AN EXPERIMENTAL INVESTIGATION ON PERVIOUS CONCRETE

Submitted in partial fulfilment of the requirements
for the degree of

BACHELOR OF ENGINEERING

by

SURYAWANSHI AKSHAY PRADEEP (13CES59)
PARAB SIDDESH DEEPAK (14CES34)
ANSARI TAUSIF AHMED MAQBOOL (15DCES60)
KHAN ALI MOHD MATEEN (15DCES70)

Under guidance of

Prof. DADA PATIL

Department Of Civil Engineering
School of Engineering and Technology
Anjuman-I-Islam's Kalsekar Technical Campus
Plot No. 2#3, Sector-16, Near Thana Naka, Khanda Gaon,
New Panvel, Navi Mumbai – 410206

2018-2019

CERTIFICATE

This is to certify that the project entitled "An Experimental Investigation on Pervious Concrete" is a bonafide work of Suryawanshi Akshay Pradeep (13CES59), Parab Siddesh Deepak (14CES34), Ansari Tausif Maqbool Ahmed (15DCES60) and Khan Ali Mohd Mateen (15DCES70) submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of "Bachelor of Engineering" in Department of Civil Engineering.

Prof. DADA PATIL
Guide

Dr. Rajendra B. Magar
Head of Department

Dr. Abdul Razzak Honnutagi
Director

PROJECT REPORT APPROVAL FOR B. E.

This project report entitled "An Experimental Investigation on Pervious Concrete" by Suryawanshi Akshay Pradeep (13CES59), Parab Siddesh Deepak (14CES34), Ansari Tausif Maqbool Ahmed (15DCES60) and Khan Ali Mohd Mateen (15DCES70) approved for the degree of "Bachelor of Engineering" in "Department of Civil Engineering".

Examiners

…………………………

…………………………

Supervisors

1. ……………………………

2. …………………………

Chairman (Director)

………………………………

DECLARATION

We declare that this written submission represents our ideas in our own words and where others ideas or words have been included. We have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

SURYAWANSHI AKSHAY PRADEEP	(13CES59)
PARAB SIDDESH DEEPAK	(14CES34)
ANSARI TAUSIF AHMED MAQBOOL	(15DCES60)
KHAN ALI MOHD MATEEN	(15DCES70)

ACKNOWLEDGEMENT

The satisfaction and euphoria on the successful completion of any task would be incomplete without the mention of the people who made it possible, whose constant guidance and encouragement crowned our effort with success. We are grateful to the Department of Civil Engineering, AIKTC, for giving us the opportunity to execute this project, which is an integral part of the curriculum in B.E programme at the AIKTC, New Panvel. We would like to take this opportunity to express heartfelt gratitude to our project guide **Prof. DADA PATIL** who provided us valuable inputs at each and every moment of this project execution. Our special thanks to **DR. R.B. MAGAR**, Head of the Civil Engineering Department, for all the facilities provided for successful completion of this work. We are very much thankful to Prof. Shafi Mujawar ,Mr. Gulab and Mr. Sarfaraz from civil engineering department. Submitting this thesis would have been a Herculean job, without the constant help, encouragement, support and suggestions from friends. Last but not the least we would like to thank all the non-teaching staff of the AIKTC.

ABSTRACT

Pervious concrete (no fines concrete) is a concrete containing little or no fine aggregate; it consists of coarse aggregate and cement paste. It seems pervious concrete would be a natural choice for use in structural applications in this age of green building. It consumes less raw materials than normal concrete (no sand), it provides superior insulation values when used in walls, and through the direct drainage of rainwater, it helps recharge groundwater in pavement applications.

The first pervious concrete was used in Europe and the united kingdom since 1930s for the building of single and multi storeyed houses, but had found little acceptance in rest of the world. Even though it is not yet widely used, pervious concrete is generally used for light duty applications, such as residential streets, parking lots, driveways, sidewalks, channel lining, retaining walls and sound walls.

The aim of this study is to investigate compressive strength of pervious concrete by eliminating the fine aggregate; additionally investigate infiltration rate of pervious concrete.

Referring to the available literature, it was attempted to mix cement & coarse aggregates at two different water-cement ratios. As the pervious concrete finds its wide application in parking areas, footpaths, garden paving, etc., higher compressive strength was not an objective. The focus of the current work was on providing adequate permeability to the concrete mass so that the water can easily pass through it. The slump required for the pavement work is exceptionally low. Therefore, production of zero slump concrete was aimed at.

The wide use of the pervious concrete for the various applications mentioned above is the need of the hour. The water infiltrated through the pervious concrete would also contribute towards enhancing the ground water level i. e. it would facilitate ground water recharge.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 General

Pervious concrete which is also known as no fines, porous, gap graded, and permeable concrete and enhance porosity concrete has been found to be as a reliable storm water management tool. By definition, pervious concrete is a mixture of gravel or granite stone, cement, water, little to no sand (fine aggregate).When Pervious concrete is used for paving, the open cell structures allow storm water to filter through the pavement and into the underlying soils. In other words, pervious concrete helps in protecting the surface of the pavement and its environment.

Figure 1.1 Pervious Concrete

The lack of sand in pervious concrete results in a very harsh mix that negatively affects mixing, delivery and placement.

Also, due to high void content pervious concrete is light in weight (about 1600 to 1900 kg/m^3). Pervious concrete void structure provides pollutant captures which also add significant structural strength as well. It also results in very high permeable concrete that drains quickly.
Pervious concrete can be used in a wide range of applications, although its primary use in pavements which are in: residual roads, alleys and driveways, low volume pavements, low water crossings, side-walks and pathways, parking areas, tennis courts, slope stabilization, sub-base for conventional concrete pavements etc.
Pervious concrete system has advantages over impervious concrete in that it is effective in managing run-off from paved surfaces, prevent contamination in run-off water, and recharge aquifer, repelling salt water intrusion, control pollution in water seepage on ground-water recharge thus, preventing subterranean storm water-sewer drains, absorbs less heat than regular concrete and asphalt, reduces the need for air-conditioning. Pervious concrete allows for increased site optimization because in most cases, its use should totally limit the need for detention and retention-ponds, swales and other more traditional storm water management devices that are otherwise required for compliances with the Federal storm water regulations on commercial sites of one-acre or more. By using pervious concrete, the ambient air temperature will be reduced, requiring less power to cool the building. In addition, costly storm water-structures such as piping, inlets and ponds will be eliminated. Apparently, when compared to conventional concrete, pervious concrete has lower compressive strength, greater permeability, and a lower unit weight (approximately 70% of conventional concrete). However, pervious concrete has a greater advantage in many regards.
Nevertheless, it has its own limitation which must be put in effective consideration when planning its use.

1.2 History

The initial use of porous concrete was in the United Kingdom in 1852 with the Construction of two residential houses. Cost efficiency seems to have been the primary reason for its earliest usage due to the limited amount of cement used. It was not until 1923 when porous concrete resurfaced as a viable construction material. This time it was limited to the construction of 2-story homes in areas such as Scotland, Liverpool, London and Manchester. Use of porous concrete in Europe increased steadily, especially in the World War II era. Since porous Concrete useless cement than conventional concrete and cement was scare at that time. It seemed that porous concrete was the best material for that period. Porous concrete continued to gain popularity and its use spread to areas such as Venezuela, West Africa, Australia, Russia and the Middle East (Wani Elista et al. 2007).
Pervious concrete was first used in the 1800s in Europe as pavement surfacing and load bearing walls. Cost efficiency was the main motive due to a decreased amount of cement. It became popular again in the 1920s for two storey homes in Scotland and England. It became increasingly viable in Europe after WWII due to the scarcity of cement. It did not become as popular in the US until the 1970s.
After World War II, porous concrete became wide spread for applications such As cast-in-place load-bearing walls of single and multi-storey houses and, in some instances in high-rise buildings, prefabricated panels, and stem-cured blocks (Ghafoori et al.1995). Also applications include walls for two-story houses, load bearing walls for high- Rise buildings (upto 10 stories) and in fill panels for high-rise buildings (Tennise et al.2004).

1.3 NEED OF THE STUDY

As urbanisation increases in India and many parts of the world, the problem of water logging and requirement of drainage has also increased. This is partly due to Impervious nature of the bituminous and concrete pavement. Pervious concrete which has an open cell helps significantly to provide high permeability due to its interconnected pores. Pervious concrete (also called porous concrete, permeable concrete and no fines concrete) is a special type of concrete with a high porosity used for concrete flat work applications that allow water from precipitation and other sources to pass directly through it, thereby reducing the run-off from a site and allowing ground water recharge. It is made using large aggregates with little to no fine aggregates. So, the vast usage of pervious concrete should be encouraged across the world. Such concrete should be used on a large scale due to its advantages.

1.4 SCOPE OF THE STUDY

The study was aimed at developing a low-strength concrete in the laboratory, which would have sufficient porosity in order to allow adequate amount of water, thereby resulting into a highly permeable system. As it is evident that pavements, parking systems, etc. are prone to flexural stresses, the study was also extended to find the tensile strength of pervious concrete.

1.5 OBJECTIVES

- To study the compressive strength of the low-strength pervious concrete.
- To check whether the concrete produced is permeable enough to allow the passage of water.
- To determine the tensile strength of pervious concrete.
- To study the suitability & feasibility of the pervious concrete for the pragmatic use.

CHAPTER 2

Literature Review

- R.Patil, A.K.Gupta, D.B.Desai in "IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)" concluded that: Our cities are being covered with building. And the air-proof concrete road more and more. In addition, the environment of city is far from natural. Because of the lack of water permeability and air permeability of the common concrete pavement, the rain water is not filtered underground. Without constant supply of water to the soil, plants are difficult to grow normally. In addition, it is difficult for soil to exchange heat and moisture with air; therefore, the temperature and humidity of the Earth's surface in large cities cannot be adjusted. This brings the phenomenon of hot island in city. At the same time, the splash on the road during a rainy day reduces the safety of traffic of vehicle and foot passenger. The research on pervious pavement materials has begun in developed countries such as the US and Japan since 1980s. Pervious concrete pavement has been used for over 30 years in England and the United States. Pervious concrete is also widely used in Europe and Japan for roadway applications as a surface course to improve skid resistance and reduce traffic noise. However, the strength of the material is relatively low because of its porosity. The compressive strength of the material can only reach about 20-30MPa. Such materials cannot be used as pavement due to low strength. The pervious concrete can only be applied to squares, footpaths, parking lots, and paths in parks. Using Selected aggregates, fine mineral, admixtures, organic intensifiers and by adjusting the concrete mix proportion, strength and abrasion resistance can improve the pervious Concrete greatly.

- Amir Golroo, and Susan L. Tighe concluded that: Pervious concrete pavement (PCP) is of significant importance in the field of storm water management in terms of reducing runoff volume.
  Storm water managers should initially ensure that PCP adequately performs overtime to be able to implement it in a storm water management system. Performance models are intended to predict the performance of an asset over its service life. To develop a performance model commonly long-term performance data are essential.

No performance model has been developed for PCP to date because PCP long term performance data are rarely available. In such a case, expert knowledge is an Alternative method to collect data for developing a performance model. This research aims to develop performance models for PCP for the first time by using an integrated Markov chain technique (combination of homogenous and non-homogenous techniques) through incorporation of expert knowledge. Both deterministic and stochastic approaches are applied to build up Markov models by using expected values per cube simulation technique, respectively. Both approaches provide consistent results and though the stochastic Markov model provides more detailed results.

- Chetanzade, Shubhangi Turukmare, Karan Sawant & Mr. Mithun K. Sawant in "Imperial journal of interdisciplinary Research" concluded that Pervious concrete is a Special type of concrete with high porosity used for concrete flat work applications that allow water from precipitation and other sources to pass directly through, thereby reducing the runoff from a site and allowing ground water recharge. This porosity is attained highly interconnected void content. Concrete as a construction material with added self-cleaning characteristics and the ability to remove pollutants is the need of the day. Self-cleaning and air-purifying pervious concrete functionality is a promising technology that can be constructed using naturally air-cleaning agents such as photo catalyst Titanium dioxide. The paper highlights the application of titanium dioxide as partial replacement with cement in pervious concrete so as to achieve eco-friendly pervious concrete.

- Michael L. Leming, H. Rooney Malcom, Paul D. Tennis concluded that Pervious Concrete can be an important part of context-sensitive construction and low-impact Development (LID), used to improve water quality by capturing the "first flush" of Surface runoff, reducing temperature rise in receiving waters, increasing base flow, and Reducing flooding potential by creating short term storage detention of rainfall. In order To fully utilize these benefits, the hydrological behavior of the pervious concrete system Must be assessed. The hydrological performance is usually a key parameter in Decisions to use this material as a best management practice (BMP) for storm water Management. This publication provides an overview of design techniques for Determining hydrological performance and provides an example spread sheet for Analysis. The critical inter-relationships between precipitation potential, pervious concrete system characteristics and site geometry are considered .This publication is intended to assist (1) civil engineers, landscape architects, and other design professionals in the design of an appropriate pervious concrete pavement system, including providing notes on limitations and additional resources, (2) permit-granting agencies in their view and acceptance of proposed pervious concrete pavement systems with either active or passive mitigation strategies, and (3) developers and owners interested in a more complete technical understanding of pervious concrete pavement systems.

- Muhannad T. Suleiman, Kasthurirangan Gopalakrishnan, and John T. Kevern, concluded that although pervious concrete material properties, mix design, and storm water applications are well documented in the literature, the structural behavior of Pervious concrete pavement systems has not been investigated. A parking lot was constructed in which traditioal impervious concrete was used on half of the parking lot and pervious concrete was used on the other half. The traditional concrete layer was placed on natural sub grade. The pervious concrete portion was divided into two sections with two pervious concrete mixtures and aggregate base thicknesses of 300 and 450mm.

To better understand the behavior of traditional and pervious concrete pavement systems of the parking lot, the sub grade soil properties were characterized by using plate load testing and nuclear density gauge. Furthermore, the aggregate base layers used in the previous concrete systems were characterized by using plate load testing. After constructing the parking lot, falling weight deflect meter (FWD) testing was performed on the traditional concrete and the two previous concrete pavement systems. In addition to summarizing the sub-grade and base material properties, this paper compares the response of the three pavement systems during FWD tests. Furthermore, artificial neural network-based back calculation models were used to better understand the response of the three pavement systems. FWD results show that a pervious concrete pavement system with 450-mm aggregate base experiences smaller measured deflections and better uniform support than the traditional concrete pavement system.

.

- C.Liana,Y.Zhugeb in their paper titled "Optimum mix design of enhanced permeable concrete – An experimental investigation" studied that permeable pavement, due to its high porosity and permeability, is considered as an alternative to traditional impervious hard pavements for controlling storm water in an economical and friendly environment way. Permeable concrete normally made of single-sized aggregate bound together by portland cement, using restrictedly as a pavement material, because of its insufficient structural strength. Aimed at developing a new type of permeable concrete with enhanced structural strength, various mix designs were attempted and their effects on the compressive strength and permeability of permeable concrete were investigated in this research. The optimum aggregate and mix components design were consequently recommended for enhanced permeable concrete.

- John T. Kevern, Vernon R. Schaefer, and Kejin Wang in "ACI Material Journal/ july august 2011"concluded that this paper describes the results of studies to develop pervious concrete for use as an overlay material over traditional concrete to reduce noise, minimizes ash and spray, and improve friction as a surface wearing course. Workability and compaction density testing methods were developed to ensure construct ability and placement consistency. The mixture testing matrix consisted of evaluating aggregate type and gradation, cementations material amounts and composition, and various admixtures. Selected mixtures were tested for permeability, strength, workability, overlay bond strength, and freezing-and-thawing durability. The selected mixture was self-consolidating and slip- formable and was placed at the MN ROAD testing facility during late October 2008. The test results indicate that pervious concrete mixtures can be designed to be highly workable, sufficiently strong, permeable, and have excellent freezing-and-thawing durability, thus being suitable for pavement.

CHAPTER 3

MATERIALS AND METHODOLOGY

Pervious concrete pavement is a unique and effective means to address important Environmental issued and support green, sustainable growth. By capturing storm water and allowing it to seep in to the ground, porous concrete is instrumental in recharging groundwater, reducing storm-water runoff, and meeting U.S Environmental Protection Agency (EPA) storm-water regulations. In fact the use of Pervious concrete is among the Best Management Practices (BMPs) recommended by the EPA and by other agencies had geotechnical engineers across the country for the management of storm water run-off on a regional and local basis. This pavement technology creates more efficient land use by eliminating the need for retention ponds, swales, and other storm-water management devices. In doing so, pervious concrete has the ability to lower overall project costs on a first-cost basis. In Pervious concrete, carefully controlled amounts of water and cement is used to create a paste that forms a thick coating around aggregates particles. A pervious concrete mixture contains little or no sands, creating a substantial void content. Using sufficient paste to coat and bind the aggregate particles together creates a system highly permeable, interconnected voids that drain quickly. Typically between 15% and 25% voids are achieved in hardened concrete and flow rates for water through pervious concrete are typically around 200 L/m^2 /min, although they can be much higher. Both the low mortar content and high Porosity also reduce strength compared to conventional concrete mixtures, but sufficient strength for many applications is readily achieved.

3.1 Materials

Pervious concrete uses the same materials as conventional concrete, with the exceptions that the fine aggregate typically is eliminated entirely, and the size distribution (grading) of the coarse aggregate is kept narrow, allowing for relatively little particle packing. This provides the useful hardened properties, but also results in a mix that requires different considerations in mixing, placing, compaction, and curing.

The mix proportions are somewhat less for giving than conventional concrete mixtures—tight control son batching fall of the ingredients are necessary to provide the desired results. Often, local concrete producers will be able to best
Determine the mix proportions for locally available materials based on trial batching and experience.

Table 3.1.Mix Proportions

Sr. No.	Materials	Proportions (kg/m^3)
1	Cement OPC 53	420
2	Coarse Aggregates (20 mm size)	1500
3	Water Cement Ratio (By Mass)	0.28 & 0.31
4	Aggregate Cement Ratio (By Mass)	3.57

3.1.1 CEMENT

As in traditional concreting, Portland cement sand blended cements may be used in pervious concrete. In addition, supplementary cementitious materials (SCMs), such as fly-ash and pozzolana and ground-granulated blast furnaces lag, may be used. But in this experiment ordinary Portland cement is used. Testing materials be forehand through trial batching is strongly Recommended so that properties that can be important to performance (setting time, rate of strength development, porosity, and permeability, among others) can be determined.

3.1.2 AGGREGATES

In pervious concrete, the fine aggregate typically is eliminated entirely, and the size distribution (grading) of the coarse aggregate is kept narrow, allowing for relatively little particle packing. In this experiment aggregates of size 20mm are used. This provides the useful hardened properties, but Also results in a mix that requires different considerations in mixing, placing, compaction, and curing. Proportioning of pervious concrete mixtures is different compared to procedures used for conventional concrete mixture proportions tight control son batching fall of the ingredients are necessary to provide the desired results.
Recent uses for pervious concrete have focused on parking lots, low-traffic pavements, and pedestrian walkways. For these applications, the smallest sized Aggregate feasible is used for aesthetic reasons. Coarse aggregate size 89 (3⁄8-in. Or 9.5-mm top size) has been used extensively for parking lot and pedestrian applications. Generally, A/C ratios are in the range of 4.0 to 4.5 by mass. These A/C ratios lead to aggregate contents of between about 2200lb/yd^3 and 3000lb/yd^3 (1300kg/m^3 to 1800kg/m^3).

Higher A/C ratios have been used in laboratory studies (Malhotra 1976), but significant reductions in strength result. Both rounded aggregate (gravel) and angular aggregate (crushed stone) have been used to produce pervious concrete. Typically, higher strengths are achieved with rounded aggregates, although angular Aggregates generally are suitable.
Aggregates for pavements should conform to ASTM D448, while ASTM C33 covers aggregates for use in general concrete construction. As in conventional concrete, pervious concrete requires aggregates to be close to a saturated, surface-dry condition or close monitoring of the moisture condition of aggregates should allow for accounting for the free moisture on aggregates. It should be noted that Control of water is important in pervious concrete mixtures. Water absorbed from the mixture by aggregates that are too dry can lead to dry mixtures that do not place or compact well. However, extra water in aggregates contributes to the mixing water and increases the water to cement ratio of the concrete.

3.1.3 WATER

Water to cement material ratio between 0.28 to 0.31 are used routinely with proper inclusion of chemical admixtures, and those as high as 0.34 and 0.40 have been used successfully. The relation between strength and water to cement material ratio is not clear for pervious concrete because unlike conventional concrete, the total paste content is less than the voids content between the aggregates. Therefore, making the paste stronger may not always lead to increased overall strength. Water content should be tightly controlled.
The correct water content has been described as giving the mixture as been, without flowing off of the aggregate. A handful of pervious concrete formed in to a ball will not crumble or lose its void structure as the paste flows in to the spaces between the aggregates. S. Pervious concrete is made with a narrow aggregate different maximum sizes. The concrete in the box contained a 1⁄4-in. (6.5-mm) top size, while that be low used a larger top size, 3/4 in. (20mm).
As a general rule, water that is drink able is suitable for use in concrete recycled water from concrete production operations may be used as well. If there is a question as to the suitability of a water source, trial batching with job materials is recommended.

3.1.4 ENGINEERING PROPERTIES

3.1.4.1 DENSITY

The density of pervious concrete depends on the properties and proportions of materials used and the compaction procedures used in placement. Generally the density of pervious concrete is in the range of 1600kg/m^3 to 1900kg/m^3.

3.1.4.2 POROSITY

Porosity is defined as the ration of the volume of voids in a test specimen to the total volume of the specimen expressed as percentage. Porosity affects strength and structural. The porosity is dependent on both the water to cement ratio, and the compaction effort. Porosity of pervious concrete ranges from 15% to 25%. Porosity also varies with depth of pavement it increases from top to bottom surface. This helps to trap solids in the runoff at the top surface itself. Decrease in void content can be considered on water cementration and compaction energy and not on aggregate to cement ratio since clogging of pores takes place.

3.1.4.3 PERMEABILITY AND INFILTRATION RATE

Permeability is generally measured by falling head method but since the permeability is too high filtration rate is preferred. But instead of infiltration rate of pervious concrete permeability of soil beneath it is more important. The most influential factor is the aggregate content in the mix that depends on the compaction effort and paste contents for permeability. For low paste mixture permeability is more than for high paste mixture; this can be attributed to the fact that excess paste clogs the pores hampering the sole purpose.

3.1.4.4 COMPRESSIVE STRENGTH

The strength of pervious concrete is less as compared to conventional concrete due to its increase in void content. Normally its compressive strength ranges from 2.8MPa to 28MPa. Compressive strength of previous concrete does depend primarily on the porosity; it is also affected by aggregate size, shape and gradation. Pervious concrete containing crushed aggregate shows superior performance to pervious concrete contain in ground aggregate in terms of strength.

3.1.4.5 FLEXURAL STRENGTH

Flexural strength of pervious concrete ranges from 1MPa to 3.8MPa. Factors influencing flexural strength are degree of compaction, porosity, and the aggregate to cement ratio.

3.1.4.6 SHRINKAGE

Shrinkage in pervious concrete develops as soon as it starts drying. This is due to low paste and mortar content. It has been observed that roughly 50% to 80% of shrinkage occurs in the first 10 days compared to 20% to 30% in the same period for conventional concrete. Because of this lower shrinkage and the surface texture, many pervious concrete pavements are made without control joints and allowed to crack randomly.

3.1.4.7 DURABILITY

The durability of pervious concrete depends mainly on Surface ravelling and clogging off pores.

Surface ravelling is removal of loose aggregate material from the pervious concrete surface and is caused by improper curing, inadequate compacting or inadequate water cement ratio. Proper curing, adequate compacting or adequate w/c ratio decreases surface ravelling.

3.1.4.8 ABRASION RESISTANCE

Because of the rougher surface texture and open structure of pervious concrete, abrasion and ravelling of aggregate particles can be a problem. Initially after the pervious concrete is opened to the traffic, it will have a few loose aggregates on the surface this is because the rocks are loosely mount to surface initially and comes out becomes of traffic load.

3.1.5 ADVANTAGES OF PERVIOUS CONCRETE

- Helps in keeping earth below wetter, greener and cooler. Eliminates use of asphalt which normally causes environmental pollution. Use of fly ash thus reducing pollution
- It reduces the rainfall runoff.
- Eliminates the need for detention ponds, gutter, storm drains and other rain water management practices
- Replenishes the aquifers and water-table.

3.1.6 DISADVANTAGES OF PERVIOUS CONCRETE

- Under drain system needed for low permeability soils.
- Higher cost compared to conventional pavements.
- Increased maintenance requirements over standard PCC.
- Potential for groundwater contamination, when non-degradable materials passes through it.
- Non-conventional practices.

3.1.7 PROBLEMS IN PERVIOUS CONCRETE

- Compressive strength of pervious concrete is relatively low as compared to conventional concrete since it has high void ratio.
- Due to negligible amount of fine aggregates, it has slow workability.
- Segregation of its constituents takes place at the time of placing.

3.2 METHODOLOGY AND EXPERIMENTAL PROCEDURE

This chapter gives a detailed account of the various materials used in the present study along with physical properties. It also gives the details of various experiments that have been conducted in the present study.

3.2.1 EXPERIMENTAL METHOD

3.2.1.1 ANGULAR AGGREGATES

Angular aggregates consists well defined edges formed at the intersection of roughly planar surfaces obtained by crushing the rocks. Angular aggregates result maximum percentage of voids (38-45%) hence gives less workability. They give 10-20% more compressive strength due to development of stronger aggregates mortar bond. So, these are useful in high strength concrete manufacturing.

3.2.1.2 CEMENT

Ordinary Portland cement of 53-grade was used in this study conforming to IS: 8112-1989 having specific gravity 3.15.

3.2.1.3 WATER

Water quality used in pervious concrete should be same as that used in conventional concrete: potable water, recycled water from the concrete industry, or tap water. Due to the sensitivity of pervious concrete, water quality control is important.

3.2.1.4 MIXING

Figure 3.1 Mixing of Pervious Concrete

Fresh pervious concrete mixtures were produced by hand-mixing. Two water-cement ratios of 0.28 & 0.31 were used.

3.2.1.5 CASTING

Figure 2.2 Casting of Cubes

30 well oiled iron mould of 0.15m x 0.15m x 0.15m were used for casting of sample cubes.

3.2.1.6 DEMOULDING

Figure 3.3 Demoulding

3.2.2 WORKABILITY TEST

- Equipment Required for Concrete Slump Test: Mould for slump test, non porous base plate, measuring scale, tamping rod. The mould for the test is in the form of the frustum of a cone having height 30 cm, bottom diameter 20 cm and top diameter 10cm. The tamping rod is of steel16 mm diameter and 60 cm long and rounded at one end.
- Sampling of Materials for Slump Test: A suitable concrete mix by weight with suitable water/cement ratio is prepared in the laboratory and required for casting 15 cubes after conducting Slump test.

Procedure for Concrete Slump Test:

1. Clean the internal surface of the mould and apply oil.
2. Place the mould on a smooth horizontal non-porous base plate.
3. Fill the mould with the prepared concrete mix in 3 approximately equal layers.

Figure 3.4 Slump Test

4. Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mould. For the subsequent layers, the tamping should penetrate in to the underlying layer.
5. Remove the excess concrete and level the surface with a trowel.
6. Clean away the mortar or water leaking between the mould and the base plate.
7. Raise the mould from the concrete immediately and slowly in vertical direction.
8. Measure the slump as the difference between the height of the mould and that of height point of the specimen being tested.

3.2.3 TEST ON AGGREGATES (20mm)

Bulk density of aggregates is the mass of aggregates required to fill the container of a unit volume after aggregates are batched based on volume. It depends on the packing of aggregate i.e. either loosely packed aggregates or well dense compacted aggregates .

In case, if the specific gravity of material is known, then it depends on the shape and size of particles. It is because, if all the particles are of same size than packing can be done up to a very limited extent. If the addition of smaller particles is possible within the voids of larger particles than these smaller particles enhance the bulk density of the packed material. Shape of the particles also influence vary widely, because looseness particles depend on the shape of aggregates. Loose bulk density can be determined by filling the container with dried aggregates until it over flows from the container. Now level the top surface of container by rolling a rod on it. After that, weight the aggregate mass that is inside the container and divide it by the volume of container. This will give you the bulk density of the loose aggregates.

3.2.4 COMPRESSIVE STRENGTH TEST & SPLIT TENSILE TEST

For most of the works cubical moulds of size 15cm x 15cm x 15cm are commonly used this concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are re moved and tests specimens are put in water for curing. The top surface of these specimens should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen.
These specimens are tested by compression testing machine after 7days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm^2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

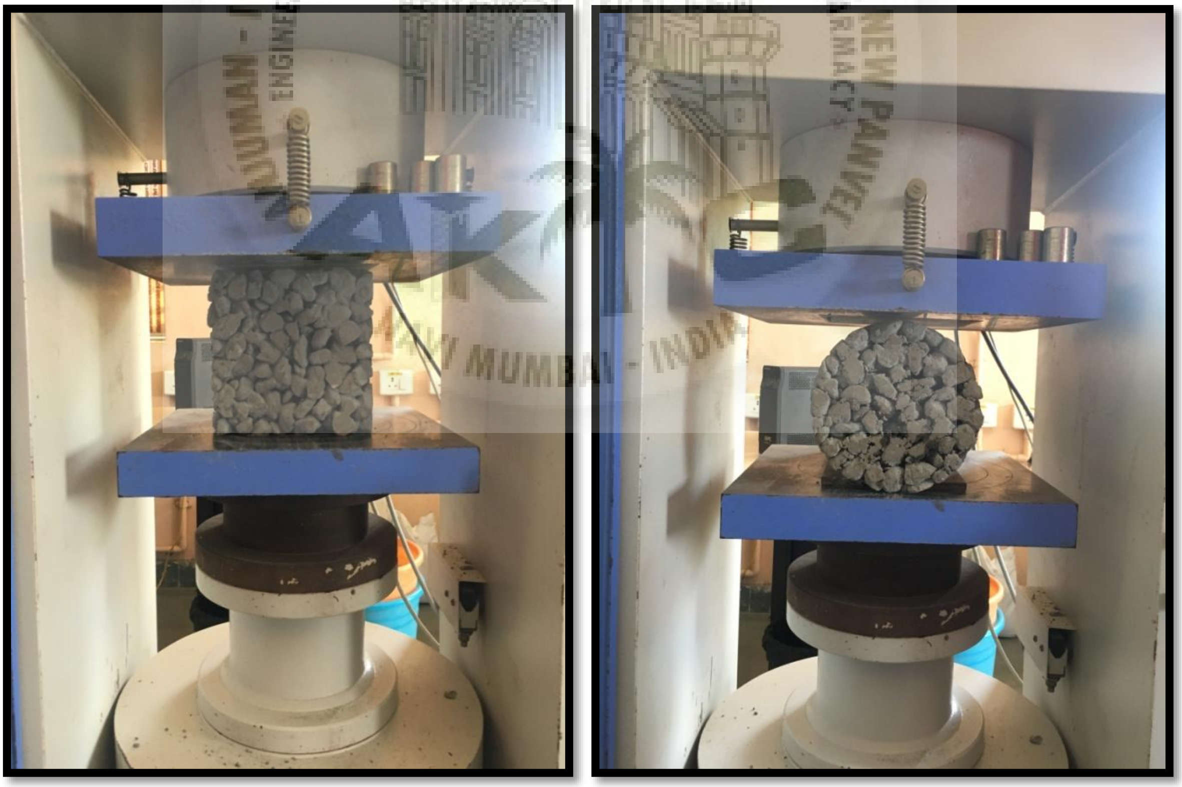

Figure 3.5 Compressive Test and Split Tensile Test

PROCEDURE FOR COMPRESSIVE TEST:

1. Remove the specimen from water after specified curing time and wipe out excess water from the surface.
2. Take the dimension of the specimen to the nearest 0.2m.
3. Clean the bearing surface of the testing machine.
4. Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.
5. Align the specimen centrally on the base plate of the machine.
6. Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
7. Apply the load gradually without shock and continuously at the rate of 140 kg/cm^2/minute till the specimen fails.
8. Record the maximum load and note any unusual features in the type of failure.

PROCEDURE FOR SPLIT TENSILE TEST:

1. Prepare three cylindrical concrete specimens.
2. After moulding and curing the specimen for 28 days in water, they were tested. The cylindrical specimen is placed in a manner such that its longitudinal axis is perpendicular to the point of application of load.
3. Two strips of steel plate nominal 25mm width were placed on sides of cylinder as support.
4. The bearing strips were placed between the specimen at both upper and lower bearing blocks of the testing machine.
5. The following formula can be used for calculation of split tensile strength:

$$T = 2P/\pi Ld$$

Where,
T= splitting tensile strength (kPa)
P= maximum applied load indicated by testing machine (KN)
L= length of cylinder (m)
d= diameter of cylinder (m)

CHAPTER 4

RESULTS & DISCUSSIONS

4.1 SLUMP CONE TEST

Table 4.1 Slump Cone Test

SR NO.	Sample	Slump value
1	Batch-1 W/C= 0.31	Zero slump
2	Batch-2 W/C= 0.28	Zero slump

- From table 4.1 it is observed that at both 0.31 & 0.28 water-cement ratio, zero slump was achieved. This is owing to the fact that it is no fines concrete; moreover, water-cement ratio is on lower side.
- However, the slump needed in the field from application point of view is zero slump or very low slump.
- It is a harsh mix which was aimed at producing the low slump with high porosity.

4.2 PERMEABILITY TEST

Table 4.2 Permeability Test

Area (m^2)	Time taken for infiltration (Sec)	Water poured (L)	Infiltration (m^3/min)	Average infiltration (m^3 /min)	Water collected in the voids (L)
0.0225	120	6.75	0.0034	0.0034	0.0562
0.0225	120	6.60	0.0033		0.0550
0.0225	120	7.05	0.0035		0.0581
0.0225	120	7.95	0.0040	0.0040	0.0662
0.0225	120	8.25	0.0041		0.0687
0.0225	120	7.65	0.0039		0.0637

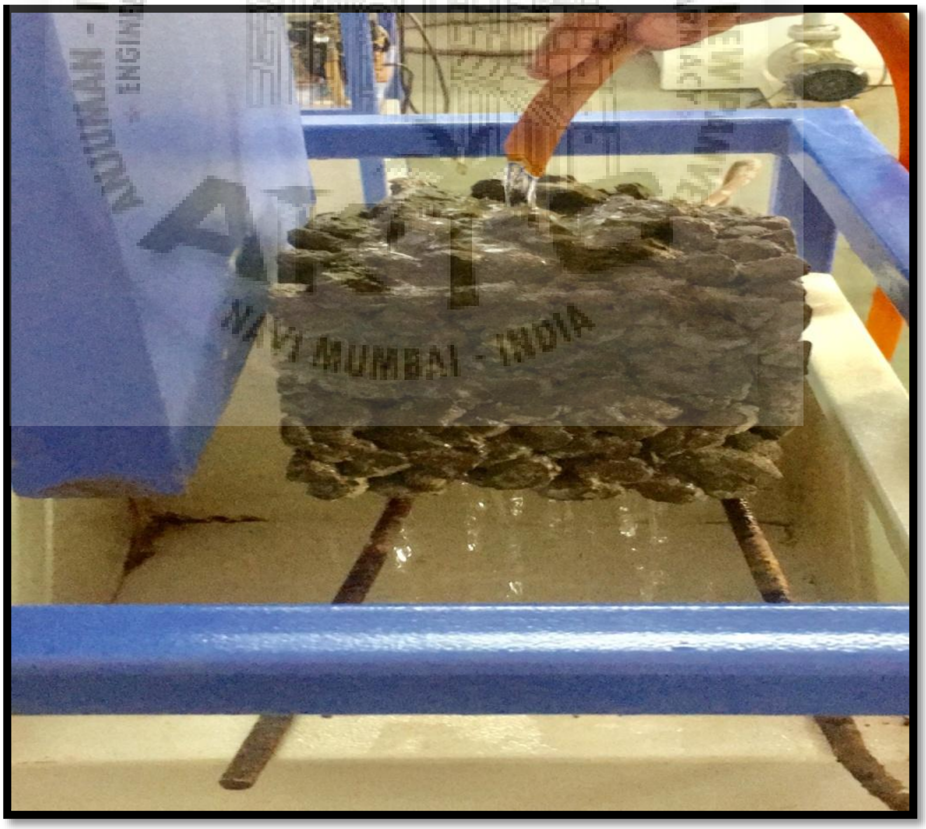

Figure 4.1 Permeability Test

- From table 4.2 it is observed that at water cement ratio= 0.28 the infiltration rate was found to be 0.0034 m^3/min.
- And at water cement ratio= 0.31 the infiltration rate was found to be 0.0040 m^3/min.
- Therefore it can be concluded that higher w/c ratio resulted in higher permeability whereas lower w/c ratio resulted in lower permeability.
- This is an adequate permeability in connection with the required functionality of the pervious concrete produced.

4.3 SPLIT TENSILE TEST

Table 2.3 Split Tensile Test

Specimen	Age of specimen (in days)	Specimen weight (in kg)	Load (in KN)	Specimen size (mm^2)	Tensile strength (MPa)
Pervious concrete	28	9.82	55.5	150 X 300	2.9
Pervious concrete	28	9.3	53.4	150 X 300	2.3

- From table 4.3, it is observed that at water cement ratio 0.28 the tensile strength is 2.9 MPa.
- From table 4.3 it is observed that at water cement ratio 0.31 the tensile strength is 2.3 MPa.
- As the water-cement ratio increased, the tensile strength decreased. This is obvious because of the fact that tensile strength of concrete is a function of its compressive strength. It is well known fact that as water cement ratio increases, compressive strength decreases. Obviously, tensile strength shows the same trend.

4.4 COMPRESSIVE STRENGTH TEST

Table 4.4 Compressive Strength Test

	Age of specimen (in days)	Specimen weight (in kg)	Load (in KN)	Specimen size (mm2)	Compressive strength (MPa)	Average Comp. Strength (MPa)
PERVIOUS CONCRETE w/c= 0.31	3	5.37	55.0	150 X 150	2.4	4.03
		6.59	129.7		5.7	
		5.59	91.8		4	
	7	5.75	96.3	150 X 150	4.2	5.3
		6.52	155.5		6.8	
		6.14	111.9		4.9	
	28	6.4	164	150 X 150	7.3	7.5
		6	182.25		8.1	
		6.3	159.75		7.1	
PERVIOUS CONCRETE w/c= 0.28	3	6.97	128.9	150 X 150	5.7	5.6
		6.97	126.8		5.6	
		6.9	124.5		5.5	
	7	7.08	171.0	150 X 150	7.6	7.35
		6.96	166.3		7.3	
		6.78	164.1		7.2	
	28	6.7	221.1	150 X 150	9.8	9.65
		6.5	217.5		9.5	
		6.56	218.9		9.65	

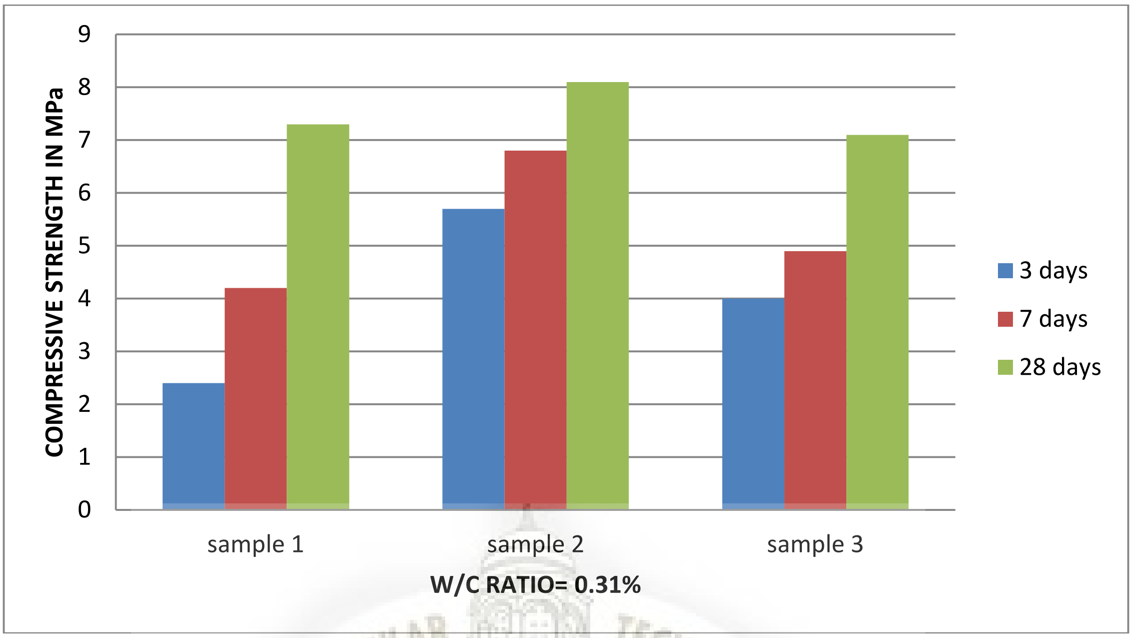

Figure 4.2 Compressive Strength with W/C= 0.31%

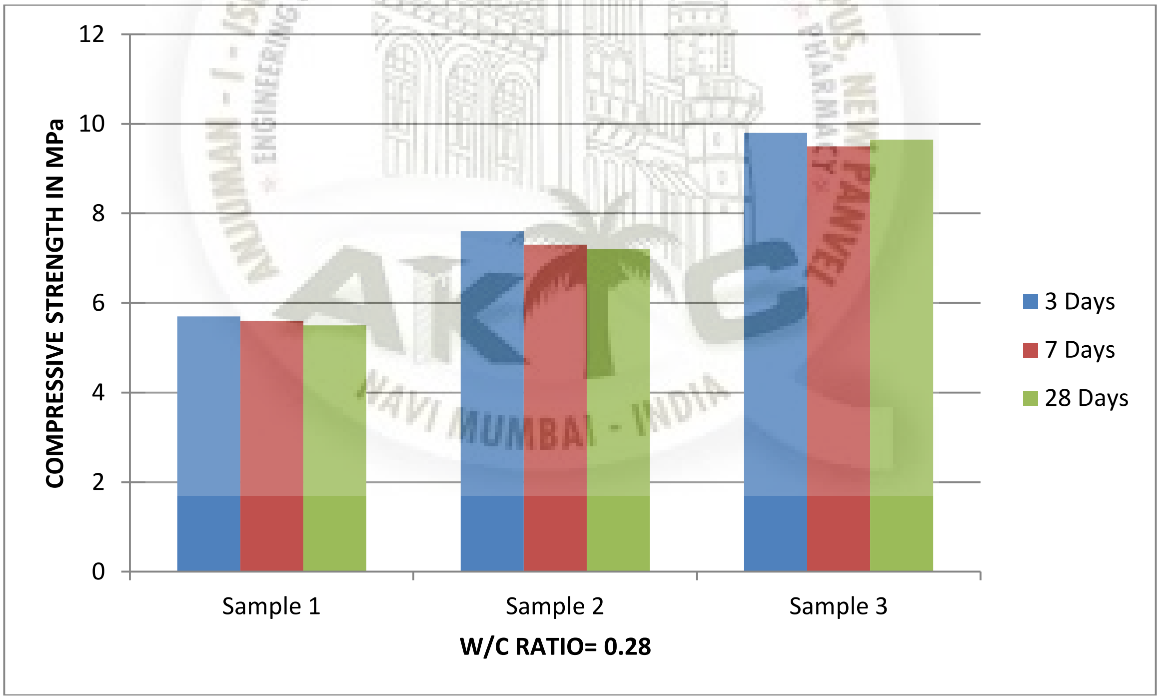

Figure 4.3 Compressive Strength with W/C= 0.28%

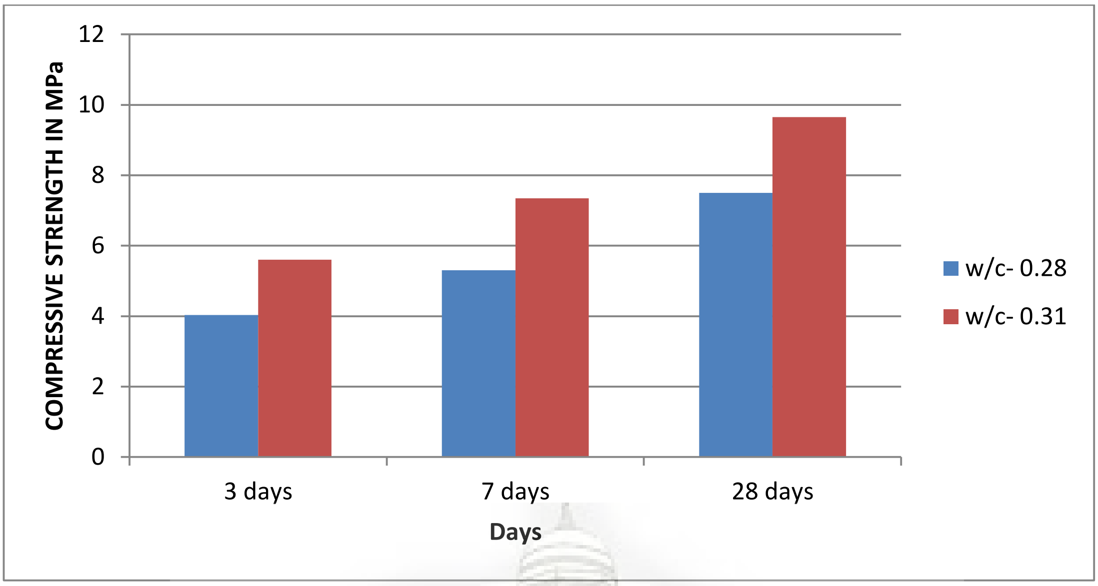

Figure 4.4 Average Compressive Strength

- From table 4.4 and graph 4.2 , it is observed that at water cement ratio 0.31 the maximum compressive strength achieved is 7.5 MPa after 28 days of curing.

- From table 4.4 and graph 4.3 , it is observed that at water cement ratio 0.28 the maximum compressive strength achieved is 9.65 MPa after 28 days of curing.

- Therefore it can be concluded that low w/c ratio resulted in higher compressive strength and vice versa.

- The weight of a normal concrete cube works out to be around 8.5 kg. Referring to table 4.4, it can be easily depicted that the concrete weight got reduced to a significant extent, owing to the fact that it is no fines concrete with plenty of pores. This leads to the low density concrete.

CHAPTER 5

CONCLUSION

- Pervious concrete can be used and it is been implemented in some metropolitan cities, in parking lots, driveways, gullies, sidewalks, roads, platforms, etc. The road around the apartments and surfacing inside the compound can be made with pervious concrete.
- The test indicated that the water passed through one end to the other end through the body of the concrete. This depicts that the concrete is adequately porous.
- Low-strength concrete is sufficient for sustaining light to moderate loads.
- The pavements, paver blocks, footpaths are subjected to bending stresses, hence split tensile tests were carried out; the values obtained are showing good trend.
- The pervious concrete has the dual advantage of supporting the light loads and passing water through it's body. The water seeped through the concrete would recharge the ground-water reserves.
- In future, with increased urbanisation, diminishing groundwater levels focus on pervious concrete is likely to become more popular in India & across the world.

CHAPTER 6

REFERENCES

- Darshan.S.Shah, Jayeshkumar Pitroda conducted an "Experimental Study on Durability and Water Absorption properties of Pervious Concrete".
- Mohammed K. Ali, Qays M. Sh. Kareem conducted an "Experimental Study on Hydrological Properties with Different Water Cement Ratio".
- Karthik H.Obla, Pervious Concrete- An overview, Indian Concrete Journal.
- R.Patil, A.K.Gupta, D.B.Desai in "*IOSR Journal of Mechanical and Civil Engineering* (IOSR-JMCE).
- Amir Golroo, and Susan L. Tighe concluded that: Pervious concrete pavement.
- Chetanzade, Shubhangi Turukmare, Karan Sawant & Mr. Mithun K. Sawant in "Imperial journal of interdisciplinary Research".