**A Project report**

**On**

# EXPERIMENTAL ANALYSIS AND RESEARCH ON PERVIOUS CONCRETE

**Submitted to**

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA**

**Partial fulfillment of the requirements for the award of degree of**

**MASTER OF TECHNOLOGY**
**IN**
**STRUCTURAL ENGINEERING**

**Submitted By**

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**2023-2024**

# CERTIFICATE

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This is to certify that the project report entitled as “**EXPERIMENTAL ANALYSIS AND RESEARCH ON PERVIOUS CONCRETE”** being submitted by VEERELLA **NAGA LAKSHMI** (Regd.No: 21GK1D8704) in partial fulfillment of the requirements for the award of the degree of “Master of Technology in CIVIL ENGINEERING with specialization in Structural Engineering’’ during 202-202. The results of investigation enclosed in this report have been verified and found satisfactory. The results embodied in the project have not been submitted to any university or institute for the award of any other degree or diploma.

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# DELCARATION

I, **VEERELLA NAGA LAKSHMI** (Regd.No: 21GK1D8704) hereby declare that the project report titled "**EXPERIMENTAL ANALYSIS AND RESEARCH ON PERVIOUS CONCRETE** "is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text. I hereby declare that this thesis has not been submitted to any other university/institute for the award of any other degree/diploma.

**VEERELLA NAGA LAKSHMI**
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# ACKNOWLEDGEMENT

First of all I would like to thank the Almighty, who has always guided me to work on the right path of the life.

I owe a profound gratitude to my advisor, **Mr. M. C. CHAKRAVARTHI, M.Tech** who has been a constant source of inspiration to me throughout the period of this project. It was his competent guidance, constant encouragement, critical evaluation and editorial assistance that helped me to develop a new insight into my project.

I gratefully acknowledge his invaluable comments while patiently going over drafts of my dissertation. Without his revisions, clarity of the presented work would have not been the same. His calm, collected and professionally impeccable style of handling situations not only steered me through every problem, but also helped me to grow as a matured person. I am also thankful to him for trusting my capabilities to develop this project under his guidance.

I'm most indebted to the head of the department **Mr. M. C.CHAKRAVARTHI, M.Tech** for providing me all the facilities to carry out this work

I'm most indebted to the PRINCIPAL **Dr. D. V. V.S PHANI KUMAR, Ph.D.** for providing me all the facilities to carry out this work.

I am also thankful to the authors whose work has been consulted, utilized and cited in my dissertation.

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# ABSTRACT

Pervious concrete is a special type of concrete, which consists of cement, coarse aggregates, water and if required, admixtures and other cementations materials. As there are no fine aggregates used in the concrete matrix, the void content is more which allows the water to flow through its body. So, the pervious concrete is also called as Permeable concrete and porous concrete. There is lot of research work is going in the field of pervious concrete. The compressive strength of pervious concrete is less when compared to the conventional concrete due to its porosity and voids. Hence, the usage of pervious concrete is limited even though it has lot of advantages. If the compressive strength and flexural strength of pervious concrete is increased, then it can be used for a greater number of applications. For now, the usage of Pervious concrete is mostly limited to light traffic roads only. If the properties are improved, then it can also be used for medium and heavy traffic rigid pavements also. Along with that, the pervious concrete eliminates surface runoff of storm water, facilitates the ground water recharge and makes the effective usage of available and the main aim of our project is to improve the strength characteristics of pervious concrete. But it can be noted that with increase.

In strength, the permeability of pervious concrete will be reduced. Hence, the improvement of strength should not affect the permeability property because it is the property which serves its purpose.

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Juni Khyat
(UGC Care Group I Listed Journal)
ISSN: 2278-4632
Vol-14 Issue-01 May 2024

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# CHAPTER-1

# INTRODUCTION

# Chapter-1

# INTRODUCTION

## 1.1 Introduction:

Apart from being used to eliminate or reduce the need for expensive retention ponds, developers and other private companies are also using it to free up valuable real estate for development, while still providing a paved park. Pervious concrete is also a unique and effective means to address important environmental issues and sustainable growth.

Pervious concrete can be used in a wide range of applications, although its primary use is in pavements which are in residential roads, alleys and driveways, low volume pavements, low water crossings, sidewalks and path ways, parking areas, tennis courts, slope stabilization, sub-base for conventional concrete pavements etc.,

**Figure1.1: Pervious concrete cube blocks.**

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 saltwater intrusion, control pollution in water seepage to ground water recharge thus, preventing sub terranean storm water sewer drains, absorbs less heat than regular concrete and asphalt, reduces the need for air conditioning. Apparently, when compared to conventional concrete, pervious concrete has a 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 limitations which must be put in effective consideration when planning its use. Structurally when higher permeability and low strength are required, the effect of variation In aggregate size on strength and permeability for the same aggregate cement ratio need to be investigated.

**Figur1.2: Water flowing through pervious concrete cube.**

## 1.2 Brief Narration:

Pervious Concrete has been around for hundreds of years. The Europeans recognized the insulating properties in structural pervious concrete for their buildings. Europeans have also usedperviousconcreteforpaving.Storiespasseddownthroughtheyearstellusthat soldiers didn’t mind walking on pervious roads during World War II because it meant their feet would be dry.

Pervious was brought to the United States after World War II. It first showed up in Florida and other southern coastal states.

In the1990’s the U.S. Environmental Protection Administration (EPA) came out with the Clean Water Act (CWA), that later led to other phases of implementation to preserve the waterways from storm water borne pollutants.EPA identifies “storm water runoff is generated when precipitation from rain and snowmelt events flow over land or impervious surfaces and does not percolate into the ground. As the runoff flows over the land or impervious surfaces (paved streets, parking lots, and building rooftops),it accumulates debris, chemicals, sediment or other pollutants that could adversely affect water quality if the runoff is discharged untreated. The primary method to control storm water discharges is the use of best management practices (BMPs).”(EPA.gov).Basically, it requires the developer/owner to keep as much storm water on property as possible. If storm waterleaves the property, it must leave cleaner and cooler than before. Pervious concrete allows for the filtering/cleaning and detainment of storm water.

### 1.3General Properties of pervious Concrete:

Slumps, the infiltration rate (permeability) of pervious concrete will vary with aggregate size and density of the mixture, but will fall into the range of 80 to 720 liters per minute per square meter. A moderate porosity pervious concrete pavement system will typically have a permeability of 143 liters per minute per square meter. Perhaps nowhere in the world would one see such a heavy rainfall. In contrast the steady state infiltration rate of soil ranges from 25 mm/hr to 0.25 mm/hr. Generally, for a given mixture proportion strength and permeability of pervious concrete are a function of the concrete density. Numerous successful projects have been successfully executed and have lasted several winters in harsh Northern climates. This is possibly because pervious concrete is unlikely to remain saturated in the field.

The freeze thaw resistance of pervious concrete can be enhanced by the following measures

1. Use of fine aggregates to increase strength and slightly reduce voids content to about 20%
2. Use of air-entrainment of the paste.

### 1.4 Benefits of pervious Concrete:

Phase II regulations provide programs and practices to help control the number of contaminants in our waterways

They are

1) Reduce the overall runoff from an area
2) Reduce the level of pollution contained in runoff

Efforts to reduce the level of pollution from storm water include requirement for developer provide systems that collect the “first flush” of rainfall, usually about 25mm, and “treat” the pollution prior to release. Pervious concrete pavement reduces or eliminates runoff and permits “treatment” of pollution two studies conducted on the long-term pollutant removal in porous pavement suggest high pollutant removal rates. By capturing the first flush of rainfall and allowing it to percolate into the ground, soil chemistry and biology are allowed to “treat” the polluted water naturally. Thus, storm water retention areas maybe reduced or eliminated allowing increased land use. Another important factor leading to renewed interest in pervious concrete is an increasing emphasis on sustainable construction. Because of its benefits in controlling storm water runoff and pollution prevention, pervious concrete has the potential to help earn a credit point in the U.S. Green

Building Council’s Leadership in Energy & Environmental Design (LEED) Green Building Rating System, increasing the chance to obtain LEED project certification

**1.5 Major Applications of Pervious Concrete:**

Following applications of pervious concrete are mention below

- Low-volume pavements
- Residential roads, alleys, and driveways
- Sidewalks and pathways
- Parking areas
- Low water crossings
- Tennis courts
- Sub base for conventional concrete pavements
- Slope stabilization
- Well linings
- Hydraulic structures
- Swimming pool decks
- Pavement edge drains and Tree grates in sidewalks
- Groins and seawalls
- Noise barriers
- Walls (including load-bearing)

# Chapter-2

# LITERATURE REVIEW

## Chapter-2

## LITERATURE REVIEW

### 2.1 Background:

To date, two key issues that have impeded the use of pervious concrete in the United States are that strengths of pervious concrete have been lower than necessary for required applications and the freeze-thaw durability of pervious concrete has been suspect. A research project on the freeze-thaw durability of pervious concrete mix designs at Iowa State University (ISU) has recently been completed (Schaefer et al. 2006). The preliminary results were reported in Kevern et al. (2005). The recent work has been limited to laboratory testing and to only a few mixes using two sources of aggregates. Preliminary laboratory testing has shown the importance of compaction energy on the properties and performance of the mixes, an issue that has direct bearing on the construction technique used to place the materials in the field. Tests conducted in Purdue University's Tire-Pavement Test Apparatus showed reduced noise levels above 1,000 hertz (Hz) and some increase in noise levels below 1,000 Hz. The increased porosity of pervious concrete increased mechanical excitation and interaction between the tire and pavement at frequencies below about 1,000 Hz and at frequencies above about 1,000 Hz; the air pumping mechanics that dominate at such frequencies are relieved by the increased porosity leading to decreased high-frequency noise levels. The National Concrete Pavement Technology Centre (National CP Tech Centre) at ISU developed a research project titled Further, constructability issues for wearing course sections were addressed to ensure that competitive and economical placement of the pervious concrete can be done in the field. The focus of the National CP Tech Centre's work on pervious concrete was the development of a durable wearing course that can be used in highway applications for critical noise, splash/spray, skid resistance, and environmental concerns. The comprehensive study is anticipated to be conducted over a five-year period and is further described below.

### 2.2 Strength development of pervious concrete:

A recent National CP Tech Centre report titled Mix Design Development for pervious Concrete in Cold Weather Climates (Schaefer et al. 2006) a summary of the available literature concerning the construction materials, material properties, surface characteristics, pervious pavement design, construction, maintenance, and environmental issues for PCPC.

The advantages of pervious concrete minimizing heat islands in large cities, preserving native ecosystems, and minimizing cost in some cases. The research conducted at ISU included studies of the materials used in the pervious concrete, the mix proportions and specimen preparation, the resulting strength and permeability, and the effects of freeze- thaw cycling. A variety of aggregate sizes was tested and both limestone aggregates and river run gravels were used. The key parameters investigated were strength, permeability, and freeze-thaw resistance. It can be seen that as the void ratio increases, the strength decreases but the permeability increases. Shown in the figure is a target range of void ratio between 15% and 19% in which the strength and permeability are sufficient for the intended purpose., adequate permeability, and freeze-thaw resistance was the addition of a small amount of sand, about5% to 7%, that increased the bonding of the paste to the aggregates. The laboratory studies also raised the issue of compaction energy on the results. The difference between the compaction energies related to the amplitude of the vibrating pan, while the frequency was constant. Samples from a Sioux City, Iowa site showed more uniform compaction in the top 150mm, with low compaction causing high voids and low strength in the bottom layer

# Chapter-3

# EXPERIMINTAL WORK

# Chapter-3

# EXPERIMINTAL WORK

## 3.1 MATERIALS USED:

### CEMENT:

Cement is a key to infrastructure industry and is used for various purposes and also made in many compositions for a wide variety of uses. Cements maybe named after the principal constituents, after the intended purpose, after the object to which they are applied or after their characteristic property. such as Portland cement, which produces a concrete resembling the Portland stone used for building.

| Name of compound | Chemical Composition | Abbreviation |
|---|---|---|
| Tricalcium Silicate | $3CaO.SiO_2$ | C3S |
| DicalciumSilicate | $2CaO.SiO_2$ | C2S |
| Tricalciumaluminate | $3CaO.Al_2O_3$ | C3A |
| Tetracalciumaluminoferrite | $4CaO.Al_2O_3.Fe_2O_3$ | C4AF |

**Table3.1:Typical Composition of Ordinary Portland Cement.**

**Figure 3.1: Ordinary Portland cement.**

These compounds interact with one another in the kiln to form a series of more complex products. Portland cement is varied in type by changing the relative proportions of its four predominant chemical compounds and by the degree of fineness of the clinker grinding. A small variation in the composition or proportion of its raw materials leads to a large variation in compound composition Calculation of the potential composition of Portland cement is generally based on the Bogue composition (R.H Bogue)

- Tricalcium Silicate, C3S hardens rapidly and is largely responsible for initial set and early strength development. The early strength of Portland cement concrete is higher with increased percentages of C3S.
- Dicalcium Silicate, C2S hardens slowly and contributes largely to strength increase at ages beyond one week.
- Tricalcium aluminate, C3A liberates a large amount of heat during the first days of hardening. It also contributes slightly for early strength development.
- Tetracalcium Alumina ferrite, Most colour effects are due to C4AF series and its hydrates. The compounds Tricalcium aluminate and Tricalcium silicate develop the greatest heat, then follows Tetracalciumalumino ferrite, with dicalcium silicate developing the least heat of all

In our project work, we have used Ordinary Portland Cement (OPC) of grade 53. In concrete mix design, for concrete M-20 and above grades a saving of 8 to 10 % of cement may be achieved with the use of 53 grade OPC. Ordinary Portland Cement (OPC) 53 Grade should surpass the requirements of IS: 12269- 1987 Grade. It is produced by inter grinding of high- grade clinker (with high C3S content) and right quality gypsum in predetermined proportions. It is recognized for its high early strength and excellent ultimate strength because of its optimum particle size distribution, superior crystalline structure and balanced phase composition and hence widely used and suitable for speedy construction, durable concrete and economic concrete mix designs.

## AGGREGATES:

### Coarse aggregates:

Aggregates were first considered to simply be filler for concrete to reduce the amount of cement required. However, it is now known that the type of aggregate used for concrete can have considerable effects on the plastic and hardened state properties of concrete. They can form 80% of the concrete mix so their properties are crucial to the properties of concrete.

Aggregates can be broadly classified into four different categories: these are heavyweight, normal weight, lightweight and ultra-lightweight aggregates. However, in most concrete practices only normal weight and lightweight aggregates are used.

The other types of aggregates are for specialist uses, such as nuclear radiation shielding provided by heavyweight concrete and thermal insulation using lightweight concrete.

**Classification of aggregates:**

The alternative used in the manufacture of good quality concrete, is to obtain the aggregate in at least two size groups, i.e

Fine aggregate often called sand which is less than 4.75mm in size.

- (Coarse aggregate, which comprises material greater than 4.75mm in size.)
- On the other hand, there are some properties possessed by the aggregate but absent in the parent rock: particle shape and size, surface texture, and absorption. All these properties have a considerable influence on the quality of the concrete, either in fresh or in the hardened state. It has been found that aggregate may appear to be unsatisfactory on some count but no trouble need be experienced when it is used in concrete.

**Aggregate properties:**

By selecting different sizes and types of aggregates and different ratios of aggregate to cement ratios, a wide range of concrete can be produced economically to suit different requirements. Important properties of an aggregate which affect the performance of a concrete are discussed as follows:

**Figure 3.2 20mmcoarseaggregates.**

**Sampling:**

Samples shall be representative and certain precautions in sampling have to be made. In the case of stockpiles, the sample obtained is variable or segregated, a large number of increments should betaken and a larger sample should be dispatched for testing.

**Fig 3.2.1 grading of coarse aggregates**

**Particle shape and texture:**

Roundness measures the relative sharpness or angularity of the edges and corners of a particle. Elongated and flaky particles are departed from equip-dimensional shape of particles and have a larger surface area and pack in an isotropic manner. Tests are useful for general assessment of aggregate but they do not adequately describe the particle shape. Affects its bond to the cement paste and also influence the water demand of the mix, especially in the case of fine aggregate. The shape and surface texture of aggregate influence considerably the strength of concrete. The effects of shape and texture are particularly significant in the case of high strength concrete. The full role of shape and texture of aggregate in the development of concrete strength is not known, but possibly a rougher texture results in a larger adhesive force between the particles and the cement matrix. The shape and texture of fine aggregate have a significant effect on the water requirement of the mix made with the given aggregate. If these properties of fine aggregate are expressed indirectly by its packing, i.e., by the percentage voids in a loose condition, then the influence on the water requirement is quite definite. The influence of the voids in coarse aggregate is less definite. Flakiness and shape of coarse aggregates have an appreciable effect on the workability of concrete.

**Bond of aggregate:**

Bond between aggregate and cement paste is an important factor in the strength of concrete, but the nature of bond is not fully understood. Bond is to the interlocking of the aggregate and the hydrated cement paste due to the roughness of the surface of the former Bond is affected by the physical and chemical properties of aggregate. For good development of bond, it is necessary that the aggregate surface be clean and free from adhering clay particles.

**Strength of aggregate:**

Such aggregate can be used only in a concrete of lower strength. The influence of aggregate on the strength of concrete is not only due to the mechanical strength of the aggregate but also, to a considerable degree, to its absorption and bond characteristics.

In general, the strength of aggregate depends on its composition, texture and structure. Thus, a low strength may be due to the weakness of constituent grains or the grains may be strong but not well knit or cemented together. A test to measure the compressive strength of prepared rock cylinders used to be prescribed.

However, the results of such a test are affected by the presence of planes of weakness in the rock that may not be significant once the rock has been reduced to the size used in concrete. In essence the crushing strength test measures the quality of the parent rock rather than the quality of the aggregate as used in concrete. For this reason, the test is rarely used.

Crushing value test BIS: 812- 1990, measures the resistance to pulverization. There is no obvious physical relation between this crushing value and the compressive strength, but the results of the two tests are usually in agreement. of the aggregate as used in concrete. For this reason, the test is rarely used. Crushing value test BIS: 812- 1990, measures the resistance to pulverization. There is no obvious physical relation between this crushing value and the compressive strength, but the results of the two tests are usually in agreement.

**Deleterious substances of aggregate:**

For satisfactory performance, concrete aggregates should be free of deleterious materials

**Grading of fine and coarse aggregate:**

- **Maximum aggregate size:**

Extending the grading of aggregate to a larger maximum size lowers the water requirement of the mix, so that, for a specified workability and cement content, the water /cement ratio can be

ISSN: 2278-4632
Vol-14 Issue-01 May 2024

lowered with a consequent increase in strength. Experimental results indicated that above the 38.1mm maximum size the gain in strength due to the reduced water requirement is offset by the detrimental effects of lower bond area of discontinuities introduced by the very large particles. Typical sizes are from 10mm to 25mm. (Tennis et al 2004).

Fine aggregates are either used sparingly or removed altogether from the mix design. void space (Tennis et al 2004). Increasing the percent number of larger aggregates will increase the void ratio in pervious concrete, but will decrease the compressive strength. Using recycled aggregates has also been researched. Four mix designs were studied using 15%, 30%, 50%, and 100% recycled aggregates and compared to the virgin pervious concrete samples.

It was found that samples containing 15% or less recycled aggregates exhibited almost identical characteristic to the virgin sample. The size of the aggregate also has an important role in pervious concrete.

While a 20mm aggregate size allows for greater void space, a 20mm aggregate improves the workability. The use of 10mm aggregate can decrease settling and workability. Recent studies have also found that pervious concrete with smaller aggregates had higher compressive strength. It was noted that the smaller aggregate sizes allowed for more cementations material to bind around the aggregate and hence allowed for greater contact between the aggregate/binder.

- **FINE AGGREGATES:**

When the sand to gravel ratio increases beyond the 8 % mark, the 7-day compressive strength begins to fall (Schaefer et al 2009). Both Europe and Japan have been using smaller aggregates as well as the inclusion of sand for their mix design. An optimization of 10%-20% of fine sand to coarse aggregate has been shown to increase compressive strength from 14 to 19 MPa. A slight decrease in permeability correlates to the increase in fine particles

**Figure 3.3: Fine aggregates**

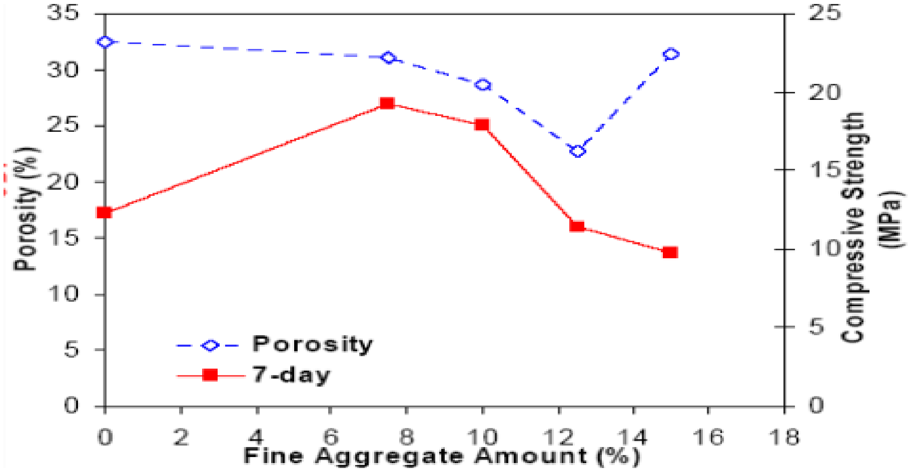

**Figure3.4: Relationships between Fine Aggregate and Porosity/Compressive strength**

### 3.1.3 WATER:

Mix design with too much water can collapse the void space, making an almost impenetrable concrete surface (NRMCA 2004). As seen in Figure, the specimen in Figure (a) has too little water, the specimen in Figure (b) has the correct amount of water, and the specimen in Figure (c) has too much water

(a)

(b)

(c)

**Figure 3.5: pervious Concrete With (a. too little Water, b. Appropriate Amount of Water, c. Too much Water)**

A study done by Meininger (1998) demonstrated the relationship between compressive strength and water-to-cement ratio. The optimal w/c ratio with the highest compressive strength was found to be between 0.3 and 0.35. Lower w/c ratios provide poor cohesion between the aggregates. Higher w/c ratios reduce the tensile capacity by the introduction of capillary pores.

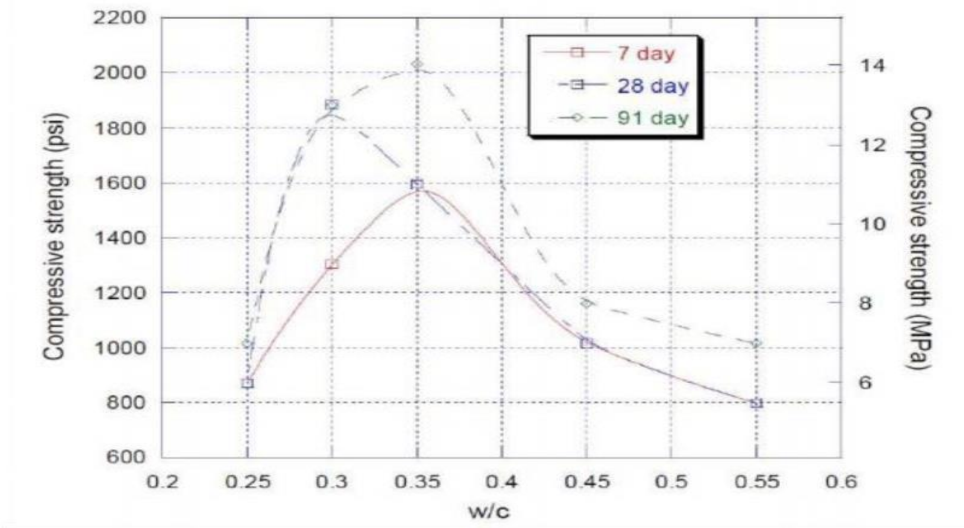

**Figure 3.6: graph showing relation between w/c ratio and compressive strength of concrete (Meininger, 1998)**

Another study by Chindaprasirt, Hatanaka, Chareerat, Mishima, and Yuasa determined that water-to-cement ratio has a direct correlation to cement paste characteristics, and mixing time of the porous concrete. It was noted that keeping a relatively low water-to-cement ratio, around 0.2 to 0.3, maintains the continuity of the paste layer with coarse aggregate. This also aids in the texture and workability of the pervious concrete. By achieving an even thickness of the paste (150-230 mm) within the porous concrete mix, this can achieve suitable void ratios of 15-25% and strengths ranges from 22-30 MPa.

### 3.1.4 SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCMS):

SCM includes fly ash, pozzolans, and slag can be added to the cement. These influence concrete performance, setting time, rate of strength development, porosity, permeability, etc

- Fly ash is the waste by-product of burning coal in electrical power plants; it used to be land filled, but now a significant amount is used in cement. This material can be used to replace 5-65% of the Portland cement
- Blast furnace slag is the waste by-product of steel manufacturing. It imparts added strength and durability to concrete, and can replace 20-70% of the cement in the mix.

In our project work, we have used fly ash and rice husk ash and mixture of both fly ash and rice husk ash as the partial replacement of cement in the quantities of 10% of cement.

### FLY ASH:

Fly ash, also known as "pulverized fuel ash", is one of (SiO2) (both amorphous and crystalline),aluminum oxide (Al2O3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata. After a long regulatory process, the EPA published a final ruling in December 2014, which establishes that coal fly ash is regulated on the federal level as "non-hazardous" waste according to the Resource Conservation and Recovery Act (RCRA). Coal Combustion Residuals (CCR's) are listed in the subtitle D (rather than under subtitle C dealing for hazardous waste, which was also considered). In the case that fly or bottom ash is not produced from coal, for example when solid waste is used to produce electricity in an incinerator, this kind of ash may contain higher levels of contaminants than coal ash. In that case the ash produced is often classified as hazardous waste.

- **Chemical Composition and Classification Fly Ash:**

Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Other phases often identified are cristobalite, anhydrite, freelime, periclase, calcium silicates and calcium aluminates identical to those found in Portland cement can be identified in Ca-rich fly ashes.

| **Compounds(%)** | **Fly Ash** | **Pond Ash** |
|---|---|---|
| SiO2 | 38-63 | 37-75 |
| Al2O3 | 27-44 | 28-53 |
| TiO2 | 0.4-1.8 | 0-1 |
| Fe2O3 | 3.3-6.4 | 17-34 |
| MnO | 0.1-0.5 | 0.1-0.6 |
| MgO | 0.01-0.5 | 0.1-0.8 |
| CaO | 0.2-8 | 0.2-0.6 |
| K2O | 0.04-0.9 | 0.1-0.7 |
| Na2O | 0.07-0.43 | 0.05-0.31 |
| LOI | 0.2-5.0 | 0.01-20.0 |
| pH | 06-09 | 06-08 |

**Table3.2:Chemical Composition of FlyAsh and PondAsh.**

Two classes of fly ash are defined by ASTMC618: Class F fly ash and Class C fly ash. The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. LOI must be under 6%.

- **Fly Ash as Replacement of Cement:**

Owing to its pozzolanic properties, fly ash is used as a replacement for Portland cement in concrete. The use of fly ash as a pozzolanic ingredient was recognized as early as 1914, although the earliest noteworthy study of its use was in 1937. Roman structures such as aqueducts or the Pantheon in Rome used volcanic ash or pozzolanic (which possesses similar properties to fly ash) as pozzolanic in their concrete.

Use of fly ash as a partial replacement for Portland cement is particularly suitable but not limited to Class C fly ashes. Class "F" fly ashes can have volatile effects on the entrained air content of concrete, causing reduced resistance to freeze/thaw damage. Fly ash often replaces up to 30% by mass of Portland cement, but can be used in higher dosages in certain applications.

**Figure3.7: Fly ash used as cement replacement.**

Fly ash can significantly improve the workability of concrete. Recently, techniques have been developed to replace partial cement with high-volume fly ash (50% cement replacement).For roller-compacted concrete (RCC) replacement values of 70% have been achieved with processed fly ash at the Ghatghar dam project in Maharashtra, India.

Due to the spherical shape of fly ash particles, it can increase workability of cement while reducing water demand. Proponents of fly ash claim that replacing Portland cement with fly ash reduces the greenhouse gas “footprint" of concrete, as the production of one ton of Portland cement generates approximately one ton of CO2, compared to no CO2 generated with fly ash. New fly ash production, i.e., the burning of coal, produces approximately 20 to 30 tons of CO2 perton of fly ash.

### 3.1.4.2 Rice Husk Ash:

- **Chemical Composition and Properties of Rice husk ash:**

Rice husk can be burnt into ash that fulfils the physical characteristics and chemical composition of mineral admixtures. Pozzolanic activity of rice husk ash (RHA) depends on

(i) silica content,

(ii) silica crystallization phase,

(iii) size and surface area of ash particles.

The effect of partial replacement of cement with different percentages of ground RHA on the compressive strength and durability of concrete is examined.

**Figure 3.8: Rice Husk Ash.**

| S. No. | Particulars | Proportion |
|---|---|---|
| 1 | Silicon Dioxide | 86.94% |
| 2 | Aluminium Oxide | 0.20% |
| 3 | Iron Oxide | 0.10% |
| 4 | Calcium Oxide | 0.3-2.25% |
| 5 | Magnesium Oxide | 0.2-0.6% |
| 6 | Sodium Oxide | 0.1-0.8% |
| 7 | Potassium Oxide | 2.15-2.30% |

**Table3.3: Chemical Properties of R.H.A**

**Rice Husk Ash as Cement Replacement:**

Rice husk ash is used in concrete construction as an alternative of cement. The rice paddy milling industries give the by-product rice husk. Due to the increasing rate of environmental pollution and the consideration of sustainability factor have made the idea of utilizing rice husk. To have a proper idea on the performance of rice husk in concrete, a detailed study on its properties must be done.

About 100 million tons of rice paddy manufacture by-products are obtained around the world. They have a very low bulk density of 90 to 150kg/m3.

Among all industries to reuse this product, cement, and concrete manufacturing industries are the ones who can use rice husk in a better way. The rice husk ash has good reactivity when used as a partial substitute for cement. These are prominent in countries where the rice production is abundant. The properly rice husk ashes are found to be active within the cement paste. So, the use and practical application of rice husk ash for concrete manufacturing are important. The incorporation of rice husk ash in concrete converts it into an eco-friendly supplementary cementations material.

The following properties of the concrete are altered with the addition of rice husk:

- The heat of hydration is reduced. This itself help in drying shrinkage and facilitate durability of the concrete mix.
- The reduction in the permeability of concrete structure. This will help in penetration of chloride ions, thus avoiding the disintegration of the concrete.

The rice husk ashes in the concrete react with the calcium hydroxide to bring more hydration products. The consumption of calcium hydroxide will enable lesser reactivity of chemicals from the external environment.

### 3.2 MIX DESIGN OF PERVIOUS CONCRETE

- **Void Content:**

At a void content lower than 15%, there is no significant percolation through the concrete due to insufficient interconnectivity between the voids to allow for rapid percolation. So, concrete mixtures are typically designed for 20% void content in order to attain sufficient strength and infiltration rate.

- **Unit Weight or Density:**

In-place densities on the order of 1600 kg/m³ to 2100 kg/m³ are common, which is in the upper range of lightweight concretes. When placed on a 150mm thick layer of open-graded gravel or crushed rock sub base, the storage capacity increases to as much as 75 mm of precipitation.

- **Water - Cement Ratio:**

The water-cementations material ratio (w/cm) is an important consideration for obtaining desired strength and void structure in pervious concrete. A high w/cm reduces the adhesion of the paste to the aggregate and causes the paste to flow and fill the voids even when lightly compacted.

- **Cement Content**

The total cementitious material content of a pervious concrete mixture is important for the development of compressive strength and void structure. An insufficient cementations content can result in reduced paste coating of the aggregate and reduced compressive strength. The optimum cementitious material content is strongly dependent on aggregate size and gradation but is typically between 267 and 415 kg/m3. The above guidelines can be used to develop trial batches. ASTM

C1688 provides the tests to be conducted in the laboratory to observe if the target void contents are attained.

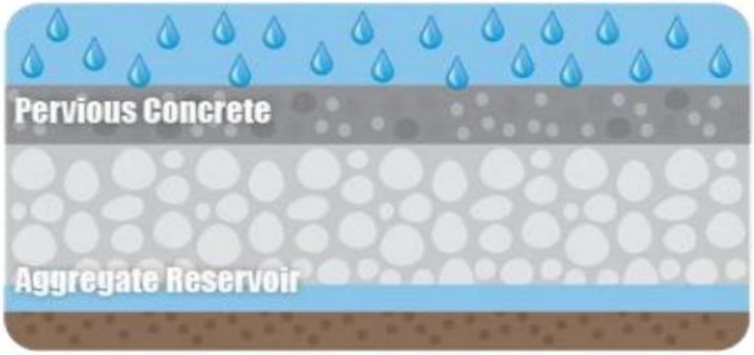

**Figure3.9: Arrangement of pervious concrete for pavements**

**Mix Design Criteria:**

Pervious concrete uses the same materials as conventional concrete, except that there is usually little or no fine aggregate. The quantity, proportions, and mixing techniques affect many properties of pervious concrete, in particular the void structure and strength. Usually single sized coarse aggregate up to 20 mm size normally adopted. Larger size aggregates provide a rougher concrete finish while smaller size aggregates provide smoother surface that may be better suited for some application such as pedestrian pathways. Although the coarse aggregate size 6 mm to 20 mm are used, the most common being 10 mm fairly uniform size is used. The aggregates may be rounded like gravel or angular like crushed stone.

Since the pervious concrete is highly permeable, the voids between aggregate particles cannot be entirely filled by cement paste. Use of smaller size aggregates can increase the number of aggregate particles per unit volume of concrete. As the aggregate particle increase the specific surface and thus increases the binding area. This results in the improved strength of pervious concrete. However, the major thrust for using pervious concrete stems from its capability to drain and potentially de-pollute enormous amounts of water in short time, thus reducing the runoff rates. The physical and mechanical properties of pervious concretes are reported elsewhere (Onstenk, 1993, Neithalath, 2004, Neithalath, 2005, Neithalath, 2006, Nelson, 1994). The use of larger size aggregates reduces clogging of pores in the pervious concrete.

The water permeation capacity or drainage properties are closely related to the porosity with coefficient of permeability to about 0.01m/s is recommended. A drainage rate of 100 to 270 lit/m2/min has been reported for pervious concrete with a porosity ranging from 17% to 28%

(Tennis, 2004). Recently it is suggested that the aggregate sizes of pervious concrete should be between 9.5 mm and 19 mm and no fine aggregate should be used.

The binder normally used in ordinary Portland cement (OPC). Pozzolanic materials like fly ash, blast furnace slag and silica fume can also be used. However, use of pozzolanic materials will affect setting time, strength, porosity and permeability of the resulting concrete. Addition of fine aggregate will reduce the porosity and increase the strength of concrete.

Chemical admixtures like water reducing admixture, retarders, hydration stabilizing admixtures, viscosity modifying admixtures and internal curing admixtures are used. Pervious concrete uses same materials as conventional concrete, except that there are usually No or little fine aggregates.

The size of the coarse aggregate used is kept fairly uniform in size to minimize surface roughness and for a better aesthetic, however sizes can vary from 6.25 mm to 12.5 mm. Water to cement ratio should be within 0.27 to 0.34. Ordinary Portland cement and blended cements can be used in pervious concrete. Water reducing admixtures and retarders can be used in pervious concrete.

General issues encountered compared to standards concrete are

1. Long mixing time in the batching plants (about 20 minutes).
2. Poor workability, very dry mix, difficult for placing.
3. Amount of water used in mix is important as same as standards concrete.
4. If too much water used, segregate is expected, usually higher than standards concrete.
5. If too little water is used, not easy to mix, balling of mix in the mixer

| **Materials** | **Proportions(Kg/m$^3$)** |
|---|---|
| Cement(OPC or blended) | 270to415 |
| Aggregate | 1190to1480 |
| Water: cement ratio (by mass) | 0.27to0.34 |
| Fine: coarse aggregate ratio(by mass) | 0to1:1 |

Chemical admixtures (retarders) are commonly used and Addition of fine aggregates will decrease the void content and increase strength

**Table3.4: Typical Mix Design of Pervious Concrete as suggested by ACI 522 R-10.**

### 3.2.6 NRMCA procedure for pervious Concrete Mixture Proportioning:

The following mixture proportioning approach can be used to quickly arrive .The paste volume (PV) is then estimated as follows:

Vp (%) = aggregate Void Content (%) + CI (%) - Vvoid (%)

Where

CI = Compaction index

$V_{void}$ =Design void content of the pervious concrete mix

The value of CI can be varied based on the anticipated consolidation to be used in the field For lighter level of consolidation, a value of 7 to 8% can be used. NRMCA used a value of 5% to get similar values between measured fresh pervious concrete.

**Void content (ASTM C1688) and design void content. Using a smaller value for CI (%) WILL reduce the past volume**

(2) Calculate the paste volume, Vp in ft3 per cubic yard of pervious concrete:

Vp, ft3 = Vp (%) × 27

(3) Select the w/c ratio for the paste. Recommended values are in the range of 0.25 to 0.36.

(4) Calculate the absolute volume of cement vc, ft3 = vp/[1+(w/c*RDc)]

Where: RDc is the specific gravity of cement (typically 3.15)

(5) Calculate the volume of water, Vw Vw, ft3 = Vp - Vc

(6) Calculate the volume of SSD aggregate (Vagg) Vagg = 27 - (Vp +Vvoid)

Where: Vvoid is the design void content for the pervious concrete mix.

Convert the volumes to weights of ingredients per cubic yard and for trial batches:

Cement (lb/yd3) = Vc ×RDc ×62.4

Water (lb/yd3) = Vw ×62.4

SSD Coarse Aggregate (lb/yd3) = Vagg × RDagg × 62.4.

Avoid excessive cementations content should be avoided. The density of the mixture should be measured in accordance with ASTM C1688 from which the void content is calculated to ensure that values are in line with the design void content. Then evaluate mixture for consistency, specification requirements and placement method used by the pervious concrete contractor.

## 3.3 COMPRESSIVE STRENGTH AND PERMEABILITY OF PERVIOUS CONCRETE

### 3.3.1 Compressive Strength of Normal Concrete:

Out of many tests applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. Compressive strength of concrete depends on many factors such as water- cement ratio, cement strength, quality of concrete material, Quality control during production of concrete etc.

Test for compressive strength is carried out either on cube or cylinder. Various standard codes recommend concrete cylinder or concrete cube as the standard specimen for the test. For cube test two types of specimens either cubes of 150 mm X 150 mm X 150 mm or 100 mm X 100 mm x 100 mm depending upon the size of aggregate are used. For most of the works cubical moulds of size 150 mmx 150 mmx 150 mm 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 removed and test specimens are put in water for curing. The top surface of this specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area specimen.

**Figure3.11: Standard compressive strength cube mould.**

These specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

**Preparation of Cube Specimens**

The proportion and material for making these test specimens are from the same concrete used in the field.

**Mixing**

Mix the concrete either by hand or in a laboratory batch mixer

**Hand Mixing:**

(i) Mix the cement and fine aggregate on a water tight none-absorbent platform until the mixture is thoroughly blended and is of uniform colour.

(ii) Add the coarse aggregate and mix with cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch.

(iii) Add water and mix it until the concrete appears to be homogeneous and of the desired consistency.

**Sampling**

(i) Clean the mounds and apply grease.

(ii) Fill the concrete in the moulds in 3 equal layers.

(iii) Compact each layer with not less than 35strokes per layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet pointed at lower end).

(iv) Level the top surface and smoothen it with a trowel.

**Curing:**

The test specimens are stored in moist air for 24hours and after this period the specimens are marked and removed from the moulds and kept submerged in clear fresh water until taken out prior to test.

**3.12 Curing of concrete**

**Procedure:**

(I) Remove the specimen from water after specified curing time and wipe out excess water from the surface.

(II) Take the dimension of the specimen to the nearest 0.2m.

(III) Clean the bearing surface of the testing machine.

(IV) Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.

(V) Align the specimen centrally on the base plate of the machine.

(VI) Rotate the movable portion gently by hand so that it touches the top surface of the specimen.

(VII) Apply the load gradually without shock and continuously at the rate of 140kg/cm2/minute till the specimen fails

(VIII) Record the maximum load and note any unusual features in the type of failure

**NOTE:**

Minimum three specimens should be tested at each selected age. If strength of any specimen varies by more than 15 per cent of average strength, results of such specimen should be rejected. Average of these specimens gives the crushing or compressive strength of concrete. The strength of concrete increases with increase in age. The following table shows the strength of concrete at different ages in comparison with the strength at 28 day after casting.

| **Age** | **Strength percent** |
|---|---|
| 1day | 16% |
| 3days | 40% |
| 7days | 65% |
| 14days | 90% |
| 28days | 99% |

**Table3.5: Compressive strength of concrete at various ages**

| Grade of Concrete | Minimum compressive strength N/mm2at 7 days | Specified characteristic compressive strength (N/mm2) at 28 days |
|---|---|---|
| M15 | 10 | 15 |
| M20 | 13.5 | 20 |
| M25 | 17 | 25 |
| M30 | 20 | 30 |
| M35 | 23.5 | 35 |
| M40 | 27 | 40 |
| M45 | 30 | 45 |

**Table3.6:Compressive strength of different grades of concrete at 7and28 days**

## COMPRESSIVE STRENGTH OF PERVIOUS CONCRETE:

Typical values are about 17 MPa. As with any concrete, the properties and combinations of specific materials, as well as placement techniques and environmental conditions, will dictate the actual in-place strength. However, currently there is no ASTM test standard for compressive strength of pervious concrete.

Testing variability measured with various draft test methods has been found to be high and therefore compressive strength is not recommended as an acceptance criterion. Rather, it is recommended that a target void content (between 15% to 25%) as measured by ASTM C 1688: Standard Test Method for Density and Void Content of Freshly Mixed pervious Concrete be specified for quality assurance and acceptance.

**Figure3.14: Cubes tested for compressive strength.**

## DENSITY AND POROSITY:

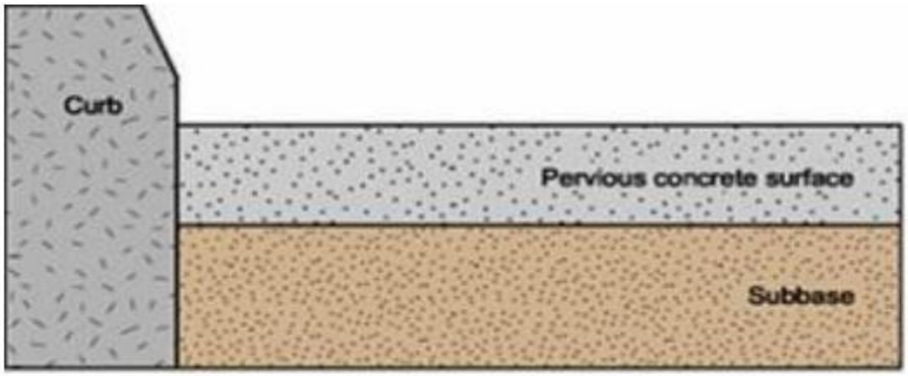

**Figure3.15: Typical cross section of pervious concrete for pavement.**

The density of pervious concrete depends on the properties and proportions of the materials used, and on the compaction, procedures used in placement.

In-place densities on the order of 1600 kg/$m^3$ to 2100 kg/$m^3$ are common, which is in the upper range of lightweight concretes.

A pavement 125 mm thick with 20% voids will be able to store 25 mm of a sustained rainstorm in its voids, which covers the vast majority of rainfall events in the U.S

**PERMEABILITY OF PERVIOUS CONCRETE:**

The permeability of pervious concrete was determined using a falling head permeability set up Figure 8. Water was allowed to flow through the sample, through a connected standpipe which provides the water head.

The permeability of the pervious concrete sample was evaluated from the expression given below:

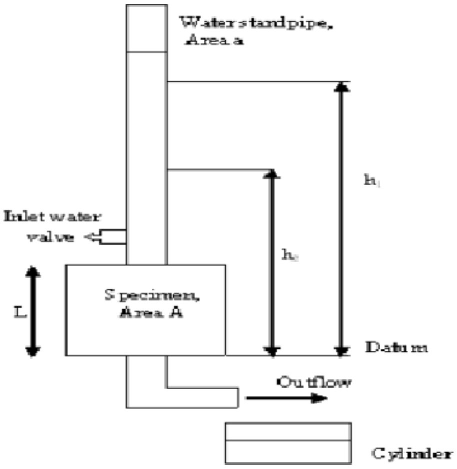

**Figure3.16: Variable head permeability test apparatus**

Formula: $K=2.303\ aL/A\ (t2-t1)\ \log(h1/h2)$

Where,

a = the sample cross section area

A = the cross section of the standpipe of diameter (d) = 0.95cm2

L = the height of the pervious concrete

(t2 - t1) = change in time for water to fall from one level to another (5secs.)

h1= upper water level

h2= Lower water level

D= diameter of sample (10.5cm)

d= diameter of standpipe (1.1cm)

Theoretically, the coefficient of permeability generally in the order of 1mm/sec for a void ratio of 20% and the rate of flow is in the range of 120 liters/min/m2 to 200 liters/min/$m^2$

In general, the concrete permeability limitation is not a critical design criterion. Designers should ensure that permeability is sufficient to accommodate all rain falling on the surface of the pervious concrete. For example, with a permeability of 140 L/m2/min, a rainfall in excess of 0.24 cm/s would be required before permeability becomes a limiting factor. The permeability of pervious concretes is not a practical controlling factor in design. However, the flow rate through the sub grade maybe more restrictive.

**Storage Capacity:**

The total volume of rain is important, but the infiltration rate of the soil also must be considered.

The theoretical storage capacity of the pervious concrete is its effective.

Porosity: that portion of the pervious concrete which can be filled with rain in service. If the pervious concrete has 15% effective porosity, then every 25 mm of pavement depth can hold 4 mm of rain. For example, a 100mm thick pavement with 15% effective porosity on top of in pervious clay could hold up to 15 mm of rain before contributing to excess rainfall runoff. Another important source of storage is the sub base. A conventional aggregate sub base, with higher fines content, will have a lower porosity (about 20%). From the example above, if 100 mm of pervious concrete with 15% porosity was placed on 150 mm of clean stone, the nominal storage capacity would be 75 mm of rain. The effect of the sub base on the storage capacity of the pervious concrete pavement system can be significant.

A critical assumption in this calculation is that the entire system is level. If the top of the slab is not level, and the infiltration rate of the sub grade has been exceeded, higher portions of the slab will not fill and additional rainfall may run to the lowest part of the slab. Once it is filled, the rain will run out of the pavement, limiting the beneficial effects of the pervious concrete. These losses in useable volume because of slopes can be significant, and indicate the sensitivity of the design to slope. Pipes extending from the trenches carry water travelling down the paved slope out to the adjacent hillside. The high flow rates that can result from water flowing down slope also may wash out sub grade materials, weakening the pavement.

### 3.4 Improvement of Strength of pervious Concrete:

- As the strength of pervious concrete is less when compared to conventional concrete, its applications are limited to great extent.

- The main aim of our project is to improve the strength of pervious concrete so that it can be used for large number of applications.
- The strength improvement can be done by

1. Addition of small quantity of fine aggregates
2. Addition of small quantities of cementations materials
3. Usage of small sized coarse aggregates
4. Using low w/c ratio etc.

- Among the above methods, we have selected addition of small quantity of fine aggregates, addition of cementations materials such as fly ash, rice husk ash and mixture of both fly ash and rice husk ash.
- The compressive strength of pervious concrete inversely proportional to permeability. As the compressive strength increases, the permeability will be decreased and vice- versa.
- The main purpose of pervious concrete is permeability. By improving the strength, we should not forget the effect of permeability.
- In our project work, we have considered both the aspects. We tried to improve the compressive strength of pervious concrete without compromising the permeability much.
- Theoretically, it is stated that the strength characteristics will be increased if the fine aggregates are added 5- 10% quantity of coarse aggregates.

# Chapter-4

# RESULTS AND DISCUSSIONS

# CHAPTER-4

# RESULTS AND DISCUSSIONS

## 4.1 Optimized Mix Design of pervious Concrete (With 20mm Aggregates, No Sand), Tested concrete technology laboratory.

Properties of materials tested in the laboratory:

### 4.1.1 Tests on cement:

OPC-53 grade cement

| S.No | Property | Value |
|---|---|---|
| 1 | Specific gravity | 3.15 |
| 2 | Bulk density | 1120kg/m3 |
| 3 | Fineness | 225m2/kg |
| 4 | Initial setting time | 35min |
| 5 | Final setting time | 132min |
| 6 | Consistency | 28% |

**Table4.1: Properties of Cement Tested at Concrete Technology Laboratory**

### 4.1.2 Tests on coarse aggregates:

Coarse aggregates (locally available 20mm size aggregates):

| S. No | Property | Value |
|---|---|---|
| 1 | Bulk density | 1583.34 kg/m$^3$ |
| 2 | Impact strength | 26.4% |
| 3 | Crushing strength | 25.45% |
| 4 | Voidc ontent | 37.16% |
| 5 | Specific gravity | 2.65 |

**Table4.2: Properties of Coarse Aggregates Tested at Concrete Technology Laboratory.**

### 4.1.3 Tests on fine aggregates:

Fine aggregates (locally available):

| S. No | Property | Value |
|---|---|---|
| 1 | Specific gravity | 2.62 |
| 2 | Fineness modulus | 2.5 |
| 3 | Dry rodded unit weight | 1720kg/m3 |
| 4 | Water absorption | 0.6% |

**Table4.3: Properties of Fine Aggregates Tested at Concrete Technology Laboratory.**

**Optimized mix proportions:**

- Optimised mix proportion is calculated with 20mm coarse aggregate as standard pervious concrete:
- The void ratio and unit weight are the important factors to be considered in mix design process.
- According to mix design, the quantity of cement calculated for one cubic meter of pervious concrete is 390 kgs based on NRMCA, USA.
- The other important considerations are aggregate to cement (A/C) ratio and water to cement (W/C) ratio. We can consider different types of aggregates to cement ratios and water to cement ratios as per our requirement.
- The mix design procedure gave the value of cement to aggregate ratio as 1:4.25 or approximately 1:4 for the size of aggregates passing through 20mm and retained on 10mm IS sieve.
- The W/C ratio for the pervious concrete should be in the range of 0.25 to 0.36. For the proper workability we have selected the W/C ratio as 0.3 and it is fixed after doing samples with water to cement ratios of 0.25, 0.30 and 0.35.
- The design void ratio of pervious concrete is 20% and the unit weight ranges from 1600 to 2100 kg/m3.
- The quantities of Materials as per mix design are given below

| | |
|---|---|
| Cement | : 390kg/m$^3$ |
| Coarse aggregate | : 1669.2 kg/m$^3$ |
| Water | :117 lit |

| **MATERIALS** | **PROPORTIONS (kg/m$^3$)** |
|---|---|
| Cement(OPC-53grade) | 390 |
| Aggregate(20mm) | 1669.2 |
| Water: cement ratio(by mass) | 0.3 |
| Fine aggregates | 0 |

**Table4.4: Optimized mix proportions.**

- The cement we used in our project work is Ordinary Portland Cement of 53 grade.
- The size of coarse aggregates is passing 20 mm and retained on 10 mm IS sieve.
- The water used is available in the laboratory.

### 4.2 Compressive strength of Standard Pervious Concrete with 0% Fines:

**Quantities of materials:**

| | |
|---|---|
| Cement | : 390kg/m$^3$ |
| Coarse aggregate | : 1669.73 kg/m$^3$ |
| Fine aggregate | :0 kg/m$^3$ |
| Water | :117 lit per CUM |

The following table provides the information of compressive strength of M20 Grade pervious concrete with 0% fine aggregates tested for 7,14 and 28 days in compression testing machine, permeability tested in variable head permeability test after 28 days and also unit weight of concrete after 24 hours from preparation of concrete.

### 4.2(a) Compressive Strength of Pervious Concrete

| **S. No** | **Age of concrete (days)** | **Compressive Strength Of M20 Grade Pervious Concrete (MPa)** | **Unit Weight After 24 Hours(Kg/m3)** |
|---|---|---|---|
| 1 | 7 | 16.72 | 2112.20 |
| 2 | 14 | 19.26 | |
| 3 | 28 | 21.06 | |

**Table4.5: Compressive Strength and Unit Weight of Standard Pervious Concrete (0%fines)**

### 4.2(b) Compressive strength comparison between Normal concrete and pervious concrete

| S.NO | Age of concrete(days) | Normal Concrete of M20 Grade( MPa) | Pervious Concrete of M20 Grade (MPa) |
|---|---|---|---|
| 1 | 7 | 18.53 | 16.72 |
| 2 | 14 | 25.67 | 19.26 |
| 3 | 28 | 28.20 | 21.06 |

**Table4.6: Comparison of Strength between Normal Concrete and Pervious Concrete.**

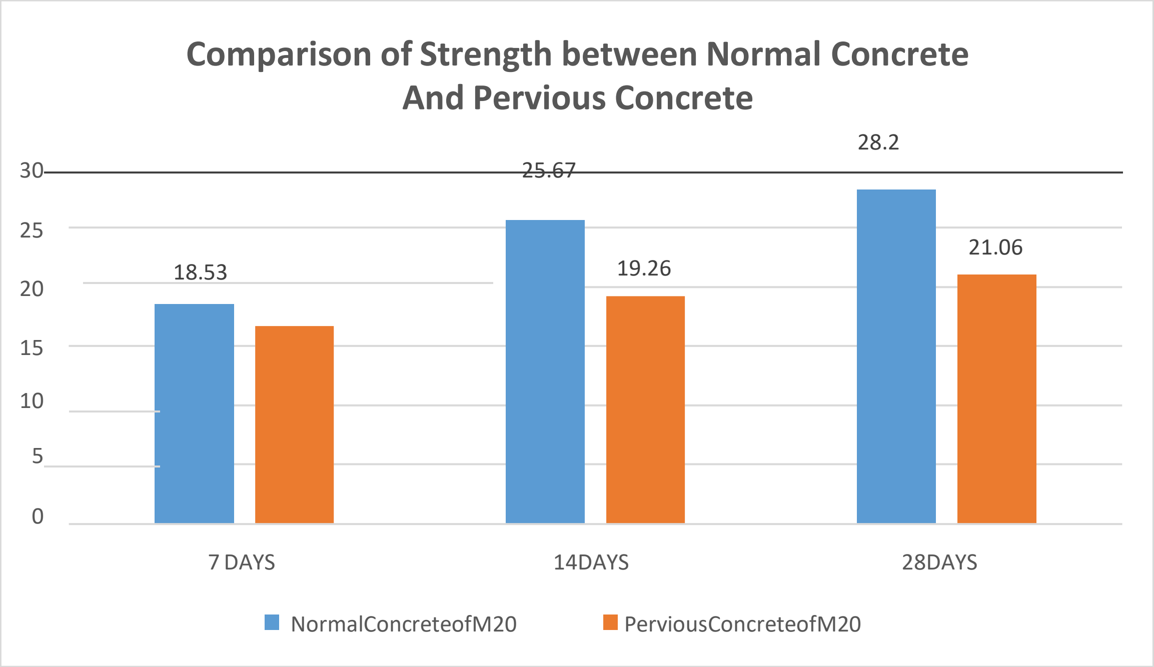

**Figure4.1: Graph of showing relation between compressive strength of normal and pervious concrete.**

The compressive strength of pervious concrete is less than the normal concrete due to the absence of fine aggregates or presence of voids. It should be noted that the normal concrete is completely impermeable in nature.

### 4.3 Compressive strength of pervious concrete with the addition of fine aggregates

#### Addition of 5% Fines in Total Coarse Aggregate Quantity

**Quantities of materials:**

Cement : 390 kgs.

Fly ash : 83 kgs

Coarse aggregates: 1577 kgs

Water : 117 liters

All the materials are calculated for 1 CUM.

| S.No | Age Of Concrete (days) | Compressive Strength of Pervious concrete with 0%fines(MPa) | Compressive Strength Of Pervious Concrete With 5% Fines (MPa) | Unit Weight After 24 Hours(Kg/m3) |
|---|---|---|---|---|
| 1 | 7 | 16.72 | 17.36 | 2065.30 |
| 2 | 14 | 19.26 | 19.60 | |
| 3 | 28 | 21.06 | 21.65 | |

**Table4.7: Compressive Strength and Unit Weight of Pervious Concrete With 5% Fines.**

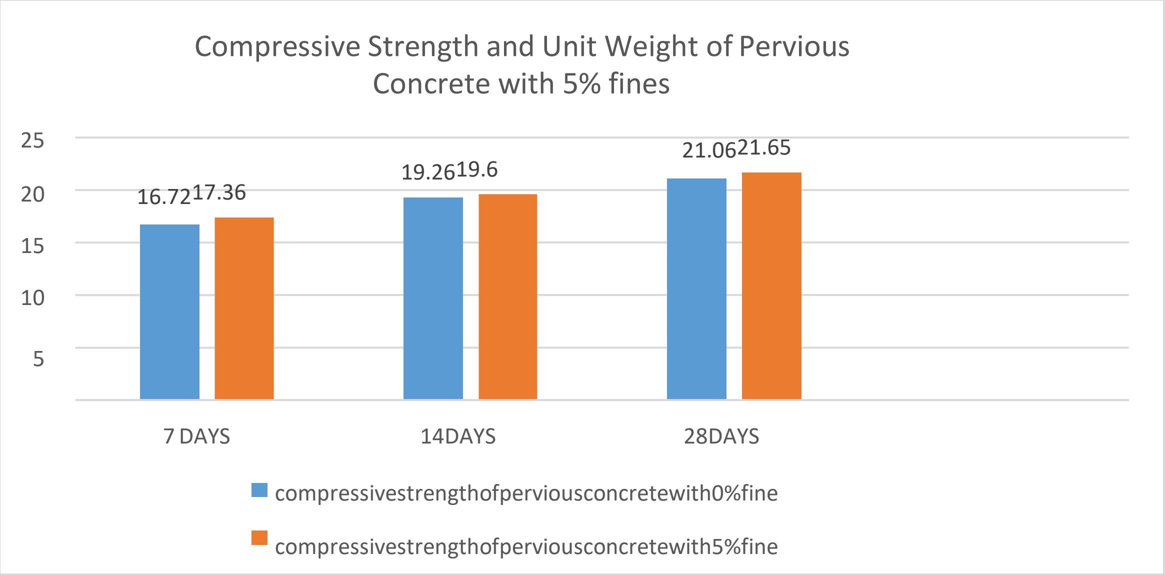

**Figure 4.2: graph of Age of concrete Vs compressive strength of 5% fines pervious concrete**

From the above table and graph, the 7, 14 and 28 days compressive strength of 5% fines pervious concrete is high. The unit weight of 5% fines pervious concrete is less due to less weight fine particles in the place of coarse aggregates.

Addition of 6% Fines in Total Coarse Aggregate Quantity

Quantities of materials:

Cement : 390 kg/m3

Coarse aggregates : 1560.40 kg/m3

Fine aggregates : 99.6 kg/m3 (6% of coarse aggregates)

Water : 117 litres per CUM

| S.No | Age of Concrete(days) | Compressive strength of Pervious concrete With 0% fines (MPa) | Compressive Strength Of Pervious Concrete With 6%Fines(MPa) | Unit Weight After 24 Hours(Kg/m3) |
|---|---|---|---|---|
| 1 | 7 | 16.72 | 17.75 | 2040.50 |
| 2 | 14 | 19.26 | 19.73 | |
| 3 | 28 | 21.06 | 22.47 | |

**Table4.8: Compressive Strength and unit weight of Pervious Concrete with 6%fines**

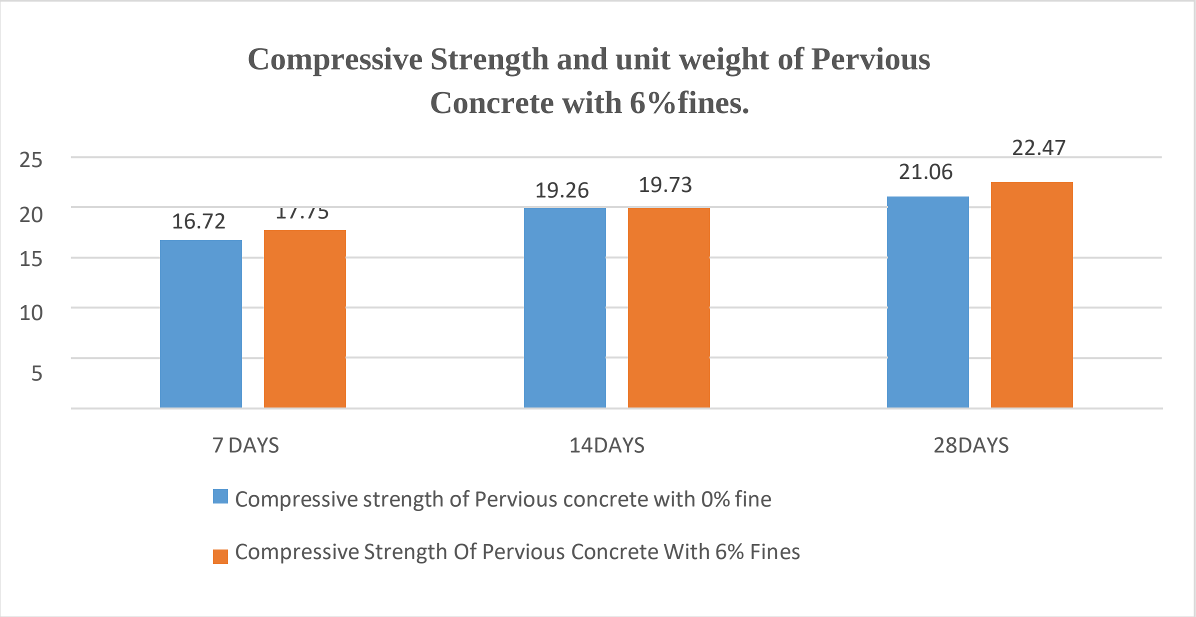

**Figure4.3: Graph of Compressive strength of pervious concrete with 0% fines Vs compressive strength of Pervious Concrete With 6% Fines.**

**Addition of 7% Fines in Total Coarse Aggregate Quantity**

Quantities of materials:

Cement : 390 kg/m3

| | |
|---|---|
| Coarse aggregates | : 1543.80 kg/m3 |
| Fine aggregates | : 116.2 kg/m3 (7% of coarse aggregates) |
| Water | : 117 litres per CUM |

| S.No | Age Of Concrete(days) | compressive strength of pervious concrete with 0% fines (mpa) | compressive strength of pervious concrete with 7% fines (mpa) | Unit weight after 24 hours(kg/m3) |
|---|---|---|---|---|
| 1 | 7 | 16.72 | 18.32 | 2025.87 |
| 2 | 14 | 19.26 | 19.93 | |
| 3 | 28 | 21.06 | 23.79 | |

**Table4.9:Compressive Strength and unit weight of Pervious Concrete with 7%fines.**

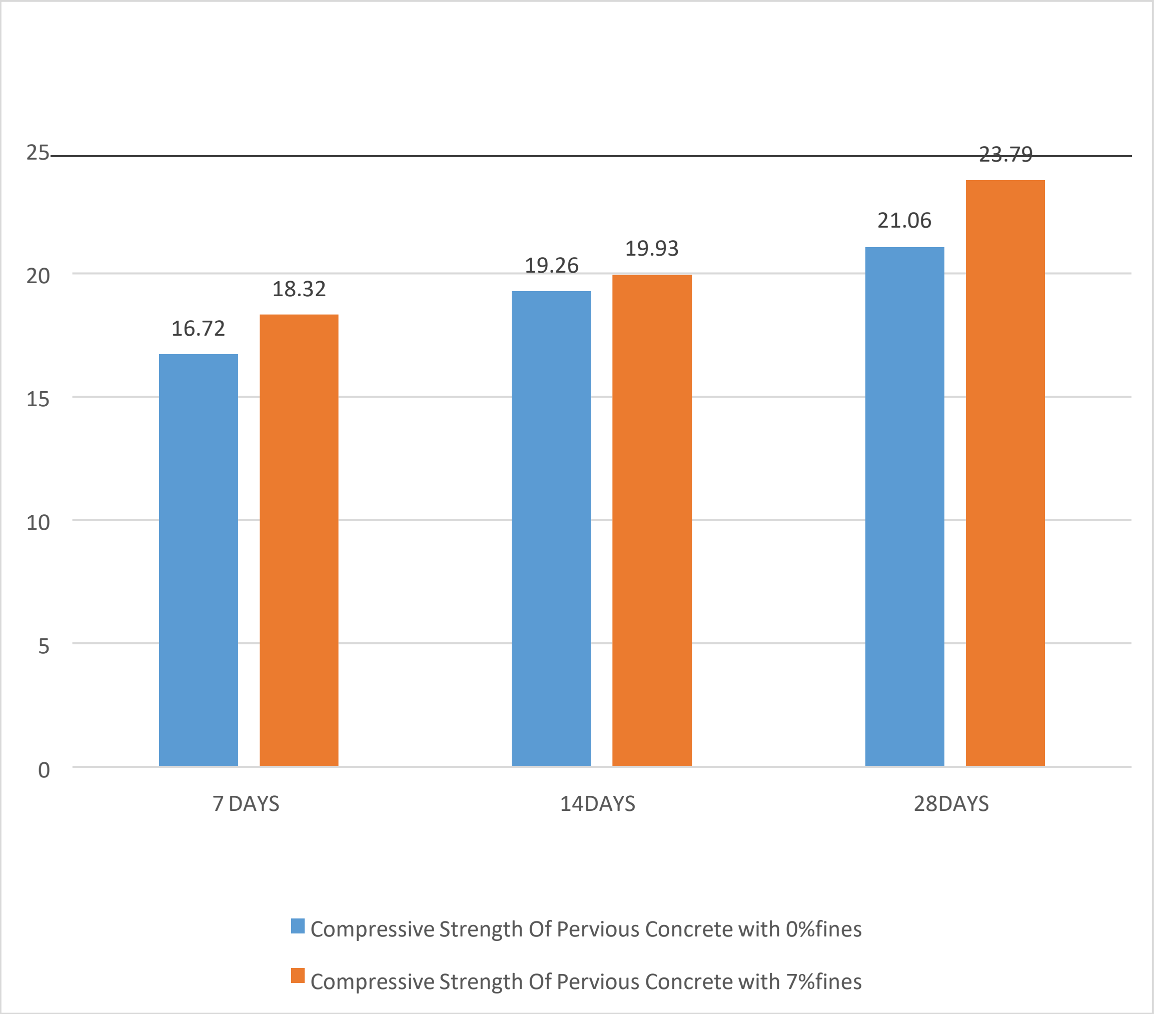

**Figure4.4: Graph of Age of concrete Vs compressive strength of 7% fines pervious concrete**

### Addition of 8% Fines in Total Coarse Aggregate Quantity

Quantities of materials:

| | |
|---|---|
| Cement | : 390 kg/m3 |
| Coarse aggregates | : 1527.20 kg/m3 |
| Fine aggregates | : 132.8 kg/m3 (7% of coarse aggregates) |
| Water | : 117 litres per CUM |

| S.No | Age Of Concrete(days) | Compressive Strength Of Pervious Concrete with 0% fines (MPa) | Compressive Strength Of Pervious Concrete With 8% Fines(MPa) | Unit Weight After 24 Hours(Kg/m3) |
|---|---|---|---|---|
| 1 | 7 Days | 16.72 | 18.98 | 1996.65 |
| 2 | 14 Days | 19.26 | 21.47 | |
| 3 | 28 Days | 21.06 | 24.13 | |

Table 4.10: Compressive Strength and unit weight of Pervious Concrete with 8% fines

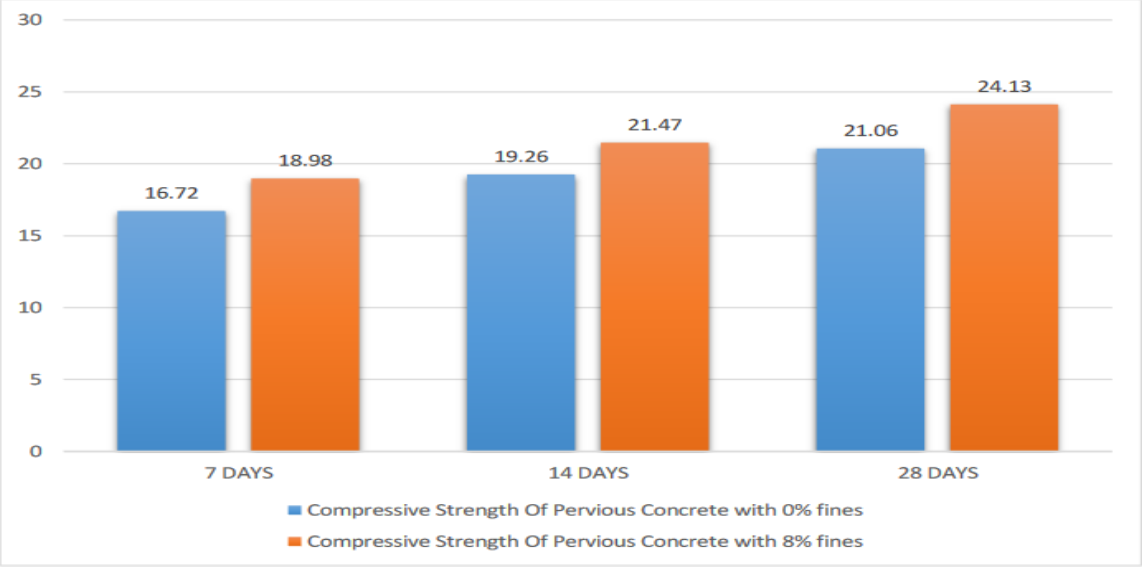

**Figure 4.5: graph of compressive strength of pervious concrete with 0% fines vs Compressive strength of pervious concrete with 8% fines**

### Addition of 9% Fines in Total Coarse Aggregate Quantity

**Quantities of materials:**

Cement: 390 kg/m3

Coarse aggregates : 1510.60 kg/m3

Fine aggregates: 149.40 kg/m3 (9% of coarse aggregates)

Water: : 117 litres per CUM

| S.No | Age Of Concrete(days) | Compressive Strength Of Pervious Concrete with 0% fines (MPa) | Compressive Strength Of Pervious Concrete With 9% Fines (MPa) | Unit Weight After 24 Hours(Kg/m3) |
|---|---|---|---|---|
| 1 | 7DAYS | 16.72 | 18.76 | 1986.26 |
| 2 | 14DAYS | 19.26 | 21.23 | |
| 3 | 28DAYS | 21.06 | 23.47 | |

**Table4.11: Compressive Strength and unit weight of Pervious Concrete with 9% fines.**

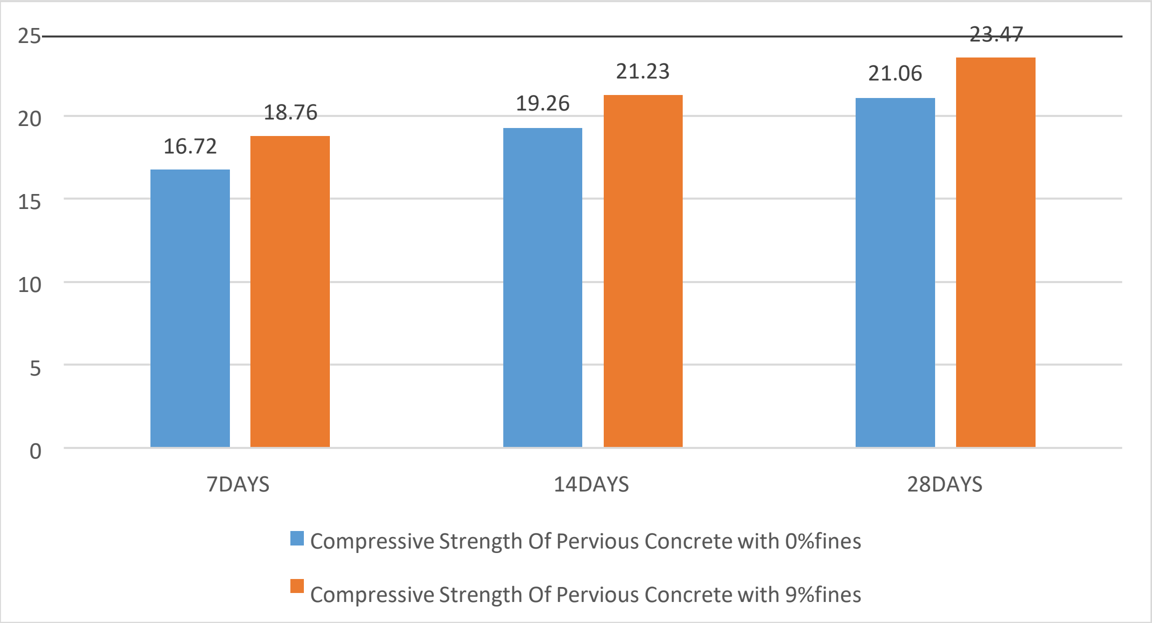

**Figure4.6: GraphofCompressiveStrengthOfPerviousConcretewith0%finesVs Compressive Strength of Pervious Concrete With 9% Fines**

**Addition of 10% Fines in Total Coarse Aggregate Quantity**

Quantities of materials:

Cement : 390 kg/m3

Coarse aggregates : 1494 kg/m3

Fine aggregates : 166 kg/m3 (10% of coarse aggregates)

Water : 117 litres per CUM

| S.No | Age Of Concrete(days) | Compressive Strength Of Pervious Concrete with 0% fines (MPa) | Compressive Strength Of Pervious Concrete With 10% Fines (MPa) | Unit Weight After 24 Hours(Kg/m3) |
|---|---|---|---|---|
| 1 | 7DAYS | 16.72 | 18.28 | 1986.26 |
| 2 | 14DAYS | 19.26 | 20.23 | |
| 3 | 28DAYS | 21.06 | 22.87 | |

**Table4.12: Compressive Strength and unit weight of Pervious Concrete with 10%fines**

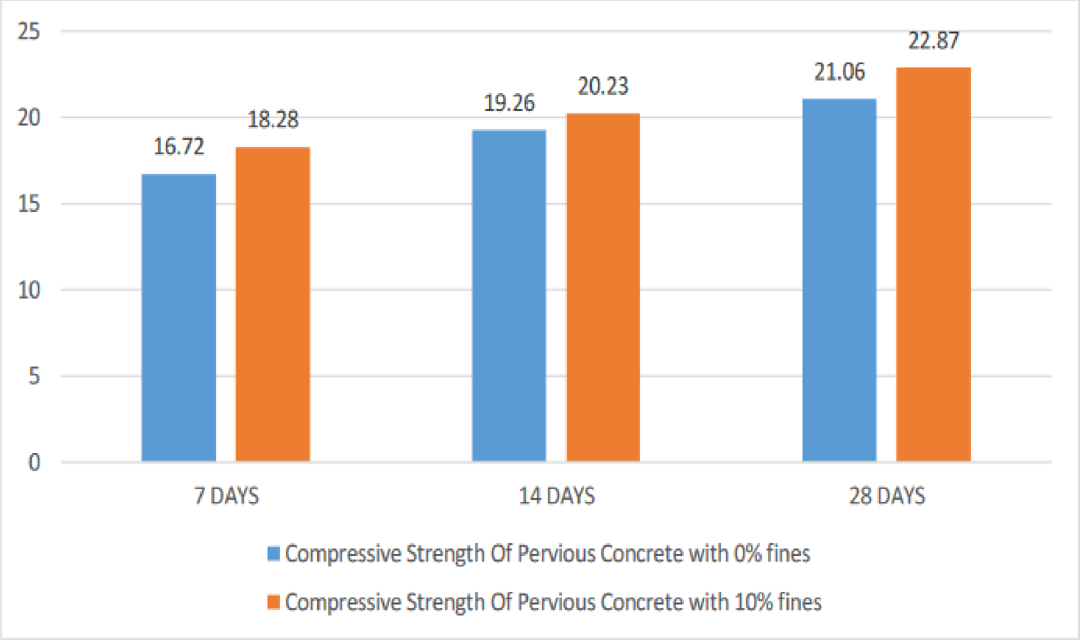

**figure4.7: graph of compressive strength of pervious concrete with 0% fines Vs Compressive strength of pervious concrete with 10% fines**

### 4.4 Compressive Strength of Pervious Concrete with the replacement of Cementitious materials:

We have tested 3 types of mixes. In the first mix, the fly ash is replaced by 10% of cement. In second mix, Rice Husk Ash is replaced by 10% of cement. In the third mix, mixture of both fly ash (5%) and Rice Husk Ash (5%) is replaced by 10% of cement.

**Replacement of Fly ash by 10% of Cement**

Quantities of materials:

| | |
|---|---|
| Cement | : 351 kgs |
| Fly ash | :39 kgs |
| Coarse aggregate | :1510.60 kgs |
| Water | :117 liters |

All the materials are calculated for 1 CUM

| S.No | Age Of Concrete (days) | Compressive StrengthOfM20grade Pervious Concrete (MPa) | Compressive Strength Of Pervious Concrete With 10%Flyash (MPa) | Unit Weight After 24 Hours(Kg/m3) |
|---|---|---|---|---|
| 1 | 7days | 16.72 | 17.26 | 1941.92 |
| 2 | 14days | 19.26 | 19.92 | |
| 3 | 28days | 21.06 | 22.87 | |

**Table4.13: Compressive Strength and Unit Weight of Pervious Concrete with 10% Fly Ash.**

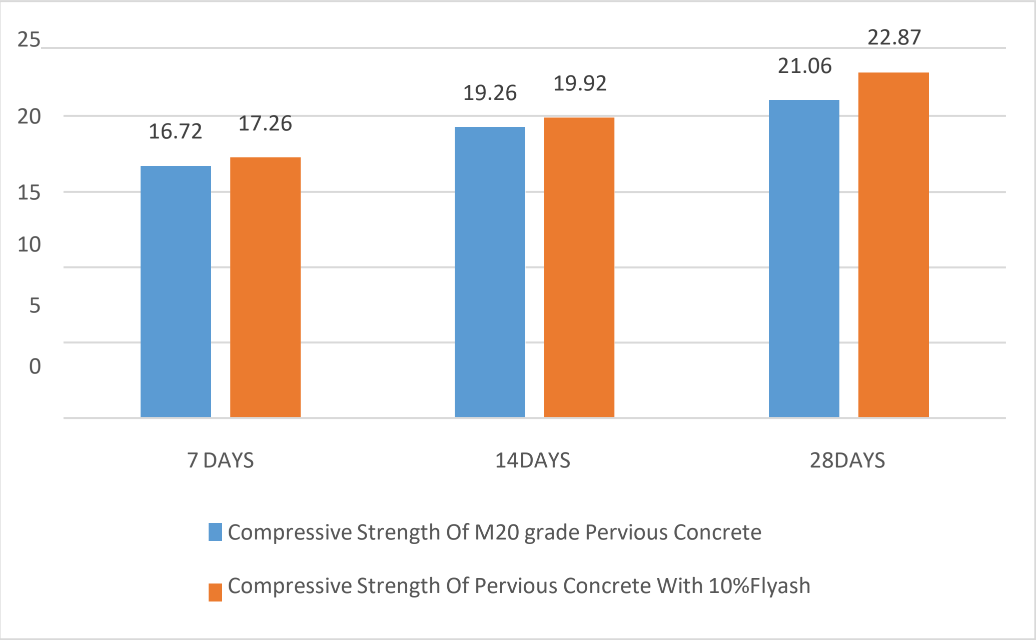

**Figure4.8: Graph of Compressive Strength of M20grade Pervious Concrete Vs Compressive Strength of Pervious Concrete With 10%Flyash**

### Replacement of Rice Husk Ash By 10% of Cement

Quantities of materials:

Cement : 351 kg/m3

Rice husk ash : 39 kg/m3

Coarse aggregates : 1510.60 kg/m3

Water : 117 litres per CUM

| S.No | Age Of Concrete(days) | Compressive Strength Of M20grade Pervious Concrete (MPa) | Compressive Strength Of Pervious Concrete With 10% Rice Husk Ash (MPa) | Unit Weight After 24 Hours(Kg/m3) |
|---|---|---|---|---|
| 1 | 7days | 16.72 | 18.47 | 1960.60 |
| 2 | 14days | 19.26 | 21.13 | |
| 3 | 28days | 21.06 | 23.93 | |

**Table 4.14: Compressive Strength and unit Weight of Pervious Concrete with 10% Rice Husk Ash.**

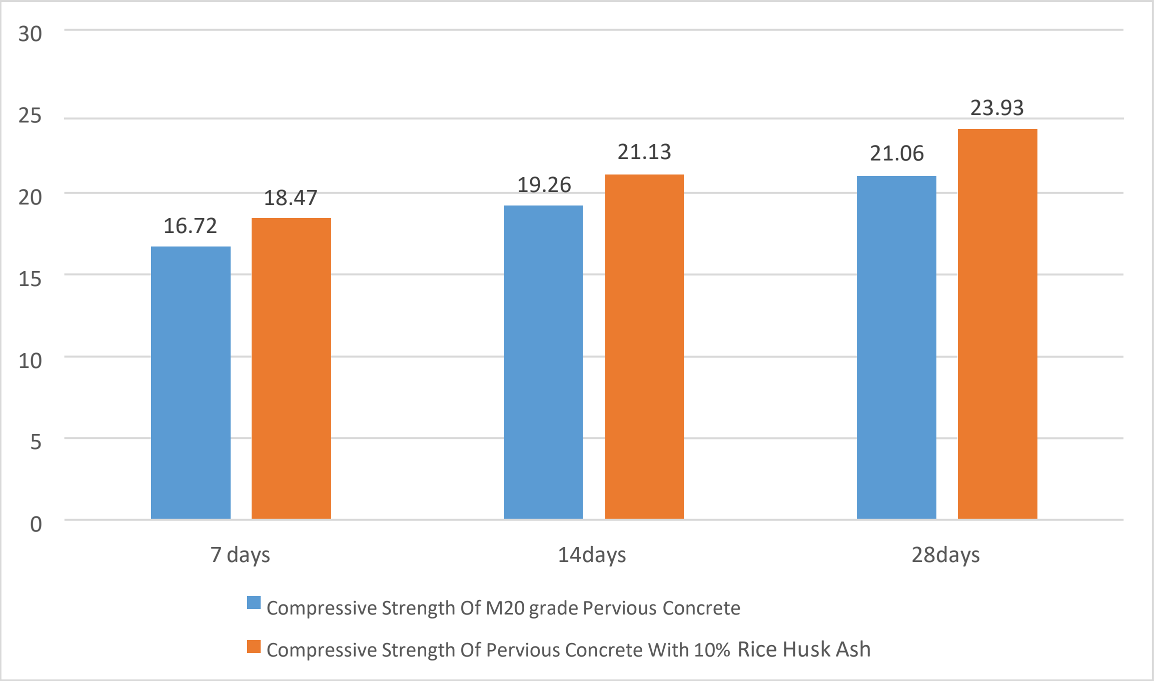

**Figure4.9: Graph of Compressive Strength Of M20 grade Pervious Concrete Vs Compressive Strength Of Pervious Concrete With 10 Rice Husk Ash**

**Replacement of Both Fly Ash (5%) And Rice Husk Ash (5%) by 10% of Cement**

Cement : 351 kg/m3

Coarse aggregates : 1510.60 kgs

Water : 117 litres

Fly ash : 19.5 kg/m3

Rice husk ash : 19.5 kg/m3

All the materials are calculated per CUM

| S.No | Age Of Concrete(days) | Compressive Strength Of M20 grade Pervious Concrete (MPa) | Compressive Strength Of Pervious Concrete With 5%Rice HuskAsh & 5% fly ash (MPa) | Unit Weight After 24 Hours(Kg/m3) |
|---|---|---|---|---|
| 1 | 7days | 16.72 | 16.79 | 1952.85 |
| 2 | 14days | 19.26 | 20.33 | |
| 3 | 28days | 21.06 | 23.12 | |

**Table4.15: Compressive Strength and Unit Weight of Pervious Concrete with10%FlyAsh and Rice Husk Ash.**

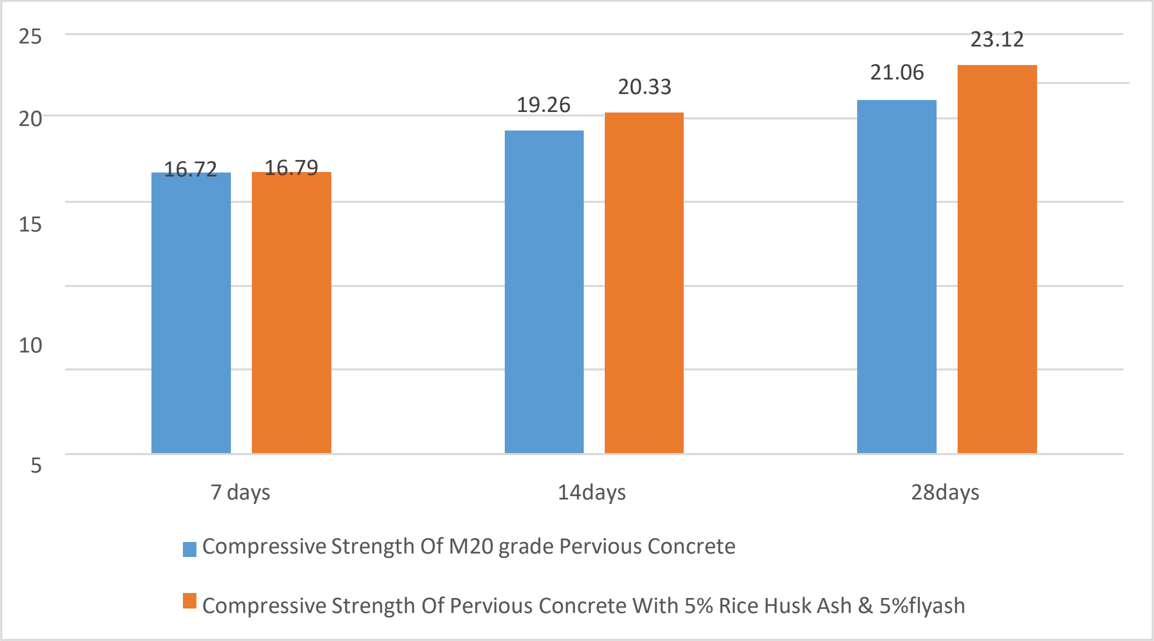

**figure4.10: Graph of Compressive Strength Of M20 grade Pervious Concrete Vs Compressive Strength Of Pervious Concrete With 5% Rice Husk Ash & 5% fly ash**

From the above three mixes, the cement replacement by mixture of fly ash and rice husk ash gives least values of compressive strength. This may due to different properties of fly ash and rice husk ash may not be homogeneous.

### 4.5 PERMEABILITY:

The permeability is the property to allow the water to flow through it. Generally, the permeability is determined either by constant head permeability test or by variable head permeability test. In our project work, we have taken variable head permeability test as it suits best for the pervious concrete.

To determine the permeability of pervious concrete, we have prepared a beam of size 400*400*60mm. The permeability test is conducted for the standard pervious concrete (0% fines), pervious concrete with 8% fine aggregates, pervious concrete with 10% fine aggregates, pervious concrete with 10% fly ash as cement replacement and pervious concrete with 10% rice husk ash as cement replacement tested after 28 days from preparation.

**Permeability of Standard pervious concrete with 0% fine aggregates**

Quantities of materials:

| | |
|---|---|
| Cement | : 390 kg/m3 |
| Coarse aggregates | : 1660 kg/m3 |
| Fine aggregates | : 0 kg/m3 |
| Water | : 117 litres per CUM |

| S.No | Unit weight of M20 Grade Pervious Concrete (0% fines) after 24 hours (kg/m3) | Coefficient of Permeability K (cm/sec) |
|---|---|---|
| 1 | 2118.84 | 1.02 |

**Table 4.16: Unit weight and co-efficient of permeability of M20 Grade Pervious Concrete with 0% fines**

**Permeability of pervious concrete with 8% fine aggregates**

Quantities of materials:

Cement : 390 kg/m3

Coarse aggregates : 1527.20 kg/m3

Fine aggregates : 132.80 kg/m3

Water : 117 litres per CUM

| S. No | Unit weight of M20 Grade Pervious Concrete (8% fines) after 24 hours (kg/m3) | Coefficient of Permeability K (cm/sec) |
|---|---|---|
| 1 | 1998.78 | 0.76 |

**Table4.17: Unit weight and Co-efficient of Permeability of Standard Pervious Concrete with 8% fines.**

**Permeability of pervious concrete with 10% fine aggregates**

Quantities of materials:

Cement : 390 kg/m3

Coarse aggregates : 1494 kg/m3

Fine aggregates : 166 kg/m3

Water : 117 litres per CUM

| S.No | Unit weight of M20 Grade Pervious Concrete (10%fines) after 24hours (kg/m3) | Coefficient of Permeability K (cm/sec) |
|---|---|---|
| 1 | 1949.76 | 0.49 |

**Table4.18:Unit weight and Co-efficient of Permeability of Standard Pervious Concrete with 10% fines.**

**Pervious concrete with 10% fly ash as cement replacement**

Quantities of materials:

Cement : 351 kg/m3

Fly ash : 39 kg/m3

Coarse aggregates : 1660 kg/m3

Fine aggregates : 0 kg/m3

Water : 117 litres per CUM

| S.No | Unit weight of M20 Grade Concrete with10%Fly Ash as Cement replacement after24hours(kg/m3) | Coefficient of Permeability K (cm/sec) |
|---|---|---|

| | | |
|---|---|---|
| 1 | 1949.76 | 0.59 |

**Table4.19: Unit weight and Co-efficient of Permeability of Standard Pervious Concrete with 10% Fly Ash as Cement replacement.**

**Permeability of pervious concrete with 10% Rice husk ash as cement replacement**

Quantities of materials:

| | |
|---|---|
| Cement | : 351 kg/m3 |
| Rice husk ash | : 39 kg/m3 |
| Coarse aggregates | : 1660 kg/m3 |
| Fine aggregates | : 0 kg/m3 |
| Water | : 117 litres per CUM |

| S.No | Unit weight of M20 Grade Concrete with 10% Rice Husk Ash asCementreplacementafter24 hours(kg/m3) | Coefficient of Permeability K (cm/sec) |
|---|---|---|
| 1 | 1949.76 | 0.53 |

**Table4.20:Unit weight and Co-efficient of Permeability of Standard Pervious Concrete with 10% Rice Husk Ash as Cement replacement.**

## 4.6 COMPARISONS:

4.6.1 Compressive Strength Comparisons:

4.6.1.1 Compressive Strength Comparison of Standard pervious Concrete and pervious Concrete with Fine Aggregates

| S.No | Age of Concrete | M20Grade Pervious Concrete (0%fines), MPa | Pervious Concrete with 5% fines, MPa | Pervious Concrete with 6% fines, MPa | Pervious Concrete with7 % fines, Mpa | Pervious Concrete with 8 % fines,MPa | Pervious Concrete with 9% fines,MPa | Pervious Concrete with 10% fines,MPa |
|---|---|---|---|---|---|---|---|---|
| 1 | 7 | 16.72 | 17.36 | 17.75 | 18.32 | 18.98 | 18.76 | 18.28 |
| 2 | 14 | 19.26 | 19.60 | 19.73 | 19.93 | 21.47 | 21.23 | 20.23 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | 28 | 21.06 | 21.98 | 22.47 | 23.79 | 24.13 | 23.47 | 22.87 |

**Table4.21: Compressive Strength of Pervious Concrete with different Quantities of Fine Aggregate**

The above table clearly shows that the compressive strength of pervious concrete increases with increase in age and percentage of fines up to 8%. Beyond this value, the compressive strength starts to decrease. A graph showing the variation in compressive strength of pervious concrete by using the above values by taking percentage fines on x-axis and compressive strength on y-axis for 7,14 and 28 days as shown below

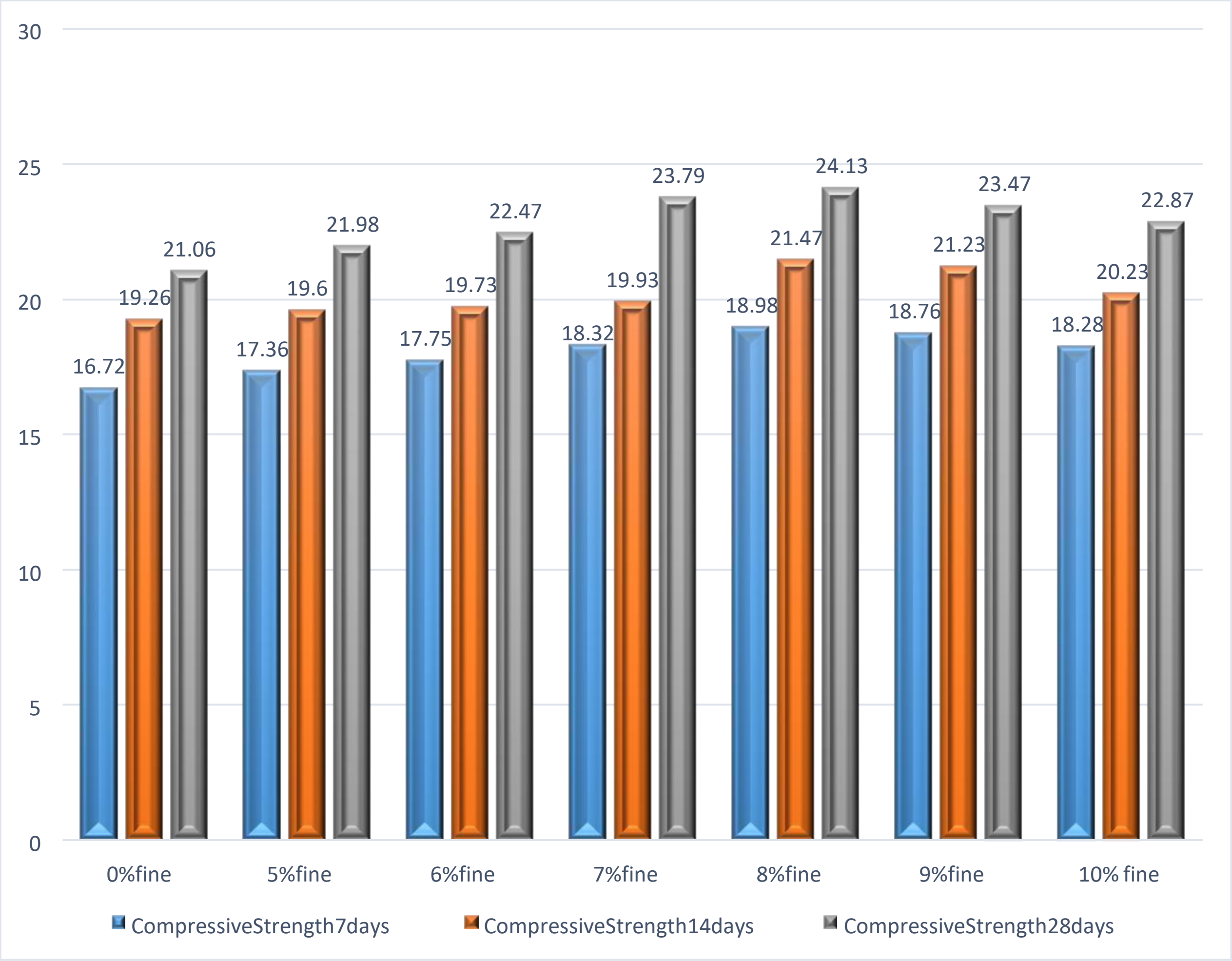

**Figure 4.11: Graph of compressive strength of pervious concrete with different quantities of fine aggregates.**

- The 7 days compressive strength of 5% fines pervious concrete is less than the standard pervious concrete with 0% fine aggregates. It may be due slow development of early strength due to mixing.
- The pervious concrete with 8% fine aggregates gives highest compressive strength beyond which the compressive strength begins to fall.

**Compressive Strength Comparison of Standard pervious Concrete and pervious Concrete with cement replacement**:

| **S.No** | **Days** | **Pervious Concrete with 0%fines, MPa** | **Pervious Concrete with 10% FA as Cement replacement, MPa** | **Pervious Concrete with10%RHAas Cement replacement, MPa** | **Pervious Concretewith10% FA and RHA as Cement replacement, MPa** |
|---|---|---|---|---|---|
| 1 | 7 | 16.72 | 17.26 | 19.92 | 17.79 |
| 2 | 14 | 19.26 | 19.92 | 21.13 | 20.33 |
| 3 | 28 | 21.06 | 22.87 | 23.93 | 23.12 |

Table 4.22: Compressive Strength of Pervious Concrete with Cement Replacement

FA = Fly Ash , RHA = Rice Husk Ash

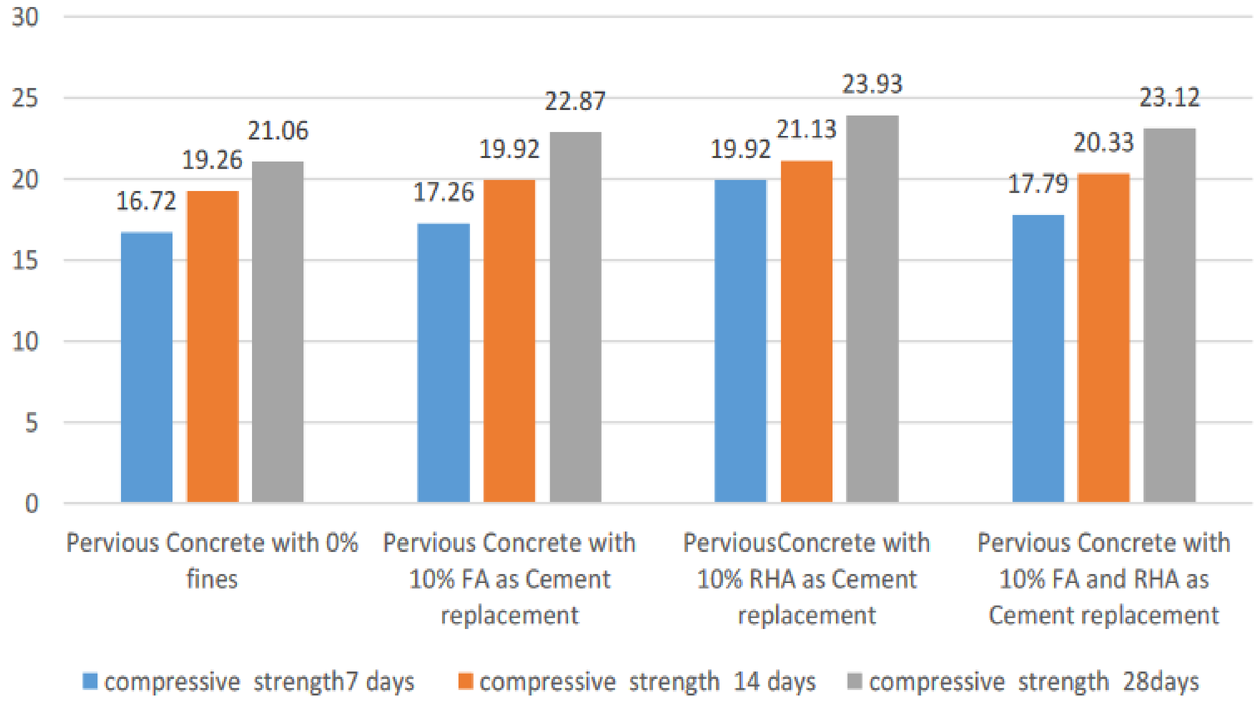

**Figure 4.12: Graph of Age of concrete Vs compressive strength value comparisons with the cementations materials.**

- The pervious concrete with 10% Rice husk ash as cement replacement gives highest value of compressive strength when compared to fly ash replacement and standard pervious concrete.
- The pervious concrete with mixture of fly ash and rice husk ash given least value of compressive strength. This may due to non-homogeneity between the two cementations materials.

### 4.6.2 Permeability Comparisons:

**Comparison of Permeability of Standard pervious Concrete and pervious Concrete with Little Amounts of Fine Aggregates:**

| S. No | Pervious Concretewith 0%Fines (cm/sec) | Pervious Concrete with8%Fine Aggregates (cm/sec) | Pervious Concrete with 10% Fine Aggregates (cm/sec) | Pervious Concretewith 10% Fly Ash as Cement Replacement (cm/sec) | Pervious Concrete with 10% RiceHusk AshasCement Replacement (cm/sec) |
|---|---|---|---|---|---|
| 1. | 1.02 | 0.76 | 0.49 | 0.59 | 0.53 |

**Table4.23:Co-efficient of Permeability of Pervious Concrete with Addition of different quantities of Fine Aggregates and Cementations Materials.**

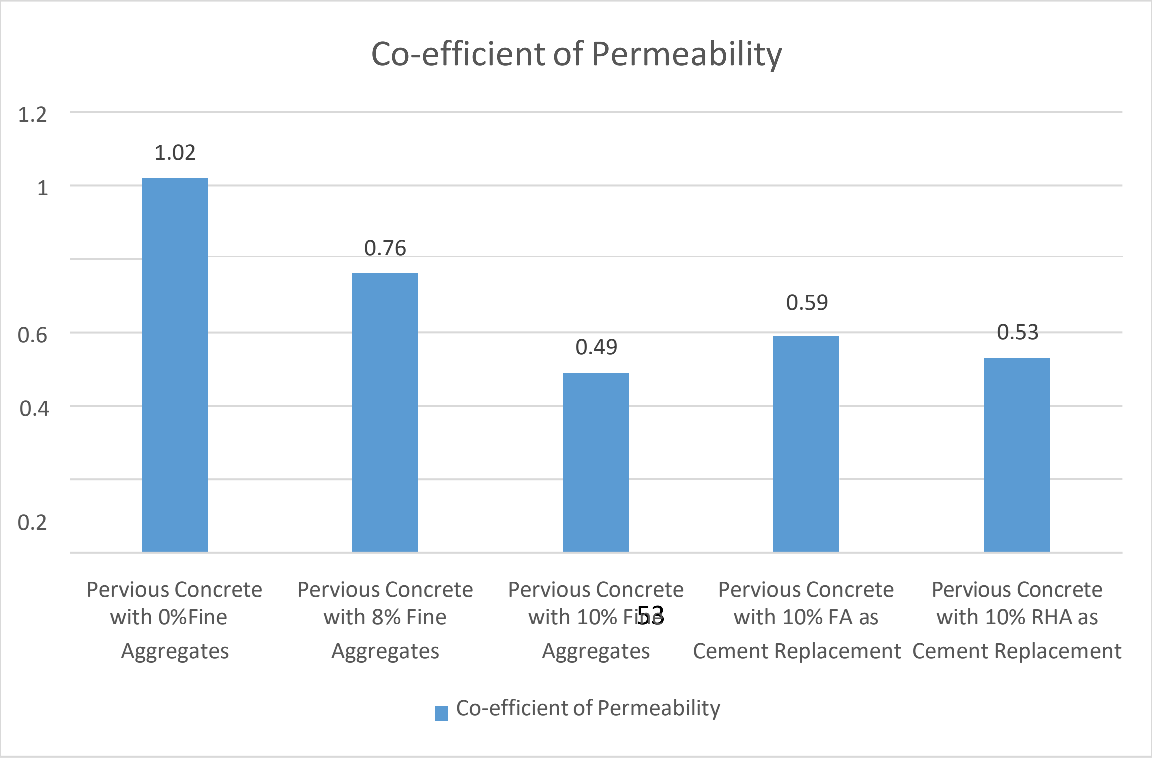

**Figure 4.13: Graph of co-efficient of permeability of pervious concrete with addition of different quantities of fine aggregates and cementations materials**

- The co-efficient of permeability is maximum of 1.02 cm/sec for standard pervious concrete with 0% fine aggregates and minimum of 0.49 cm/sec for pervious concrete with 10% fine aggregates.
- The pervious concrete with 10% fly ash has minimum co-efficient of permeability of 0.59 cm/sec and that of rice husk ash is 0.53 cm/sec. The reason for least values of permeability is due to fineness of cementations materials.

### 4.6.3 Unit Weight Comparison:

**Method-1:**

| S.No | Pervious Concrete (0%fines), kg/m³ | Pervious Concrete with 5% Fines, kg/m³ | Pervious Concrete with 6% Fines kg/m³, | Pervious Concrete with 7% fines, kg/m³ | Pervious Concrete with 8% fines, kg/m³ | Pervious Concrete with 9% fines, kg/m³ | Pervious Concrete with10% fines, kg/m³ |
|---|---|---|---|---|---|---|---|
| 1. | 2112.20 | 2056.30 | 2040.50 | 2025.87 | 1996.65 | 1986.26 | 1945.26 |

**Table4.24:Unit weight of Pervious Concrete with different quantities of Fine Aggregates**

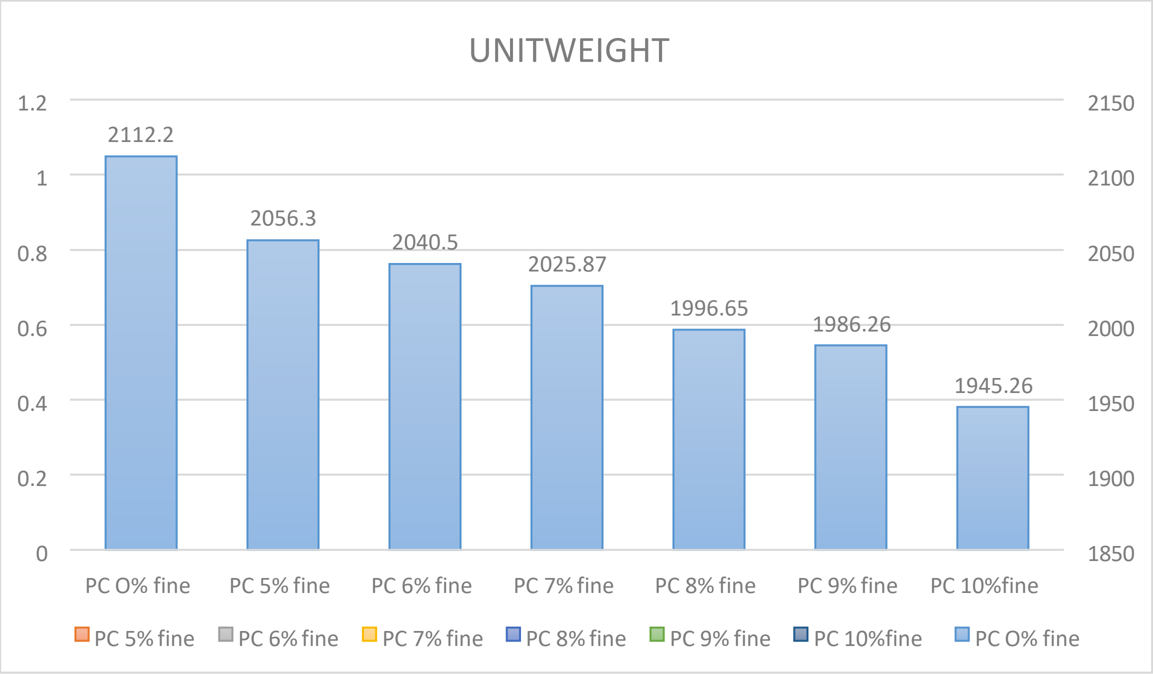

**Table4.24: Unit weight of Pervious Concrete with different quantities of Fine Aggregates**

## Method-2:

| S. No. | Pervious Concrete with 0% Fine Aggregates ,kg/m3 | Pervious Concrete with 10% FA as Cement replacement, Kg/m3 | Pervious Concrete with 10% RHA as Cement replacement, Kg/m3 | Pervious Concrete with 10% FA and RHA as Cement replacement, ,Kg/m3 |
|---|---|---|---|---|
| 1 | 2112.20 | 1941.92 | 1960.60 | 1931.85 |

**Table4.25:Unit weight of Pervious Concrete with Cementations Materials Replacement.**

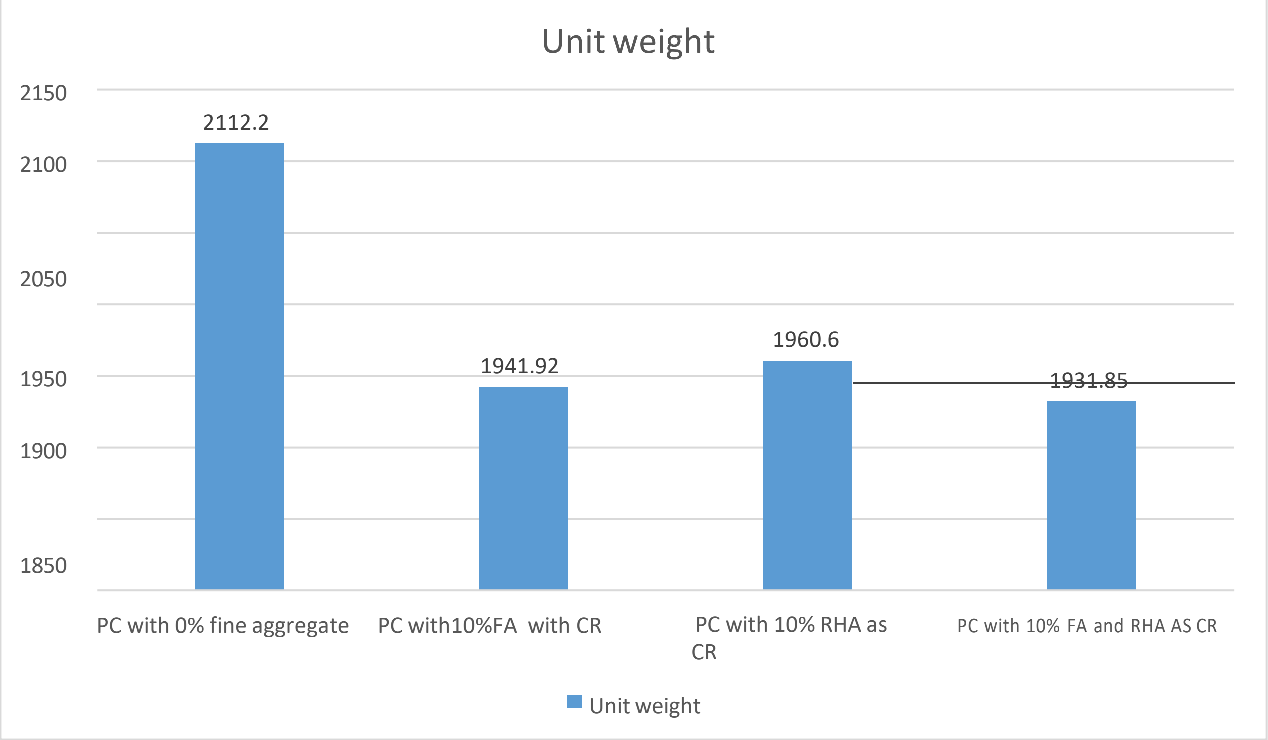

**Figure 4.15: Graph of unit weight of Pervious Concrete with cementitious materials replacement.**

- The unit weight of pervious concrete decreases with increase in quantity of fine aggregates as the volume is replaced by less weight fine particles.
- The unit weight is high for standard pervious concrete with 0% fine aggregates and low for pervious concrete with 10% fine aggregates in mix- 1.

- The unit weight of standard pervious concrete with 0% fines is high and pervious concrete with mixture of fly ash and rice husk ash is least in mix-2

**Cost Comparison:**

In general, initial costs for pervious concrete pavements are higher than those for conventional concrete or asphalt paving. But total costs can be substantially lower.

The material itself is only a little more expensive, but we tend to install pervious concrete thicker than regular concrete.

The reason is that we know the water is going to go through and saturate the sub grade underneath. So we have to design for a weaker sub grade. With a pervious parking lot, we may go 6 inches thick versus 4 inches for conventional concrete.

When we compare overall installation and life-cycle costs, pervious concrete is the clear winner. For parking lot owners, pervious concrete is a sustainable product that actually saves them money. It ends up being less expensive than a conventional parking lot.

The possible reasons are mentioned below

- **Lower installation costs**

According to the Centre for Watershed Protection, installing traditional curbs, gutters, storm drain inlets, piping, and retention basins can cost two to three times more than low-impact strategies for handling water runoff, such as pervious concrete.

Projects that use pervious concrete typically don't need storm sewer ties-ins, which eliminates the cost of installing underground piping and storm drains. Grading requirements for the pavement are also reduced because there is no need to slope the parking area to storm drains.

- **Permits the use of existing sewer systems**

Pervious concrete may also reduce the need for municipalities to increase the size of existing storm sewer systems to accommodate new residential and commercial developments.

Cities love pervious concrete because it reduces the need to rebuild storm sewer systems when new developments go up (Youngs.)

- **Increased land utilization**

Because a pervious concrete pavement doubles as a storm water management system, there is no need to purchase additional land for installing large retention ponds and other water-retention and filtering systems.

That means developers and property owners can use land more efficiently and maximize the return on their investment.

- Lower life-cycle costs

Pervious concrete is a sustainable paving material, with a life expectancy equal to that of regular concrete. Most parking areas, when properly constructed, will last 20 to 40 years, according to the Southern California Ready Mixed Concrete Association.

For the cost comparison nominal thickness of Conventional Concrete considered is 150mm whereas nominal thickness of pervious Concrete considered is 250mm. Also 30% wastage of aggregates is considered while calculating the cost for pervious concrete. This wastage can be reduced by using special crushing equipment which will be used to obtain the narrowly crushed aggregates. This will help in reducing the cost of pervious Concrete to Rs. 1000 per sq.ft.

| S.No | Type of Pavement | Rate (Rs/sq.ft) | Perviousness | Remarks |
|---|---|---|---|---|
| 1 | Conventional Concrete | 1400 | Impermeable | Drainage is required |
| 2 | Pervious Concrete | 1200 | Permeable | Drainage is not required |

**Table4.26: Cost Comparison between Conventional Concrete and Pervious Concrete**

From above Table, it can be shown that the difference between costs of Conventional Concrete and pervious Concrete is very small. In the above table rates are calculated considering only materials and their costs. Since in pervious Concrete sand is not used or sometimes very small amount of sand is used pervious Concrete is economic as compared to Conventional Concrete in terms of materials.

By using pervious concrete for storm water management, we can reduce the cost of storm water management machineries like pumps, generator (for electricity). Hence it reduces the cost of the project and its infiltration rate is also very high, hence it reduces the time of infiltration also. It takes only few minutes to percolate all the water in soil and it avoids ponding of water on road in heavy rainy season.

But unlike Conventional Concrete, pervious Concrete needs special treatment while laying, compacting, curing and also it requires special maintenance for durability criteria. It also requires special equipment's and sometimes it may be required to use geo-synthetic material. This makes pervious Concrete uneconomic in terms of operational costs. When Conventional Concrete is compared to Pervious Concrete based on criteria of cost, and other properties such as durability, maintenance, and long term savings, pervious Concrete is slightly on the lower side of the Conventional Concrete.

The important observations in our project work are as follows.

- The addition of fine aggregates in the small quantities of total coarse aggregates and replacement of cementitious materials like fly ash and rice husk ash has increased the compressive strength of pervious concrete in our project.
- The addition of fine aggregates in the small quantities of total coarse aggregates and replacement of cementitious materials like fly ash and rice husk ash has decreased the permeability property of pervious concrete in our project.
- The maximum compressive strength of pervious concrete is attained when 8% of fine aggregates of total coarse aggregates added to standard pervious concrete which has the value of 23.45 MPa after 28 days.
- Beyond 8% of fines, the value of compressive strength begins to fall due to increase in volume of fines in the place of coarse aggregates.
- The compressive of strength of pervious concrete has 22.45 MPa when rice husk ashis replaced by 10% of cement. It is higher than the standard pervious concrete without any replacement of 21.06 MPa after 28 days.
- The maximum amount of co-efficient of permeability of 1.02cm/sec has occurred for standard pervious concrete with 0% fines.
- The co-efficient of permeability is decreased to a minimum of 0.49cm/sec when 10% of fines are added to standard pervious concrete.
- The replacement of cement by rice husk ashby 10% has also decreased co-efficient of permeability to 0.53cm/sec.
- The addition of 10% fine aggregates in the total coarse aggregate quantity gave least value of co-efficient of permeability due to the reduction in voids as the volume of fines increased.

# Chapter-5

# CONCLUSIONS AND SCOPE FOR FUTURE WORK

## Chapter-5

## CONCLUSIONS AND SCOPE FOR FUTURE WORK

### 5.1 Conclusions:

- The size of coarse aggregates, water to cement ratio and aggregate to cement ratio plays a crucial role in strength of pervious concrete.
- The void ratio and unit weight are two important parameters of pervious concrete in the context of mix design.
- The compressive strength and co-efficient of permeability of pervious concrete are inversely proportional to each other up to addition of 8% of fines.
- Among the two methods of increasing compressive strength of pervious concrete, the addition of fines has given more value when compared to replacement of cementitious materials.
- The addition of fines and replacement of Cementitious will reduce the permeability capacity of pervious concrete.
- The compressive strength of pervious concrete is increased by 4.36% when 5% fine aggregates were added to the standard pervious concrete. [Ref.Table:4.7]
- The compressive strength of pervious concrete is increased by 6.69% when 6% fine aggregates were added to the standard pervious concrete. [Ref.Table:4.8]
- The compressive strength of pervious concrete is increased by 12.96% when 7% fine aggregates were added to the standard pervious concrete. [Ref.Table:4.9]
- The compressive strength of pervious concrete is increased by a maximum of 14.57% when 8% fines were added to standard pervious concrete. [Ref.Table:4.10]
- The compressive strength of pervious concrete is increased by 11.44% when 9% fine aggregates were added to the standard pervious concrete. [Ref.Table:4.11]

- The compressive strength of pervious concrete is increased by 8.59% when 10% fine aggregates were added to the standard pervious concrete. [Ref.Table:4.12]
- The compressive strength of pervious concrete is increased by 8.59% when 10% fly ash was replaced in the place of cement. [Ref.Table:4.13]
- The compressive strength of pervious concrete is increased by 13.62% when 10% Rice Husk Ash was replaced in the place of cement. [Ref.Table:4.14]
- The compressive strength of pervious concrete is increased by 9.78% when 5% fly ash and 5% Rice Husk Ash was replaced in the place of cement. [Ref.Table:4.15]
- The coefficient of permeability is decreased by 22.54% when 8% fines are added to standard pervious concrete. [Ref.Table:4.17]
- The coefficient of permeability is decreased by 51.96% when 10% fines are added to standard pervious concrete. [Ref.Table:4.18]
- The coefficient of permeability is decreased by 42.15% when 10% cement is replaced by Fly ash in standard pervious concrete. [Ref.Table:4.19]
- The coefficient of permeability is decreased by 48.03% when 10% cement is replaced by Rice Husk ash in standard pervious concrete. [Ref.Table:4.20]

Hence it is recommended that addition of 8% fine aggregates to the pervious concrete will satisfy both the compressive strength and permeability of pervious concrete.

## 5.2 Scope for Future Work:

In the past due to the scarcity of cement, the pervious concrete has been used extensively.

The pervious concrete has lost its importance after successful production of cement in large quantities.

But now-a-days, the usage pervious concrete has gained its popularity due to many advantages.

The urban areas all over the world have become CONCRETE JUNGLES. The discharge of storm water is very difficult problem in the present conditions.

By using the pervious concrete we can able to recharge the groundwater table and the storm water disposal can also be done.

So, in future to tackle aforesaid problems and to protect people from flood prone areas, the pervious concrete is one effective solution.

## 5.3 PERVIOUSCONCRETE-INDIAN SCENARIO:

Pervious concrete can be successfully used in India in applications such as parking lots, drive ways, gullies or sidewalks, road platforms etc., over the next 20 years, there is expected to be a significant amount of housing construction in India. The around the apartments, houses and the compound can be made with pervious concrete.

Massive urban mitigation in Indian cities is causing the ground water to go much deeper and is causing water shortages. For example, in states like Tamilnadu residents commonly pay for water delivered and it is not uncommon to receive water only for a few days of a week in many parts of the country. Flooding and extended water-logging in urban areas is common since all the barren land which could not hold the rain water are being systematically converted into valuable real estate with a result that impervious surfaces such as roads, roof tops, parking lots are covering the natural vegetation. It is indeed ironical that even the world's wettest place CHERRAPUNJI suffers drought while the monsoons brings flooding. Further, the rain water that falls on the concrete and asphalt surface tend to carry a high level of pollution and this pollution ends up in our water ways ultimately. The use of pervious concrete can help alleviate the damage of all of these ill effects. Another significant advantage of India as compared to western countries is the significantly lower cost of the labour. Much of the pervious concrete construction is manual and can be done without heavy equipment and therefore, pervious concrete can be placed at a lower cost even in the rural areas.

A caution is though is the highest prevalence of air-borne dust in India that could lead to clogging of the pervious concrete. Pervious concrete can function with no maintenance with some level of clogging. Nevertheless, frequent preventative maintenance is recommended. In apartment communities, resident associations could perhaps take this over and those applications would be the first ones to be attempted.

In future with increased urbanisation, diminishing ground water level and focus on sustainability, technologies such as pervious concrete are likely to become more popular in India as well as other countries.

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