"Study of Properties of Fresh and Hardened Pervious Concrete and its Durability"

A PROJECT

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BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

Mr.Abhilash Shukla
(Assistant Professor)

By

Tshering Yangki Moktan(121638)

Shimoni Thakur(121671)

to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT SOLAN – 173234

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CERTIFICATE

This is to certify that the work which is being presented in the project title "**Study of Properties of Fresh and Hardened Pervious concrete and its Durability**" in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by Tshering Yangki Moktan and Shimoni Thakur during a period from July, 2015 to June, 2016 under the supervision of Mr.Abhilash Shukla (Assistant Professor), of Civil Engineering Department, Jaypee University of Information Technology, Waknaghat. The above statement made is correct to the best of my knowledge.

Date:

Dr. Ashok Kumar Gupta	Mr. Abhilash Shukla
(Professor & Head of Department)	(Assistant Professor)
Civil Engineering Department	Civil Engineering Department
JUIT, Waknaghat	JUIT, Waknaghat.

External examiner.

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LIST OF ABBREVIATIONS:

SCM	Supplementary cementitious material
PPC	Polymer modified pervious concrete
SF	Silica fume
SP	Super plasticizers
Mpa	Mega Pascal
SPC	Supplementary modified pervious concrete
PCC	Pervious cement concrete
CS	Crushed stone
RS	River sand
SHA	State highway administration
Kg	Kilo Gram
M	Meter
N	Newton
mm	Millimeter

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ABSTRACT

The main objective of the project was to determine the compressive strength, durability and the properties of the pervious concrete keeping in mind of the materials used in the preparation of the concrete mix. Finding the correct mix proportion for the making of the pervious concrete is an important factor to be considered.

Firstly, we determined the materials used and the mix design of pervious concretes per IS 10262-2009 for the mix proportion to calculate its compressive strength of not less than 25 MPa. The aggregates that we have used are single sized angular aggregates with different sizes of aggregate. We also made sure that the aggregates were washed thoroughly until all the sand particles were removed. Aggregate tests like Impact test, Los Angeles abrasion test, Crushing Value test, specific gravity test and water absorption test were done.

Cubes of 10*10*10 cm cubes were being casted. Before mixing the concrete, proper dry mixing of cement and aggregate was done to get a fine even mix before the water was added.

The moulds were fixed properly closing all the joints tightly and leaving no space in between in order to prevent bleeding of concrete. The concrete was casted and kept for 24 hours. Then the concrete was de-moulded after 24 hours.

After 7 days and 28 days of curing, the concretes were tested for compressive strength.

Infiltration rate was found using ASTMc1701 for both first and second trial pervious concretes. An infiltration ring was temporarily sealed over the surface of pervious concrete. We used the cello tape as the infiltration ring since our cubes were small. A given mass of water was poured into the ring and the time of the water to infiltrate is noted down. Then the infiltration rate was calculated.

Fresh properties of pervious concrete like compaction factor test and slump test were conducted and compared with the normal concrete.

We also focused on increasing compressive strength by using different aggregates and also determine durability properties by performing acid attack test and sulphate attack test and comparing its results.

We also compared the pervious concrete with nominal concrete in terms of strength, durability, cost, permeability, density, shrinkage and physical appearanc

CHAPTER 1: INTRODUCTION

1.1 General

Concrete is a composite material composed of aggregate bonded together with a fluid cement which hardens over time. Most use of the term "concrete" refers to Portland cement concrete or to concretes made with other hydraulic cement. However, road surfaces are also a type of concrete, "asphaltic concrete", where the cement material is bitumen.

In Portland cement concrete (and other hydraulic cement concretes), when the aggregate is mixed together with the dry cement and water, they form a fluid mass that is easily molded into shape. The cement reacts chemically with the water and other ingredients to form a hard matrix which binds all the materials together into a durable stone-like material that has many uses. Often, additives (such as pozzolans or super plasticizers) are included in the mixture to improve the physical properties of the wet mix or the finished material. Most concrete is poured with reinforcing materials embedded to provide tensile strength, yielding reinforced concrete.

There are many types of cement available, created by varying the proportions of the main ingredients that is cement, aggregates and water. In this way or by substitution for the cementitious and aggregate phases, the finished product can be tailored to its application with varying strength, density, or chemical and thermal resistance properties.

Concrete production is the process of mixing together the various ingredients—water, aggregate, cement, and any additives—to produce concrete. Concrete production is time-sensitive. Once the ingredients are mixed, workers must put the concrete in place before it hardens.

Workability is the ability of a fresh (plastic) concrete mix to fill the form/mold properly with the desired work (vibration) and without reducing the concrete's quality. Workability depends on water content, aggregate (shape and size distribution), cementitious content and age (level of hydration) and can be modified by adding chemical admixtures, like super plasticizer. Raising the water content or adding chemical admixtures increases concrete workability.

1.2 Pervious concrete

The term “pervious concrete” typically describes a zero slump, open-graded material consisting of portland cement, coarse aggregate, little or no fine aggregate, admixtures and water. Pervious concrete is a mixture of gravel or stone, cement, water and little or no sand which creates an open cell structure that allows water and air to pass through it

It is also called as porous concrete, permeable concrete, no fines concrete and porous pavement and it is a special type of concrete with a high porosity used for concrete flatwork applications that allows water from precipitation and other sources to pass directly through, thereby reducing the runoff from a site and allowing groundwater recharge.

The combination of these ingredients will produce a hardened material with connected pores, ranging in size from 2 to 8 mm that allow water to pass through easily.

The voids can range from 18 to 35% with compressive strengths of 10 to 30MPa. The infiltration rate of pervious concrete will fall into the range 500 to 2000 inch/hour. Addition of small amounts of fine aggregates will gradually reduces the void content and increase the strength, which may be desirable in certain situations. This material is sensitive to changes in water content, so field adjustment of fresh mixture is usually necessary. The correct quantity of water in the concrete is critical. Too much water will cause segregation, and too little water will lead to balling in the mixer and very slow mixer unloading.

Figure 1.1 water passing through a Pervious concrete

1.2.1 Materials and mix proportion for Pervious concrete

The basic ingredients of pervious cement concrete mix are not very different from the conventional cement concrete mix, except in the proportion of ingredients. The main ingredients are cement, water, coarse aggregate and if required, admixtures for strength development and durability.

Pervious concrete is a mixture of a single-size coarse aggregate (9 to 19 mm) and cement combined at low water to cement ratios. The water cement ratio usually ranges from 0.26 to 0.4 and the ratio of aggregate to cement should range from 4:1 to 7.5:1

1.2.2 Applications of Pervious concrete

Figure 1.2 Pervious concrete pavements

Pervious concrete is traditionally used in parking areas, areas with light traffic, residential streets, pedestrian walkways, and greenhouses.

It is an important application for sustainable construction and is one of many low impact development techniques used by builders to protect water quality.

Pervious Concrete is used as a Road pavement, Low-volume pavements, Sidewalks and pathways, Residential roads and driveways, Parking lots, Noise barriers, Slope stabilization, Hydraulic structures, Swimming pool decks, Tennis courts.

1.3 History

It was not until 1923 when porous concrete resurfaced as a viable construction material. Use of porous concrete in Europe increased steadily, especially in the World War II era. Since porous concrete use less 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 Concern has been growing in recent years toward reducing the pollutants in water supplies and the environment. In 1960s, engineers realized that runoff from developed real estate had the potential to pollute surface and groundwater supplies. Further, as land is developed, runoff leaves the site in higher rates and volumes, leading to downstream flooding and bank erosion. Pervious concrete pavement reduces the impact of development by reducing runoff rates and protecting water supplies.

1.4 Advantages of Pervious concrete

1. The rainwater can quickly filter into ground, so the groundwater resources can renew in time. As the pavement is air permeable and water permeable, the soil underneath can be kept wet.

2. The pervious concrete pavement can absorb the noise of vehicles, which creates quiet and comfortable environment.

3. In rainy days, the pervious concrete pavement has no plash on the surface and does not glisten at night. This improves the comfort and safety of drivers.

4. The pervious concrete pavement materials have holes that can cumulate heat. Such pavement can adjust the temperature and humidity of the Earth's surface and eliminates the phenomenon of hot island in cities.

5. The pervious concrete pavement materials have holes that can cumulate heat. Such pavement can adjust the temperature and humidity of the Earth's surface and eliminates the phenomenon of hot island in cities.

1.5 Placing of Pervious concrete

An experienced installer is vital to success of pervious concrete pavements as with any concrete pavement, proper sub grade preparation is important. The sub grade should be properly compacted to provide a uniform and stable surface. When pervious pavement is placed directly on sandy soil it is recommended to compact the sub grade to 92 to 96% of the maximum density. With silty or clayey soils, the level of compaction will depends on specifics of pavement design and a layer open graded stone may have to be placed over soil.

1.6 Cement

The cement we used was Ordinary Portland Cement of 43 grade. The cement was pre-hydrated and thus lumps were present. Due to cold temperature cement did not gain its strength.

1.7 Aggregate

Different sizes of aggregates are used for making the pervious concrete samples. For first type of sample aggregates size used are 20 mm and second type of sample the aggregates used are 12.5 mm pass and 10 mm retained. Oven dried aggregates are being used having impact value as 20.95% and crushing value as 28.75 % with specific gravity of 2.5 and water absorption rate of 0.627% .

CHAPTER 2: LITERATURE REVIEW

2.1 Pervious concrete pavement performance in field applications and laboratory testing by Vimy Henderson, (2010)[1].

Description: The Cement Association of Canada, the Centre for Pavement and Transportation

Technology (CPATT) have partnered to carry out the laboratory and field project to evaluate the performance of pervious concrete pavement in the Canadian freeze-thaw climate to develop a design, maintenance guide for the use of pervious concrete pavement.

Field test-Test areas like parking lots and driveways are constructed to demonstrate the behavior of pervious concrete pavement in low volume applications. They are monitored regularly for changes in permeability.

The laboratory test-it involves accelerated freeze-thaw cycling of multiple pervious concrete slabs. Various winter maintenance techniques are performed and changes in permeability are monitored.

The performance of the slabs in the laboratory and field sites will be compared.

Conclusion: The permeability data from the field sites indicates that performance is high in areas used for static traffic rather than areas with excessive traffic movement.

The common occurrence of aggregate fracturing indicates that a strong aggregates or a different paving material should be placed in areas of repeated high loading.

The laboratory research indicated that the maintenance should be considered before winters to avoid water being trapped in debris on the surface and causing raveling of slabs. The results indicate that the use of salt solutions on pervious concrete pavement decreased the permeability. Loading of pervious concrete with sand material generally decreases the permeability.

2.2 Pervious concrete: new era for rural road pavement by Prof. Darshan S. Shah. (2013)[2]

Description: It focuses on Pervious concrete for rural road pavement due to the increase in the problems such as erosion, floods, ground water level depletion and pollution of rivers. Pervious concrete offers the inherent durability and retains storm water runoff by capturing rainwater in a network of voids and allowing it to percolate into the underlying soil.

It focuses on benefits like reducing the storm water runoff, eliminating the need for detention ponds and mitigating the surface runoff and replenishes the aquifers and water table.

It also gives its application such as Low-volume pavements Sidewalks, pathways Residential roads and Parking lots, Hydraulic structures and Swimming pool decks.

It gives the factors to be considered when designing and the guidelines for the installation of pervious concrete.

Conclusion: Pervious concrete pavement in rural areas is becoming more suitable to meet their requirement such as to reduce the storm water runoff, to increase the ground water level, to eliminate the costly storm water management practices. we concluded that there is a considerable saving in amount. Pervious concrete is extensively used worldwide because of their environmental benefits, hydraulic and durability properties.

2.3 Strength, and fracture of Pervious concrete by Yu Chen. (2013)[3]

Description: In the present study, strength and fracture toughness of two types of pervious concrete, supplementary cementitious material (SCM)-modified pervious concrete (SPC) and polymer-modified pervious concrete (PPC), are investigated. The results indicate that high strength pervious concrete (32–46)MPa at 28 days depending upon the porosity) can be achieved through both SCM modification using silica fume (SF) and super plasticizer (SP), and polymer-modification, using polymer SJ-601. For both SPC and PPC, porosity significantly affects compressive strength, but it has little effect on the rate of strength development. Flexural strength of pervious concrete is more sensitive to porosity than compressive strength. Pervious concrete has more significant size effect than conventional concrete.PPC demonstrates much higher fracture toughness and far longer fatigue life than SPC at any stress level.

Conclusion: For both SPC and PPC, porosity significantly affects compressive strength of pervious concrete, but it has little effect on the rate of strength development.SPC gains compressive strength rapidly at early ages, while its strength increments are rather low after 28 days. Differently, PPC gains strength slowly at early ages, but its development accelerates at later Ages.PPC has both higher flexural strength and higher flexural-to compressive strength than SPC at the same porosity level at 28 days. The flexural-to compressive strength ratio of both PPC and SPC decrease with increasing porosity, indicating that flexural strength is more sensitive to porosity than compressive strength.

2.4 Pervious Concrete-Over View By Karthik H. Obla. (2010)[4]

Description: It focuses on the properties of pervious concrete such as void content(18 to 35%),slump(20 to 50mm),compressive strength(3.44 to 27.5 MP and flexural strength(1.034 to 3.79 MPa).

It also gives the advantages of pervious concrete. It describes the relationship between compressive strength and void content, infiltration rate and void content, compressive strength and infiltration rate. Water/cement ratio of 0.26 to 0.4 will give the best aggregate coasting and stability.

t also explains about the design of pervious concrete such that it support traffic load and also manage storm water by selecting proper material , proper thickness and characteristics.

It also focuses on proper construction and the sub grade below the concrete should be proper and prepared well and also the soil present below for infiltration.

Conclusion: Other than reducing surface runoff, it naturally filters storm water and reduces pollutants. Due to its light color, pervious concrete is used as pathways as it provides lights at night.

If the concrete density is high, compressive strength also increases but the infiltration rate decreases.

Thickness of pervious concrete used over an aggregate base is 5 to 6 inch but 8 to 12 inch for heavier load traffics.

The sub grade should be properly compacted to provide uniform and stable surface. The level of compaction is typically 90%.

2.5 Use of Pervious concrete in construction of pavement for improving their performance by Mr. V. R. Patil (2010)[5]

Description: The main objective of this investigation is to develop a strong and durable pervious cement concrete (PCC) mix using different types of fine aggregates varying the quantity of fine aggregates..

The percentage of fine aggregates used in PCC mix is 15 per cent. The properties of PCC mixes investigated are compressive strength, flexural strength, abrasion resistance, permeability, and clogging potential.

Attempts were made to improve the 28-day flexural strength of the pervious concrete mixes using different additives like silica fume, keeping the permeability factor in mind.

Conclusion: After identification of problem and setting the objectives of the research, the research methodology has carefully design to achieve these objectives like-

-Collection and study of literature pertaining to the dissertation work.

-Determine the engineering properties of pervious concrete and compare them with conventional concrete.

-Cast various trial mixes with varying percentages of pervious concrete and compare for the compressive strength.

-Prepare test samples with the percentage value and test these samples for the various pavements properties.

2.6 Development of Pervious concrete by Yukari Aoki (2009)[6]

Description: The main objectives of this study are to:

1. Investigate the properties of pervious concrete with and without fly ash.

2.To determine water permeability of pervious concrete and mortar.
3.Develop pervious mortar suitable for pavement application.
4.Investigate the performance of a pervious concrete and pervious mortar combinative layer as a pavement system.

Conclusion: Pervious concrete has high water permeability due the presence of interconnected air voids. The presence of high porosity relative to conventional concrete makes the pervious concrete to become lightweight concrete with limited compressive strength. However, pervious concrete has been significantly popular for a few decades due to its potential to reduce the incidence of flooding, and to assist in recharging the ground water level.

2.7 State highway administration (SHA) in the year (2013)[7]

Description: One of the objectives of this research was to develop a preliminary pervious concrete specification for Maryland conditions. The study utilized aggregates that are used in SHA projects and the durability studies that were conducted assumed Maryland weather conditions. Investigations were conducted to enhance the structural and durability characteristics of pervious concrete through the use of different admixtures. The admixtures include cellulose fibers, a delayed set modifier and a viscosity modifier. Pervious concrete specimens were tested for density, void content, compressive strength, split tensile strength, permeability, freeze-thaw durability, and abrasion resistance.

Conclusion: Although limited in its applications, pervious concrete has the potential to help mitigate many of the urban storm water quality issues. Lack of extensive research on pervious concrete has led to some misunderstanding and narrow focus on the use of pervious concrete. The study found that of the different admixtures tested, cellulose fibers had the largest impact in improving durability.

2.8 Objectives

- To prepare a mix design for pervious concrete according to IS-10262-2009(volume based method).
- To study the fresh and hardened concrete properties of pervious concrete and compare with the normal concrete.
- To check the durability of Pervious Concrete.

CHAPTER 3: PLANNING OF LABORATORY WORK

3.1 Aggregates

The aggregates that we have used are single sized angular aggregates of size 20mm and the aggregates passing from 12.5mm sieve and retaining on 10mm sieves. The aggregates were washed thoroughly until all the sand particles were removed. And it was oven dried for 4 hours till all the water was dried.

Aggregate tests like Impact test, Los Angeles abrasion test, Crushing Value test, specific gravity test and water absorption test were done.

3.2 Cement

The cement we used was of 43 grade Ordinary Portland Cement. Due to the pre-hydration of cement and the cold temperature, lumps were formed. And the lumps in the cement were broken by proper gauging before casting of pervious concrete.

3.3 Preparation of Concrete Mix

Cubes of 10*10*10 cm cubes were being casted.

Before mixing the concrete, proper dry mixing of cement and aggregate was done to get a fine even mix. Then the water was added and was mixed for 5 minutes till the wet concrete was properly mixed. Then the concrete was put into the mould in three layers each time tamping 25 times with the tamping rod.

3.4 Preparation of Moulds

The moulds were fixed properly closing all the joints tightly and leaving no space in between in order to prevent bleeding of concrete. And the mould was oiled from all the sides to decrease the friction between the mould and the concrete. The concrete was casted and kept for 24 hours. Then the concrete was de-moulded after 24 hours.

3.5 Calculation of Strength and Infiltration Rate of Pervious Concrete

After 7 days and 28 days of curing, the concretes were tested for compressive strength in compressive testing machines.

Infiltration rate was found using ASTMc1701 for both first and second trial pervious concretes. An infiltration ring was temporarily sealed over the surface of pervious concrete. We used the cello tape as the infiltration ring since our cubes were small A given mass of water was poured into the ring and the time of the water to infiltrate is noted down. Then the infiltration rate was calculated.

3.6 Determining of Fresh Properties of Pervious Concrete

Fresh properties of pervious concrete like compaction factor test and slump test were conducted and compared with the normal concrete.

3.7 Determination of Durability Properties.

We performed sulphate attack test.

- Firstly the solution was prepared which contained 5% dilution of sodium sulphate.
- The cubes that we casted were put into the container and closed from top.
- The cubes were kept in the container for 14 days.

Acid attack test was also performed.

- Firstly the solution was prepared which contained 5% dilution of sulphuric acid.
- The cubes that we casted were put into the container and closed from top.
- The cubes were kept in the container for 14 days.

CHAPTER 4: METHODOLOGY.

4.1 Preparing first mix design for pervious concrete of strength not less than 25MPa.

4.1.1 Stipulation and proportioning.

- Grade designation : M25
- Type of cement : Ordinary Portland cement.
- Maximum nominal size of coarse aggregates : 20 mm.
- Maximum nominal size of fine aggregates : 4.75mm
- Type of aggregate: Angular aggregates.
- Minimum cement content : 300 kg/m^3
- Maximum cement content : 450 kg/m^3
- Specific gravity of coarse aggregates : 2.55
- specific gravity of fine aggregates :2.55

4.1.2 Target mean strength.

$f'ck = fck + 1.65\ s$

Where,

f 'ck = Target mean strength,

fck = characteristics compressive strength, and

s = Standard deviation.

Table 1 Assumed Standard Deviation
(*Clauses* 3.2.1.2, A-3 *and* B-3)

Sl No. (1)	Grade of Concrete (2)	Assumed Standard Deviation N/mm^2 (3)
i)	M 10	3.5
ii)	M 15	
iii)	M 20	4.0
iv)	M 25	
v)	M 30	5.0
vi)	M 35	
vii)	M 40	
viii)	M 45	
ix)	M 50	
x)	M 55	

Table 4.1 Assumed standard deviation from IS: 10262-2009

From table 1 of IS: 10262-2009, s = 4 N/mm^2

Therefore f 'ck = 20 + 1.65 * 4 = 26.6 N/mm^2

4.1.3 Selection of water cement ratio

From Table 5 of IS: 456, maximum water-cement ratio is 0.4 for m 25,hence OK.

Table 5 Minimum Cement Content, Maximum Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size

(*Clauses* 6.1.2, 8.2.4.1 *and* 9.1.2)

Sl No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete	Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete
1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Mild	220	0.60	-	300	0.55	M 20
iii)	Moderate	240	0.60	M 15	300	0.50	M 25
iii)	Severe	250	0.50	M 20	320	0.45	M 30
iv)	Very severe	260	0.45	M 20	340	0.45	M 35
v)	Extreme	280	0.40	M 25	360	0.40	M 40

Table 4.2 Maximum water cement ratio and minimum grade of cement.

4.1.4 Selection of water content

From table 2 of IS: 10262-2009, maximum water content for 20 mm aggregates is 186 liter.

Table 2 Maximum Water Content per Cubic Metre of Concrete for Nominal Maximum Size of Aggregate

(*Clauses* 4.2, A-5 *and* B-5)

Sl No.	Nominal Maximum Size of Aggregate mm	Maximum Water Content [1)] kg
(1)	(2)	(3)
i)	10	208
ii)	20	186
iii)	40	165

Table 4.3 Maximum water content per cubic meter of concrete for nominal maximum size of aggregate.

4.1.5 Calculation of cement content.
Water-cement ratio = 0.4

Water content = 186 liter.

Cement content = $\frac{186}{0.4}$ = 465kg/m^3

Maximum cement content is 450 kg/m^3.Therefore, the amount of cement content used is 450kg/m^3.Hence OK.

4.1.6 Proportion of volume of fine aggregates and coarse aggregates
In Pervious concrete, volume of fine aggregates is less than 10% by weight of the total aggregates.

We took 3% by weight of the total aggregates, therefore, volume of fine aggregate = 0.03.

Volume of coarse aggregate is = 1 - 0.03 =0.97.

4.1.7 Mix calculations
The mix calculation per unit volume is as follows:

a) Volume of concrete = 1m^3

b) Volume of cement = $\frac{\text{mass of cement}}{\text{specific gravity of cement}} * \frac{1}{1000}$

$$= \frac{450}{3.15} * \frac{1}{1000} = 0.143 \text{ m}^3.$$

c) Volume of water = $\frac{\text{mass of water}}{\text{specific gravity of water}} * \frac{1}{1000}$

$= \frac{186}{1} * \frac{1}{1000}$

= 0.18 m^3.

d) Volume of all in aggregates = 1 - (0.143 + 0.18)

=0.677.

e) Mass of coarse aggregate = e * volume of coarse aggregates * specific gravity of coarse aggregates * 1000

= 0.677 * 0.97 * 2.55 * 1000 = 1674.5 kg

f) Mass of fine aggregate = e * volume of fine aggregates * specific gravity of fine aggregates * 1000

=0.677 * 0.03 * 2.55 * 1000 =51.79 kg

4.1.8 Mix proportion for first mix design of pervious concrete

Cement = 450 kg/m^3.

Water = 186 kg/m^3.

Coarse aggregate = 1674.5kg/m^3.

Fine aggregate = 51.79kg/m^3.

Volume for casting 3 cubes of 10cm *10cm *10cm size =$\frac{10*10*10*3}{10^6}$ = 0.003m^3.

Therefore,

Amount of cement for 0.003m^3 of concrete= 450*0.00 = 1.35 kg.

Amount of water for 0.003m^3 of concrete =186*0.003 = 0.558kg

Amount of coarse aggregate for 0.003m^3 of concrete = 1674.5*0.003 = 5kg.

Amount of fine aggregate for 0.003m^3 of concrete =51.79*0.003 = 0.15kg.

Aggregate to cement ratio = 4:1.

Water to cement ratio: 0.4

4.2 Casting of cubes of first trial mix design

Figure 4.1 Three cubes casted in 10*10*10 cm mould according to first mix design

Cubes of 10*10*10 cm cubes were being casted. The cement was properly gauged breaking all the lumps and the single sized angular aggregates were properly washed removing all the sand particles and were oven dried for 3 hours.

Before mixing the concrete, proper dry mixing of cement and aggregate was done to get a fine even mix, then the water was added and was mixed for 5 minutes till the wet concrete was properly mixed. Then the concrete was put into the mould in three layers each time tamping 25 times with the tamping rod.

The moulds were fixed properly closing all the joints tightly and leaving no space in between in order to prevent bleeding of concrete. And the mould was oiled from all the sides to ease decrease the friction between the mould and the concrete. The concrete was casted and kept for 24 hours.

Figure 4.2 Pervious concrete of 20 mm aggregate size after 24 hours.

Figure 4.3 Water passing through first trial pervious concrete and checking its permeability.

4.3 Preparing second mix design for pervious concrete of strength not less than 25MPa

4.3.1 Stipulation and proportioning

- Grade designation : M25
- Type of cement : Ordinary Portland cement.
- Maximum nominal size of coarse aggregate :12mm passing and 10mm retaining
- Type of aggregate : Angular aggregates.
- minimum cement content : 300 kg/m^3
- maximum cement content : 450 kg/m^3
- Specific gravity of coarse aggregates : 2.55

4.3.2 Target mean strength

f 'ck = fck + 1.65 s

Where,

f 'ck = Target mean strength,

fck = characteristics compressive strength, and

s = standard deviation.

Table 1 Assumed Standard Deviation
(*Clauses* 3.2.1.2, A-3 *and* B-3)

Sl No. (1)	Grade of Concrete (2)	Assumed Standard Deviation N/mm^2 (3)
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vi)	M 35	
vii)	M 40	
viii)	M 45	
ix)	M 50	
x)	M 55	

Table 4.1Assumed standard deviation from IS: 10262-2009

from table 1 of IS:10262-2009, s = 4 N/mm^2

Therefore f 'ck = 20 + 1.65 * 4 = 26.6 N/mm^2

4.3.3 Selection of water cement ratio

From first trial, water cement ratio was little higher. In second trial we decrease the water-cement ratio from 0.4 to 0.3 to make it more porous.

4.3.4 Selection of water content

From table 2 of IS 10262-2009, maximum water content for 20 mm aggregates is 186 liter. Since water content is also very high, we reduce water to 100 liter in our second trial.

4.3.5 Calculation of cement content

Water-cement ratio = 0.3

Water content = 100 liter

Cement content = $\frac{100}{0.30}$ = 333.3kg/m^3

Maximum cement content is 450 kg/m^3. Therefore, the amount of cement content used is 333.3 kg/m^3.Hence OK.

4.3.6 Proportion of volume of fine aggregates and coarse aggregates

In Pervious concrete, volume of fine aggregates is less than 10% by weight of the total aggregates.

We took no fine aggregates.

Volume of coarse aggregate is = 1

4.3.7 Mix calculations

The mix calculation per unit volume is as follows:

a) Volume of concrete = 1m^3

b) Volume of cement = $\frac{\text{mass of cement}}{\text{specific gravity of cement}} * \frac{1}{1000}$

$$= \frac{333.3}{3.15} * \frac{1}{1000} = 0.105 \text{ m}^3.$$

c) Volume of water = $\frac{\text{mass of water}}{\text{specific gravity of water}} * \frac{1}{1000}$

$= \frac{100}{1} * \frac{1}{1000}$

= 0.1 m^3.

d) Volume of all in aggregates = 1 - (0.105 + 0.1) =0.79.

e) Mass of coarse aggregate = e * volume of coarse aggregates * specific gravity of coarse aggregates * 1000

= 0.79 5* 1 * 2.55 * 1000 = 2027.25 kg.

4.3.8 Mix proportion for second mix design of pervious concrete
Cement = 333.3 kg/m^3.

Water = 100 kg/m^3.

Coarse aggregate = 2027.25kg/m^3.

Volume for casting 3 cubes of 10cm *10cm *10cm size =$\frac{10*10*10*3}{10^6}$ = 0.003m^3.

Therefore,

Amount of cement for 0.003m^3 of concrete= 333.3*0.003 = 1. kg.

Amount of water for 0.003m^3 of concrete =100*0.003 = 0.3kg

Amount of coarse aggregate for 0.003m^3 of concrete = 2027.25*0.003 = 6.08kg.

Aggregate to cement ratio = 6:1

Water-Cement ratio = 0.3

Figure 4.4 Demoulding of second trial pervious concrete.

Figure 4.5 Second trial pervious concrete of aggregate size 12 mm after demoulding .

Figure 4.6 Second trial pervious concrete below the tap of water to check its permeability.

The second pervious concrete was also made same as first pervious concrete but with different mix design. But the second pervious was seen more porous and was kept below the tap to check its infiltration. Hence the second trial pervious concrete was more porous with satisfying infiltration rate.

4.5 Determining the pervious concrete strength properties and infiltration rate

We will now be conducting various tests like compressive strength test and infiltration test and determining its results and we will be comparing its properties with normal concretes.

4.6 Durability test.

4.6.1 Sulphate attack test

Sulphate attack is a chemical breakdown mechanism where sulfate ions attack components of the cement paste. The compounds responsible for sulfate attack are water-soluble sulfate-containing salts, such as alkali-earth (calcium, magnesium) and alkali (sodium, potassium) sulfates that are capable of chemically reacting with components of concrete

Procedure

1. Firstly the solution was prepared which contained 5% dilution of sodium sulphate.
2. The cubes that we casted were put into the container and closed from top.
3. The cubes were kept in the container for 14 days.
4. The cubes were taken out from the container.
5. Finally the compressive strength was found for the cubes.

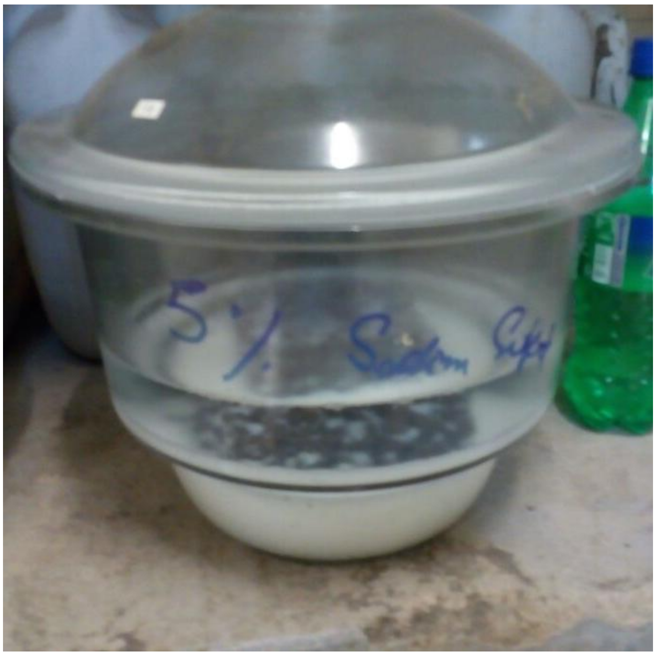

Figure 4.7 Sulphate attack test

4.6.2 Acid attack test

Acids attack concrete by dissolving both hydrated and un-hydrated cement compounds as well as calcareous aggregate. In most cases, the chemical reaction forms water-soluble calcium compounds, which are then leached away.

Procedure

1. Firstly the solution was prepared which contained 5% dilution of sulphuric acid.
2. The cubes that we casted were put into the container and closed from top.
3. The cubes were kept in the container for 14 days.
4. The cubes were taken out from the container.
5. Finally the compressive strength was found for the cubes.

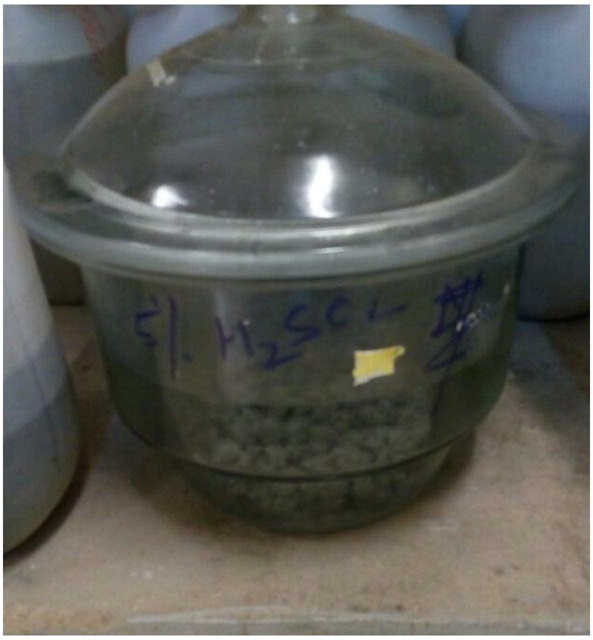

Figure 4.8 Sulphuric acid attack Test

CHAPTER 5: RESULTS AND DISCUSSION

5.1 Aggregates

5.1.1 Impact value of aggregates

Procedure

1. The test sample consists of aggregates passing 12.5 mm sieve and retaining on 10 mm sieve and dried in an oven for 4 hours at a temperature of 100-110 ^{o}C.
2. The aggregates are filled up to one-third full in the cylindrical measure and tamped 25 times with rounded end of a tamping rod
3. The rest of the cylindrical measure is filled by two layer and each layer being tamped 25 times.
4. The overflow of aggregate sample in a measuring cylinder up to 0.01 gram.
5. The aggregate from the cylindrical measure are carefully transformed into the cup which is firmly fixed in the position. Then it is tamped 25 times.
6. Aggregate impact value is expressed as the % of fines formed in terms of the total weight of the sample.

Observation.

S. No	Details of sample	Trial 1	Trial 2	Average
1	Total wt of aggregate sample filling the cylinder measure w1 gm.	400 gm	400 gm	400 gm
2	Weight of aggregate passing 2.36mm IS sieve w2 gm.	83.5	80.4	81.95
3	Weight of aggregate retained on 2.36 mm IS sieve after the test w3 gm.	316.5	319.6	318.9
4	Aggregate impact value (w2/w1)*100%	20.875	20.11	20.98

Table 5.1 Impact value observation table

Result:-The mean average impact value is 20.98%

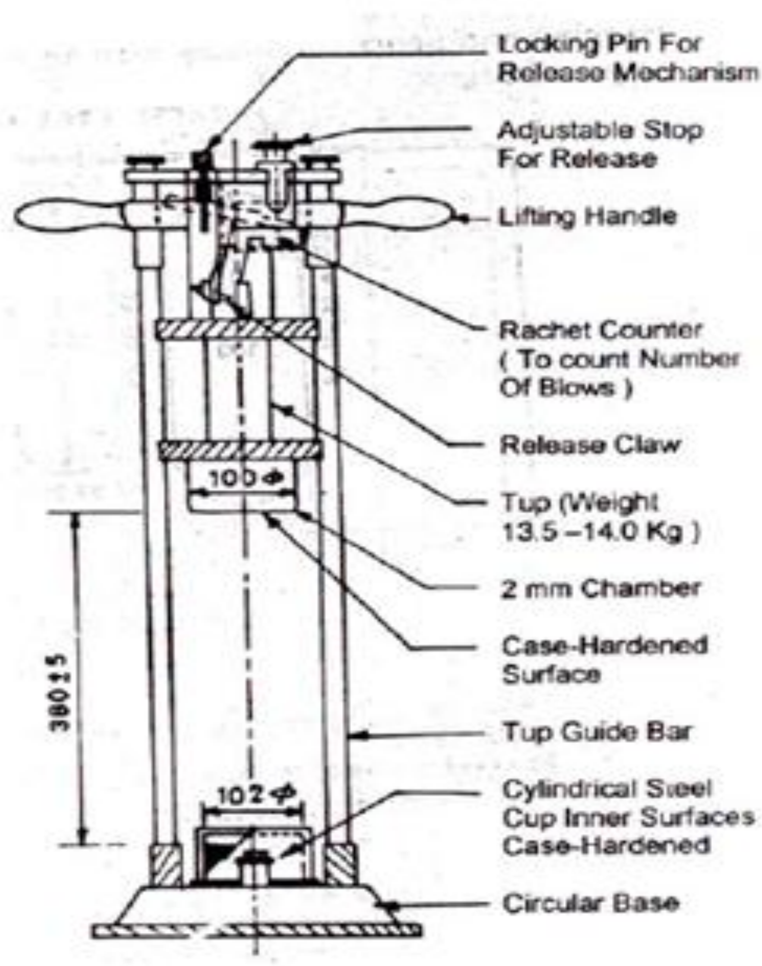

Figure 5.1 Impact Value Testing Machine

5.1.2 Crushing value of aggregate

Procedure

1. Aggregate passing 12.5 mm IS sieve and retained on 10 mm sieve is taken and dried. This aggregate filled in the cylindrical measure in three equal layers and each layer tamped 25 times by tamping rod.
2. Now, the test sample is weighed (w) and filled in the test cylinder in three equal layers and tamped each layer 25 times.
3. Now the plunger is placed on top of test specimen and whole apparatus is put in the compression testing machine.
4. Now the specimen is loaded to total load of 40 tonnes at the rate of 4 tonnes per min.
5. Now the test cylinder is removed from the compression machine and aggregate sieved through 2.30 mm sieve. The material passed through the 2.36 mm sieve is weighed .let the weight be w2 kg.

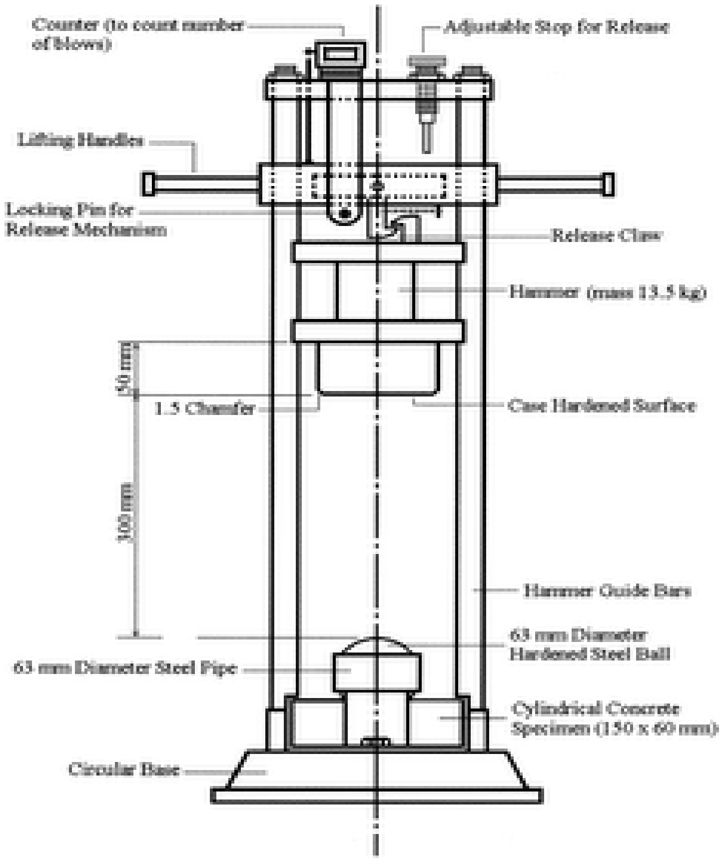

Figure 5.2 Crushing Value Testing Machine.

Observation.

Total weight of aggregate sample filling the cylindrical measure =2500 gm

Weight of aggregate passing 2.6 mm sieve =718 gm

Weight of aggregate retained on 2.36 mm sieve =1782 gm

Aggregate crushing value = (w2/w1)*100

= (718/2500)*100
= 28.75%

Result:-Aggregate crushing value is 28.75%

Test 2 with stronger aggregates

Observation

Total weight of aggregate sample filling the cylindrical measure =2500 gm

Weight of aggregate passing 2.6 mm sieve =725gm

Weight of aggregate retained on 2.36 mm sieve =1782 gm

Aggregate crushing value = (w2/w1)*100

= (725/2500)*100
= 29%

Result:-Aggregate crushing value is 29%

5.1.3 Los Angeles Abrasion value

Procedure:

1. Clean and dry aggregate sample confirming to one of the grading A to G is used for the test.
2. Aggregate weighing 5 kg for A, B, C or D and 10 kg for E, F and G grades may be taken as test specimen and placed in the cylinder.
3. The abrasion charge is also chosen in according with the table and placed in the cylinder of the machine and cover is fixed to make it tight.
4. Machine is rotated at speed of 30-33 rev per min.
5. Machine is rotated for 300 revolutions for grade A, B, C and D, for grades E, F and G it shall be 1000 revolutions.
6. After rev. Machine is stopped and material is discharged from the machine taking care to take out entire stone dust.
7. Using sieve of size larger than 1.70 mm of IS sieve, material is first separated into two parts and finer position is taken out and sieved further on a 1.70 mm IS sieve.
8. Let original weight of aggregate be w1, weight of aggregate retained be w2 gm.

Los Angeles abrasion value (%) = ((w1-w2)/w1)*100

Observation

Original weight of aggregate	Sample 2500 gm
Net weight of the aggregate	500 gm
Weight retained on 1.7 mm IS sieve	3548 gm
% wear=((w1-w2)/w1)*100	(1.459/500)*100 =29.02%

Table 5.2a Observation table for Los Angeles Abrasion test

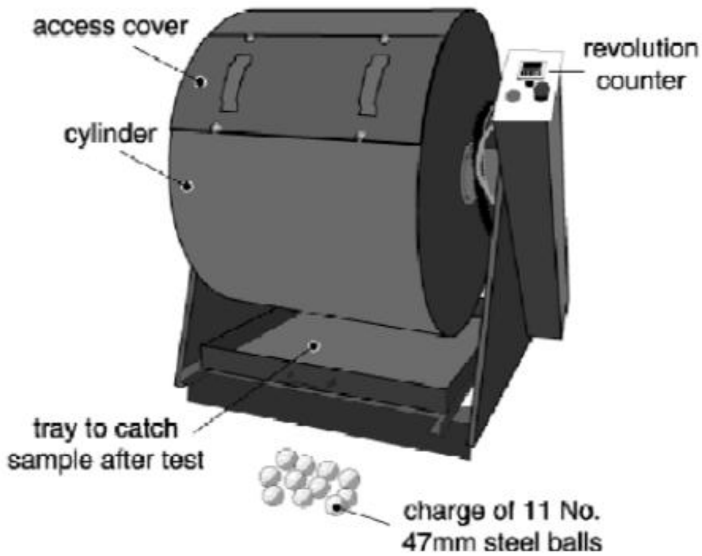

Figure 5.3 Los Angeles Abrasion testing machine.

Result:-The wear or Los Angeles Abrasion value = 29.02%.

OBSERVATION

Original weight of aggregate	Sample 2500 gm
Net weight of the aggregate	500 gm
Weight retained on 1.7 mm IS sieve	3548 gm
% wear=((w1-w2)/w1)*100	(1342/500)*100 =26.84%

Table 5.2b Observation Table for Los Angeles Abrasion test

Result:-The wear or Los Angeles Abrasion value = 26.84%.

5.1.4 Specific Gravity and water absorption of aggregate

Procedure.

1. Take w1 gm of aggregates.
2. Put the aggregates in the bucket and immerse them in water 2-3 minutes and weigh them while immersed in water.
3. Remove the aggregate from water, allow to drain for few minutes. Dry them using an absorbent cloth. Again weigh them with bucket.
4. Aggregate is then placed in shallow tray and kept in an oven maintained at a temperature of 110 degree centigrade for 24 hours.
5. It is then removed from the oven cooled in an airtight container and weighed.
6. Weigh the bucket in air (empty).

Figure 5.4 Density Bucket used for Testing.

Observation.

Weight of saturated aggregate in water with bucket = w1 gm
Weight of bucket suspended in water = w2 g
Weight of saturated aggregate =(Ws) g =(w1-w2) g
Weight of saturated, surface dry aggregate =w3 g
Weight of oven dried aggregates =w4 g

W1 =1500 g	W2 =520g
W3 =1605 g	W4 =1595 g
Ws =980 g	W3-Ws =675 g

Calculations.

Specific gravity

=(dry weight of aggregate/weight of equal volume of water)
=(W4/(W3-Ws))
=(1595/625)
=2.5

Water absorption

=((Ws-W4)/W4)*100
=(10/1595)*100
=0.627%

Result.

The value for specific gravity is 2.5 and water absorption value is 0.627%

5.2 Cement

5.2.1 Initial and final setting time of cement
Procedure.

1. Weigh 400 gm of cement.
2. 0.85P % water by weight of cement and mix it thoroughly where P is the nominal consistency of cement.
3. Fill the mould with cement paste and level off the cement surface with top of mould. The gauging time should not be less than 3 minutes and should not be more than 5 minutes.
4. Place the mould on the non porous plate under the needle (1mm sq)of apparatus.
5. Bring the needle in contact with the cement surface and release it.
6. Repeat the step until the needle fails to pierce the sample for about 5mm measured from the bottom of the mould, note down this time. It is the initial setting time.
7. Replace the needle by need annular attachment.
8. Bring the needle with attachment near the surface of cement and release it.
9. The cement shall be considered as finally set when leveling the attachment gently over the test block, the center needle makes an impression while the circular cutting edge of the attachment fails to do so.
10. Repeat the steps until surface so hard that the center needle does not pierce through the paste more than 0.5 mm.
11. The time taken is final setting time.

Observation .

Quantity of cement = 400 g

Normal consistency =35%

Initial setting time =45 minutes

Final setting time =6.35 hours

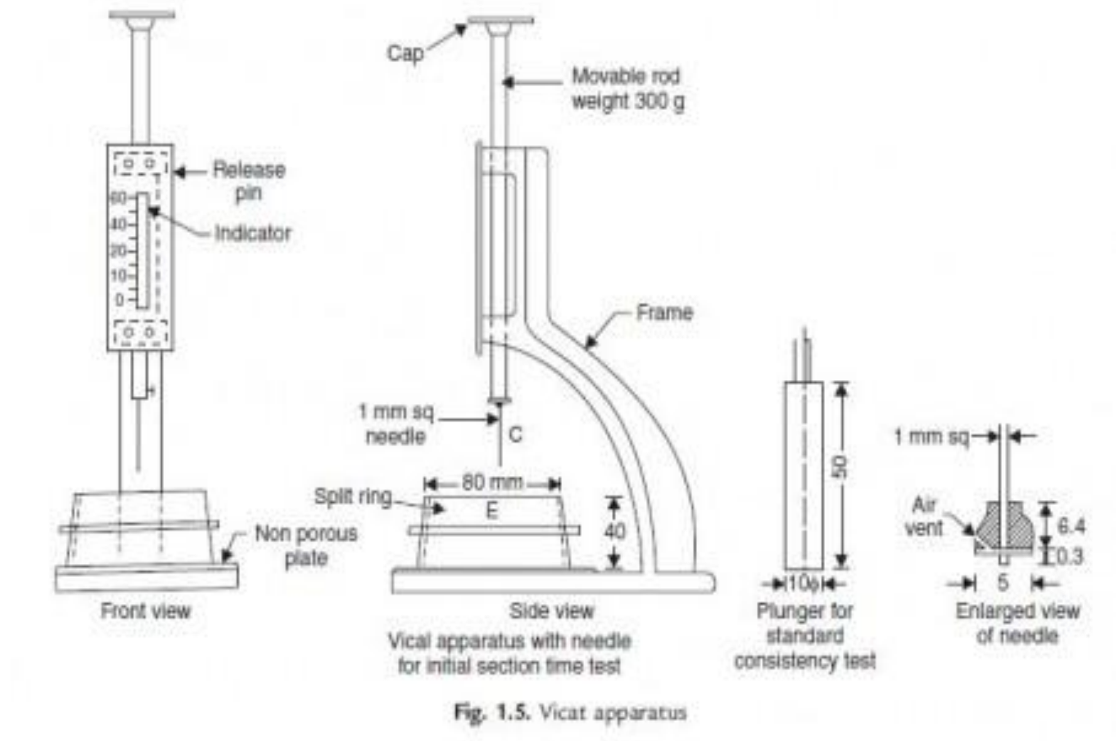

Figure 5.5 Vicat Apparatus

Calculations.

Quantity of water required =0.85*P*(weight of cement/100)

=0.85*35*4

=119 ml

Result:-The initial setting time of cement is 45 minutes and final setting time is 6.35 hours.

5.3 Compressive test results of Pervious concrete

Sample	Compressive Strength of seven days (MPa)	Compressive Strength of twenty eight days (MPa)
1	4.6	9
2	4.2	8.8
3	4	8.2

Table 5.3 First trial result.

Sample	Compressive Strength of seven days (MPa)	Compressive Strength of twenty eight days (MPa)
1	3.5	7.8
2	3.2	7.6
3	3.5	7.6

Table 5.4 Second trial result.

Sample	Compressive strength of seven days (MPa)	Compressive strength of twenty eight days (MPa)
1	5.82	14
2	6.0	14.2
3	5.91	14.2
4	5.74	14.4

Table 5.5 Compressive strength of pervious concrete with stronger aggregate

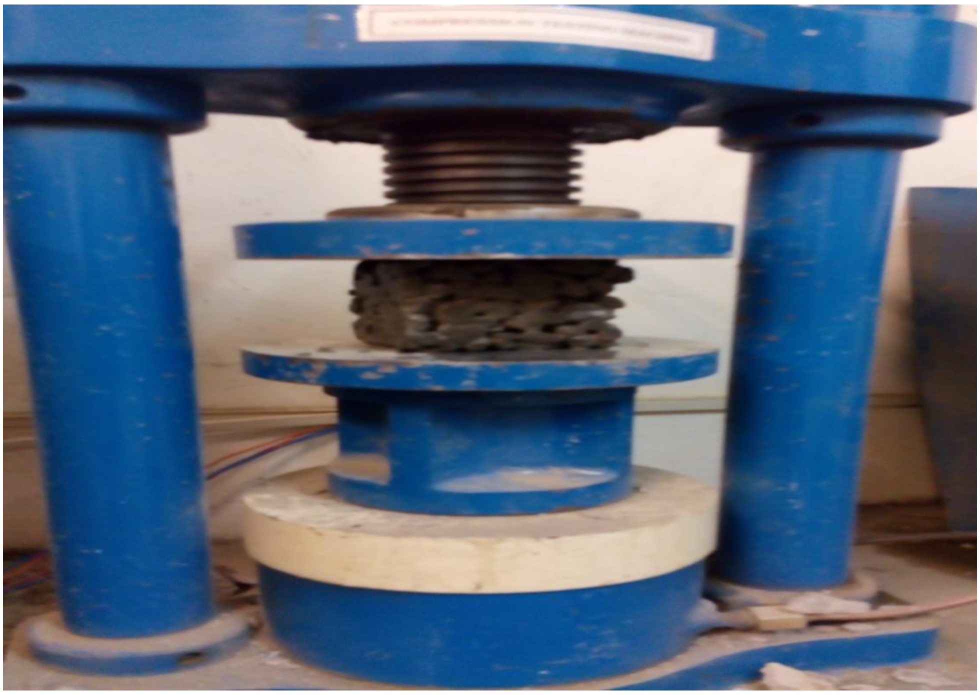

Figure 5.6 Pervious concrete under compressive testing machine.

5.4 Infiltration test of Pervious concrete

Aim: This test method is to determine the infiltration rate of pervious concrete according to ASTM c1701.

Apparatus used: infiltration ring, 2 liters container, water and timer.

Procedure: An infiltration ring is temporarily sealed over the surface of pervious concrete.

A given mass of water is poured into the ring.

The time of the water to infiltrate is noted down.

The infiltration rate is calculated according to this formula:

I: $\frac{KM}{D^2T}$, where,

I=Infiltration rate,

K=126870(constant),

D=ring diameter, and

T= time to infiltrate al the water.

Sample	Mass of water(lb)	Ring diameter(inch)	Time(second)	Infiltration Rate(in/hr)
1	4	3	72	783.14
2	4	3	83	679.35
3	4	3	78	722.9

Table 5.6 First trial infiltration test result.

Figure 5.7 Infiltration test onfirst trial pervious concrete.

Sample	Mass of water(lb)	Ring diameter(inch)	Time(second)	Infiltration Rate(in/hr)
1	4	3	32	1762.1
2	4	3	28	2013.8
3	4	3	37	1523.9

Table 5.7 Second trial infiltration test result.

5.4.1 Pervious concrete with stronger aggregates.

Sample	Mass of water(lb)	Ring diameter(inch)	Time(second)	Infiltration rate(inch/hour)
1	4	3	75	751.8
2	4	3	87	648.1
3	4	3	83	679.35
4	4	3	81	696.13

Table 5.8 Infiltration test results of pervious concrete with stronger aggregates

Fig 5.8 Infiltration test on Pervious concrete.

5.5 Durability.

5.5.1 Sulphate attack results.

Weight of the cube	2.35
Colour	Dark gray (same as before)
Compressive strength	3 MPa
Difference in size	No increase or decrease in size but small cracks.

5.5.2 Acid attack results

Weight of the cube	1.8
Colour	Light gray
Compressive strength	1.5 MPa
Difference in size	The size of the cube was same but few aggregates from the surface of the cube were segregated.

Figure 5.9 Cubes after sulphate attack and acid attack tests.

Figure 5.10 Acid solution after taking out the concrete cubes after 14 days.

5.6 Graph showing compressive strength results between normal and pervious concrete

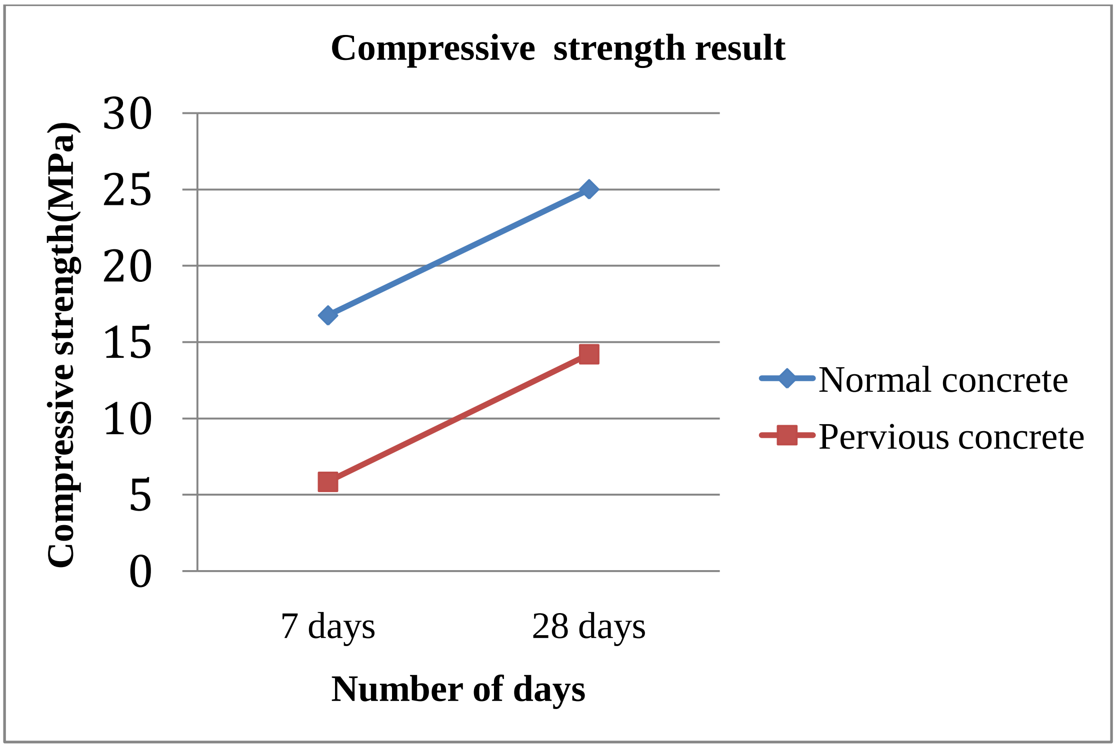

Figure 5.11 Compressive strength results between Normal and Pervious concrete

5.7 Graph showing changes in Compressive strength after Durability tests

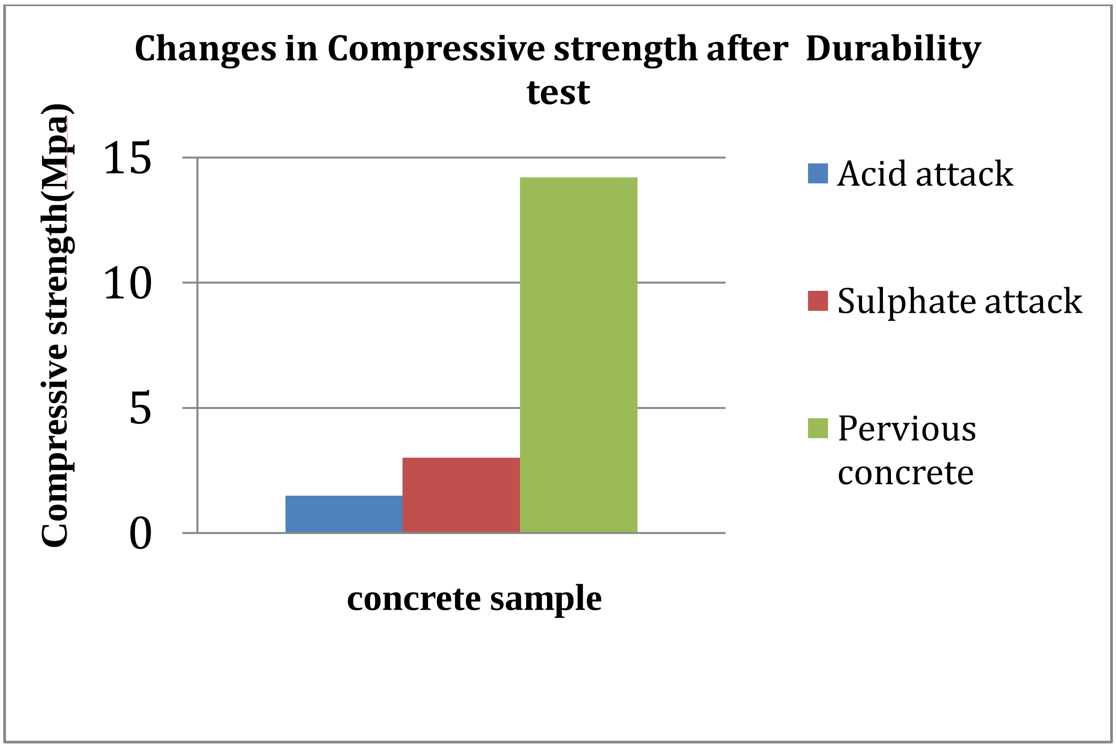

Figure 5.12 Changes in Compressive strength after Durability tests

5.8 Discussions

5.8.1 Compressive strength

From our compressive strength test, we observed that the first trial pervious concrete had compressive strength of around 4,5 MPa after 7 days and around 8.5MPa after 28 days .The second trial pervious concrete had compressive strength of around 3MPa after 7 days and around 7MPa after 28 days. Hence we observed that the first trial pervious concrete had higher compressive strength than the second trial pervious concrete. Some of the reasons of decrease in strength of second trail pervious concrete are:

- We used less water cement ratio on the latter pervious concrete of 0.3.
- Amount of cement was used was very less.
- Amount of water used was very less.
- No fine aggregates were used.
- Smaller sized angular aggregates were used.
- Weaker aggregates were used.
- The strength of the cement may have been less due to the lumps formed and as it was stored in a cold temperature.

<u>Pervious concrete with stronger aggregates.</u>

There was an improvement of twenty eight days compressive strength with the use of stronger aggregates because:

- The aggregates we used had more crushing value and lesser abrasion value which increased its strength and resistance to wear and tear.
- The aggregates were also found to be more tough and could resist more impact.

5.8.2 Failure to achieve compressive strength of 25 MPa.

Though we achieved a better compressive strength, we could still not achieve our desired compressive strength. Some of the reasons could be:

1. Low water/cement ratio.
2. No fine aggregates are used.
3. The amount of cement used is very less compared to aggregates.
4. The binding strength is still low.
5. No admixture or super plasticizers are used.
6. No viscosity enhancing agents were used.

5.8.3 Infiltration rate.

The second trial pervious concrete had a higher infiltration rate than the first trial pervious concrete. The main factors attributing to increase in permeability were:

- Decrease in size of aggregates.
- Less water cement ratio of 0.3.
- Cement used was very less.
- Amount of water was decreased.
- No fine aggregates.
- Aggregate to cement ratio was increased to 6:1 from 4:1.

5.8.4 Durability:

Sulphate attack

- The cubes after sulphate attack test showed better durability as there was no significant change in weight and colour. The only change was in compressive strength and the formation of cracks. The decrease in compressive strength is because:
    1. The sulphate destroyed the CSH (Calcium Silicate Hydrate) gel which binds The material together.
    2. The cube lost their binding strength and decreased its compressive strength.
- The cracks on the cube was due to:
    1. Formation of ettingrite which further cracks the cement paste and damaging the concrete.

Acid attack.

- The cubes after acid attack test showed poor durability as there was a drastic change in weight, very low compressive strength and change in colour. The change in weight was mainly because :
    1. Few aggregates had already fallen from the cube.
    2. The acid destroyed the flux material and Calcium Silicate Hydrate (CSH) gel due to which aggregates started segregating.
    3. The acid also caused the cement to segregate due to which the colour of the cube became lighter.
    4. The acid also removed the part of the set concrete such as cement.
    5. The colour of the acid after 13 days was also changed from transparent to gray since the cement from the set concrete had segregated and mixed with acid.

5.9 Comparing normal concrete with pervious concrete

Properties	**Pervious Concrete**	**Normal Concrete**
Durability	20-40 years	30 years
Cost	Low	High
Compressive Strength	Lower	Higher
Fine Aggregates	<10%	Varies.
Permeability	0.2 cm/s to 0.54 cm/s	1 x 10^{-10} cm/sec
Surface	Rough	Smooth
Suitability	For light traffic pavements	For all types of traffic pavement
Shrinkage	Less as compared to normal concrete	Rapid shrinkage takes place
Density	1600 kg/m^3 to 2000 kg/m^3)	2240 - 2400 kg/m^3

Table 5.9 Comparison between pervious and normal concrete.

5.10 Fresh properties of concrete

Sample	Normal slump	Pervious slump
1	65 mm	75 mm
2	80 mm	84 mm
3	55 mm	72 mm

Table 5.10 Slump test results

Sample	Normal concrete	Pervious concrete
1	0.7	0.73
2	0.78	0.82
3	0.74	0.79

Table 5.11 Comparison between normal and pervious concrete test results

Compaction factor of pervious concrete was higher than the normal concrete because the cement content used in pervious concrete is very less due to which friction increases and the aggregates can easily fall increasing the compaction factor.

From slump test, we determine the workability and the consistency of the concrete. Pervious concrete had higher slump value because the difference in the height of the mould was more. Some of the reasons are:

- Binding of the cement with the aggregates and with each other was not good.
- Due to the absence of fine aggregates.

5.11 Graph showing compaction factor results between Normal and Pervious concrete

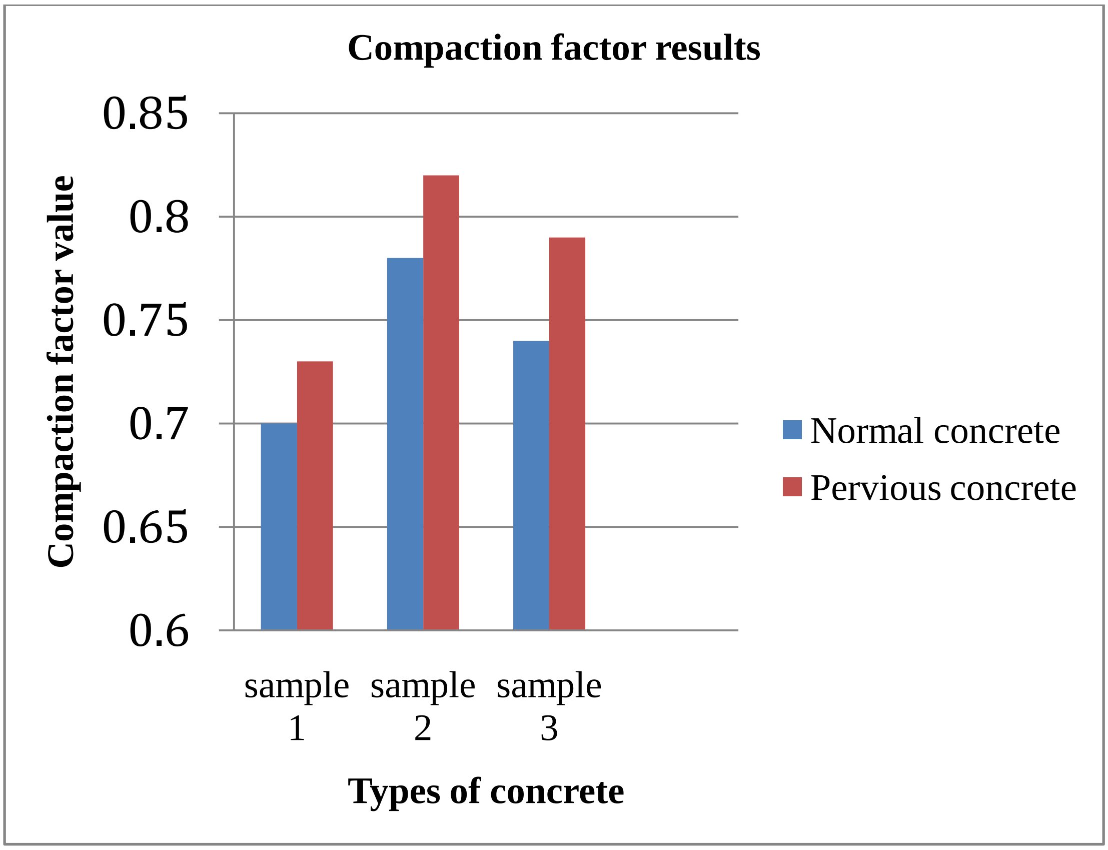

Figure 5.13 Compaction factor results between Normal and Pervious concrete

5.12 Graph showing Slump test results between Normal and Pervious concrete

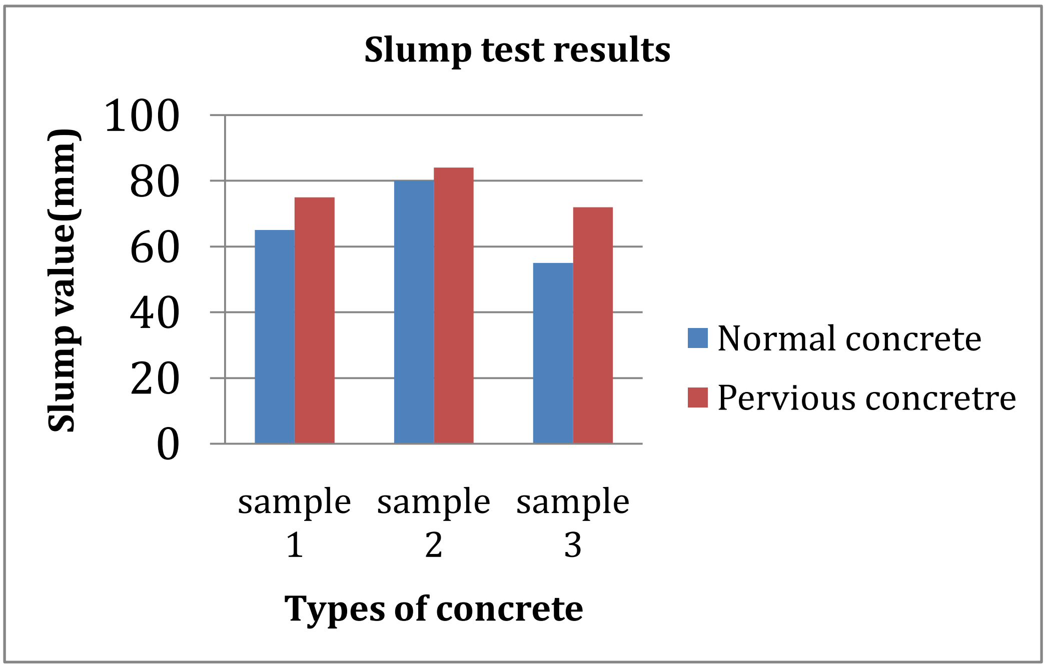

Figure 5.14 Slump test results between Normal and Pervious concrete

CHAPTER 6: CONCLUSION

We have studied few of research papers and collected some valuable information and materials that would help us and guide us towards our own project. We have come to learn about pervious concrete's properties, materials and its application towards our day to day activities. Pervious concrete has come to be more advantageous in terms of its permeability, absorption of noises, heat accumulation, cost effectiveness and light providing properties. And here are the following conclusions.

- The workability of pervious concrete is low so it is important to provide sufficient working time at the jobsite and viscosity enhancing agents is also used to improve workability.
- The properties of pervious concrete include void content (18 to 35%),infiltration rate(500 to 2000 inch/hour),slump(20 to 50mm),compressive strength(3.44 to 27.5 MPa) and flexural strength(1.034 to 3.79 MPa).
- We also came to learn about relationships between compressive strength and void content, infiltration rate and void content, compressive strength and infiltration rate.
- Water/cement ratio of 0.26 to 0.4 will give the best aggregate coasting and stability because lower water/cement ratio will reduce adhesion of paste and make the paste to flow and fill the pores and higher water/cement ratio will prevent good mixing and cause balling of concrete.
- We made two types of samples where in the first trial we used aggregates greater than 20 mm and a very less quantity of fine aggregates and as a result it came out to be very less porous with an average infiltration rate of 728 inch/hour.
- In the second trial we use only coarse aggregates passing from 12.5 mm sieve and retaining at 10 mm sieve and as a result it was porous with an average infiltration rate of 1766 inch/hour. We did not use fine aggregates in the second trial.
- Now looking at the compressive strength of these two trials, the first trial gave us better compressive strength of 9MPa than the second having compressive strength of 7 MPa. This was because the size of the aggregates used was big in the first one and fine aggregates were also present which gave a better binding strength.
- But we could still not achieve our target compressive strength.
- Then we made pervious concrete using stronger aggregates having more crushing value and less abrasion value and there was an increase in twenty eight days compressive strength of 14MPa than the previous pervious concrete.
- We also determined its durability properties by performing acid attack and sulphate attack test where by the concrete showed to be more durable with sulphate attack test and less durable with acid attack test.

- There was decrease in weight of the cube as the flux material was destroyed and also the CSH (Calcium silicate hydrate) gel. This caused decrease in compressive strength.
- The colour of the cube after acid attack had also changed to light gray as the acid removed the parts of the set concrete such as cement and caused all the materials to segregate.
- Therefore, the strength of pervious concrete can be increased more by using silica fumes, super-plasticizers and viscosity agents and we can also improve durability by using epoxy, latex paint and the densifier and by not letting the Calcium silicate hydrate (CSH) gel to get destroyed.

CHAPTER 7: SCOPE OF THE PROJECT

7.1 Pervious concrete of higher strength.

We can also make pervious concrete of higher strength using silica fumes, super-plasticizers and viscosity enhancing agents for constructing parking lots.

Viscosity enhancing agents can be used to bind the aggregates properly and add more water without causing the paste to drain out. So we can use silica fumes and super plasticizer to increase the strength and to improve the quality and its workability properties.

Stronger aggregates having higher impact value and crushing value and different types of aggregates like river gravel and crushed lime stones can also improve pervious concrete.

7.2 Durability of pervious concrete

Along with compressive strength, focus on improving the durability of the pervious concrete can be done by improving the binding properties and by not letting the Calcium silicate hydrate (CSH) gel to get destroyed. The use of epoxy, latex paint and the densifier can provide the best improvement in durability of pervious concrete.

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