EXPERIMENTAL STUDY ON PERVIOUS CONCRETE WITH ADDITION OF POLYMER ADMIXTURE

C. Indiragith Sakar[1], M. Ponraj[2], V.R. Raji[3], J.P. Praveena[4]

[1] PG Student, Civil Engineering, Jaya Engineering College, India
[2] Assistant Professor, Civil Engineering, Jaya Engineering College, India
3 Assistant Professor, Civil Engineering, Jaya Engineering College, India
4 Assistant Professor, Civil Engineering, Jaya Engineering College, India

ABSTRACT

Pervious concrete is a special type of concrete, which consists of cement, coarse aggregates, water and chemical admixtures. 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.
The aggregate usually consists of a single size which has 20mm and is bonded together at its point of contacts by a past formed cement, water and admixture. Then usually as high percentage connected of inter connected voids unlike conventional concrete, normally pervious concrete has void ratio in between 10-30%
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, so me added polymer admixture to increase the compressive strength and flexural strength as well as it also reduces the curing time of concrete.
If the compressive strength and flexural strength of pervious concrete is increased, then it can be used for more number of applications. For now, the usage of pervious concrete is mostly limited to places only. If the properties are improved, then it can also be used for medium and heavy traffic rigid pavements. Along with that, the pervious concrete eliminates surface runoff of storm water, facilitates the ground water recharge and makes the effective usage of available land.
The main aim of our project is to improve the strength characteristics of pervious concrete. But when 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.

Keyword: - *Permeable Concrete, Polymer Admixture, Compressive Strength, Flexural Strength, Split Tension Test, and Concrete Pavement etc….*

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1. INTRODUCTION

Pervious concrete which is also known as the no-fines, porous, and permeable concrete and enhance porosity concrete have been found to be a reliable storm water management tool. By definition, pervious concrete is a mixture of coarse aggregate, cement, water. When pervious concrete is used for paving, the open cell structures allow storm water to filter through the pavement and into the underlying soils. In other words, pervious concrete helps in protecting the surface of the pavement and its environment.

As stated above, pervious concrete has the same basic constituents as conventional concrete, 10 -30% of its volume consists of interconnected void network, which allows water to pass through the concrete. Pervious concrete can allow the passage of 11.35-18.97 liters of water per minute through its open cells for each square foot ($0.0929m^2$) of surface area which is far greater than most rain occurrences. 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. density of pervious concrete is generally lies between 1800 kg/m^3 to 2000 kg/m^3.

When it rains, pervious concrete automatically acts as a drainage system, thereby putting water back where it belongs. Carefully controlled amount of water and cementitious materials are used to create a paste. The paste then forms a thick coating around aggregate particles, to prevent the flowing off of the paste during mixing and placing. Using enough paste to coat the particles maintain a system of interconnected voids which allow water and air to pass through it. Generally the size of aggregate will be in 12mm to 24mm.

1.1 Concept

Pervious concrete void structure provides pollutant captures which also add significant structural strength as well. It also results in a very high permeable concrete that drains quickly. 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 pathways, parking areas, tennis courts, slope stabilization, sub-base for conventional concrete pavements etc.,

Pervious concrete system has advantages over impervious concrete in that it is effective in managing run-off from paved surfaces, prevent contamination in run-off water, and recharge aquifer, repelling salt water intrusion, control pollution in water seepage to ground water recharge thus, preventing subterranean storm water sewer drains, absorbs less heat than regular concrete and asphalt, reduces the need for air conditioning. Pervious concrete allows for increased site optimization because in most cases, its use should totally limit the need for detention and retention ponds and other more traditional storm water management devices that are otherwise required for compliances with the Federal storm water regulations on commercial sites of one acre or more.

By using pervious concrete, the ambient air temperature will be reduced, requiring less power to cool the building. In addition, costly storm water structures such as piping, inlets and ponds will be eliminated. due to harsh site conditions. Apparently, when compared to conventional concrete, pervious concrete has a lower compressive strength, greater permeability, and a lower unit weight. 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.

1.2 Major Application of Pervious Concrete

- Low-volume pavements
- Residential roads, alleys, and driveways
- Sidewalks and pathways
- Parking areas
- Tennis courts
- Sub base for conventional concrete pavements
- Slope stabilization
- Swimming pool decks
- Pavement edge drains and Tree grates in sidewalks

1.3. ADVANTAGES AND DISADVANTAGES

Pervious concrete is advantageous for a number of reasons. Of top concern is its increased permeability compared with conventional concrete. Pervious concrete shrinks less, has a lower unit weight, and higher thermal insulating values than conventional concrete.

Although disadvantage in many regards, pervious concrete has limitations that must be considered when planning its use. The bond strength between particles is lower than conventional concrete and therefore provides a lower compressive strength. There is potential for clogging thereby possibly reducing its permeability characteristics.

2. Materials Used

2.1 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 may be named after the principal constituents, after the intended purpose, after the object to which they are applied or after their characteristic property. Cement used in construction are sometimes named after their commonly reported place of origin, such as Roman cement, or for their resemblance to other materials, such as Portland cement, which produces a concrete resembling the Portland stone used for building in Britain. Cement, in the general sense of the word, described as a material with adhesive and cohesive properties, which make it capable of bonding mineral fragments in to a compact whole. The first step of reintroduction of cement after decline of the Roman Empire was in about 1790, when an Englishman, J.Smeaton, found that when lime containing a certain amount of clay was burnt, it would set under water. This cement resembled that which had been made by the Romans. Further investigations by J. Parker in the same decade led to the commercial production of natural hydraulic cement.

Name of compound	Chemical Composition	Abbreviation
Tricalcium Silicate	$3CaO.SiO_2$	C3S
Dicalcium Silicate	$2CaO.SiO_2$	C2S
Tricalcium aluminate	$3CaO.Al2O_3$	C3A
Tetracalcium alumino ferrite	$4CaO.Al2O_3.Fe_2O_3$	C4AF

Table -1: Typical Composition of 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). In addition to the main compounds, there exist minor compounds such as MgO, TiO_2, K_2O and Na_2O; they usually amount to not more than a few percent of the mass of the cement. Two of the minor compounds are of particular interest: the oxides of sodium and potassium known as the alkalis. They have been found to react with some aggregates, the products of the reaction causing disintegration of the concrete and have also observed to affect the rate of gain of strength of cement.

2.2 Aggregate

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. Coarse aggregate, which comprises material greater than 4.75mm in size.

2.2.1 Coarse Aggregate

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

2.2.2 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

2.2.3 Sampling

Samples shall be representative and certain precautions in sampling have to be made. No detailed procedures can be laid down as the conditions and situations involved in taking samples in the field can vary widely from case to case. Nevertheless, a user can obtain reliable results bearing in mind that the sample taken is to be representative of the bulk of the material. The main sample shall be made up of portions drawn from different parts of the whole. In the case of stockpiles, the sample obtained is variable or segregated, a large number of increments should be taken and a larger sample should be dispatched for testing.

2.2.4 Particle Shape and Texture

Roundness measures the relative sharpness or angularity of the edges and corners of a particle. Roundness is controlled largely by the strength and abrasion resistance of the parent rock and by the amount of wear to which the particle has been subjected. In the case of crushed aggregate, the particle shape depends not only on the nature of the parent rock but also on the type of crusher and its reduction ratio, i.e. the ratio of the size of material fed into the crusher to the size of the finished product. Particles with a high ratio of surface area to volume are also of particular interest for a given workability of the control mix. Elongated and flaky particles are departed from equi-dimensional shape of particles and have a larger surface area and pack in an isotropic manner.

Flaky particles affect the durability of concrete, as the particles tend to be oriented in one plane, with bleeding water and air voids forming underneath. The flakiness and elongation tests are useful for general assessment of aggregate but they do not adequately describe the particle shape. The presence of elongated particles in excess of 10 to 15% of the mass of coarse aggregate is generally undesirable, but no recognized limits are laid down .Surface texture of the aggregate 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.

2.2.5 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. A rougher surface, such as that of crushed particles, results in a better bond due to mechanical interlocking; better bond is not usually obtained with softer, porous, and minor logically heterogeneous particles. 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 .The determination of the quality of bond of aggregate is difficult and no accepted tests exist. Generally, when bond is good, a crushed specimen of normal strength concrete should contain some aggregate particles.

2.2.6 Strength of Aggregate

The compressive strength of concrete cannot significantly exceed that of the major part of the aggregate contained. If the aggregate under test leads to a lower compressive strength of concrete, and in particular if numerous individual aggregate particles appear fractured after the concrete specimen has been crushed, then the strength of the aggregate is lower than the nominal compressive strength of the concrete mix. Such aggregate can be used only in a concrete of lower strength. A test to measure the compressive strength of prepared rock cylinders used to be prescribed. 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. 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.

2.2.7 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 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. In structural concrete of usual proportions, there is no advantage in using aggregate with a maximum size greater than about 25 or 40mm when compressive strength is a criterion.

The standard type aggregate for use in pervious concrete is typically crushed stone or river gravel. Typical sizes are from 10mm to 25mm. (Tennis et al 2004). Fine aggregates are either used sparingly or removed altogether from the mix design. It has been shown that using smaller aggregates increases the compressive strength of pervious concrete by providing a tighter bond between coarse aggregate and cement.

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 cementitious material to bind around the aggregate and hence allowed for greater contact between the aggregate/binder

2.3 Water

While any potable water can be used for mixing, the amount of water is critical for the formation of the voids in pervious concrete. Water-to-cement ratios can range from 0.27 to 0.30 with ratios as high as 0.40. Careful control of water is critical. A mix design with little water can create a very weak binder. This will create a very dry mix that is susceptible to spalling and crumbling. A mix design with too much water can collapse the void space, making an almost impenetrable concrete surface (NRMCA 2004).

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.

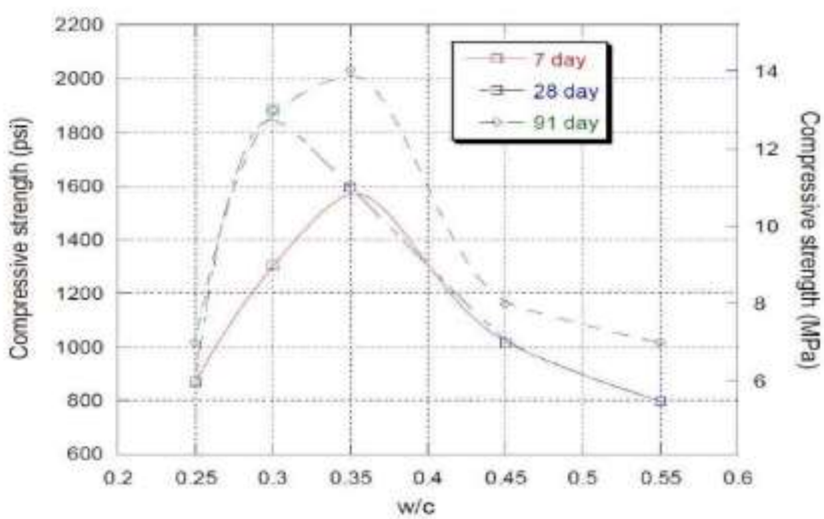

Fig 1: Graph Showing Relation Between W/C Ratio and Compressive Strength of Concrete (Meininger, 1998)

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-tocement 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.

2.4 Polymer Admixture

The concept of polymer admixture adding in concrete is not new, since it considerable research and development of chemical admixture have been performed for the past several years as result various polymer based admixture have been developed like this polymer based admixture have several in types like polymer based material for replacement of aggregate, polymer based cement for replacement of a cement mortar and also chemical based polymer admixture for improving property of a concrete.

3. MIX DESIGN OF PERVIOUS CONCRETE

3.1 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.

3.2 Unit Weight or Density

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/m³ to 2100 kg/m³ 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. 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.

3.3 Water – Cement Ratio

The water-cementitious 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. A low *w*/*cm* will prevent good mixing and tend to cause balling in the mixer, prevent an even distribution of cement paste, and therefore reduce the ultimate strength and durability of the concrete. *w/cm* in the range of 0.26 to 0.40 provides the best aggregate coating and paste stability. The conventional *w*/*cm*-versus-compressive strength relationship for normal concrete does not apply to pervious concrete. Careful control of aggregate moisture and *w*/*cm* is important to produce consistent pervious concrete.

3.4 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 cementitious 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.

3.5 Mix Design Criteria

Pervious concrete uses the same materials as conventional concrete, except that there are 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

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)	270 to 415
Aggregate	1190 to 1480
Water: cement ratio (by mass)	0.27 to 0.34
Fine: coarse aggregate ratio (by mass)	0 to 1:1

Table 2: Typical Mix Design of Pervious Concrete as Suggested by ACI 522 R-10

Fig 2: Preparation of Pervious Concrete Cubes

Fig 3: Preparation of Pervious Concrete Prism

3.6 CALCULATION FOR VOLUME OF CONCRETE CUBE

cube size = 150 x 150 x 150 mm

= 3.375×10^{-3} mm^3

density of concrete = 2000 kg/m^3

= $2000 \times 3.375 \times 10^{-3} = 7.5$ kg/m^3

Ratio = 1:5

Cement = 1/6 x 7.5 = 1.249kg

Aggregate = 5/6 x 7.5 = 6.24kg

Water =1.249 x 0.32 =0.399 kg

=0.399x1000 = 399ml

2% of admixture =1.35/100x2 = 0.024 kg

= 0.024x1000 = 24ml.

3% of admixture = 1.35/100x3 = 0.037 kg

= 0.037x1000 = 37ml.

3.7 CALCULATION FOR VOLUME OF A PRISM

Prism size = 450 x 150 x 150mm

$=10.125\text{x}10^{-3}$ mm^3

density of concrete = 2000 kg/m^3

= 2000 x $10.125\text{x}10^{-3}$

= 20.25 kg/m^3

Ratio = 1:5

Cement = 1/6 x 20.25 = 4.05kg

Aggregate = 5/6 x 20.25 = 20.25kg

Water = 3.375 x 0.32 = 1.08kg

= 1.08 x 1000 = 1080 ml

2% of admixture = 4.05/100 x 2 = 0.0675kg

= 0.0675 x 1000 = 67.5ml

3% of admixture = 3.375/ 100 x 3 = 0.10071 kg

= 0.10071 x 1000 = 100.71 ml.

3.8 CALCULATION FOR VOLUME OF CYLINDERICAL MOULD:

Diameter = 10cm = 0.1m

Length = 20cm = 0.2m

Volume of cylinder = Area x length

$= \pi d^2 /4 \text{ x } 0.2\text{m}$

$= \pi \text{ x } 0.01/4 \text{ x } 0.2 = 1.57\text{x}10^{-3}$ mm^3

Unit weight of concrete = 2000kg/m^3

$=2000 \text{ x } 1.57\text{x}10^{-3}$ =3.14 kg

Ratio = 1:5

cement = 1/6 x 3.14 = 0.523 kg

aggregate= 5/6 x 3.14 = 2.61 kg

water = 0.523 x 0.32 = 0.167 kg

= 0.167 x 1000 = 167 ml

2% admixture =0.523 /100 x 2 = 12ml.

3% admixture = 0.523 /100 x 3 = 15.69 ml.

4. Test on Pervious Concrete

4.1 Compressive Strength of Pervious Concrete

Out of many test 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 15 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 mm x 150 mm x 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 these specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen.
These specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm^2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

In the laboratory, pervious concrete mixtures have been found to develop compressive strengths in the range of 3.5 MPa to 28 MPa, which is suitable for a wide range of applications. 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:

Fig 4: Compressive Test on Cube

4.2 Flexural Strength on Pervious Concrete

Flexural strength, also known as modulus of rupture, or bend strength is a material property this define as stress in a material just before it yield in flexural test. Flexural represent the highest stress experienced within the material at its movements of yield, Flexural strength on pervious concrete generally range between about 1Mpa to 3.8Mpa. Many factor influence the flexural strength, particular degree of compaction, porosity, and aggregate to cement (A/C) ratio.

Fig 5: Flexural Strength Test on Prism

4.3 Split Tensile Test on Pervious Concrete

A method of determining the tensile stress of concrete using cylindrical concrete which split across. Tensile strength for concrete specimen is defined as the tensile developed due to application compressive load to the concrete specimen. Split tensile strength 1:5 cement to total aggregate mix increased b about an addition of 2 of polymer admixture when compare it with the mix having no polymer admixture. It found that the strength and permeability of pervious concrete depend upon shape and size of the aggregates and water to cement ratio.

Fig 6: Split Tensile Test on Cylinder

4.4 Permeability of Pervious Concrete

The permeability of pervious concrete was determined using a falling head permeability set up. Water was allowed to flow through the sample, through a connected standpipe which provides the water head. Before starting the flow measurement, the samples were wrapped with polythene inside the cylinder. Then the test started by allowing water to flow through the sample until the water in the standpipe reached a given lower level. A constant time of 5seconds was taken for the water to fall from one head to another in the standpipe. The standpipe was refilled and the test was repeated when water reached a lower. The permeability of the pervious concrete sample was evaluated from the expression given below:

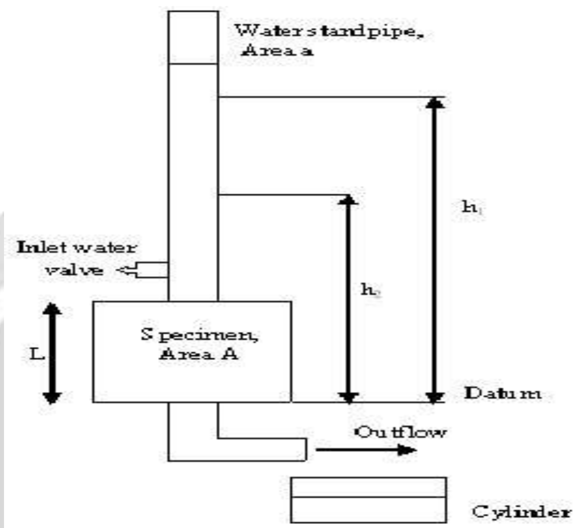

Fig 7: Falling Head Permeability Test Apparatus

Fig 8: Water Passes Through Pervious Concrete Cube.

4.4.1 Formula to Find Permeability

$K=2.303\ aL/A\ (t_2-t_1)\ \log (h_1/h_2)$

Where,

A= the sample cross section area

a = the cross section of the standpipe of diameter

L = the height of the pervious concrete
$(t_2 - t_1)$ = change in time for water to fall from one level to another (5secs.)
h_1= upper water level
h_2= Lower water level
d= diameter of standpipe (0.975cm)

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 8 to 20mm/sec.

In general, the concrete permeability limitation is not a critical design criterion.
Consider a passive pervious concrete pavement system overlying a well-draining soil. 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/m^2/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 may be more restrictive.

4.4.2 Calculation for Permeability of Cube

Formula: $K=2.303\ aL/A\ (t_2-t_1)\ \log (h_1/h_2)$

Data,

A= 0.15 x 0.15 x 0.15 = 3.375 x $10^{-3}mm^3$
a = 0.15 x 0.15 x 0.975 = 0.0219mm^3
L = 0.15 cm
(t2-t1) = 5 sec, h1= 180, h2= 172,
k =2.303 x (0.0219 x 0.15) / 3.375 x 10^-3 x 5 x log 1.047
k = 15 mm/sec.

4.5 Storage Capacity

Storage capacity of a pervious concrete system typically is designed for specific rainfall events, which are dictated by local requirements. The total volume of rain is important, but the infiltration rate of the soil also must be considered. The total storage capacity of the pervious concrete system includes the capacity of the pervious concrete pavement, the capacity of any sub base used, and the amount of water which leaves the system by infiltration into the underlying soil. 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 impervious 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.

5. RESULT AND DISCUSSION

5.1 Optimized mix design of pervious concrete (with 20mm aggregate):

properties of materials tested in the laboratory:

5.1.1 Test on cement:

OPC-53 grade cement:

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

Table 3: Properties Of cement Tested At Concrete Technology Laboratory

5.1.2 Test on coarse aggregate:

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	Void content	37.16%
5	Specific gravity	2.65

Table 4: properties of coarse aggregates tested at Concrete technology laboratory

5.2 Test on perious concrete by compressive strength method:

5.2.1: Optimized mix proportion:

Optimized mix proportion is calculated with 20mm coarse aggregate as standard pervious concrete:

1. The void ratio and unit weight are the important factors to be considered in mix design process
2. According to mix design, the quantity of cement calculated for one cube(150 x 150 x 150 mm) of pervious concrete is 1.249 kg and also polymer admixture are added by 2% as well as 3% in a concrete cube.
3. 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.
4. The mix design procedure gave the value of cement to aggregate ratio as 1:5.25 or approximately 1:5 for the size of aggregates passing through 20mm.
5. 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 0.32 and it is fixed after doing samples with water to cement ratios as 0.25, 0.32 and 0.35.

Materials	**Proportions (Kg)**
Cement (OPC-53 grade)	1.249
Aggregate (20mm)	6.249
Water: cement ratio	0.32
2 polymer admixture	0.024
3 polymer admixture	0.037

Table 5: optimised mix proportions of compressive strength

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

5.2.2: Result on Compressive Strength of Standard Pervious Concrete and Pervious Concrete with polymer admixture:

S.No	Age of concrete	Standard pervious concrete, Mpa	Pervious concrete with 2% of polymer admixture, Mpa	Pervious concrete with 3% of polymer admixture, Mpa
1	7	12.75	13.38	13.72
2	14	13.24	13.74	14.04
3	28	13.51	14.08	14.27

Table 6: Compressive Strength of Pervious Concrete With Different Quantities of Polymer Admixture

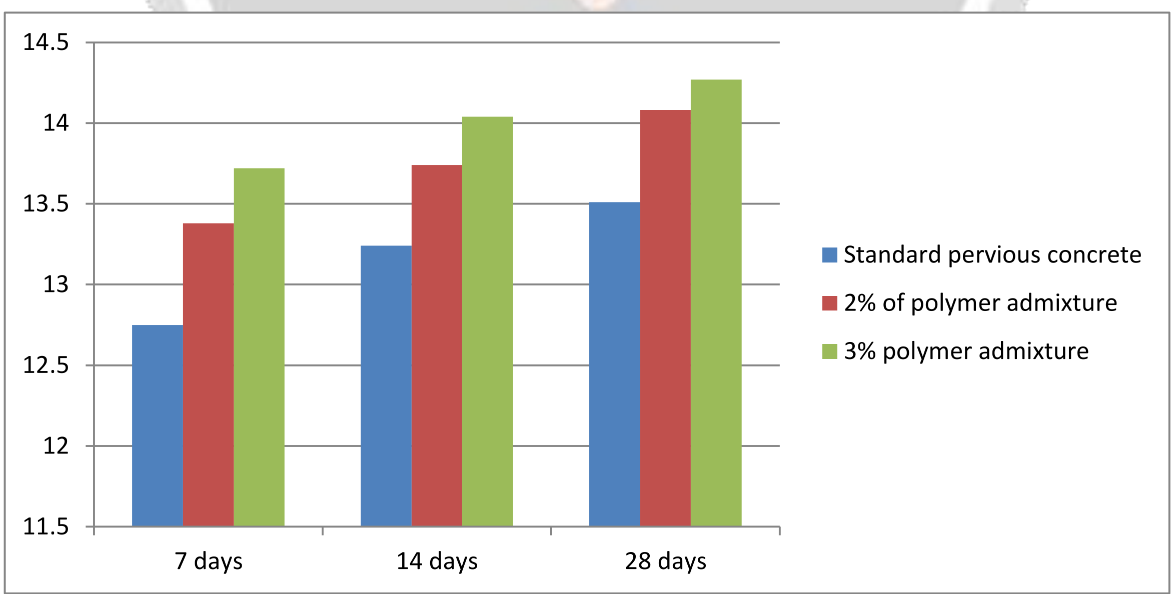

Fig 9: Graph on Compressive Strength Test Result

5.3 Test on perious concrete by flexural strength:
5.3.1: Optimized mix proportion:

Optimized mix proportion is calculated with 20mm coarse aggregate as standard pervious concrete:

1. The void ratio and unit weight are the important factors to be considered in mix design process
2. According to mix design, the quantity of cement calculated for one prism(450 x 150 x 150 mm) of pervious concrete is 3.375 kg and also polymer admixture are added by 2% as well as 3% in a concrete prism.
3. 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.
4. The mix design procedure gave the value of cement to aggregate ratio as 1:5.25 or approximately 1:5 for the size of aggregates passing through 20mm.
5. 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 0.32 and it is fixed after doing samples with water to cement ratios as 0.25, 0.32 and 0.35.
6. The design void ratio of pervious concrete is 20% and the unit weight ranges from 1600 to 2100 kg/m^3.

Cement	3.375 kg/m^3
Coarse aggregates	16.875 kg/m^3
Water	1080 ml
2% polymer admixture	67.5 ml
3% polymer admixture	100 ml

Table 7: Optimised Mix Proportions of Flexural Strength

5.3.2: RESULT ON FLEXURAL STRENGTH OF STANDARD PERVIOUS CONCRETE WITH POLYMER ADMIXTURE:

S.No	Age of concrete	Standard pervious concrete, Mpa	Pervious concrete with 2% of polymer admixture, Mpa	Pervious concrete with 3% of polymer admixture, Mpa
1	28	2.81	3.41	3.85

Table 8: Compressive Strength of Pervious Concrete With Different Quantities of Polymer Admixture

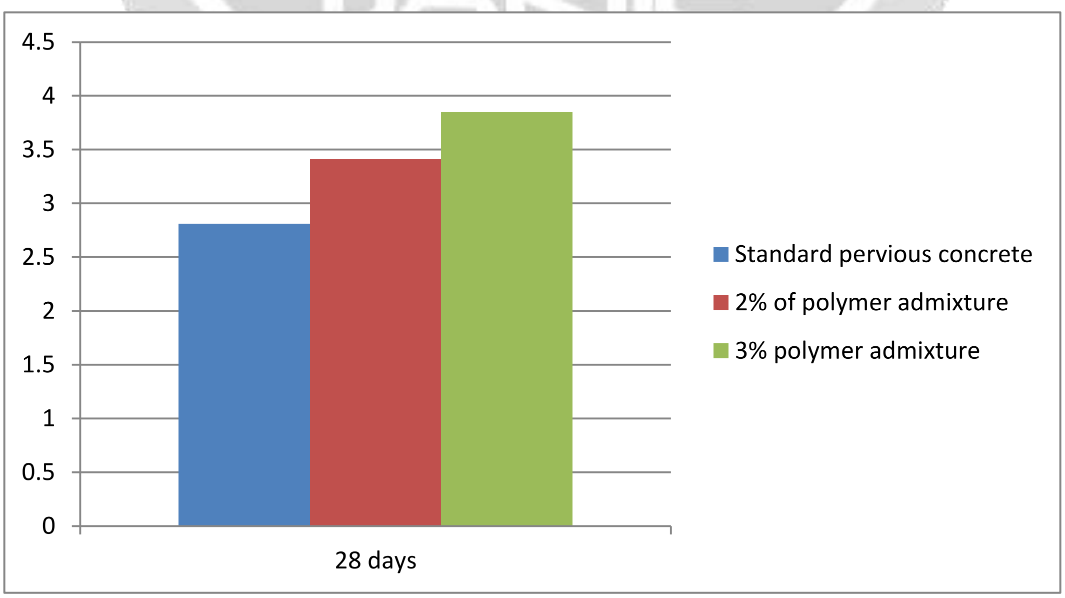

Fig 10: Graph on Flexural Strength Test Result

5.4 Split tensile of pervious concrete cylinder:
5.4.1 Optimized mix proportion:

Optimized mix proportion is calculated with 20mm coarse aggregate as standard pervious concrete:
1.The void ratio and unit weight are the important factors to be considered in mix design process
2.According to mix design, the quantity of cement calculated for one cylinder diameter 10 and length of 20cm of pervious concrete is 0.523 kg and also polymer admixture are added by 2% as well as 3% in a concrete prism.
3.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.
4.The mix design procedure gave the value of cement to aggregate ratio as 1:5.25 or approximately 1:5 for the size of aggregates passing through 20mm.
5.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 0.32 and it is fixed after doing samples with water to cement ratios as 0.25, 0.32 and 0.35.
6.The design void ratio of pervious concrete is 20% and the unit weight ranges from 1600 to 2100 kg/m^3
7.The cement we used in our project work is Ordinary Portland Cement of 53 grade
8. The size of coarse aggregates is passing 20 mm and retained on 10 mm IS sieve
9. The water used is available in the laboratory.

Cement	0.523 kg/m^3
Coarse aggregates	2.61 kg/m^3
Water	167 ml
2% polymer admixture	10.46 ml
3% polymer admixture	15.69 ml

Table 9: Optimized Mix Proportions of Split Tensile

5.4.2: Result on split tensile of Standard Pervious Concrete and Pervious Concrete with polymer admixture:

S.No	Age of concrete	Standard pervious concrete, Mpa	Pervious concrete with 2% of polymer admixture, Mpa	Pervious concrete with 3% of polymer admixture, Mpa
1	28	1.46	1.65	1.75

Table 10: Split Tensile of Pervious Concrete With Different Quantities of Polymer Admixture

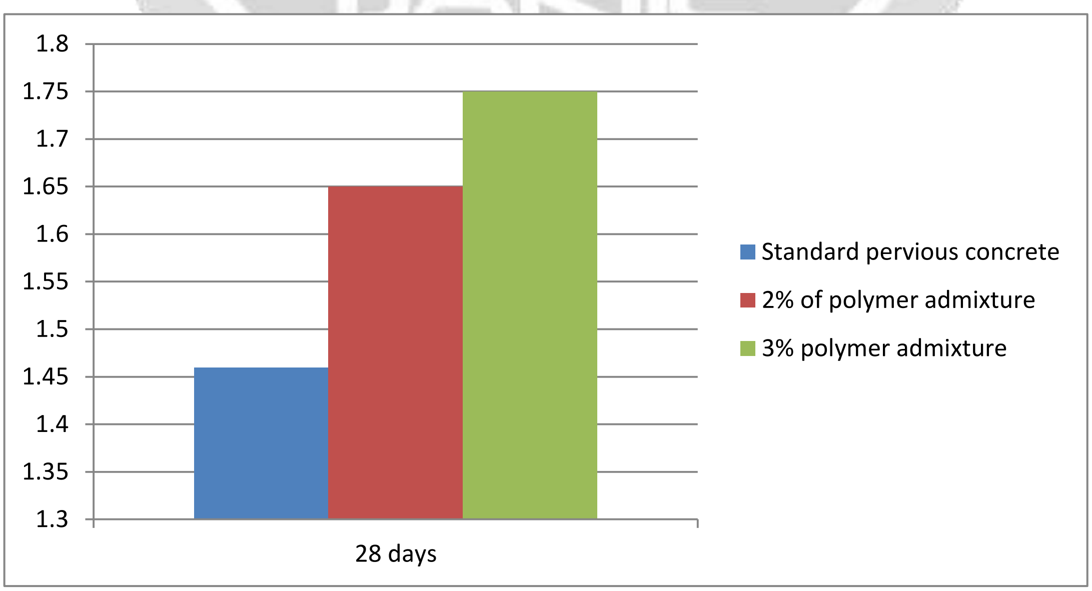

Fig 11: Graph on Split Tensile Test Result

5.5 Unit weight comparison:

Unit weight comparison for cube, prism, cylinder of pervious concrete.

S.No	pervious	Standard pervious concrete, (kg)	Pervious concrete with 2% of polymer admixture, (kg)	Pervious concrete with 3% of polymer admixture, (kg)
1	cube	6.988	**7.17**	**7.257**
2	prism	24.38	24.56	24.74
3	cylinder	3.06	3.13	3.17

Table 11: Unit Weight Comparison for Cube, Prism, Cylinder of Pervious Concrete.

5.6: 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 cube of size 150x150x150 mm. The permeability test is conducted for the standard pervious concrete, pervious concrete with 2% polymer admixture, pervious concrete with 3% polymer admixture, tested after 28 days from preparation.

S.No	Age of Concrete	Standard pervious concrete, (mm/sec)	Pervious concrete with 2% of polymer admixture, (mm/sec)	Pervious concrete with 3% of polymer admixture, (mm/sec)
1	28	15.00	12.01	11.02

Table12: Permeability of Standard Pervious Concrete With Different Quantities of Polymer Admixture.

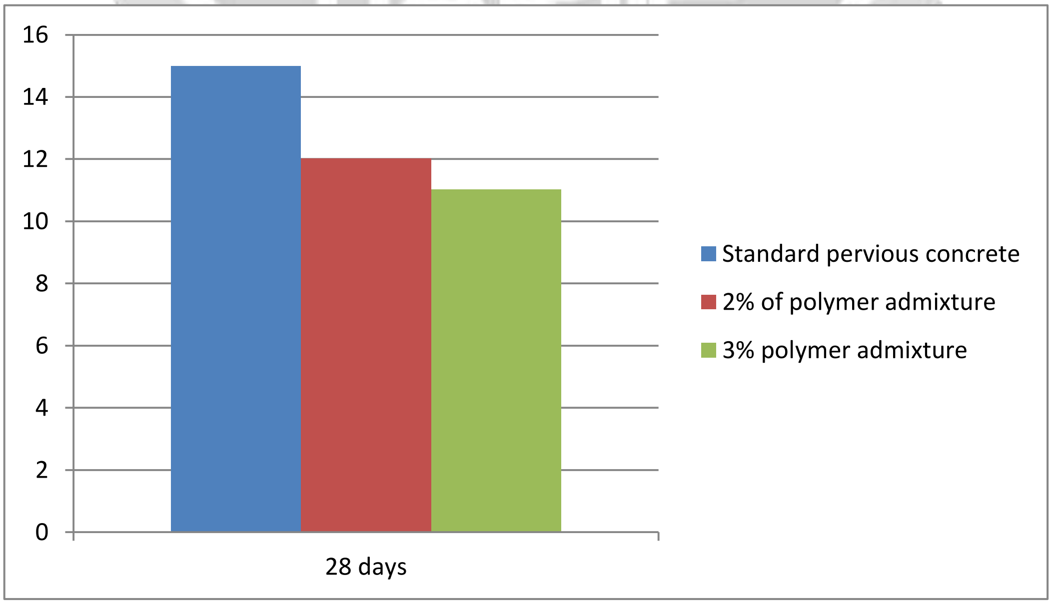

Fig 12: Graph on Permeability Result

5.7 Cost Comparison:

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

- **Lower installation costs**, According to the Center 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.

- **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.

S.No	Type of pavement	Rate (Rs/sq.ft)	Perviousness	Remarks
1	Conventional concrete	1400	impermeable	Drainage is requird
2	Pervious concrete	1200	permeable	Drainage is not required

Table13: 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.

The important observations in our project work are as follows.

- The addition of polymer admixture in the small quantities of total cement, has increased the compressive strength of pervious concrete in our project.
- The addition of polymer admixture in the small quantities of total cement, has decreases the permeability property of pervious concrete in our project
- The maximum compressive strength of pervious concrete is attained when 3% of polymer admixture of total cement added to standard pervious concrete.

6. Conclusion and Scope for Future Work

6.1: Conclusion:

In this report, me trying to increase the compressive strength, flexural strength, permeability and split tensile strength by using the chemical admixture on pervious concrete, it will also reduce the curing time of concrete. The goal is to achieve a maximum compressive strength without inhibiting the permeability characteristics of the pervious concrete. This will be accomplished through extensive experiments on test cylinders, cubes and prism created for this purpose.

Experiments include flexural test, split tensile test and compression tests. Existing pervious concrete pavements are studied. As with further research, the experiments performed are subject to future works. These limitations are in regards to the type and size of aggregate used and the curing process.

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. In this methods of increasing compressive strength of pervious concrete, the addition of polymer admixture has gave more value when compared to conventional concrete. The compressive strength of pervious concrete is increased by 4.36% when 2% polymer admixture were added to the standard pervious concrete. The compressive strength of pervious concrete is increased by 6.69% when 3% polymer admixture were added to the standard pervious concrete.

6.2: Scope for Future Work:

- In the past due to the scarcity of sand, the pervious concrete has been used extensively.
- The pervious concrete has lost its importance after successful production of sand 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 jungle. The discharge of storm water is very difficult problem in the present conditions.
- By using the pervious concrete we can able to recharge the ground water 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.

6.3: Pervious Concrete-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 Tamil nadu 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 levels 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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