pervious concrete, the researchers found that using smaller-sized aggregate was effective. However, to maintain the appropriate balance in the mixture, adjustments in the cement quantity were necessary. The study demonstrated that the inclusion of silica fume (SF) and superplasticizer (SP) in pervious concrete greatly improved its strength. Maintaining a specific pressing force to ensure a unit weight in the range of 1900–2100 kg/m³ was crucial for achieving good water penetration. The introduction of organic polymer also exhibited the potential to enhance strength but posed challenges related to water penetration and higher costs due to a greater dosage. The researchers developed pervious pavement materials comprising a surface layer and a base layer. These materials exhibited impressive performance characteristics, with a compressive strength of up to 50 MPa and a flexural strength of 6 MPa. Additionally, these materials showcased excellent water penetration, abrasion resistance, and resistance to freezing and thawing, making them suitable for use in both footpaths and vehicle roads. Moreover, the pervious pavement materials were deemed environmentally friendly. In summary, this study sheds light on various strategies to improve the strength of pervious concrete, such as adjusting aggregate size, incorporating silica fume and superplasticizer, and considering organic polymers, while highlighting the successful development of durable and environmentally friendly pervious pavement materials for a range of applications in road construction.

Mahboub, et.al (2001), delves into the unique characteristics and testing considerations associated with pervious concrete, which differs significantly from traditional portland cement concrete (PCC). Pervious concrete is distinct from PCC, and this raises questions about the applicability of standard concrete testing protocols to it. The paper highlights the need for specialized testing methods to account for the unique features of pervious concrete. The primary focus of this study is on the compaction and consolidation of pervious concrete. The research presents techniques for preparing cylindrical specimens in the laboratory that closely resemble field-installed pervious concrete slabs. This allows for more accurate testing and analysis. Additionally, the study provides a straightforward correlation

that enables concrete designers to estimate the porosity of pervious concrete based on the bulk density of its aggregate when using crushed limestone. This practical tool simplifies the process of designing mixtures for pervious concrete, saving both time and resources. One of the significant challenges in working with pervious concrete is accurately measuring its air content due to its highly porous nature. While existing literature suggests that the air porosity of pervious concrete should fall within the range of 18% to 35% to ensure desirable permeability, there are currently no appropriate test methods defined by organizations such as AASHTO or ASTM International for determining air porosity in this specific type of concrete. Recognizing this gap, researchers from Tennessee Technological University took it upon themselves to address the issue. They conducted research to develop a new test method for determining the air porosity of pervious concrete, which is a crucial factor for its performance in permeable applications. In addition to these technical considerations, the researchers also investigated various mechanical properties of pervious concrete, including flexural, split-tensile, and compressive strengths. These findings are valuable inputs for pavement design using pervious concrete. Overall, this study contributes to a better understanding of pervious concrete's properties, testing requirements, and design considerations, which is crucial for its effective use in construction and infrastructure projects.

Rasiah, et.al. (2012). Conducted a study on Mix Design for Pervious Recycled Aggregate Concrete. *International Journal of Concrete Structures and Materials*. 6. 10.1007/s40069-012-0024-x. Pervious concrete is a tailored-property concrete with high water permeability which allow the passage of water to flow through easily through the existing interconnected large pore structure. This paper reports the results of an experimental investigation into the development of pervious concrete with reduced cement content and recycled concrete aggregate for sustainable permeable pavement construction. High fineness ground granulated blast furnace slag was used to replace up to 70 % cement by weight. The properties of the pervious concrete were evaluated by determining the compressive strength at 7 and 28 days, void content and water permeability under falling head. The compressive strength of pervious concrete increased with a reduction in the maximum aggregate

size from 20 to 13 mm. The relationship between 28-day compressive strength and porosity for pervious concrete was adversely affected by the use of recycled concrete aggregate instead of natural aggregate. However, the binder materials type, age, aggregate size and test specimen shape had marginal effect on the strength–porosity relationship. The results also showed that the water permeability of pervious concrete is primarily influenced by the porosity and not affected by the use of recycled concrete aggregate in place of natural aggregate. The empirical inter-relationships developed among porosity, compressive strength and water permeability could be used in the mix design of pervious concrete with either natural or recycled concrete aggregates to meet the specification requirements of compressive strength and water permeability.

CHAPTER 3

AIM AND SCOPE

3.1. AIM

The aim of "Investigating Strength Characteristics of Pervious Concrete for Sustainable Construction" is to comprehensively assess the mechanical properties and structural performance of pervious concrete with a focus on its strength attributes. This investigation seeks to determine the viability of pervious concrete as a sustainable construction material by evaluating its capacity to withstand loads, resist deformation, and maintain structural integrity under various environmental conditions. Ultimately, the aim is to provide valuable insights into the suitability of pervious concrete for sustainable construction practices, contributing to the advancement of environmentally friendly building materials and technologies the advancement of environmentally-friendly building materials and technologies

3.2 Objectives

- 1.To identify the most suitable mix proportions and ingredients to achieve the desired strength and permeability characteristics.
- 2.To determine the permeability of pervious concrete to assess its ability to allow water to pass through while filtering out impurities.
- 3.To assess the compressive strength of pervious concrete to understand its load-bearing capacity and structural performance.
- 4.To measure the flexural strength of pervious concrete to evaluate its ability to withstand bending and cracking.

CHAPTER 4

MATERIALS AND METHODS

4.1 Methodology

The following figure 4.1 explains the methodological sequence of present study.

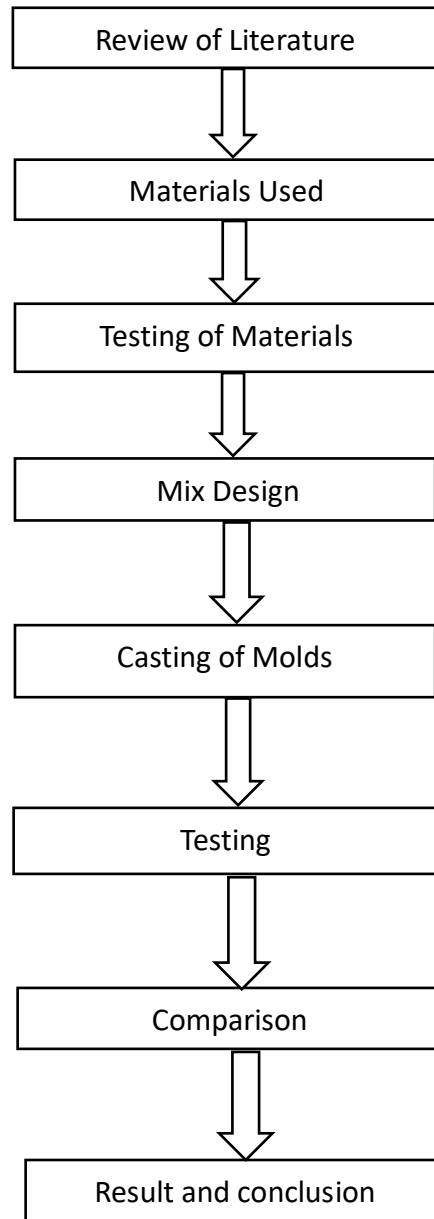


Fig 4.1: METHODOLOGY CHART

4.1.1 Experimental Investigation

The concrete cube size measuring 150×150×150 mm and concrete cylindrical size mold (100 mm diameter 200 mm thickness) in dimension were used. The batching of the concrete was carried out by weight. Concrete cubes and cylindrical molds are casted based on the mix design by adding the admixture in the specimen. The mix design was calculated by referring the code book. Concrete was properly placed beneath and along the sides of the mold with the help of trowel and the concrete cube molds were filled to one third of their height and compacted 25 times. The concrete cubes were demolded after 24 hours of casting and half of them were cured in water . The cubes were cured for 7,14 and 28 days, respectively.

The following tests are conducted on the concrete samples

- Compressive strength (150 x 150 x 150 mm)
- Split tensile strength (100 mm diameter 200 mm thickness)

For each of the hydration period, cubes were tested, and the average compressive strength recorded. The concrete cubes were tested in compression testing machine and the result were reported.

4.2 MATERIALS AND PROPERTIES

The materials used in this research and their characteristics are given below:

- Cement
- Ground Granulated blast Furnace slag
- Fine aggregate
- Coarse aggregate
- water
- Fly ash

4.2.1 Cement

A cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind fine aggregate and coarse aggregates together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Concrete is the most widely used material in existence and is only behind water as the planet's most-consumed resource. Portland cement is manufactured by crushing, milling, and proportioning the following materials:

- Lime or calcium oxide, CaO : from limestone, chalk, shells, shale, or calcareous rock
- Silica, SiO_2 : from sand, old bottles, clay or argillaceous rock
- Alumina, Al_2O_3 : from bauxite, recycled aluminum, clay
- Iron, Fe_2O_3 : from from clay, iron ore, scrap iron and fly ash
- Gypsum, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$: found together with limestone

The cement (fig 4.2)used in the research work is Ordinary Portland cement 53. The properties of cement are tested by referring IS code specifications and guidelines.



Fig 4.2: Cement OPC 53

The Table 4.1 shows that physical properties of cement test result i.e. Specific gravity, Consistency, Initial setting time and Final setting time.

Table 4.1 Properties of OPC53 Cement

Physical Properties of cement	
Test Conducted	Results
Fineness	2%
Specific Gravity	3.15
Consistency Time	35%
Setting Time	
Initial setting time	60 minutes
Final setting time	245 minutes

4.2.2 Ground Granulated blast Furnace slag

Ground granulated blast furnace slag is obtained during the manufacturing process of pig iron in blast furnace. The slag is a mixture of lime, silica, and alumina, the same oxides that make up Portland cement, but not in the same proportion. This nonmetallic product consisting essentially of silicates and aluminates of calcium and other bases. GGBS is used to make durable concrete structures in combination with ordinary Portland cement or other pozzolanic materials. GGBS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years.

The following figure(Fig 4.3) showsGGBS



Fig 4.3: GGBS

The physical properties of GGBS is given in Table 4.2

Table 4.2 Properties of GGBS

Physical Properties of GGBS	
Test Particulars	Results
Specific Surface Area	2%
Specific Gravity	2.85
Bulk Density	1050 to 1320 (kg/m^3)
Physical forms	Powdered form

4.2.3 fly ash

Fly ash is a fine powder residue generated from the combustion of pulverized coal in thermal power plants. It is a byproduct of coal combustion and is composed primarily of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3), and iron oxide (Fe_2O_3). Due to its pozzolanic properties, fly ash is widely used as a supplementary cementitious material in concrete production. When mixed with cement and water, fly ash reacts chemically to form cementitious compounds, enhancing the strength, durability, and workability of concrete. Additionally, the use of fly ash in concrete

reduces the demand for traditional cement, thereby decreasing greenhouse gas emissions and conserving natural resources. Moreover, incorporating fly ash in concrete contributes to sustainable construction practices by mitigating waste generation and promoting the utilization of industrial byproducts in infrastructure development.

4.2.4 silica fume

Silica fume concrete is composed of cement, silica fume, fine aggregate, coarse aggregate, and water. Fresh and hardened properties of silica fume concrete is superior to conventional concrete. For instance, it has higher compressive and flexural strength.

4.2.5 Fine aggregate

The fine aggregate used for this experimental investigation is M- sand. Manufactured sand (M-Sand) is a substitute of river sand for concrete construction. Manufactured sand is produced from hard granite stone by crushing. Manufactured sand is an alternative for river sand. Due to fast growing construction industry, the demand for sand has increased tremendously, causing deficiency of suitable river sand in most part of the world.

Fine aggregate moisture content influences the mix proportion substantially. It specifies the amount of water that may be added to subtracted to the mixture. Mix design of concrete cannot be carried out without specific gravity of fine aggregate, and higher specific gravity produced stronger concrete. Finally, the presence of silt in sand would increase water demand in concrete mixture and may reduce concrete strength.

Various tests are conducted such as specific gravity, fineness. These test results are presented in the given Table 4.3

Table 4.3 Properties of Fine aggregates

Physical Properties of GGBS	
Test Conducted	Results
Quality of sand	M- sand
Specific Gravity	2.70
Fineness Modulus	2.0
Particle Shape and Size	Round 4.82mm above and below

4.2.6 Coarse aggregate

Coarse aggregate is the portion of the concrete which is made up of the larger stones embedded in the mix. They are particulates that are greater than 4.75mm. The usual range employed is between 9.5mm and 37.5mm in diameter. It is one of the essential components of concrete and occupies the largest volume in the mix. That is why it greatly affects the concrete mix design. And their properties such as strength, maximum size, shape, and water absorption influence water demand, the quantity of cement and fine aggregate in concrete mixture.

Various tests are conducted such as specific gravity, water absorption. These tests results are presented in the given Table 4.4

Table 4.4 Properties of Coarse aggregates

Physical Properties of Coarse Aggregate	
Test Conducted	Results
Aggregate Size	10mm to 20mm
Specific Gravity	2.75
Water absorption	5%

4.2.7 water

Ordinary clean portable water free from suspended particles and chemical substances was used for both mixing and curing of concrete cubes cast with fresh water. Water is one of the most important elements in construction and is required for the preparation of mortar, mixing of cement concrete and for curing work etc. The quality of water used has a direct impact on the strength of the mortar and cement concrete in the construction work. The water used for curing and mixing must be free from high quantities of alkalis, acid, oils, salt, sugar, organic materials, vegetable growth, etc that might be deleterious to bricks, concrete or iron.

4.3 Mix design

Mix design for pervious concrete is a critical step in the development of a successful pervious concrete pavement or structure. Pervious concrete, also known as porous concrete or permeable concrete, is a unique type of concrete that is designed to have a high porosity, allowing water to pass through it and infiltrate the ground. This is particularly important for managing stormwater runoff, preventing flooding, and recharging groundwater. Proper mix design is essential to achieve the desired permeability, strength, and durability of pervious concrete.

Materials Selection:

Cement: Portland cement is commonly used, but supplementary cementitious materials like fly ash, slag, or silica fume can be added to enhance performance.

Aggregates: Pervious concrete typically uses coarse aggregates with a size range of 3/8 inch to 3/4 inch. These aggregates should be clean, well-graded, and free of fine materials that can clog the pores.

Water: Use clean, potable water. The water-cement ratio is typically kept low to ensure sufficient strength.

Cementitious Content: The cement content in pervious concrete is usually lower than that in traditional concrete. A common range is 300 to 450 pounds of cement per cubic yard. The cement content should be optimized to balance the need for strength with the desire for porosity. Higher cement content can lead to reduced permeability.

Water-Cement Ratio: A low water-cement ratio is essential to achieve strength and durability. Typically, it's kept below 0.28. The water-cement ratio must be carefully controlled to prevent excess paste that can clog the voids. Aggregate

Grading: Pervious concrete mix design often employs a gap-graded aggregate blend to create voids between the aggregates. This promotes permeability. The aggregates should be well-graded, with a balance of coarse and fine particles to ensure proper compaction and minimal void obstruction.

Admixtures: Chemical admixtures can be added to improve workability, reduce the water content, or enhance durability. Air-entraining agents may be used to increase freeze-thaw resistance.

Testing: Extensive testing is crucial to determine the mix's properties, such as compressive strength, permeability, and durability. Test specimens should be made and cured under field conditions to replicate the actual construction process.

Optimizing Porosity: The void content in pervious concrete is typically targeted at 15-25%. This can be adjusted based on the specific requirements of the project. Achieving the right balance between porosity and strength is crucial, and it often requires iterative adjustments to the mix design.

Workability: Pervious concrete mix should be workable enough to be placed and compacted effectively, but not overly wet, which could lead to cement paste runoff.

Compaction: Adequate compaction is essential to ensure the aggregates are in close contact and that the voids are interconnected. A heavy roller is often used for compaction.

Curing: Proper curing is vital for the development of strength and durability. Curing methods may include covering with wet burlap, plastic sheeting, or applying curing compounds.

Field Testing: After installation, field tests can be conducted to ensure that the finished pervious concrete meets the specified permeability requirements.

Maintenance Proper maintenance, including regular vacuum cleaning and occasional power is necessary to prevent clogging of the voids over time. Pervious concrete mix design is a complex and highly specialized process, and it should be performed by experienced engineers or concrete experts who are well-versed in the unique requirements and challenges of creating permeable concrete. The mix design will vary depending on the specific project's goals and local environmental conditions, so a customized approach is essential.

- a) Grade designation = M₂₀
- b) Type of cement = OPC 53 grade IS 1269
- c) Maximum nominal size of aggregate = 20mm
- d) Minimum cement content = 310kg/m³
- e) Minimum water cement ratio = 0.35
- f) Workability = 0mm (no slump)
- g) Exposure condition = Normal
- h) Method of concrete placing = Hand
- i) Degree of supervision = Good
- j) Chemical admixture type = fly ash, GGBS, silica fume

Test Data for Materials

- 1) Cement used = OPC 53 grade
- 2) Specific gravity of cement = 3.13
- 3) Specific gravity of coarse aggregate = 2.66
- 4) Specific gravity for fine aggregate = 2.81

Target Strength For Mix Proportion

$$f'_{ck} = F_{ck} + 1.65S$$

Where f'_{ck} = Target average compressive strength 28 days

F_{ck} = Characteristic compressive strength 28 days

$$S = \text{Standard deviation IS 456-T-8 Target mean strength} = 20 + (1.65 \times 4) \\ = 26.6 \text{ N/mm}^2$$

Selection of W/C Ratio

T-8 IS 456

Maximum w/c ratio = 0.55

Adopt w/c ratio = 0.35

$0.35 < 0.55$

Selection of Water Content

From T-2

Maximum water content for 20mm aggregate = 186 lit

Calculation of cement content

$$\begin{aligned} \text{w/c ratio} &= 0.35 \text{ } 186 / 0.35 \\ &= 541.43 \text{ kg/m}^3 \end{aligned}$$

Mix Calculation

a) Volume of concrete = 1m^3

b) Volume of cement content = mass of cement / sp.g of cement $\times 1/1000$
 $= 541.43/3.13 \times 1/1000 = 0.1698 \text{ m}^3$

c) Volume of water = mass of water/sp.g of water $\times 1/1000$
 $= 186/1 \times 1/1000 = 0.186 \text{ m}^3$

Material requirement M_{20}

Cement = 531.43 kg/m^3

Fine aggregate = 543.73 kg/m^3

Coarse aggregate = 1063.73 kg/m^3

Water = 0.704 lit

Water-cement ratio = 0.35

For one cube,

Size of cube = $0.15\text{m} \times 0.15\text{m} \times 0.15\text{m}$

volume $3.375 \times 10^{-3} \text{ m}^3$

= volume $\times$ unit weight

$= 3.375 \times 10^{-3} \times 2400$

= 8.1 kg

Mix proportion 1: 1.02: 2

= 4.02

Cement quantity for one cube = $1/4.02 \times 8.1$

= 2.01 kg

Coarse aggregate for one cube = $3.02/4.02$

= 6.085 kg

Water for one cube = $2.01 \times 0.35 = 0.7040 = 0.704 \text{ lit}$

Material requirement m_{20}

Cement = 531.43 kg/m^3

Fine aggregate = 543.73 kg/m^3

Coarse aggregate = 1063.73 kg/m^3

Water = 0.704 lit

Water-cement ratio = 0.35

For one cube,

Size of cube = $0.15\text{m} \times 0.15\text{m} \times 0.15\text{m}$

volume $3.375 \times 10^{-3} \text{ m}^3$

= volume $\times$ unit weight

$= 3.375 \times 10^{-3} \times 2400$

= 8.1 kg

Mix proportion 1: 1.02: 2

= 4.02

Cement quantity for one cube = $1/4.02 \times 8.1$

= 2.01 kg

Coarse aggregate for one cube = $3.02/4.02$

= 6.085 kg

Water for one cube = $2.01 \times 0.35 = 0.7040 = 0.704 \text{ lit}$

Size of cylinder = $0.15\text{m} \times 0.15\text{m} \times 0.30\text{m}$

Volume, $V = \pi d^2 h/4$

$= (3.14 \times 0.15\text{m} \times 0.15\text{m} \times 0.30\text{m})/4$

$= 5.29 \times 10^{-3} \text{ m}^3$

= volume $\times$ unit weight

$= 5.29 \times 10^{-3} \text{ m}^3 \times 2400$

= 12.696 kg

Cement quantity for one cylinder = $1/4.02 \times 12.696$

= 3.13 kg

Coarse aggregate for one cylinder = $3.02/4.02 \times 12.696$

= 9.7 kg

Water for one cylinder = $3.13 \times 0.35 = 1.09 \text{ L}$

FOR M1 :-

Size of coarse aggregates = 12.5mm to 16mm

Cement required for 6 cubes and 6 cylinders = $6 \times (\text{cement required for 1 cube} + \text{cement required for 1 cylinder})$

$= 6 \times (2.01 + 3.13) \text{ kg}$

$$= 6 \times 5.14 \text{ kg}$$

$$= 30.84 \text{ kg}$$

Replacement of cement by admixtures,

Admixtures required = 10% GGBS by weight of cement + 10% silica fume by weight +

5% fly ash by weight

$$10\% \text{ GGBS by weight} = 30.84 \times 10/100$$

$$= 3.084 \text{ kg}$$

$$10\% \text{ silica fume by weight} = 30.84 \times 10/100$$

$$= 3.084 \text{ kg}$$

$$5\% \text{ fly ash by weight} = 30.84 \times 5/100$$

$$= 1.542 \text{ kg}$$

$$\text{Total admixtures} = 3.084 + 3.084 + 1.542$$

$$= 7.71 \text{ kg}$$

After replacement,

$$\text{Total cement required} = 30.84 - 7.71 \text{ kg}$$

$$= 23.13 \text{ kg}$$

Sand required for 6 cubes and 6 cylinders

$$= 6 \times (\text{sand required for 1 cube} + \text{sand required for 1 cylinder})$$

$$= 6 \times (2.05 + 3.22)$$

$$= 6 \times 5.27$$

$$= 31.62 \text{ kg}$$

Coarse aggregate required for 6 cubes and 6 cylinders

$$= 6 \times (\text{CA required for 1 cube} + \text{CA required for 1 cylinder})$$

$$= 6 \times (6.085 + 9.5)$$

$$= 6 \times 15.585$$

$$= 93.51 \text{ kg}$$

Water required for 6 cubes and 6 cylinders

$$= 6 \times (\text{water required for 1 cube} + \text{water required for 1 cylinder})$$

$$= 6 \times (0.074 + 1.09)$$

$$= 6 \times 1.794$$

=10.764 Litres

FOR M2 :-

Size of coarse aggregates = 16 to 19.5 mm

Cement required for 6 cubes and 6 cylinders

= 6*(cement required for 1 cube + cement required for 1 cylinder)

= 6*(2.01 + 3.13) kg

= 6*5.14 kg

= 30.84 kg

Replacement of cement by admixtures,

Admixtures required = 10% GGBS by weight of cement + 10% silica fume by weight +

5% fly ash by weight

10% GGBS by weight = $30.84 * 10/100$

= 3.084 kg

10% silica fume by weight = $30.84 * 10/100$

= 3.084 kg

5% fly ash by weight = $30.84 * 5/100$

= 1.542 kg

Total admixtures = 3.084 + 3.084 + 1.542

= 7.71 kg

After replacement,

Total cement required = 30.84 – 7.71 kg

= 23.13 kg

Sand required for 6 cubes and 6 cylinders

= 6 * (sand required for 1 cube sand required for 1 cylinder)

= 6* (2.05 + 3.22)

= 6 * 5.27

= 31.62 kg

Coarse aggregate required for 6 cubes and 6 cylinders

= 6*(CA required for 1 cube + CA required for 1 cylinder)

$$= 6*(6.085 + 9.5)$$

$$= 6*15.585$$

$$= 93.51 \text{ kg}$$

Water required for 6 cubes and 6 cylinders

$$= 6*(\text{water required for 1 cube} + \text{water required for 1 cylinder})$$

$$= 6*(0.074 + 1.09)$$

$$= 6*1.794$$

$$= 10.764 \text{ Litres}$$

FOR M3 :-

Size of coarse aggregates = 16 to 19.5 mm

Cement required for 6 cubes and 6 cylinders

$$= 6*(\text{cement required for 1 cube} + \text{cement required for 1 cylinder})$$

$$= 6*(2.01 + 3.13) \text{ kg}$$

$$= 6*5.14 \text{ kg}$$

$$= 30.84 \text{ kg}$$

Sand required for 6 cubes and 6 cylinders

$$= 6 * (\text{sand required for 1 cube} + \text{sand required for 1 cylinder})$$

$$= 6 * (2.05 + 3.22)$$

$$= 6 * 5.27$$

$$= 31.62 \text{ kg}$$

Coarse aggregate required for 6 cubes and 6 cylinders

$$= 6*(\text{CA required for 1 cube} + \text{CA required for 1 cylinder})$$

$$= 6*(6.085 + 9.5)$$

$$= 6*15.585$$

$$= 93.51 \text{ kg}$$

Water required for 6 cubes and 6 cylinders

$$= 6*(\text{water required for 1 cube} + \text{water required for 1 cylinder})$$

$$= 6*(0.074 + 1.09)$$

$$= 6*1.794$$

$$= 10.764 \text{ Litres}$$

4.4 PREPARATION OF MATERIALS

4.4.1 Preparation of the Concrete Molds

To make the molds for usage, the joints are thinly lined with mold oil and also implemented between the surfaces at the lowest of the mold and within the interiors of the mildew and ensure there must be no getaway of water during the filling. the following fig 4.4.



Fig 4.4 : Concrete molds

4.4.2 Mixing concrete

The concrete was mixed manually. Carrying out hand mixing of concrete requires special skills and care during the process for quality control of fresh concrete. The precautions and the correct way of performing hand mixing of concrete is to undergo the mixing process as recommended by the standard procedures. The main purpose of mixing the concrete is to finally obtain a uniform mixture that shows uniformity in terms of colour and consistency.



Fig 4.5: Hand Mixing of a Fresh Concrete

4.5 TEST ON SPECIMEN

4.5.1 Preparation of specimen

The concrete is placed in the molds by tamping the specimen with a tamping rod at the time one third of filling to avoid voids present in the concrete. Concrete specimens that are representative of a distinct batch of concrete must be sampled and analyzed for the purpose of quality control. Cylinder molds should be made of steel, cast iron, or other nonabsorbent material that does not react with concrete containing Portland cement or other hydraulic cements. Molds should hold their dimensions and shapes under conditions of severe use. They should be able to hold, without leakage, the water poured into them. Before using the molds, coat them lightly with mineral oil or a suitable nonreactive form of release material.



Fig 4.6: Casting of Specimen

4.5.2 Demoulding

Test cubes should be demoulded between 16 and 24 hours after they have been made. If after this period the concrete has not achieved sufficient strength to enable demoulding without damaging the cube, then the demoulding should be delayed for a further 24 hours. When removing the concrete cube from the mould, take the mould apart completely. Take care not to damage the cube because, if any cracking is caused, the compressive strength may be reduced.

4.5.3 Curing

Cubes must be cured before they are tested. Unless required for test at 24 hours, the cube should be placed immediately after demoulding in the curing tank or mist room. The curing temperature of the water in the curing tank should be maintained at 27-30°C. If curing is in a mist room, the relative humidity should be maintained at no less than 95%. Curing should be continued if possible, up to the time of testing. Curing of Concrete is a method by which the concrete is protected against loss of moisture required for hydration and kept within the recommended temperature range. Curing will increase the strength and decrease the permeability of hardened concrete. Hydration is the chemical reaction between cement and water that results in the formation of various chemicals contributing to setting and hardening. The hydration process is affected by the initial concrete temperature, the ambient air temperature, the dimensions of the concrete, and mix design. Therefore, for this

process to progress well, in-situ concrete must have sufficient moisture and a temperature that favours this chemical reaction at a rapid and continuous rate. Curing of concrete should occur as soon as it has been placed. If water evaporates from the concrete before it has attained its maximum strength, there will not be enough water remaining in the concrete to fully hydrate the cement and achieve maximum compressive strength. The following fig (4.7) shows



Fig 4.7: Curing of Specimen

4.6 Tests on Hardened Concrete

4.6.1 Compression Strength Test

Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during the production of concrete, etc. Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. The concrete cubes were cured for 7 and 14 and 28 days, respectively. For each of the hydration period, cubes were tested, and the average compressive strength recorded. The concrete cubes were tested in compression testing machine and the result were reported.

$$\text{Compressive strength (N/mm}^2\text{)} = \frac{\text{Maximum Load}}{\text{Area of Cross section}} = \frac{P}{A}$$

4.6.2 Split Tensile Strength test

The tensile strength of concrete is one of the basic and important properties which greatly affect the extent and size of cracking in structures. Moreover, the concrete is very weak in tension due to its brittle nature. Hence, it is not expected to resist the direct tension. So, concrete develops cracks when tensile forces exceed its tensile strength.

To calculate the splitting tensile strength of the specimen as follows:



Fig 4.8: Split Tensile strength

$$\text{The Split Tensile Strength} = \frac{2P}{\pi LD}$$

Where,

P = applied load

D = diameter of the specimen= 150mm

L = length of the specimen= 300 mm

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Compressive Strength

The specimen is tested by compression test machine after 7 days, 14 days and 28 days curing. Load should be applied gradually at the rate of 140kg/cm² per minute till specimen fails. Load at the failure divided by area of specimen gives the compressive strength. Compressive loading was applied to the cube specimens for a standard dimensions 150 mm X 150 mm X 150 mm and testing has 3 trials with similar specimens, mean values are noted in the table.

$$FC = P/A$$

Where, FC= Compressive strength (N/mm²)

P = Ultimate load (N) or Breaking Load

A = Loaded area (150 mm X 150 mm) = 22500 mm²

Apparatus required

The standard sand to be used in the test shall conform to IS: 650-1966, Vibration Machine, Poking Rod, Cube Mold of 70.6 mm size conforming to IS: 10080-1982, Balance, Gauging Trowel, Stopwatch, Graduated Glass Cylinders, etc.

A. Procedure

- Place the cube at the center of the lower platen of the compression testing machine in such a manner that the load shall be applied to opposite sides of the cube as cast, that is, not to the top and bottom.

- The axis of the specimen shall be carefully aligned with the center of the thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine.
- The load shall be applied without shock and increased continuously at a rate of approximately 140kg/cm²/min. until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained.
- The maximum load applied to the specimen shall then be recorded.
-

Table 5.1 Compressive strength of the specimens

Day	M1	M2	M3
7	11.77	12.42	9.11
14	14	14.66	13.77
28	17.33	18.60	16.66

M1 – coarse aggregate ranging for 19.5 -16 mm

M2 – coarse aggregate ranging for 16-12.5 mm

M3 – coarse aggregate ranging for 19.5 -16 mm without replacing cement

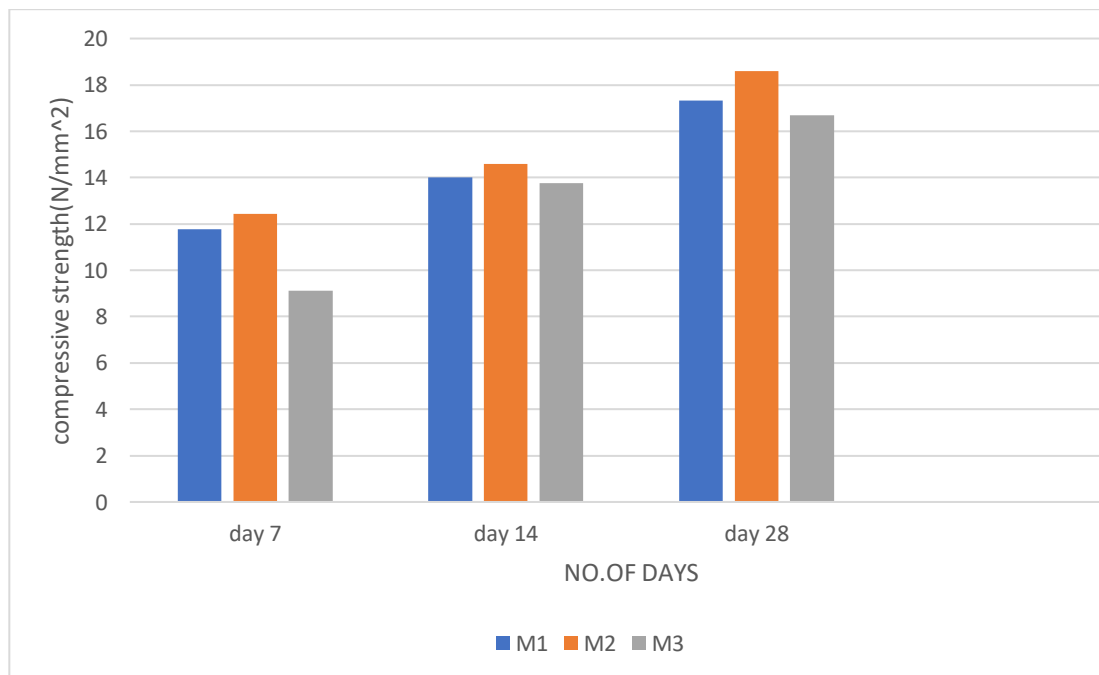


Fig 5.1 Graph showing Compressive Strength

M1 – coarse aggregate ranging for 19.5 -16 mm

M2 – coarse aggregate ranging for 16-12.5 mm

M3 – coarse aggregate ranging for 19.5 -16 mm without replacing cement

Table 5.2 Split tensile strength of the specimens

Day	M1	M2	M3
7	1.34	1.45	1.49
14	1.55	1.62	1.53
28	1.66	1.69	1.61

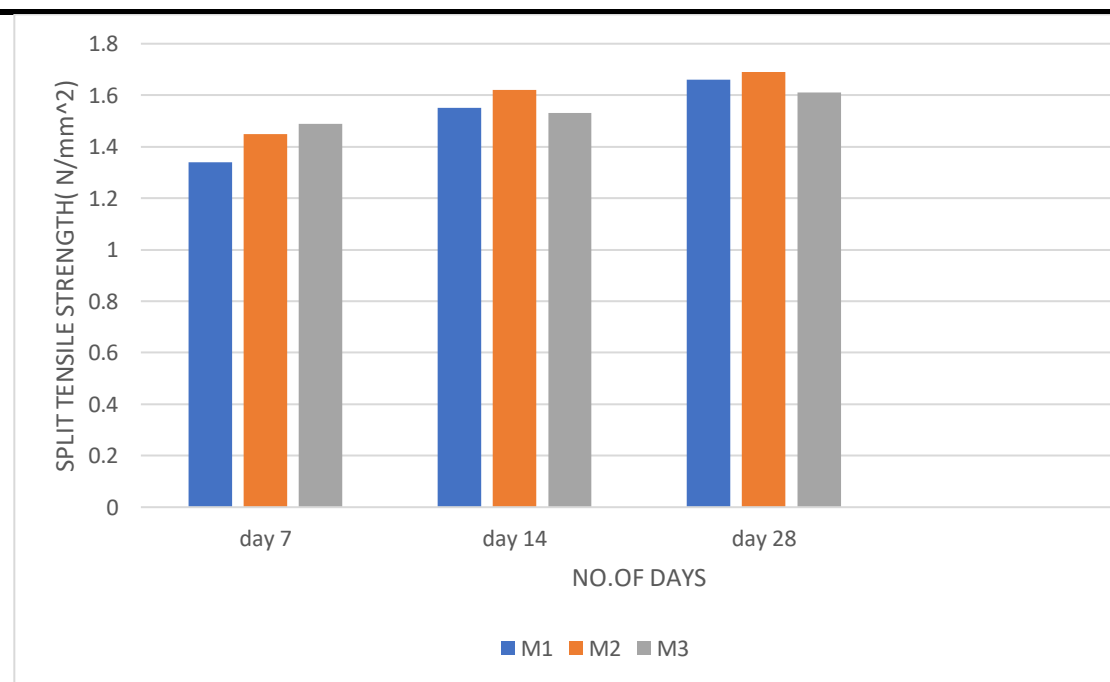


Fig 5.2 graph showing Split Tensile Strength

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 GENERAL

Series of experiment were conducted on M20 grade of concrete by this project work, compressive strength and split tensile strength of concrete was investigated.

6.1.1 Compressive strength

From Table 5.4 following points are noted and listed below:

- Compressive strength of control specimen and the Tested specimen (GGBS and silica fumes) has increased gradually for 7, 14 and 28 days curing under the conditions of the environment.
- Whereas in GGBS and silica fume concrete, strength is observed in 14 days, and 28 days curing the value has increased.
- Approximately 15% to 25% of the total volume of the pervious concrete mixture consists of void spaces, allowing water to permeate through the material.

6.1.2 Split Tensile strength

From Table 5.5 following points are noted and listed below:

- Split Tensile strength of control specimen and the Tested specimen (GGBS and silica fume) has increased gradually for 7, 14 and 28 days curing under standard conditions

Further the present study shows the improved strength potential of GGBS concrete which ensures the suitability of GGBS especially for the structures. It is also suggested to analyse

- i. The microstructural arrangement of GGBS concrete for justifying the improved strength characteristics
- ii. Variation of mix proportion in order to assess the optimal % replacement of GGBS

6.2 CONCLUSION

- There is marginal increase in the compressive strength of concrete which replaces OPC with 25% of GGBS and silica fumes than the concrete without any replacement.
- It is also observed that the use of GGBS and silica fumes in cement has perceptible effect on the compressive strength on conventional concrete
- The compressive strength and split tensile strength of conventional concrete was found to be lower than the concrete whose cement has been replaced with GGBS and silica fumes.
- The permeability varies as the aggregate size increases but shows a decreasing trend when some fines were added to it.

References

1. Aamer Rafique Bhutta a, Tsuruta b, mirza c ((2012)), “evaluation of high-performance porous concrete properties” construction and building materials 31 (2012) 67–73.
2. Admire, Gandhi, Adsul, Agarkar, Bhore, Kolte, (2017), “Permeable Pavement new technology for Construction of Road in India” International Research Journal of Engineering and Technology” (IRJET) - Volume 4 Issues 4.
3. Anush k. Chandrappa, Krishna Prapoorna Biligiri (2016) “pervious concrete as a sustainable pavement material – research findings and future prospects: a state-of-the-art review” construction and building materials 111 (2016) 262–274.
4. Aoki, Sri Ravindrarajah &Khabbaz (2012) properties of pervious concrete containing fly ash, road materials and pavement design, 13:1, 1-11, DOI:10.1080/14680629.2011.651834
5. Darshan S. Shah, Jayeshkumar Pitroda(2013), . Bhavsar, “Pervious Concrete: New Era for Rural Road Pavement”. International Journal of Engineering Trends and Technology (IJETT)- Vol.4 Issue 8.
6. Gautav Uttam Shinde & Valunekar S. S (2015), "Cost and Time Control in Storm Water Management using Pervious Concrete". (IJSRD) - International Journal for Scientific Research & Development - Vol. 3, Issue 02, - ISSN (online):2321–0613.
7. HandeSagar S., Wavhal Rahul K., Pawar Sachin A., Gaikwad Mahesh J. & Phatangare Roshani(2017). “Water permeable road pavements”, International Journal of Engineering Sciences & Management [Hande, 7(1) ISSN 2277 – 5528.
8. Hao Wua, Zhuo Liu a, Beibei sun a, Jian yin c (2016) “experimental investigation on freeze–thaw durability of portland cement pervious concrete (pcpc)” construction and building materials 117 63–71.
9. Jannathul Thasni P, Jouhar Shareef, (May 2018), “Water Absorbing Pavements by using Porous Concrete”, International Research Journal of Engineering and Technology (IRJET) -Volume 5 Issues 5.
10. Jing Yang, Guoliang jiang (2003) “experimental study on properties of pervious concrete pavement materials” cement and concrete research 33 381–386

11. John t. Kevern, Vernon r. Schaefer, and Kejin wang (2009) "temperature behaviour of pervious concrete systems" transportation research board of the national academies, Washington, D.c., 2009, pp. 94–101. Doi: 10.3141/2098-10
12. Mageswari, Karthikeyan, Pavitran, Rajkumar & Govindrajan(2016), "High Strength Permeable Pavement using No Fines Concrete ". SSRG International Journal of Civil Engineering (SSRG-IJCE)-Vol.3Issues 3
13. Mahboub, Jonathan Canler, Robert Rathbone, Thomas roble, and Blake Davis "pervious concrete: compaction and aggregate gradation" title no. 106-m58
14. Masoud Kayhanian, Hui Li, John T. Harvey, Xiao Liang, (2019) "Applications of Permeable Pavements in Highways for stormwater runoff management and pollution prevention". International Journal of Transportation Science and Technology8
15. Mohammed Sonebia, Mohamed Bassuonib, Ammar Yahia c. (2016)"Pervious Concrete: Mix Design, Properties and Applications".RILEM technical letters 2016.
16. Muhannad t. Suleiman, Lusu Ni, and Anne Raich, "development of pervious concrete pile ground-improvement alternative and behaviour under vertical loading" Doi: 10.1061/(asce)gt.1943-5606.0001135.
17. Qiao dong, hao Wu, Baoshan Huang, Xiang Shu, and Kejin wang, "investigation into laboratory abrasion test methods for pervious concrete" Doi: 10.1061/(asce)mt.1943- 5533.0000683.
18. Saurabh Y. Kale¹, Amit P. Halwele², Kartik Rathod³, Mayur A. Jira pure, (January 2017), "Permeable Pavement a step towards Sustainable Urban Drainage System" International Advanced Research Journal in Science, Engineering and Technology (IARJSET) – Volume 4 Issues 3.
19. Sriravindrarah, do & Nguyen & Aoki "effect of clogging on the water permeability of pervious concrete".
20. Vikram¹, Mehli R. P. (2015) 2 International Journal for Research in Applied Science and Engineering Technology (2015) (IJRASET).

