# INVESTIGATING & ANALYZING THE STRUCTURAL BEHAVIOR OF PERVIOUS CONCRETE USING INDIGENOUS MATERIALS

## FINAL YEAR PROJECT OF 2016

**BY**


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This is to certify that the

Final Year Project Titled

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# DEDICATION

This thesis is dedicated to our parents who taught us that with perseverance one can achieve any goal in life, our friends for their constant moral support, and last but not the least all our teachers who have been encouraging, motivating and mentoring us throughout our entire life.

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# LIST OF ACRONYMS

**ASTM** – American Society for Testing and Materials

**OBC** – Optimum Moisture Content

**UTM** – Universal Testing Machine

**VA** – Air Voids

**PC**–Pervious Concrete

**PCPC** – Portland cement pervious concrete

**W/C** – Water to Cement Ratio

**NFC** – No Fine Concrete

**C/A** – Cement to Aggregate Ratio

**SSD** – Saturated Surface Dry

**MNAS** – Maximum Nominal Aggregate Size

**OPC** – Ordinary Portland cement

**NC** – Normal Concrete

**FA** – Fine Aggregate

# LIST OF TABLES

# ABSTRACT:

Pervious concrete is very different from traditional Portland cement concrete (PCC). The test specimens would be produced and tested for standard concrete properties like compressive, split tensile, flexural strength, permeability, porosity by using indigenous materials based on trial and error method. The optimum values of compressive strength, permeability, split tensile, freeze thaw would be selected depending upon the rainfall intensities and precipitation characteristics of Islamabad, Pakistan. Most urban areas of the world are covered by reinforced concrete buildings and impervious roads mainly due to the continuous development of contemporary urbanization. Compared to natural soils, concrete pavements generally lack the ability to breathe, absorb heat, and infiltrate rainwater leading to a series of environmental problems. As an example, nonpoint source pollution (NPS) is caused by surface runoff, rainfall, drainage, and seepage, which has been proven to be an important factor affecting the water quality of receiving waters. PCPC can be beneficial in supplementing the groundwater level, reducing storm water runoff, reducing the impact and cost of rainwater treatment facilities and underground aquifer. The areas of application are in residential roads, shoulders, swimming pools, golf courts.

**Key Words:**

Compressive strength, Permeability, Pervious Concrete pavement, Porosity, Storm water, Testing, No Fines

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# CHAPTER 1 INTRODUCTION

## 1.1 Background:

The term “pervious concrete” typically describes a near zero-slump, open-graded material consisting of Portland cement, coarse aggregate, little or no fine aggregate, admixtures, and water. The combination of these ingredients will produce a hardened material with connected pores, ranging in size from 0.08 to 0.32 in. (2 to 8 mm), that allow water to pass through easily. The void content can range from 15 to 35%, with typical compressive strengths of 400 to 4000 psi (2.8 to 28 MPa). The drainage rate of pervious concrete pavement will vary with aggregate size and density of the mixture but will generally fall into the range of 2 to 18 gal./min/ft2 (81 to 730 L/min/m2) or 192 to 1724 in. /h (0.14 to 1.22 cm/s).

Typical concrete pavement are impervious surfaces that shed storm water as runoff. Pervious concrete, the use of non-rigid pavers, and open-cell pavers help to reduce runoff from these surfaces by allowing storm water to be absorbed into the ground. The two basic components, which concrete is mainly composed of are binder (paste) and aggregates. The paste, which mainly consists of cement, water and supplementary cementitious materials, has main functions of binding up the aggregates, filling up the voids and thus making concrete strong and dense. The aggregates, both coarse and fine, provide volume to concrete. The voids in coarse aggregates are filled up by the fine aggregates and voids in the fine aggregates are filled up by cement, thus helping in making concrete a densely packed system. The strength of concrete increases with the decrease in voids. As compared to other road making materials concrete pavements have higher modulus of elasticity and rigidity. Due to this property the pressure on the subgrade gets limited. The thickness of the concrete pavement is mainly determined by the magnitude of the wheel or axle loads and by the flexural strength of the concrete and there is no significant contribution provided by sub-bases.

Pervious concrete pavement is a unique and effective means to address important environmental issues and support green, sustainable growth. By capturing storm water and allowing it to seep into the ground, porous concrete is instrumental in recharging groundwater, reducing storm water runoff.

## 1.2 Problem Statement:

Now-a-days our modernized cities are covered with waterproof and building material. It obstructs the lack of air and water permeability common concrete pavement, so that the rainwater is not filtered underground. A large amount of rainwater ends up falling on impervious surface such as parking lots, driveways, sidewalks and streets rather than soaking into soil. This creates a natural imbalance in the ecosystem and leads to various problems like soil erosion, floods, ground water depletion. A simple solution to avoid these problems to stop construction impervious surface and switch to pervious concrete.

Flooding happens when an extraordinary volume of water is conveyed by waterways and streams. Because of high precipitation roads are going to be filled with water and failure of drainage systems. Due to such inconvenience and loss caused to people there arises a need to find an alternative to conventional roads and drainage systems which can help in controlling floods and make people's life easier.

One of the solution to this problem is Pervious Concrete which can not only drain heavy
monsoon rainwater but also helps to recharge ground water level and prevents pollutants to meet into water sources due to water runoff.

## 1.3 Application Of Pervious Concrete

Now-a-days, Pervious concrete is considered as one of the best management practices and most important environmentally materials for managing storm-water runoff, recharging groundwater and improving water quality .The use of PC in specific applications requiring high permeability is very attractive. There is also an increasing interest for PC in low-traffic roads, parking lots, driveways and sidewalks to reduce the risk of flash flooding runoff. It can also be used for sustainable constructions because of its high insulation performance and noise reduction. The reduction of heat islands in town is another attractive property of this material. In terms of environmental performance, Pervious concrete can be also used to filter contaminants, such as chemicals and heavy metals within the pervious structure.

## 1.4 Research Objective:

The aim of the present research was to preparation of pervious material using indigenous materials-Margallah Crush, Lawrenspur Sand and Best way Cement- with an aim to ground water recharging and pavement application. The main objectives of this study are to enhance the Mechanical as well as Hydraulic properties of pervious concrete that can be used in pavement. A complete experimental report would be required to know the impacts of cement to aggregate ratio, Water to cement ratio and effect of fines on pervious concrete to get higher strength and satisfactory building properties of pervious concrete.

## 1.5 Scope Of Research Work

This research study was conducted on pervious concrete mixtures prepared from Margallah crush as aggregate sources. Tests and analyses were conducted on both aggregate and pervious concrete mixtures in accordance with the following two steps:

### 1.5.1 Material Characterization

- Measuring the particle size of coarse aggregate through sieve analysis.
- Measuring the engineering properties of Margallah aggregate such as crushing strength, impact test, abrasion test, sieve analysis, specific gravity test and water absorption test.
- Selection of final coarse aggregate -Aggregate from Multani Builders-

### 1.5.2 Pervious Concrete Mix Testing

- Measuring the density, paste thickness, compressive strength, and flexural strength and splitting tensile strength and image analysis of Porous concrete.
- Measuring the rate of permeability and porosity of the pervious concrete mixtures.
- Optimization the final mix design for fabrication of pervious concrete for pavement

## 1.6 Organization of Thesis

The introduction and motivation of the present work followed by objectives and scope of the thesis are discussed in the following introductory chapter. Chapter in the thesis and their briefly stated below.

### 1.6.1 Chapter 1 Introduction:-

This chapter provides a brief introduction of pervious concrete and highlights the research objectives and scope of the investigation.

### 1.6.2 Chapter 2 Literature Review:-

This chapter discusses a comprehensive literature survey on various methods of preparation, characterization, application and other environmental benefits of pervious material

### 1.6.3 Chapter 3 Materials and Experimental Procedure:-

This chapter describes the preparation of pervious concrete in large scale. This chapter divided into two parts. The first part of this chapter elaborates the selection of the material and testing on the materials. The second part of this chapter describes the fabrication process of porous pervious concrete.

### 1.6.4 Chapter 4 Results and Discussion:-

This chapter explain the results and discussion of the experimental work. This chapter has two sub-chapters. First one presents extensive analysis results of pervious concrete. The second one offers relation among the properties of pervious concrete. E.g. Effect of percentage of fines on porosity, permeability and compressive strength etc.

### 1.6.5 Chapter 5 Conclusions and Recommendations:-

This chapter highlights the major conclusion received from the analysis and experiments carried out of this study. This chapter also explain the possibility the use of pervious concrete in various field.

# CHAPTER 2 LITERATURE REVIEW

## Introduction

More than 60 research papers from across the globe were studied and following conclusions were made based upon the perimeters studied.

### 2.1 Impervious Surfaces:

Anthropogenic surfaces that prevent the infiltration of water into the underlying soil such as buildings and paved surfaces (asphalt, concrete), roads, parking lots are called impervious surfaces. Increasing urbanization and pressure of population stimulates the growth of impervious surfaces in the cities [1, 2]. Impervious surface increases the frequency and intensity of downstream runoff and decreases water quality. Increasing urbanization has resulted in increased amounts of impervious surfaces - roads, parking lots, roof tops, and so on - and a decrease in the amount of forested lands, wetlands, and other forms of open space that absorb and clean storm water in the natural system[3-5]. Many authors have noted that an increase in impervious surface reduces base flow. This is because impervious surfaces prevent infiltration, thereby reducing groundwater recharge and base flow [6].

### 2.2 Groundwater Recharge Hindrances:

Watersheds with large amounts of impervious cover may experience an overall decrease of groundwater recharge and base flow and an increase of storm flow and flood frequency [7, 8]. Furthermore, imperviousness is related to the water quality of a drainage basin and it's receiving streams, lakes, and ponds. Increase in impervious cover and runoff directly impact the transport of non-point source pollutants including pathogens, nutrients, toxic contaminants, and sediment [9]. Land development causes pervious soft surfaces such as grass lands, water bodies and green vegetation being replaced by hard impervious surfaces. While forests capture much precipitation through interception and infiltration, even more is vapor-transpired by the trees Compared to natural soils, concrete pavements generally lack the ability to breathe, absorb heat, and infiltrate rainwater, leading to a series of environmental problems [10].

### 2.3 Groundwater Recharge System:

Open land, such as a pasture or cultivated land, allows less infiltration than forest, and is often more prone to runoff. Water enters the soil through infiltration and the velocity with which water enters the soil is infiltration rate. Land use can have significant impacts on the amount and speed of infiltration in a basin. Impermeable surfaces, such as roofs, parking lots, and roads allow zero infiltration, forcing all water that falls onto them to runoff. The changing proportions of these land use types within a basin can have serious effects on discharge and response to storms, either increasing total yield of water or decreasing and smoothing the hydrograph. Increased impervious cover generally results in more storm water runoff and less ground water recharge. More runoff, in turn, increases stream flows during storm periods [11]. Groundwater contamination is extremely difficult, and sometimes impossible, to clean up. Groundwater is one of our most valuable drinking water resources [12].

## 2.4 Permeability of Subgrade Soil:

Permeability of soil is an important property required for various civil engineering applications such as ground water recharge, riverbank filtration and ground water flow etc. It is the capacity of a soil mass to allow the passage of flow of liquid through its interconnected voids. The interconnected voids in turn depend upon the shape and size of particles. In natural conditions the passage of flow may be parallel, inclined and vertical to the bedding plane. Each layer will have its own value of permeability (k) depending upon the direction of flow. The minimum recommended percolation rate for pavement that intended to infiltrate storm water rather than merely detain it is 104 cm/s (0.1417 in/h) [13].The observed value of coefficient of permeability of the stratified deposit depends upon the direction of flow with respect to the orientation of bedding plane. The most simple and generally observed phenomenon is when flow is perpendicular to the stratified deposit [14, 15].

## 2.5 Effect of Coarse Aggregate

Yu Fan , et al performed experimentations to study the influence of aggregate size on compressive strength of pervious concrete. They concluded that with the increase of aggregate size, the compressive strength increases first. When the aggregate size is greater than 7 mm, the compressive strength doesn't change obviously. While the cementitious paste thickness is less than 1.15 mm, the compressive strength increases slowly with the cementitious paste thickness increases. Once the cementitious paste thickness exceeds 1.15 mm, the compressive strength remains relatively stable. The aggregate size of 9.5 mm was found as optimum for ordinary Portland cement pervious concrete. The distribution of cementitious paste thickness is complicated, and mainly concentrates between 0.3 mm and 2.7 mm. . . . Addition of sand will improve the mechanical strengths but at the same time the hydraulic conductivity will be reduced.

The hydraulic conductivity increases as the size of coarse aggregate is increased. Maximum porosity of 21.25% with aggregate size of 8mm-9.5mm while maximum compressive strength of 32 MPa with aggregate size of 10-15mm. [36]

Wang, .H. et al performed extensive testing on investigating the mechanical properties of pervious concrete. The results shows that maximum porosity of 25.7% was obtained using mix with W/C and C/A ratios are 0.31 & 0.18 respectively, with aggregate size 4.75-9.5mm. The superior range of C/A ratio was 0.20-0.24 while optimum value was 0.22. [25]

Joshangi, .A. et al performed experiments for optimization of concrete pavement mix design. The results concluded that with the increase of aggregate size, the compressive strength increases first. When the aggregate size is beyond 7 mm, the compressive strength doesn't change obviously. The most influential control factors in compressive strength is the paste content. The study suggests a mixture design with aggregate size ranges between 4.75 mm and 9.5 mm, water to cement ratio of 0.35, and the paste content of 28% as the optimum design. [44]

## 2.6 Effect of Fine Aggregate:

Sulaiman, M. N. et al studied the mechanical properties of pervious concrete for its use in parking areas. The w/c ratio was kept 0.38. The fine aggregate is added at 10% -of total volume of coarse aggregate-increment with maximum value of 40%. The laboratory tests revealed that pervious

Concrete with 20% fines-having compatible strength and permeability-is suitable for low volume parking areas. [37]

Modhvadia .Ram had studied the effect of fine aggregate on the strength and porosity. Size of coarse aggregate ranges from 4.75mm to 10mm. Fine aggregate is used from 0-20% at interval of 10% at three W/C ratios- 0.3,0.35 and 0.4- having C/A of 0.25. He concluded that permeability is higher in case of the 0% sand compare to the 10% and 20%. [58]

Manan, A. et al. performed experiments to investigate the effect of sand reduction- from 100% to 0%- on the compressive strength and permeability of pervious concrete. W/C ratio was kept constant, 0.69. The results depicts that 90% reduction of sand from concrete give considerable compressive strength of 2150 psi and infiltration rate of 1.51mm/s. The permeability or infiltration rate depends on the size of course aggregate, infiltration rate depends on the size of course aggregate. [41]

Mishra, S. et al performed experiments to investigate the effect of fly ash on the properties of pervious concrete. Partial replacement of fly ash with cement up to 40% with an incremental value of 10%. In cement replacement with Fly ash with 10 % shows highest compressive strength, high water permeability i.e.0.17 cm/s and porosity of 22.4%. [38]

## 2.7 Effect of Water-Cement Ratio:

Bonicelli, A. et al. studied the effect of water proportion, cement content and compaction energy on volumetric and mechanical properties of pervious concrete mixtures. The water cement ratio and C/A was kept between 0.20 to 0.42 and 0.18 to 0.23 respectively. The maximum size of coarse aggregate was 9mm. The study inferred that Compaction energy contributes 77.08% and 71.29% in strength and porosity respectively C/A contributes the most to the variation of indirect tensile strength, elastic modulus and porosity. Most of the strength variation is consequence of changes in porosity. [40]

Khan, H. A. et al. (2017) studied the porous concrete in laboratory for the purpose of low volume traffic and parking areas. In this research the water to cement ratio was kept as 0.38 with 20% fines.

Ibrahim, M.M.Y et al studied the effect of different curing methods on pervious concrete. The W/C and C/A ratios were 0.34 and 0.40 respectively. The conclusion was made that curing in polythene

Bag was more affective in the strength's parameters whether compressive, tensile or the flexural strength. [47]

Water-to-cement ratios between 0.30 and 0.38 were tested, resulting in an optimal water to cement ratio of 0.32–0.34 which have sufficient compressive strength without compromising on permeability. [61]

Proper concrete curing is particularly important for developing high quality pavement. Proper curing of concrete defined providing a satisfactory moisture and temperature conditions for a period of time immediately to promote cement hydration and concrete microstructure development, so that the desired properties for its intended uses may developed [67, 68]. Proper curing of the concrete plays a very important role to increase durability, strength, water tightness, abrasion resistance, volume stability and resistance to freezing and thawing and deicers [68, 69]. Curing in polyethylene bag is a best method. [70]

## 2.8 Factors Affecting Permeability:

Gersson F. B. et al studied the correlation between permeability and porosity of pervious concrete. The C/A and W/C ratios for all mixes were 0.31 and 0.34 respectively. The experimental results show that the porosity varied from 19.1 to 28.6%, whereas the permeability varied from 4.3 to 15.3mm/s. Maximum compressive and flexural strength of 10.10 and 2.92MPa was obtained respectively. Maximum porosity of 27.06% and maximum permeability of 15.08mm/s was obtained. [49]

Selvaraj .R performed experimentation on some aspects of pervious concrete. The crushed angular blue granite stones of different sizes were used. W/C ratio was kept constant, 0.35. He concluded that the hydraulic conductivity increases as the size of coarse aggregate is increased. Addition of sand will improve the mechanical strengths but at the same time the hydraulic conductivity will be reduced. [36]

Sartipi, M. et al studied the behavior of porous concrete pavement. The pumice aggregate with mean diameter of 2.5mm were used. The study shows that in case the pervious pavements are being utilized, the storm water retention capacity of the region will be increasing to 0.082 L/s assuming an average pavement thickness of 15 cm for the pavements. Samples containing silica fume were performed a better permeability. [43]

Debnath, .B. et al performed experiments to study the permeability and porous structure of pervious concrete using crushed brick, as an aggregate. The results depicts that coarse aggregate size of 13.2mm-12.5mm yields maximum porosity and permeability ; 25.95% and 1.91mm/s respectively. W/C ratio has inverse relation with permeability, and it should be kept between 0.30 to 0.32. From the comparison of single graded and dense graded mix, it is found that the single graded mix increases the permeability of the mix. [45]

Chandrappa, A.K studied the effect of size of aggregate on permeability of pervious concrete. The W/C and C/A ratio used in experiment were 0.25 & 0.33 respectively. He concluded that permeability of aggregate size 13.2–9.5 mm and 19–13.2 mm had higher values as compared to 6.7–4.75 mm and 9.5–6.7 mm. And Permeability of pervious concrete specimens ranged from 0.076 to 3.5 cm/s. C/A ratio had the largest contribution in defining the variation in permeability followed by w/c ratio and gradation respectively having approximately 50 and 30% contribution towards C/A ratio. *[52]*

Zhi-Guang Niu, Zhi-Wei Lv studied the infiltration performance of porous pavement laid on the layers of single graded gravel followed by coarser sand. They inferred that the optimal thickness of the sand bedding layer was 5 cm (the infiltration rate=32.3 mm/h), the sub-base layer was 30 cm (42.3 mm/h). [55]

The permeability or the saturated hydraulic conductivity of the pervious concrete signifies its capacity to drain the ponding water from the concrete surface. During the measurement, a pervious concrete sample is subjected to a water pressure that is lower sufficiently to support a laminar flow [62, 63]. The associated flowing rate is measured to estimate the permeability. The applied pressure during the measurement can be maintained to be constant, referred to as CHM, or be allowed decaying, called FHM [64]. The CHM measures the permeability of pervious concrete by applying a constant water head on the surface of the sample and by weighting the water volume flowing through the sample at a designed time interval. The FHM allows the water head above the sample surface dropping from a starting level to a designed level and then records the time interval during this dropping process. [65, 66]

## 2.9 Design and Strength of Concrete:

Gupta Akash worked on mix design and factors affecting the strength of concrete. The results indicates that maximum compressive strength of 14.341 MPa was obtained using A/C ratio of 6.0 and W/C ratio of 0.38. [38]

Shaik .Fazul studied comparative analysis on various properties of pervious concrete with conventional concrete. Single sized aggregate (3/8 inch) was used. W/C ratio ranges from 0.27 to 0.34. The compressive strength was 15.1 to 25.53 Mpa. Density was 1612kg/$m^3$ to 1685 kg/$m^3$ and the permeability was 2.9*10^-3m/s to 6.6*10^-3m/s for pervious and conventional concrete respectively. [57]

## 2.10 Porosity and Pore Structure:

Martinez, E.et al reviewed porous concrete as multifunctional and sustainable pavement studied that porous pavement has a high air void content, normally around 15–30% which results in permeability rates between 1.0 and 47.7 mm/s. The use of certain admixtures in PC, such as bottom ash and peat moss, has been found to provide surface temperature reductions of about 0.1C in relation to asphalt mixtures. [42]

Singh, .R. et al reviewed the recent advancements in proportioning of No-Fine Concrete. The analysis depicts that Strength of NFC can be increased by factors such as paste volume, small size aggregates, addition of sand, mineral admixture and mix design. Admixture such as FA, SF when added to concrete, have potential to increase mechanical and durability properties of No Fine Concrete. [53]

## 2.11 Summary:

The effect of different parameters on the strength and permeability of pervious concrete were studied in detail. It was found that the strength and permeability increase as the size of coarse aggregate increases and vice versa. The effect on fine aggregate with permeability was also studied and it was concluded that permeability decreases as the percentage of fine aggregate increases. Other parameters were also studied, and it was found that permeability and porosity have direct relation with each other. Higher the permeability, higher is the porosity and vice versa.

# CHAPTER 3 MATERIALS AND METHODOLOGY

## 3.1 Introduction:

Materials used in the manufacturing of pervious concrete .i.e. coarse aggregate , fine aggregate , cement etc. have been discussed. In this study mechanical characteristics of pervious concrete are also considered. The objective is maximizing strength and permeability rate. Then, the design parameters affecting the performance measure is assigned. Parameters are variables within the process that affect the measure. One parameter-W/C ratio- is selected. The two w/c ratios were selected in this research.

## 3.2 Aggregates:

Lawrenspur Sand is used as Fine aggregate, amount was kept limited -0% 5% and 10%- in pervious concrete mixtures because it tends to compromise the connectedness of the pore system. The addition of fine aggregate may increase compressive strengths and density but correspondingly reduce the flow rate of water through the pervious concrete mass. The aggregate used in pervious concrete has the grading between #4 and 3/4 inch (4.75mm to 19mm). The crushed Margallah limestone having nominal size of 12.5mm, conforming to ASTM C33 is used to make pervious concrete. The effective range of the C/A ratio is 0.22 to 0.24.Aggregate samples were taken from five different suppliers and after performing different tests on these samples we selected Multani Kacha Mor.

## 3.3 Cement:

Ordinary Portland cement (OPC) type I “Best way cement” conforming to ASTM C150 is used to make pervious concrete. The amount of the cement per cubic meter would be calculated from C/A ratio selected from literature review. Setting time tests of cement were conducted using Vicat Needle apparatus. The initial and final time of cement paste was 145 minutes and 183 minutes -Conforming to ASTM C191- respectively. The soundness of cube was 3mm and consistency was 27%.

## 3.4 Water:

Water quality for pervious concrete is governed by the same requirements as those for conventional concrete. The general range of water to cementitious material is 0.26-0.40, because an excess amount of water will lead to drainage of the paste and subsequent clogging of the pore system. The values opted for this research are 0.30 and 0.35.

## 3.5 Mixture Design:

The mixture design for each pervious concrete batch had a target void content of 15–30% as recommended by literature review

# 3.6 Sample Preparation:

The original mixture contained crushed gravel, Type I cement and water. All mix designs were adjusted according to required objectives of this research. The pervious concrete mixtures were batched in a pan mixer type. The mixing and curing were performed in accordance with ASTM C192. A total number of specimens made for this study was 180. The specimens were cylinders having 100 mm diameter and 200 mm height. Concrete mixtures were mildly compacted as much as possible in order to increase the void ratio. However, it caused to decrease the compressive strength. The freshly consolidated concrete specimens were placed in shed of structure lab at temperature of approximately 18 C.

# 3.7 Testing Procedure:

## 3.7.1 Density and Void Content of Fresh Concrete:

**Density and Void content in Hardened Pervious Concrete**

Average length of sample 225 mm

Average Diameter of sampl 112.5 mm

Constant K 1273240

| | 3 Days | | | | 14 days | | | | 28 days | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Serial # | Oven Dry Weight (g) | Submerge Weight (g) | Density (Kg/m^3) | Void content (%) | Oven Dry Weight (g) | Submerge Weight (g) | Density (Kg/m^3) | Void content (%) | Oven Dry Weight (g) | Submerge Weight (g) | Density (Kg/m^3) | Void content (%) |
| 1 | 4119 | 2495 | 1841.68 | 27.39 | 3980 | 2489 | 1779.53 | 33.33 | 4030 | 2529 | 1801.89 | 32.89 |
| | | | | | 4135 | 2429 | 1848.84 | 23.72 | 4021 | 2455 | 1797.86 | 29.98 |
| 2 | 4000 | 2542 | 1788.47 | 34.81 | 4266 | 2573 | 1907.41 | 24.30 | 4119 | 2603 | 1841.68 | 32.22 |
| | | | | | 4260 | 2820 | 1904.73 | 35.61 | 4159 | 2559 | 1859.57 | 28.46 |
| 3 | 4024 | 2570 | 1799.21 | 34.99 | 3031 | 1909 | 1929.60 | 49.83 | 3132 | 1868 | 1993.89 | 19.53 |
| | | | | | 3042 | 1838 | 1936.60 | 46.17 | 3111 | 1893 | 1980.52 | 22.46 |
| 7 | 4310 | 2526 | 1927.08 | 20.23 | 4158 | 2527 | 1859.12 | 27.07 | | | | |
| | 4090 | 2473 | 1828.71 | 27.70 | 4220 | 2488 | 1886.84 | 22.56 | | | | |
| 8 | 3976 | 2462 | 1777.74 | 32.31 | 4288 | 2585 | 1917.24 | 23.86 | 4076 | 2485 | 1822.46 | 28.86 |
| | | | | | 4309 | 2581 | 1926.63 | 22.74 | 4150 | 2495 | 1855.54 | 26.00 |
| 9a | 4205 | 2523 | 1880.13 | 24.79 | | | | | | | | |
| | | | | | | | | | | | | |
| 9b | 3167 | 1950 | 2016.18 | 45.59 | | | | | | | | |
| | | | | | | | | | | | | |
| 13 | 3975 | 2403 | 1777.30 | 29.71 | 4116 | 2532 | 1840.34 | 29.18 | 4196 | 2510 | 1876.11 | 24.62 |
| | | | | | 4417 | 2648 | 1974.92 | 20.90 | 4258 | 2523 | 1903.83 | 22.42 |
| 14 | 4309 | 2634 | 1926.63 | 25.11 | 4296 | 2360 | 1920.82 | 13.44 | 4186 | 2496 | 1871.64 | 24.44 |
| | | | | | 4348 | 2408 | 1944.07 | 13.26 | 4068 | 2430 | 1818.88 | 26.76 |
| 15 | 4441 | 2645 | 1985.65 | 19.70 | 4419 | 2648 | 1975.82 | 20.82 | 4598 | 2684 | 2055.85 | 14.42 |
| | | | | | 4764 | 2743 | 2130.07 | 9.64 | 2886 | 1756 | 1837.29 | 28.06 |
| 22 | 4176 | 2520 | 1867.17 | 25.96 | 4256 | 2558 | 1902.94 | 24.08 | 4116 | 2615 | 1840.34 | 32.89 |
| | | | | | 4109 | 2430 | 1837.21 | 24.93 | 4363 | 2630 | 1950.78 | 22.51 |
| 23 | 3201 | 1845 | 2037.82 | 39.37 | 4130 | 2510 | 1846.60 | 27.57 | 4106 | 2435 | 1835.87 | 25.29 |
| | | | | | 4336 | 2630 | 1938.71 | 23.72 | 4153 | 2480 | 1856.88 | 25.20 |
| 24 | 3314 | 1976 | 2109.76 | 40.18 | | | | | | | | |

ASTM C1688 is used to determine the density of freshly mixed pervious concrete followed by void content of pervious concrete.

#### 3.7.1.1 Density or Unit Weight:

The concrete is consolidated using a standard Proctor hammer (Procedure A).

**(Unit Weight)** is calculated using following formula

$$\textbf{Density(Unit Weight)}\ \ D = \frac{M_c - M_m}{V_m}$$

*Where* Mc *mass of the measure is* filled with concrete, Mm is net mass of the concrete and Vm is the volume of the measure.

#### 3.7.1.2 Theoretical Density:

Theoretical density is calculated from the following equation:

$$T = \frac{M_s}{V_s}$$

Where *Ms* is sum of the masses of the cement, fine aggregate, coarse aggregate and water in the batch. The absolute volume *Vs* of each ingredient is equal to the quotient of the mass of that ingredient divided by the product of its relative density (specific gravity) times the density of water as recommended by ASTM C29.

#### 3.7.1.3 Void Content:

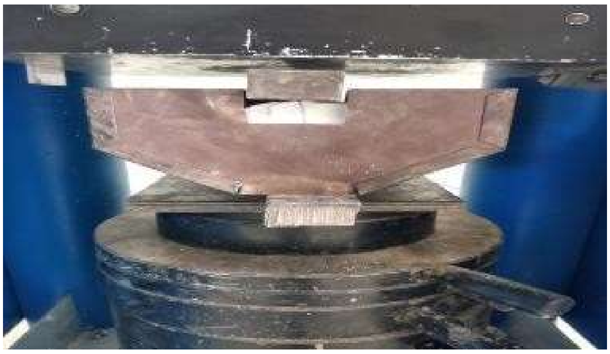
The percentage of voids in fresh pervious concrete is calculated using following formula:

$$U = \frac{T-D}{T} * 100$$

### 3.7.2 Compressive Strength:

Cylindrical specimens were placed under hydraulic testing machine, and the loading speed was fixed at a rate of 0.021 mm/ s until the specimens failed. The standard compressive and splitting tensile tests were performed on the cylinders in accordance with the procedures given in ASTM C39, ASTM C496 respectively. Replicates were performed for each test and the average of strength values was reported. All tests were carried out in three ages: 3-, 14-, 28-day. 15 specimens were made for each mixture design.

### 3.7.3 Split Tensile Strength:



The split tensile strength of pervious concrete is calculated using ASTM 496 (2016).

### 3.7.4 Porosity And Density Of Hardened Concrete:

The pervious concrete porosity was calculated using standard method ASTM C1754 by taking the difference in weight of oven dry and saturated, submerged under water. Cylindrical specimens of 100 mm in diameter and 200 mm in length are used.

## 3.8 Porosity:

Porosity is the percentage of voids in concrete. The target porosity ranges from 20% - 30%.

As the porosity increases, strength decreases but permeability increases and vice versa.

The percentage of pores depends upon the

- Gradation of aggregates
- Type of aggregate
- Quantity of cement, aggregate and water
- Level of compaction

### 3.8.1Method of measurement:

The porosity of samples can be calculated from the following formula:

$$\mathbf{P = [1\text{-}(\frac{W2-W1}{V.\rho w}) ] \times 100\%}$$

Where

P = Total porosity in %

W2 =Weight in water (Kg)

W2 = Oven dry weight (Kg)

V = Volume of sample Kg/cm^3

ρw = Density of water (Kg/cm^3)

Where *B* is the submerged mass of the specimen, g [lb.], and *ρw* = density of water at temperature of the water bath in kg/m3 [lb. /ft3].

The hardened density of the concrete is also calculated using ASTM C1754M-12 Method B. The cylindrical specimen of hardened pervious concrete have nominal 100 mm [4 in.] diameter. The density of the specimen is calculated from the following formula

$$\textbf{Density} = \frac{K*A}{D^2*L}$$

where *A* is the dry mass of the specimen, g [lb.], *D is the* average diameter of the specimen, mm [in.], *L is the* average length of the specimen, mm [in.] and *K* is 1273240 in SI units or 2 200 in [inch-pound] units.

## 3.9 Summary:

In this chapter ingredients of pervious concrete were discussed in detail. Samples of different companies, suppliers etc. were bought and after performing different tests on these materials their selection was done. Then mixture design and sample preparation has been discussed. After that tests performed on this concrete were also discussed. These tests were Density and Void Content of Fresh Concrete, Compressive Strength, tensile strength, permeability, Porosity and Density of Hardened Concrete. The ASTM standards, formulas etc. used in these tests have also explained. Different parameters in this project have been selected. These parameters are the variables which can be varied during practical work. W/c ratio is also one of the parameters. The two w/c ratios were selected for this project.

# CHAPTER 4 TEST RESULTS & DISCUSSION

## 4.1 Introduction:

The study includes the Fresh concrete tests and the other is Hardened concrete tests. The Fresh Concrete tests explain the fresh properties of concrete like compacting factor value, slump, porosity and density. The values and data of fresh concrete properties can be obtained just after the mixing of concrete. The hardened concrete tests describes the hardened properties of Concrete like compressive strength, tensile strength, permeability.

The values and data of hardened concrete is obtained after 3, 14 and 28 days in Compressive testing machine, bouncy balance and falling head method. In this chapter firstly the fresh concrete results are shown and later on the hardened concrete results are depicted in the tabular form. The different serial number shown in the table means the different mix design with the variation of c/a, w/c and Fine aggregate ratio**.**

## 4.2 Compaction Factor Test:

The workability of Pervious Concrete is assessed through compaction factor. The less compacting factor value indicates the water content is less as compared to conventional concrete. The fresh PC is different from normal concrete (NC). As the aggregate is covered with the cement paste, it seems to be segregated, mainly due to less fine content, which in our case is only 0, 5 and 10% of course aggregate.

### 4.2.1 Compacting Factor Values for Serial#1, #2, #3, #7

| Serial # | Description | Serial#1 | Serial#2 | Serial#3 | Serial#7 |
|---|---|---|---|---|---|
| 1 | Wt. Of Empty Cylinder (W1) | 6840 | 6840 | 6840 | 6840 |
| 2 | Wt. Of Empty Cylinder (W1)+Free Fall Concrete(W2) | 14550 | 14740 | 15180 | 15020 |
| 3 | Wt. Of Empty Cylinder Hand Compacted Concrete(W3) | 15850 | 15900 | 16210 | 16320 |
| 4 | Wt. of Partially Compacted Concrete(Wp=W2-W1) | 7710 | 7900 | 8340 | 8180 |
| 5 | Wt. of Fully Compacted Concrete(Wf=W3- W1) | 9010 | 9060 | 9370 | 9480 |

| | | | | | |
|---|---|---|---|---|---|
| 6 | Compaction Factor=Wp/Wf | 0.86 | 0.87 | 0.89 | 0.86 |

### 4.2.2 Compacting Factor Values for Serial#8, #9a, #9b, #13

| Serial # | Description | Serial#8 | Serial#9a | Serial#9b | Serial#13 |
|---|---|---|---|---|---|
| 1 | Wt. Of Empty Cylinder (W1) | 6840 | 6840 | 6840 | 6840 |
| 2 | Wt. Of Empty Cylinder (W1)+Free Fall Concrete(W2) | 15000 | 15060 | 15670 | 14990 |
| 3 | Wt. Of Empty Cylinder Hand Compacted Concrete(W3) | 16340 | 16610 | 17180 | 16540 |
| 4 | Wt. of Partially Compacted Concrete(Wp=W2-W1) | 8160 | 8220 | 8830 | 8150 |
| 5 | Wt. of Fully Compacted Concrete(Wf=W3- W1) | 9500 | 9770 | 10340 | 9700 |
| 6 | Compaction Factor=Wp/Wf | 0.85 | 0.84 | 0.85 | 0.84 |

### 4.2.3 Compacting Factor Values for Serial#14, #15, #22, #23

| Serial # | Description | Serial#14 | Serial#15 | Serial#22 | Serial#23 |
|---|---|---|---|---|---|
| 1 | Wt. Of Empty Cylinder (W1) | 6840 | 6840 | 6840 | 6840 |
| 2 | Wt. Of Empty Cylinder (W1)+Free Fall Concrete(W2) | 14840 | 15090 | 15380 | 15590 |
| 3 | Wt. Of Empty Cylinder Hand Compacted Concrete(W3) | 16290 | 16460 | 16500 | 16430 |
| 4 | Wt. of Partially Compacted Concrete(Wp=W2-W1) | 8000 | 8250 | 8540 | 8750 |
| 5 | Wt. of Fully Compacted Concrete(Wf=W3- W1) | 9450 | 9620 | 9660 | 9590 |

| | | | | | |
|---|---|---|---|---|---|
| 6 | Compaction Factor=Wp/Wf | 0.84 | 0.86 | 0.88 | 0.91 |

### 4.2.4 Compacting Factor Values for Serial#24

| Serial # | Description | Serial#24 |
|---|---|---|
| 1 | Wt. Of Empty Cylinder (W1) | 6840 |
| 2 | Wt. Of Empty Cylinder (W1)+Free Fall Concrete(W2) | 14860 |
| 3 | Wt. Of Empty Cylinder Hand Compacted Concrete(W3) | 16690 |
| 4 | Wt. of Partially Compacted Concrete(Wp=W2-W1) | 8020 |
| 5 | Wt. of Fully Compacted Concrete(Wf=W3-W1) | 9850 |
| 6 | Compaction Factor=Wp/Wf | 0.81 |

## 4.3 Slump:

The Second method through which the workability of concrete is measured is slump Test. The workability of Pervious Concrete is also assessed through slump test. The slump test was performed, and Pervious Concrete has itself proved that it is zero slump concrete. This least slump is due to lower water content. The fresh PC is different from normal concrete (NC). As the concrete is more permeable because of less percentage of fines (0, 5%, 10%, and 20%). The serials in which water to cement ratio value is 0.35 shows some value of slump because of addition of sand increase its workability.

### 4.3.1 Concrete Slump

| Serial# | Slump Value(inch) | Serial# | Slump Value(inch) |
|---|---|---|---|
| 1 | 0 | 13 | 0 |
| 2 | 0 | 14 | 4 |
| 3 | 0 | 15 | 2 |
| 7 | 0 | 22 | 2.5 |
| 8 | 0 | 23 | 3 |
| 9a | 0 | 24 | 4 |
| 9b | 0 | | |

## 4.4 Porosity in Fresh Concrete:

The void content of fresh PC is determined using ASTM standards. Porosity is the function of weight of cylinder containing fresh concrete. The weight of cylinder depends upon correctness of concrete ingredients. Hence w/c, C/A and percentage of fines affects the % age of void content. The FPC properties have great impact upon mechanical and hydraulic properties of hardened PC. The Serials in which sand content is more are less permeable and with the passage of time the voids content in concrete sample decrease because of increasing strength and density. The void content of pervious concrete also depends upon the variables like w/c ratio, percentage of fines etc.

### 4.4.1 Porosity in concrete

| Serial# | Empty Weight W1(g) | Full Compacted Weight W2(g) | Porosity=(1-W1/(W2-W1)(g) |
|---|---|---|---|
| 1 | 6840 | 16580 | 29.77 |
| 2 | 6840 | 17020 | 32.81 |
| 3 | 6840 | 17370 | 35.04 |
| 7 | 6840 | 18200 | 39.79 |
| 8 | 6840 | 17280 | 34.48 |
| 9a | 6840 | 17440 | 35.47 |
| 9b | 6840 | 17990 | 38.65 |
| 13 | 6840 | 17946 | 38.41 |
| 14 | 6840 | 18470 | 41.11 |
| 15 | 6840 | 17980 | 38.6 |
| 22 | 6840 | 17620 | 36.54 |
| 23 | 6840 | 18080 | 39.15 |
| 24 | 6840 | 17750 | 37.305 |

## 4.5 Compressive Strength:

Compressive strength is the function of C/A, % age of FA and paste content. The concrete samples in which w/c and FA is more shows more strength as compared to other samples and vice versa.

### 4.5.1 Effect of W/C Ratio:

The w/c affects the compressive strength. From experiments we see that serial # 1 having w/c ratio of 0.3 , 0% fine and C/A 0.22 shows the compressive strength of 5.71MPa while serial # 13 having same credentials of serial # 1 but w/c of 0.35 shows compressive strength of 7.63 MPa . Hence for PC as w/c ratio increases, the compressive strength increases.

### 4.5.2 Effect of Aggregate Content:

The amount of aggregate in mix proportion is governed by C/A ratio. Form results it is evident that as the C/A ratio decrease from 0.24 to 0.22, the compressive strength increases from 6.75 MPa to 8.90 MPa respectively for serial # 2$ 8 respectively. Hence also the amount of aggregate increases, the compressive strength of samples increases.

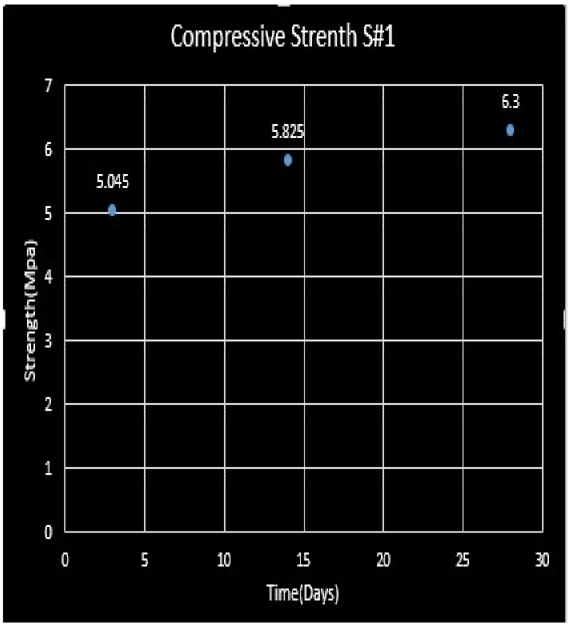
### 4.5.3 Effect of Fines:

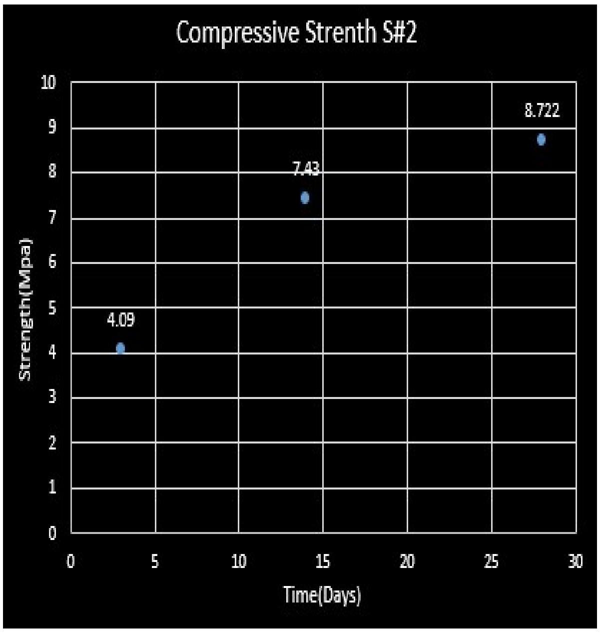
As the percentage of fines increases the compressive strength of samples would also increase. From results it is shown that from serial # 1, 2, 3, as the percentage of fines increases from 0 to 10% the compressive strength increases from 5.73 MPa to 10.87 MPa. Same trend can be found for serial # 13 , 14 ,15 having 0 , 5 , 10% fines shows compressive strength of 7.63 Mpa , 9.13 MPa and 11.88 MPa respectively.

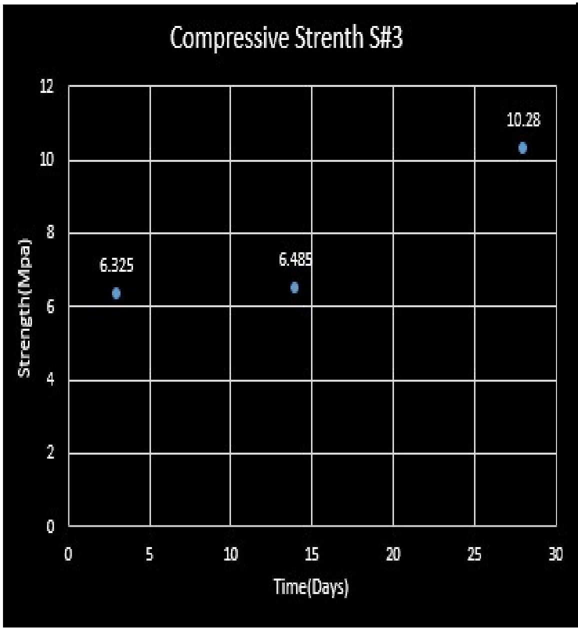
### 4.5.4 Compressive Strength Table And Graphs:

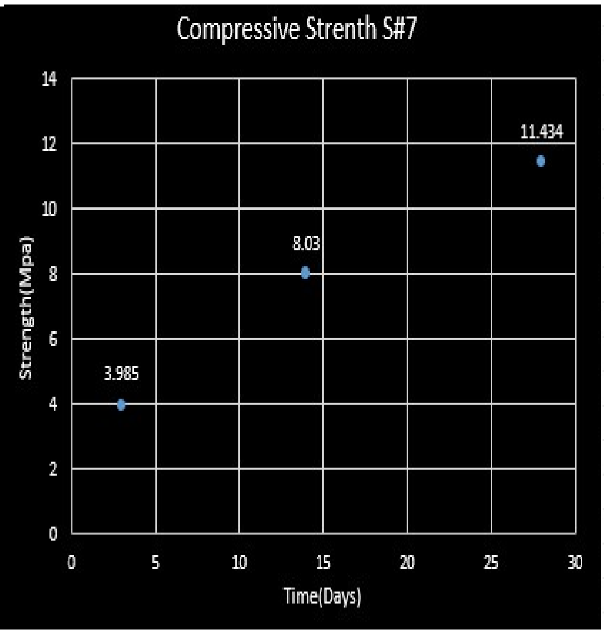
| Serial # | 3 Days | | Avg | 14 Days | | Avg | 28 days | | Avg |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.69 | 5.4 | 5.045 | 6.46 | 5.19 | 5.825 | 6.89 | 5.71 | 6.3 |
| 2 | 3.64 | 4.54 | 4.09 | 7.45 | 7.41 | 7.43 | 8.543 | 8.9 | 8.7215 |
| 3 | 6.69 | 5.96 | 6.325 | 6.71 | 6.26 | 6.485 | 9.684 | 10.87 | 10.277 |
| 7 | 4.14 | 3.83 | 3.985 | 7.08 | 8.98 | 8.03 | 10.265 | 12.61 | 11.43 |
| 8 | 4.075 | 3.97 | 4.0225 | 6.49 | 5.98 | 6.235 | 7.8 | 6.75 | 7.275 |

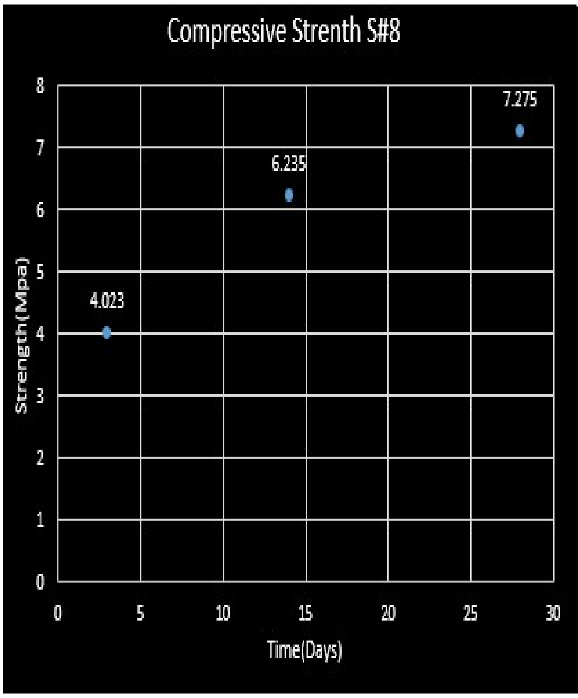
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 9a | 9.53 | 9.61 | 9.57 | 9.615 | 11.03 | 10.323 | 11.37 | 13.57 | 12.47 |
| 13 | 3.52 | 4.18 | 3.85 | 6.75 | 5.35 | 6.05 | 7.96 | 7.63 | 7.795 |
| 14 | 5.06 | 5.1 | 5.08 | 6.76 | 7.96 | 7.36 | 9.33 | 11.07 | 10.2 |
| 15 | 5.127 | 4.52 | 4.8235 | 10.35 | 7.952 | 9.151 | 10.78 | 11.88 | 11.33 |
| 22 | 5.246 | 4.541 | 4.8935 | 7.31 | 6.65 | 6.98 | 9.425 | 8.697 | 9.061 |
| 23 | 8.05 | 10.6 | 9.325 | 9.66 | 9.234 | 9.447 | 12.68 | 14.27 | 13.475 |

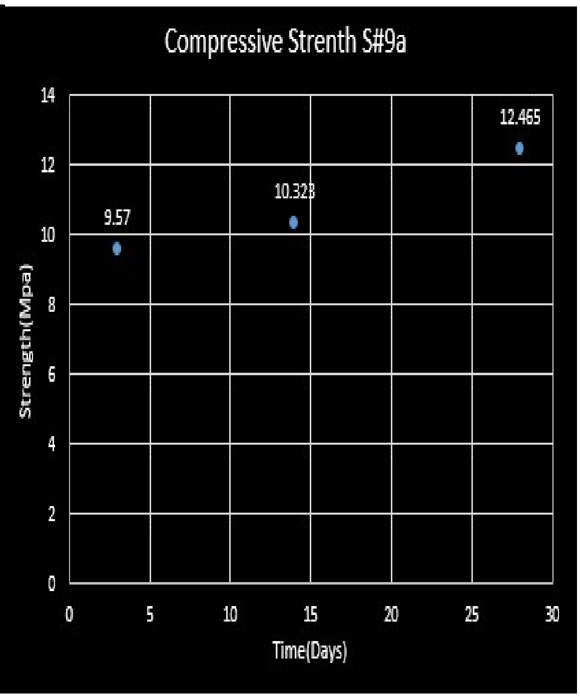


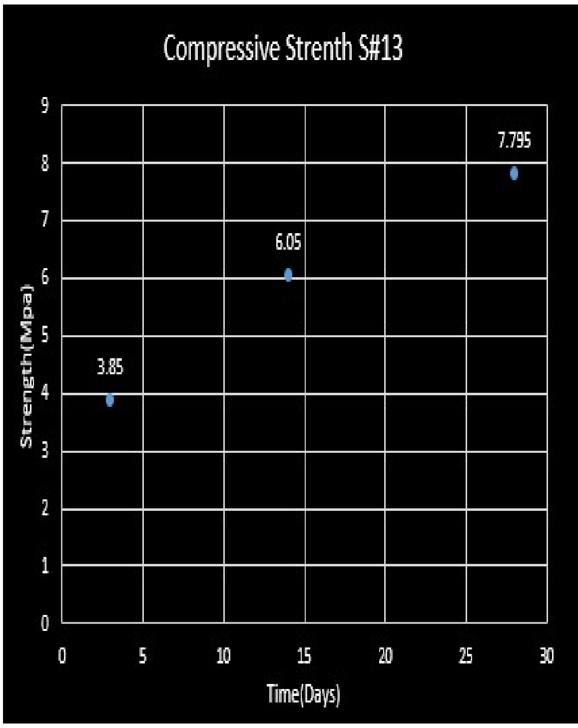



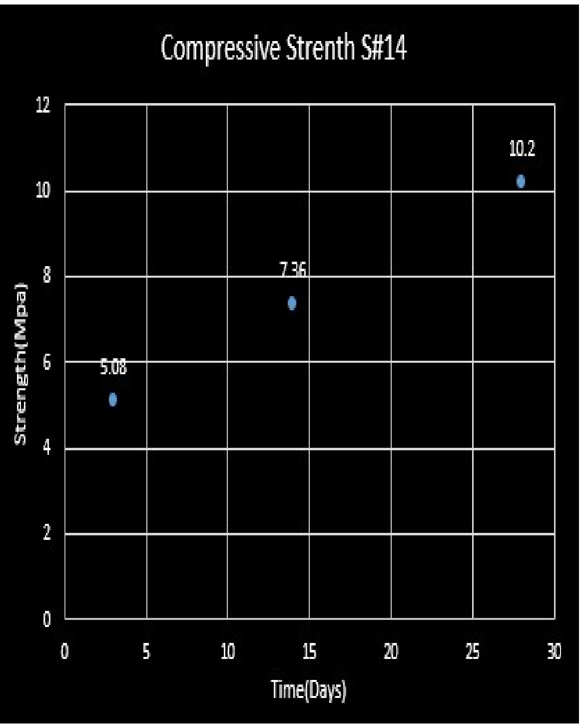

Compressive Strenth S#3
Strength(Mpa)
Time(Days)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
6.325
6.485
10.28

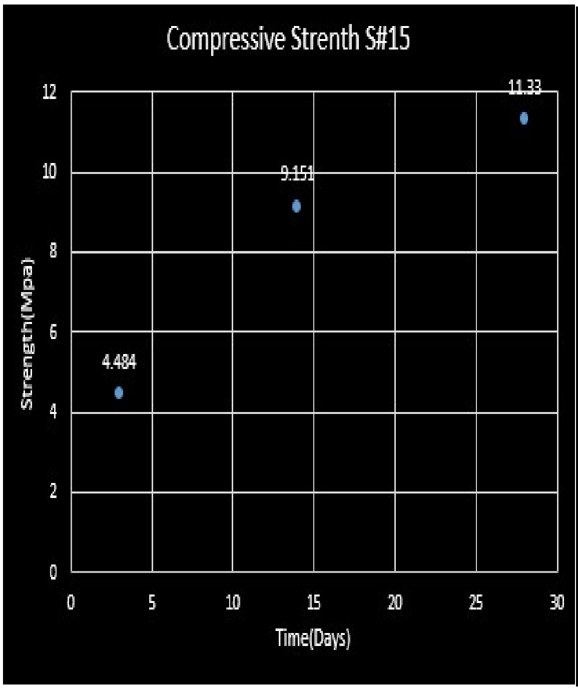

Compressive Strenth S#7
Strength(Mpa)
Time(Days)
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
3.985
8.03
11.434

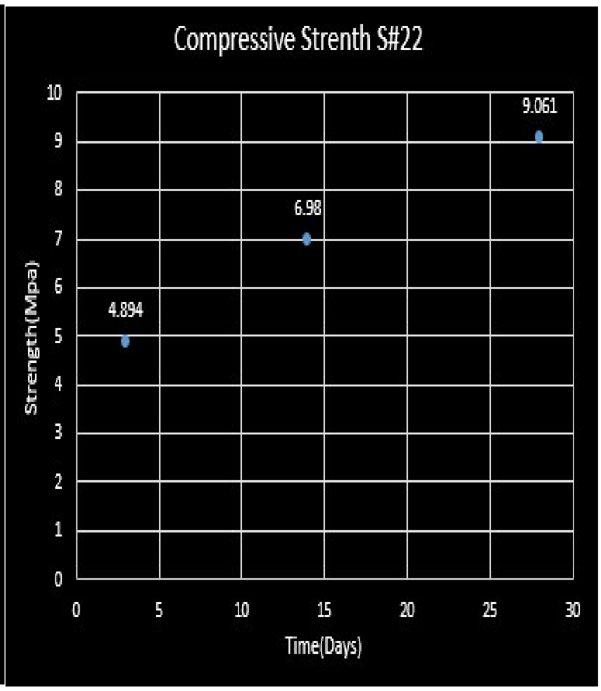

Compressive Strenth S#8
Strength(Mpa)
Time(Days)
0
1
2
3
4
5
6
7
8
0
5
10
15
20
25
30
4.023
6.235
7.275

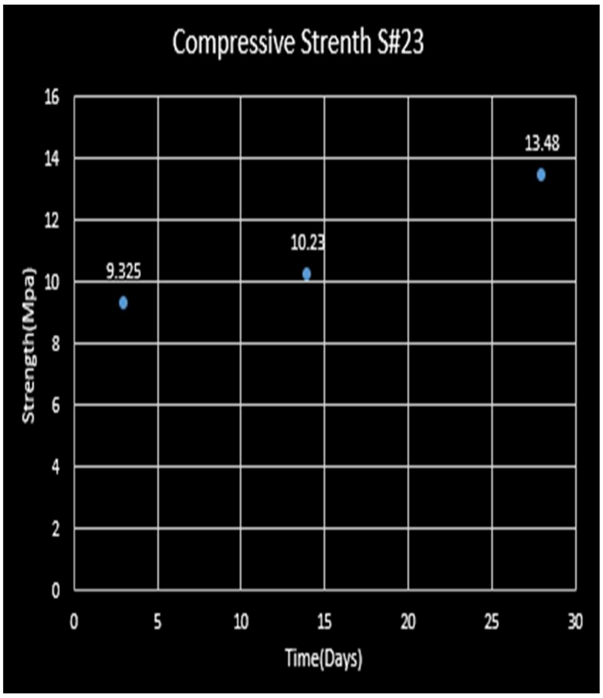

Compressive Strenth S#9a
Strength(Mpa)
Time(Days)
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
9.57
10.323
12.465


Compressive Strenth S#13
Strength(Mpa)
Time(Days)
3.85
6.05
7.795


Compressive Strenth S#14
Strength(Mpa)
Time(Days)
5.08
7.36
10.2


Compressive Strenth S#15
Strength(Mpa)
Time(Days)
4.484
9.151
11.33


Compressive Strenth S#22
Strength(Mpa)
Time(Days)
4.894
6.98
9.061




## 4.6 Tensile Strength:

Tensile strength is basically the function of compressive strength. From experimental results it is evident that for serial # 1, 2, 3 having compressive strength of 5.71, 8.9 & 10.87 MPa respectively shows tensile strength of 1.91, 1.57 & 1.32 MPa. Hence for pervious concrete as the compressive strength increases, the tensile strength decreases.

| | |
|---|---|
| Length of Sample = | 200mm |
| Diameter of sample = | 100mm |

### 4.6.1 Split Tensile Test Strength for 28 Days

| Serial # | Load (kN) | Strength (Mpa) |
|---|---|---|
| 1 | 59.901 | 1.91 |
| 2 | 49.343 | 1.57 |
| 3 | 41.478 | 1.32 |
| 7 | 44.296 | 1.41 |
| 8 | 51.121 | 1.63 |
| 9a | 63.240 | 2.013 |
| 13 | 50.959 | 1.62 |
| 14 | 43.039 | 1.37 |
| 15 | 58.972 | 1.88 |
| 22 | 40.256 | 1.27 |
| 23 | 66.812 | 2.126 |

## 4.7 Void Content:

| | | |
|---|---|---|
| Average length of sample | 225 | mm |
| Average Diameter of sample | 112.5 | mm |

| | |
|---|---|
| Constant K | 1273240 |

### 4.7.1 Effect of Fines:

From experimental results it is evident that as % of fines and w/c ratio increases the void content in PC samples starts decreasing. For example, serial # 1 having w/c ratio of 0.3 with 0% fines have void content of 36.69% while the samples of serial # 24 having w/c of 0.35 with 0% fines shows void content of 21.75%.

### 4.7.2 Effect of W/C Ratio:

The effect of w/c ratio can be seen from results of serial # 3 and serial # 5 having w/c of 0.3 and 0.35 With void content of 33.56% $ 19.70 % respectively. Hence as the w/c and % offines increases the void content decreases.

### 4.7.3 Void Content For 3 Days:

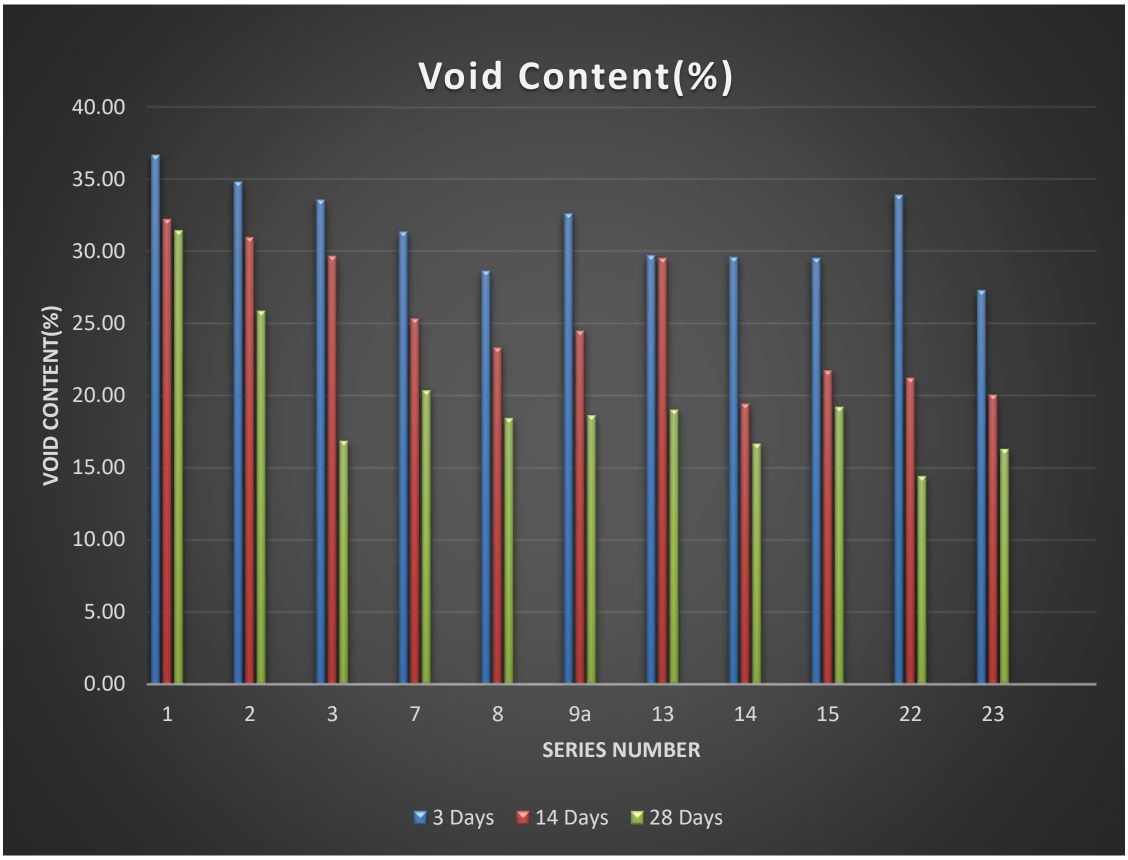
| Serial # | Oven Dry Weight (g) | Submerge Weight (g) | Void content (%) |
|---|---|---|---|
| 1 | 4011 | 2595 | 36.69 |
| 2 | 4000 | 2542 | 34.81 |
| 3 | 4056 | 2570 | 33.56 |
| 7 | 4122 | 2587 | 31.37 |
| 8 | 4058 | 2462 | 28.64 |
| 9a | 4205 | 2698 | 32.62 |
| 13 | 3975 | 2403 | 29.71 |
| 14 | 4209 | 2634 | 29.58 |
| 15 | 4341 | 2765 | 29.53 |
| 22 | 4176 | 2698 | 33.92 |
| 23 | 3028 | 1402 | 27.30 |

### 4.7.4 Void Content For 14 Days:

| Serial # | Oven Dry Weight (g) | Submerge Weight (g) | Void Content (%) |
|---|---|---|---|
| 1 | 4012 | 2496 | 32.22 |
| 2 | 4165 | 2621 | 30.96 |
| 3 | 3165 | 1692 | 34.14 |
| 7 | 4177 | 2507 | 25.33 |
| 8 | 4298 | 2583 | 23.32 |
| 9a | 4256 | 2567 | 24.48 |
| 13 | 4266 | 2690 | 29.53 |
| 14 | 4276 | 2474 | 19.43 |
| 15 | 4395 | 2645 | 21.75 |
| 22 | 4256 | 2494 | 21.22 |
| 23 | 4358 | 2470 | 15.58 |

### 4.7.5 Void Content For 28 Days:

| Serial # | Oven Dry Weight (g) | Submerge Weight (g) | Void content (%) |
|---|---|---|---|
| 1 | 4025 | 2492 | 31.46 |
| 2 | 4239 | 2581 | 25.87 |
| 3 | 3186 | 1880 | 16.86 |
| 7 | 4259 | 2478 | 20.37 |
| 8 | 4389 | 2565 | 18.45 |
| 9a | 4385 | 2565 | 18.62 |
| 13 | 4327 | 2516 | 19.03 |
| 14 | 4327 | 2463 | 16.66 |
| 15 | 3125 | 1856 | 19.21 |
| 22 | 4339 | 2425 | 14.42 |
| 23 | 4429 | 2457 | 11.83 |


Void Content(%)
VOID CONTENT(%)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1
2
3
7
8
9a
13
14
15
22
23
SERIES NUMBER
3 Days
14 Days
28 Days

## 4.8 Density:

The effect and trend of density is same as the Void Content.

### 4.8.1 Effect of Fines:

From experimental results it is evident that as % of fines and w/c ratio increases the void content in PC samples starts decreasing. For example, serial # 1 having w/c ratio of 0.3 with 0% fines have void content of 36.69% while the samples of serial # 24 having w/c of 0.35 with 0% fines shows void content of 21.75%.

### 4.8.2 Effect of W/C Ratio:

The effect of w/c ratio can be seen from results of serial # 3 and serial # 5 having w/c of 0.3 and 0.35 With void content of 33.56% $ 19.70 % respectively. Hence as the w/c and % offines increases the void content decreases.

The density increases from 1793.93 kg/m^3 for serial 1 to 2028.27 kg^m3 for serial 3. Also the effect of W/C can be seen on density as the density increases from 1813.51 kg/m^3 for serial 3 to 2028.27 kg/m^3

### 4.8.3 Density for 3 Days:

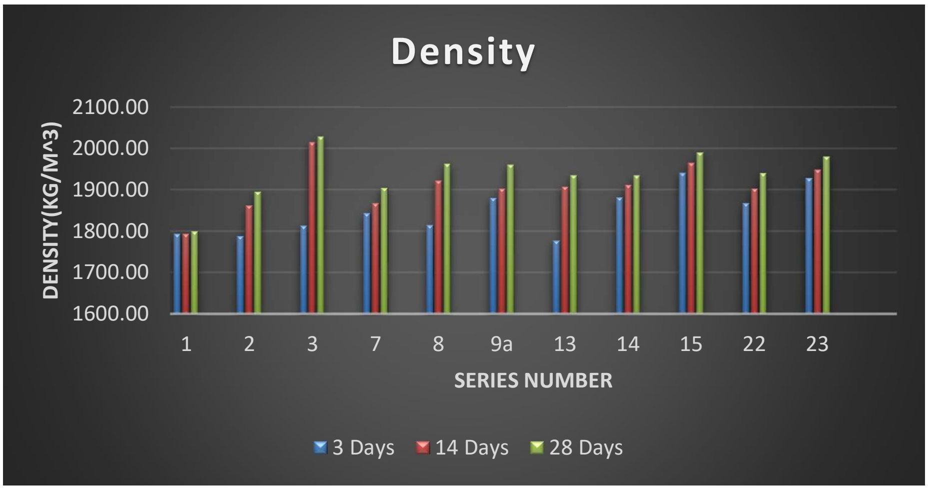
| Serial # | Oven Dry Weight (g) | Submerge Weight (g) | Density (Kg/m^3) |
|---|---|---|---|
| 1 | 4011 | 2595 | 1793.39 |
| 2 | 4000 | 2542 | 1788.47 |
| 3 | 4056 | 2570 | 1813.51 |
| 7 | 4122 | 2587 | 1843.02 |
| 8 | 4058 | 2462 | 1814.41 |
| 9a | 4205 | 2698 | 1880.13 |
| 13 | 3975 | 2403 | 1777.30 |
| 14 | 4209 | 2634 | 1881.92 |
| 15 | 4341 | 2765 | 1940.94 |
| 22 | 4176 | 2698 | 1867.17 |
| 23 | 3028 | 1402 | 1927.69 |

### 4.8.4 Density for 14 Days:

| Serial # | Oven Dry Weight (g) | Submerge Weight (g) | Density (Kg/m^3) |
|---|---|---|---|
| 1 | 4012 | 2496 | 1793.84 |
| 2 | 4165 | 2621 | 1862.25 |
| 3 | 3165 | 1692 | 2014.90 |
| 7 | 4177 | 2507 | 1867.61 |
| 8 | 4298 | 2583 | 1921.72 |
| 9a | 4256 | 2567 | 1902.94 |
| 13 | 4266 | 2690 | 1907.41 |
| 14 | 4276 | 2474 | 1911.88 |
| 15 | 4395 | 2645 | 1965.09 |
| 22 | 4256 | 2494 | 1902.94 |
| 23 | 4358 | 2470 | 1948.54 |

### 4.8.5 Density for 28 Days:

| Serial # | Oven Dry Weight (g) | Submerge Weight (g) | Density (Kg/m^3) |
|---|---|---|---|
| 1 | 4025 | 2492 | 1799.65 |
| 2 | 4239 | 2581 | 1895.34 |
| 3 | 3186 | 1880 | 2028.27 |
| 7 | 4259 | 2478 | 1904.28 |
| 8 | 4389 | 2565 | 1962.40 |
| 9a | 4385 | 2565 | 1960.61 |
| 13 | 4327 | 2516 | 1934.68 |
| 14 | 4327 | 2463 | 1934.68 |
| 15 | 3125 | 1856 | 1989.44 |
| 22 | 4339 | 2425 | 1940.05 |
| 23 | 4429 | 2457 | 1980.29 |




## 4.9 Void Structure Analysis

The void distribution in pervious concrete also has great impact upon compressive strength and permeability of concrete. The size of voids has inverse relation with compressive strength and direct relation with permeability. The unequal distribution of pores/voids in pc sample adversely effects both compressive strength and permeability. There should be uniform and closely interconnected voids web within the PC samples for smooth flow of water through PC. The void distribution in different concrete samples can be seen in LIST OF PICTURES.

## 4.10 Summary

In this chapter the fresh concrete and hardened concrete test were performed. The result obtained from compacting factor and slump were to discuss the fresh properties of concrete. The low value of slump and compacting factor shows the workability of concrete is low. From UTM Split Tensile and Compressive strength is obtained using size of cylinder 4.5"*9" in which we have given dimensions of cylinder and in return the machines gives the value of force applied on that specimen and the compressive strength of cylinder. As the void content are greater in specimen results in more permeability and less compressive strength and vice versa. The Void contents were obtained from buoyancy balance in which we first dry specimen in oven for 24 hours and place in bucket until the value becomes stable. The maximum and minimum void content that we obtained are 31.46% and 11.83% for 28 days respectively.

# CHAPTER 5- CONCLUSIONS AND RECOMMENDATIONS:

## 5.1 CONCLUSION:

The workability of pc depends upon the amount of water added in the sample. w/c ratio of 0.35 shows more workability than 0.30. The compressive strength of PC increases with increase of pore content, w/c ratio % of fines and vice versa. It returns with the increase in voids content. The tensile strength of pervious concrete decreases as the compressive strength increases. The density of PC increases with an increase in W/C ratio and percentage of fines. The void content decrease with increase in W/C ratio and percentage of fines. Density of PC samples increase with the passage of time. The permeability of PC samples decreases with an increase in the percentage of fines, W/C ratio and amount of aggregate. The permeability of PC sample increase with an increase in %age of interconnected voids.The optimum and recommended mix design is found to be serial #23 having following properties.

| Optimum Mix Design Properties | |
|---|---|
| Serial No 23 | |
| W/C Ratio | 0.35 |
| C/A ratio | 0.24 |
| MNAS | 12.5mm |
| CMS | 1:0.21:4.17 |
| F.A | 5% |
| Compressive Strength | 13.48 Mpa |
| Tensile Strength | 2.126 Mpa |
| Porosity | 16.80 % |
| Permeability | |
| Density | 1980.29 kg/m^3 |

## 5.2 RECOMMENDATIONS:

In our scope of research, the following two parameters were studied in detail:

- Strength
- Permeability

It is recommended to study various parameters of pervious concrete as well like durability. For durability we have freeze- thaw test. The pore structure should also be studied. It will include study on tortuosity and honey combing of pervious concrete and its relationship with strength and permeability. The effect of pervious concrete on the environment is also of great importance as it increase the ground water recharge and base-blow.

## Appendix A

# LIST OF PICTURES:

### Procurement:

### Coarse Aggregate Testing:

**Mixing and Casting Of Pervious Concrete Samples:**


**Testing on Fresh Pervious Concrete:**

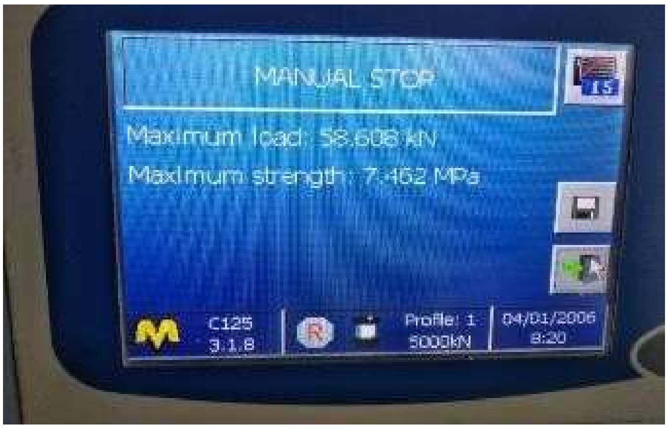








**Tests on Hardened Pervious Concrete:**





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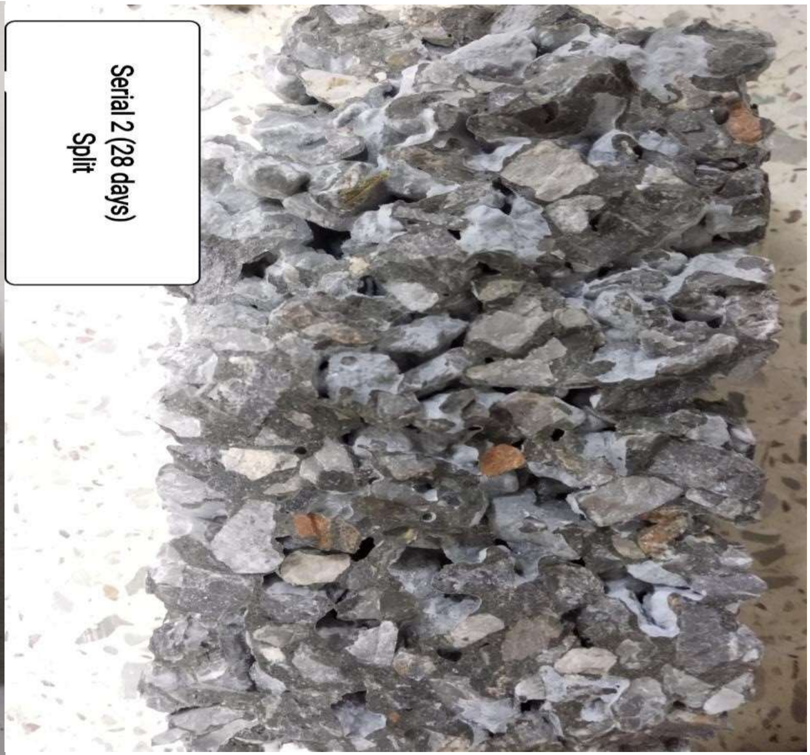
# APPENDIX B
## POROUS STRUCTURE OF PERVIOUS CONCRETE

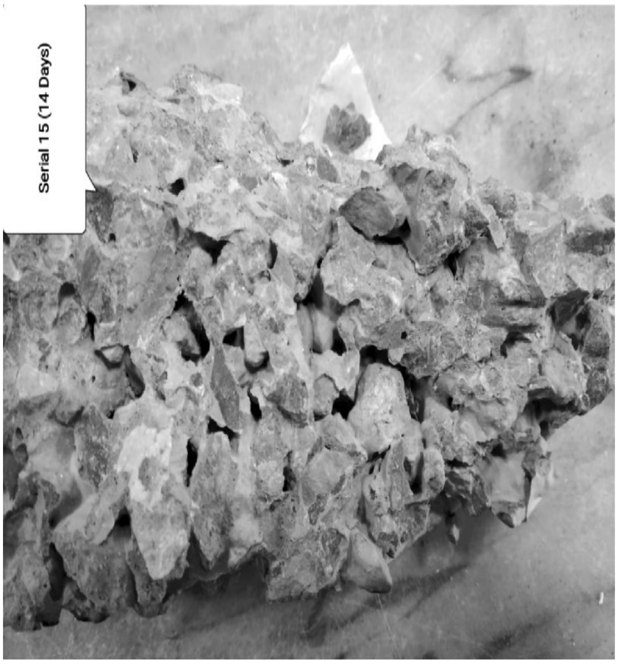






Serial #13(28 days)


Normal Concrete


Serial 1 (28
Split


Serial 15 (14 Days)


Serial#22(split)

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