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Analysis and Design of Pervious Concrete

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ABSTRACT :- To model the complex behaviour of reinforced concrete analytically in its non-linear zone is difficult. This has led engineers in the past to rely heavily on empirical formulas which were derived from numerous experiments for the design of reinforced concrete structures.

For structural design and assessment of reinforced concrete members, the non-linear analysis has become an important tool. The method can be used to study the behaviour of reinforced concrete structures including force redistribution.

This analysis of the nonlinear response of RC structures to be carried out in a routine fashion. It helps in the investigation of the behaviour of the structure under different loading conditions, its load deflection behaviour and the cracks pattern.

In the present study, the non-linear response of RCC frame using SAP2000 under the loading has been carried out with the intention to investigate the relative importance of several factors in the non-linear analysis of RCC frames. This include the variation in load displacement graph.

Key Words:- complex behaviour, redistribution, RC structures, routine fashion, RCC frame.

I. INTRODUCTION

Pervious concrete is a special type of concrete that is used for flatworks and allow water to seep through the concrete due to its high permeable structure. Water coming from precipitation or rainfall gets infiltrated into ground after passing through porous concrete thereby reducing the run-off as well as also helps in recharging ground water table. Generally, pervious concrete consist of small amount of fines or sometimes no fine aggregate, in that case it is also called no-fines concrete. The amount of cement in pervious concrete should be adjusted such that cement just coats the aggregates without interfering with porosity and permeability of pervious concrete. Fine aggregate proportion is adjusted on basis of strength requirement. Generally, Void content in pervious concrete ranges from 15 to 25% and its compressive strength ranges from 3.5 MPa to 28 MPa. Compressive strength greater than 28 MPa can also be achieved but it interferes with permeability of concrete and makes concrete less permeable.

Figure 1.1: Water Draining Through Pervious Concrete

The term "Pervious concrete" typically describes a nearly zero slump concrete, open graded matrix structure which can drain water through its structure as shown in figure 1.1. Pervious concrete consist of cement, coarse particles, fine particles in very small amount or sometimes absent, admixtures and water. Pervious concrete is a composite material that consists of Portland cement, coarse aggregate, fine

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aggregate (in small amount) and water. It is different from conventional concrete in a fact that amount of sand or fine aggregate used is in very small amount in pervious concrete. The coarse aggregate used are generally, single sized aggregate because it give rise to high permeable structure than that of graded aggregate. Graded aggregate gives higher strength but on other hand it reduces the permeability of the concrete. Coarse aggregate are connected at its ends by sand and cement paste to transfer the load and pores between it allows water to pass through the concrete. Properly designed concrete will give rise to instant seepage of water through the concrete. Engineering properties of pervious concrete is somewhat different than conventional type of concrete. Strength of pervious concrete is less than conventional concrete while porosity of pervious concrete (15 to 25%) is greater than conventional concrete (3 to 5%). The unit weight of pervious concrete is nearly 70 to 80% of conventional concrete.

Specific surface area of pervious concrete is very high as compare to normal concrete so it catches major pollutants and filters the water that pass through it. Hence it decrease the amount of pollutants which will otherwise go into some reservoir meant for that area or into some stream.

The color of pervious concrete is light grey and has very small heat absorption due to sunlight when compared to bituminous roads. Pervious concrete has porous matrix ,hence small amount of heat stored and it cools very rapidly thereby reducing heat island effects and these conditions are very favorable for trees and plants planted in nearby areas and in sidewalks. Vehicles having high axle load are not permitted on pervious concrete pavements but pervious concrete pavements are still safe during rainy seasons because it offers non skidding surface even in rainy weather.

1.1.1 Pervious concrete mainly consist of four constituents:

1. Portland cement
2. Coarse aggregate
3. Fine aggregate
4. Fly Ash (to replace the cement content)
5. Water

Figure 1.2 fly ash, cement and coarse aggregate

The mix for pervious concrete contains all component same but fines are present in low amount or sometimes absent. Quantity of water is also very small; hence slump is also very low. For the testing of mixes, various types of samples are prepared like some cube blocks for split tensile strength test.

The process of mixing remains same as that of conventional concrete but placing and vibrating technique are somewhat different. There is need of high degree of control in mix proportioning as well as during placing and compaction process. The compaction of pervious concrete is done using roller screed followed by cross rolling with hand rollers. In

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case of pervious concrete aggregate to aggregate bonding is necessary and that bond is formed by cement and sand paste. If quantity of water added is more than desired cement
Will flow downward and then aggregate would not get coated properly and mix would
Have poor strength and poor abrasion resistance.

1.2 HISTORICAL BACKGROUND

The initial use of porous concrete was in the United Kingdom in 1852 with the construction of two residential houses and a sea groyne. Cost efficiency seems to have been the primary reason for its earliest usage due to the limited amount of cement used. It was not until 1923 when porous concrete re surfaced as a viable construction material. This time it was limited to the construction of 2-story homes in areas such as Scotland, Liverpool, London and Manchester. Use of porous concrete in Europe increased steadily, especially in the World War II era. Since porous concrete 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 (Wanielista et al. 2007). After World War II, porous concrete became wide spread for applications such as cast-in-place load-bearing walls of single and multistory houses and, in some instances in high-rise buildings, prefabricated panels, and stem-cured blocks (Ghafoori et al. 1995). Also applications include walls for two-story houses, load-bearing walls for high-rise buildings (up to 10 stories) and infill panels for high-rise buildings (Tennis et al. 2004).

The use of no-fines concrete as a pavement material has been extremely limited and has only recently been developed for this particular application. However, no-fines concrete has been used extensively as a structural building material in Europe, Australia and the Middle East over 70 years (Macintosh et al. 1965). The earliest known application of no-fines Concrete occurred in England in 1852 with the construction of two residential houses and a sea groyne 61 m long and 2.15 m wide (Francis 1965).

The use of no-fines concrete became considerably more widespread during the material shortages after World War 2, for cast-in place load bearing walls of single and multi-storey buildings. The early use of no-fines concrete was primarily for two-storey structures, however this expanded to five-storey buildings in the 1950's and continues to expand. In recent years no-fines concrete has been used as a load bearing material in high rise buildings up to ten-storey. The most remarkable use of this form of concrete was undertaken in Stuttgart, Germany where a high rise building was constructed using conventional concrete for the six bottom storey and no-fines for the remaining thirteen upper storeys (Malhotra 1976).

1.3 ADVANTAGES AND DISADVANTAGES OF PERVIOUS CONCRETE

1.3.1 Advantages of Pervious Concrete

These are the following advantages of pervious concrete:

- Traditional applications of pervious concrete include parking areas, light traffic areas, greenhouses, pedestrian walkways and residential streets. In fact, pervious concrete stands is one of the most sustainable construction elements and thus often used by builders to safeguard water quality.
- In addition, appropriate use of pervious concrete is an acknowledged Best Management Practice issued by the Environmental Protection Agency or the EPA for storm water and flush pollution control and management.
- Typically, this concrete is mainly used for construction. Apart from building, this concrete is used in decks of swimming pool, tennis courts, patios and drains. Pervious concrete decreases the overflow of rainwater from the paved areas. Because of this function, you do not need separate ponds for storm water retention.
- In addition, it filters the storm water thus reducing the number of pollutants entering the rivers and ponds. Pervious concrete also improves the growth of trees. The pavements made from this concrete allow transfer of air and water to the roots of trees that help trees to flourish.
- This concrete also decreases operational costs and helps the developers to make maximum utilization of their property. Adding to all these factors, pervious concrete also minimizes the infrastructure expenses. There are many economic benefits provided by this concrete
- Extended Pavement Life Due to Well Drained Base and Reduced Freeze-Thaw

Less Lighting Needed Due to Highly Reflective Pavement Surface Limitations.

- This concrete helps in Quantity and Flood Control, Recharges Groundwater and Water Quality Treatment.
- This concrete Suitable for Cold-Climate Applications, Maintains Recharge Capacity When Frozen, reduced Surface Temperatures; Minimizes the Urban Heat Island Effect.

1.3.2 Disadvantages of Pervious Concrete

These are the following disadvantages of pervious concrete:

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- Its applicability being limited to the Coastal Plain and Sand hills regions.
- The potential for clogging of porous media by sediment, which could lead to reduced effectiveness without proper maintenance.
- It's not applicable for high-traffic areas or for use by heavy vehicles.
- Completed permeable pavement installation must have a slope less than 0.5% and the top 3-ft of soil must have no finer texture than "Loamy Very Fine Sand" as determined by a soil analysis done by the NC Division of Water Quality.
- Low compressive strength is major problems of the pervious concrete
- Abrasion of pervious concrete may limits its utilization
- Clogging is an avoidable problem due to the existence of voids in pervious concrete
- Pervious concrete is more vulnerable may be destroyed under freeze thaw weather.

1.4 NEED AND OBJECTIVE OF STUDY

1.4.1 Need

A large amount of rain water ends up falling on impervious surfaces such as parking lots, drive ways, sidewalks, and streets rather than soaking into the soil. This creates an imbalance to the natural ecosystem and leads to lots of problems including erosion, floods, ground water level depletion and pollution of rivers, lakes etc. A simple solution to avoid these problems is to stop constructing impervious surfaces that block natural water infiltration into the soil. Instead of constructing them with conventional concrete or asphalt, we should be switching to pervious concrete. Pervious concrete naturally filters water from rainfall or storm and can reduce pollutant loads entering into streams, ponds and rivers. So in this way it helps in ground water recharge.

1.4.2 Objective

The main objective of this investigation is to develop a strong and durable pervious concrete mix using different percentage of fly ash with varying the quantity of fine aggregates. However, the specific objectives of the following study are as below:

1. To design the concrete mix for pervious concrete with and without fine aggregate and fly ash.
2. To study the compressive strength of pervious concrete with varying percentage of fly ash.
3. To study the permeability of pervious concrete with varying percentage of fly ash.
4. To compare the carbon footprint of various pervious concrete designed.
5. Evaluating the cost benefit analysis and performance of pervious concrete.

II. LITERATURE REVIEW

Pervious concrete as described by the American Concrete Institute (ACI) is a "near-zero slump, open-graded material consisting of Portland cement, coarse aggregate, little or no fine aggregate, admixtures, and water with void contents ranging from 15% to 35% and compressive strengths of 400 to 4000 psi (2.8 to 28 MPa)" (ACI 2006). The primary benefit offered by pervious concrete is its ability to transport water through its structure, thus reducing storm water runoff and recharging groundwater. At the same time, pollutants may be attenuated as the storm water flows through the pervious concrete and the sub base materials. In order to obtain the targeted void content and compressive strength, the proportions of the different cementitious materials and aggregate, the water-to-cement (w/c) ratio, and the casting and compaction procedure are important determining factors.

2.1 PERVIOUS CONCRETE USING FLY ASH

Fly Ash is a fine residue powder byproduct from burning pulverized coal in electric power generating plants. It is the finest and is the most broadly used material of all the byproducts. It is called "fly" ash because it is transported from the combustion chamber by exhaust gases. . Not only fly ash gives a better final product but also it is a sensible way to control the pollution. The overall performance of pervious concrete can be enhanced by using fly ash as a mineral admixture. CO2 emissions created during cement production are greatly reduced by using fly ash as a partial replacement of cement, which decreases the negative effect on our atmosphere.

Fly ash can be used in pervious concrete as a substitute for a portion of the cement. Two types of fly ash which are Class C and Class F fly ash are both able to used in pervious concrete. Currently, fly ash can replace 5-65% of the Portland cement in conventional

Ready Mix Concrete Association (SCRMC) recommended amount of ASTM C-618 fly ash is only 50-116lb/yd3 in pervious concrete. The advantage of using fly ash is obvious: fly ash is a by-product of coal burning in power plants, its utilization saves the energy required to produce the cement. In addition, fly ash improves the flow ability and workability of concrete.

Biji.u.i et al (2016) experimented on applicability of pervious concrete for pavements one of the objectives of this research was to develop a preliminary pervious concrete specification for Maryland conditions. Several admixtures have been tested as part of this research with the objective of increasing strength, durability and workability of pervious concrete. Improved strength, durability and workability would lead to a wider application of pervious concrete. The types of admixtures that were tested as part of this research included delayed set modifier, viscosity modifier, and cellulose fibers. The ability to discharge, place, and finish pervious concrete within a relatively short time span is a major concern for concrete producers. The relatively short working time window with pervious concrete often leads to a very fast paced, labor intensive effort. Incorporating a delayed set modifying admixture into the pervious concrete mix design inevitably allows a longer working window for placement.

Sukamal kant ghosh et al (2015) studied on performance of pervious concrete using waste materials Utilization of fly ash in pervious concrete by replacing a portion of cement gives better long term compressive strength and it will decrease with increase in fly ash content while it is not effecting Permeability. In pervious concrete RHA can't be use as full replacement of cement. We should use it as partial replacement of cement and the RHA content should not be more than 10-12%. More than that will reduce the compressive strength, flexural strength and permeability also which are the major properties of pervious concrete. Ground granulated blast furnace slag (GGBFS) can be used in place of cement but it is not ideal for pervious concrete as it decreases permeability. But in case of electric arc furnace slag not only it gives higher water

permeability and compressive strength than gravels but also provides greater anti-skid capability and better interface bonding due to interlocking effect. Though the permeability of the pervious concrete decreases to some extent with the addition of silica fume, the strength of the concrete increases to a great extent. So, we can say that the influence of silica fume on strength of the concrete is much more than its influence on permeability of the concrete. If more amount of silica fume is added then it is advised to add superplasticiser to improve workability. The mechanical properties of pervious concrete experiences a negative effect when waste rubber tires are introduced as its ingredients i.e. the utilization of rubber materials in pervious concrete reduces its compressive strength and flexural strength. Though compressive strength is decreasing but it is within acceptable range. On the other hand the abrasion resistance and freeze thaw improves significantly, whereas Permeability is also fell into acceptable limits by using waste rubber tires. These are the most important parameters reqd. for a pervious concrete pavement.The compressive, tensile and flexural strength characteristics of porous concrete will significantly increase with the addition of glass powder as well as it will help in improving the durability and workability of the concrete. Addition of hypo sludge will improve the permeability of the pervious concrete as well as it can be used as pozzolanic material due to its high pozzolanic property. Although use of hypo sludge will reduce the compressive strength but it will help in producing "greener" concrete which is a very environment friendly way of concrete production. Ceramic powder upon addition will improve the permeability and durability of concrete. Besides these properties it also helps in increasing the compressive strength of concrete and at the same time acts as good pozzolanic material. Since ceramic powder is obtained from ceramic wastes so the addition of ceramic powder to improve the properties of concrete is a very economical process. MSWIBA is a very stable and durable material, so, upon addition it will increase the durability of concrete but it does not have much influence on the permeability and strength of the pervious concrete. ¬ It is crystal clear that the utilization of these waste materials is beneficial from the environmental and economical point of view.

Yukari et al. (2009) experimented on the properties of pervious concrete by replacing the cement with 20% and 50% of fly ash. He concluded that compressive strength decreases with increment of fly ash content. When fly ash content is increased up to 20% in concrete permeability is decreasing, but after that when fly ash content reach to 50% in concrete permeability is increased which is nearly similar to no fly ash pervious concrete. **Ravindrarajah et al. (2010)** investigated the properties of pervious concrete by replacing 20% and 50% of cement with fly ash. He found out that pervious concrete with high porosity shows low compressive strength and high permeability. The results of their investigation described that the permeability of pervious concrete was not notably affected when 50% of cement was replaced by fly ash and compressive strength will decrease with increase of the fly ash content . Na Jin (2010) worked on "fly ash applicability in pervious concrete" using 2% and 32% fly ash in pervious concrete. He found out that using 2% fly ash pervious concrete can achieve higher compressive strength than that of using 32% fly ash in pervious concrete. He also indicated that fly ash helps to increase long term compressive strength of pervious concrete. Vanchai Sata et al.(2012), evaluated the properties of pervious concrete made of high-calcium fly ash. The tests were conducted on pervious concrete to find out void content of concrete, water permeability coefficient, compressive strength, and split tensile strength of concrete. The compressive strengths were found out in the range of 5.43 and 11.49 MPa and splitting tensile strengths were found out in the range of 0.75 and 1.43 MPa were obtained. This is slightly more than conventional concrete strength. They concluded that the high void contents at 25 - 30% led to the high water permeability coefficients between 1.5 and 6 cm/s.

Rahul Bansal (2015) studied the basic replacement of cement to fly ash. It was observed that

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10% replacement of fly ash was 20% and 50% decrease the compressive strength after 7 and 28 days respectively. In 20% replacement, 7% and 11% increase in compressive strength was observed at the age of 7 and 28 days respectively. In 30% replacement 23% and 19% increase the compressive strength was observed at the age of 7 and 28 days respectively. They concluded that As the fly ash content increases there was increase as well as decrease in the strength of concrete. It was also observed that with increase in age the compressive strength also increased for fly ash replaced concrete. **M. Uma Maguesvari et al. (2013),** investigated the influence of fine aggregate and coarse aggregate quantities on the properties of pervious concrete and observed that the increase in fine aggregate results in reduction of volume of voids which in turn increase of compressive strength, flexural strength and split tensile strength. This study illustrates angularity number, which affects the properties of pervious concrete like Coefficient of permeability increases from 0.4cm/sec to 1.26 cm/sec when the angularity number is in the range of 4 to 8.

2.2 INFILTRATION OF PERVIOUS CONCRETE

2.2.1 Permeability

The permeability of pervious concrete is a measure of the water flow through the pore spaces or fractures in the pervious concrete. The permeability of pervious concrete is determined using the falling head permeability test and is estimated based on Darcy's Law. Permeability is an important parameter used in the hydrological design of pervious concrete. Typical permeability values range from 3 gal/ft2/min (120 L/m2/min or 0.2 cm/s) to 17 gal/ft2/min (700 L/m2/min or 1.2 cm/s) (Montes and Haselbach 2006).

2.2.2 Air Voids

The average pore sizes of pervious concrete typically range from 2 mm to 8 mm. The void ratio ranges from 15% to 35% by volume. The air void content of pervious concrete can be determined using either an automatic image analysis device, Rapid Air, according to ASTM C457 (2012) "Standard Test Method for Microscopically Determination of Parameters of the Air-Void System in Hardened Concrete" or the flatbed scanner method (Peterson et al. 2009). Another method is the standard linear-traverse test method (ASTM C1754 2012). In contrast to ASTM C457, in ASTM C1754 the measured points are counted manually.

III. MATERIALS AND METHODOLGY

Several laboratory activities have been conducted in context of this thesis. This chapter will provide a description of the experimental design of these activities. All experimental activity was performed at the concrete research facility in structure lab of college. The experimental work done in connection with this thesis can be divided into three main groups: Aggregates testing, Concrete experiments and calculation for runoff difference.

In this chapter firstly focus on material properties and the procedures utilized for creating and testing of pervious concrete. The tests were conducted to study the following properties: density, void ratio, water permeability and compressive strength. Secondly focus on calculation procedures used to find potential of pervious concrete to manage storm water in Chandigarh city.

3.1 MATERIALS USED

Materials were chosen that gives strength as well as permeability. The reason for this is to create a correlation of results between the strength and permeability. The materials in the concrete were also chosen to accommodate the fact that the concrete should be easy to produce with materials that are commonly used in Chandigarh. Based on these parameters the following materials were chosen for use in the batches of pervious concrete.

Cement: PPC 43 grade and OPC 43 grade, confirm to IS269:1989

Fine aggregate/Sand: locally available material confirm to IS383:1970

Water: normal tap water

Fly ash conforms to AS 3582 (1998).

3.1.1 Cement

Ordinary Portland cement of grade 43 conforming to IS: 8112-1989 was used. Cement was tested according to IS: 4031-1988. The cement was of uniform color i.e. grey with light greenish shade. The properties of cement are given in table 3.1.

Table 3.1: Physical properties of cement

S.NO	Physical Property	Experimental Value
1	Consistency of cement	29%
2	Specific gravity	3.15
3	Initial setting time	30 min.
4	Final setting time	600 min.
5	Fineness of Cement	2%
6	Compressive Strength at 3days (N/mm^2) Compressive strength at 7 days (N/mm^2)	23 N/mm^2 33 N/mm^2

3.1.2 Fine aggregates

River sand has been sieved from IS 1.18mm sieve. It did not contain any impurities such as vegetable matters, organic matter, lumps, etc. The various properties conform to IS: 383-1970 as given in table 3.2 & table 3.3.Weight of sample taken = 1kg.Sand corresponds to grading zone IV of IS 383.

Table 3.2 Sieve analysis of fine aggregates.

Sieve size (mm)	Retained weight (g)	% weight Retained	Cumulative %weight Retained
10	0	0	0
4.75	0	0	0
2.36	0	0	0
1.18	0	0	0
600µ	624	62.4	62.4
300 µ	192	19.1	81.5
150 µ	155	15.5	96.5
Total			240.4

Fineness modulus of fine aggregates = 240.4/100 = 2.404

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Table 3.3 Physical properties of fine aggregates.

Physical tests	Values
Specific gravity	2.63
Fineness modulus	2.404
Water absorption	1.7
Bulk density(compacted) (kg/m^3)	1982
Bulk density (loose) (kg/m^3)	1668

3.1.3 Coarse aggregates

The material which is retained on 4.75 mm sieve is known as coarse aggregate. Coarse aggregate passing 10 mm IS sieve was used in this work conforming to IS: 383-1970, with properties as given in table 3.4 & 3.6 respectively. Maximum size of aggregate was limited to 10mm as higher size of aggregate hindered the placement of POF

Fig. 3.1 laboratory sieve of 9.5 mm and 4.75mm

Table 3.4 Sieve analysis of 10mm down coarse aggregates

Sieve size (mm)	Retained weight (g)	% weight Retained	Cumulative %weight Retained	% Passing
20	0	0	0	100
16	0	0	0	100
12.5	20	1	1	99
10	236	11.8	12.8	87.2
4.75	1456	72.8	85.6	14.4
2.36	269	13.45	99.05	0.95
Pan	19			_
Total	2000		198.45	_

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The aggregate is single sized aggregate as per IS 383
Fineness modulus of fine aggregates = (198.45+400)/100 = 5.98

Table 3.5 Physical properties 10mm down of coarse aggregates.

Physical tests	Values
Specific gravity	2.5
Fineness modulus	5.98
Bulk density (compacted) (kg/m^3)	1649.7
Bulk density (loose) (kg/m^3)	1452.9

3.1.4 Fly ash

Fly ash is a by-product of the combustion of crushed coal in thermal power plant. It is widely used as supplementary cementitious material in concrete mixture..Table 3.6

Table 3.6 chemical composition of fly ash

Chemical composition	Value (%)
Loss of ignition	2.52
Silica as Sio2	51.56
Iron as Fe2o3	7.15
Alumina as Al2 o3	23.23
Calcium as Cao	10.78
Magnesium as Mgo	2.90

In table 3.7 shows that the comparison between the fly ash and cement in somehow property the fly ash lacks in comparison to cement but fly ash is solid waste material use as construction material help to reduce carbon emission from the nature.

3.2 MATERIALS TESTING

Locally available materials are used in producing pervious concrete and several properties were determined in laboratory. Properties are to be find in the laboratory are describes in this chapter.

3.2.1 Specific Gravity Test

Specific gravity is the ratio of the density of a substance to the density of a reference substance; equivalently, it is the ratio of the mass of a substance to the mass of a reference substance for the same given volume. Specific gravity of cement and aggregates are determined in the laboratory by using aggregates in pervious concrete are normally uniform-sized coarse aggregates with a low degree of proper packing. The coarse aggregates should be coated with a cement paste with little or no fines which will harden between the stones. Portland cement is often used as the main binder with a w/c in between 0.26-0.5. Due to the paramount importance of different aggregates in concrete, and especially in pervious concrete, various material properties are determined which is used in pervious concrete are shown in Table 3.1

Table 3.8 Specific Gravity of Material Used in Pervious Concrete

S.No.	Material name	Specific gravity
01	Cement(PPC and OPC)	3.0 and 3.15
02	10mm coarse aggregates	2.65
03	20mm coarse aggregates	2.65
04	Fine aggregates	2.68

3.2.2 Initial and Final Setting Time

Initial setting time duration is required to delay the process of hydration or hardening. Final setting time is the time when the paste completely loses its plasticity. It is the time taken for the cement paste or cement concrete to harden sufficiently and attain the shape of the mould in which it is cast. The initial and final setting time of cement that was determined in the laboratory as per IS: 4031(part 5)-1988 by using Vicat apparatus confirming to IS: 5513-1976 are shown in Table3.2.

Table 3.9 Initial and Final Setting Time of Binder Used in Pervious Concrete

S.No.	Binder used	Initial setting time	Final setting time
01	Pozolona Portland cement	40 Min	10 Hrs
02	Ordinary Portland cement	30 min	10 Hrs

3.2.3 Strength

The strength of pervious concrete is normally substantially lower than other Portland cement concretes of similar w/c. Both the flexural and compressive strength of pervious concrete is highly influenced by mixture proportions and compacting. The flexural strength of structures produced in pervious concrete suffers due to the fact that infiltration of water and corrosive elements makes pervious concrete generally ineligible for reinforcing with steel. Compressive strengths in high permeability pervious concrete are usually in the order of approximately 3 MPa but can be increased up to around 28 MPa by sacrificing void space and thus the percolation rate through the material. This test was conducted on compressive testing machine confirming to IS: 14858-2000

3.2.4 Void Content

The void content in pervious concrete directly affects the rate of percolation and strength in the material. High void content leads to low strength and high permeability, while low void content leads to higher strengths with low permeability. Designing pervious concrete is therefore based on finding the balance between these two factors. For a concrete to be called pervious it must be able to transport water through its structure. As a general rule this means that a void content of approximately 15 % is a minimum.

3.3 PROPORTIONING AND MIXING PROCEDURE

1) For making pervious concrete proportioning and mixing is done by standard method. **3.4.1 Proportioning:**

The process of relative proportions of cement, sand, coarse aggregate and water, so as to obtain a concrete of desired quality is known as the proportioning of concrete. Proportioning is done in two methods.

- Volume method
- Weight method

3.3.2 Standard Mixing:

Mixing is a process to complete blending of the materials which are required for the production of a homogeneous concrete. This can vary from hand to machine mixing, with machine mixing being the most common. Procedure involved in mixing are given below and mixing showing in Figure 3.1

- Dry mix. All the dry materials and aggregates are added according to volume required mixed for 1 min.
- Wet mix. The water containing all liquid admixtures is added to the dry mix over the course of 30 seconds. The wet mix is blended for 2 min.
- Setting. The machine is stopped and the mix is allowed to set for 2 min.
- Remix. The machine is started again and the mixture is mixed for an additional 1 min.

3.4 MATERIALS AND MIX PROPORTIONS

3.4.1Pervious concrete and conventional concrete

Two types of binder materials were used in this study; the first is Type GP Portland cement (AS3972 1997), and the second is fly ash conforming to AS3582 (1998). 10 mm to 20mm crushed gravel, which is well graded, was used as coarse aggregate.

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Mix	C (%)	F (%)	W/B Ratio	CA/B Ratio	FA/B Ratio
A	100	0	0.36	4.0	-
B	80	20	0.37	4.0	-
C	70	30	0.37	4.0	-
D	60	40	0.37	4.0	-
E	100	0	0.36	3.8	0.2

Table 3.10 Mix proportions for pervious and conventional concrete mixes, by weight

C: cement; F: fly ash; B: binder (cement plus fly ash); W: water: CA: coarse aggregate; and FA: fine aggregate

The basic mix proportion for no-fines pervious concrete is binder materials, coarse aggregate and water: 1:4:0.36 respectively.

The water/cement ratio was determined by a trial test, which consisted of forming a concrete ball with hand, as shown in Figure 3.3. Water/binder ratio of 0.36 is found to be suitable to produce mould able pervious concrete. Hence, for all pervious concrete mixes this water/ binder ratio was used.

Table 3.11: Mix proportions for pervious concrete mixes with and without fine aggregate by weight.

Mix	Cement%	Fly ash %	Fine aggregate	W/C Ratio	CA/C Ratio

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A	100%	0%	0%	0.36	4
B	80%	20%	0%	0.37	4
C	70%	30%	0%	0.37	4
D	60%	40%	0%	0.37	4
E	100%	0%	5%	0.36	3.8

IV. RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

The results of the experimental investigation are presented in this chapter. Section 5.2 provides the results of pervious concrete with100% cement, fine aggregate and three different percentages of fly ash. The relationships among density, porosity, compressive strength and water permeability of all pervious concrete are discussed in Section 5.3.

4.2 COMPARATIVE ASSESSMENT OF PERVIOUS CONCRETE

Mix Design	**DAYS**	**Porosity**	Mean **Porosity**
100% Cement (Mix A)	7 14 28	0.32 0.34 0.37	0.34
80%cement+ 20% fly ash (Mix B)	7 14 28	0.36 0.33 0.30	0.33
70%cement+ 30% fly ash (Mix C)	7 14 28	0.35 0.33 0.30	0.32
60%cement+ 40% fly ash (Mix D)	7 14 28	0.35 0.34 0.32	0.33

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100%cement+ 0% flyash+5%fine aggregate (Mix E)	7 14 28	0.33 0.31 0.30	0.31

4.2.1 Density

The densities of all pervious concrete samples after 7 days, 14 days and 28 days of castings are calculated using standard method. Density of Mix A at 7, 14 and 28 days are 1835kg/m^3, 1810kg/m^3 and 1800kg/m^3 respectively. Density of Mix B at 7,14 and 28 days are 1720kg/m^3, 1726kg/m^3 and 1729kg/m^3 respectively. Density of Mix C at 7,14 and 28 days are 1740kg/m^3, 1745kg/m^3 and 1747 kg/m^3 respectively. Density of Mix D at 7,14 and 28 days are 1720kg/m^3, 1730 kg/m^3 and 1734 kg/m^3 respectively. Density of Mix E at 7,14 and 28 days are 1720kg/m^3, 1735kg/m^3 and 1737kg/m^3 respectively. Mean densities of concrete are calculated for all mixes. Densities of mixes ai different curing days are given in table 4.1.

Table 4.1: Density for pervious concrete with and without containing fly ash

Mix Design	DAYS	Density (kg/m^3)	Mean Density (kg/m^3)
100% Cement (Mix A)	7 14 28	1835 1810 1800	1815
80%cement+ 20% fly ash (Mix B)	7 14 28	1720 1726 1729	1725
70%cement+ 30% fly ash (Mix C)	7 14 28	1740 1745 1747	1744
60%cement+ 40% fly ash (Mix D)	7 14 28	1720 1730 1734	1728
100%cement+5%fine aggregate (Mix E)	7 14 28	1720 1735 1737	1730

Table 4.2: Porosity for pervious concrete with and without containing fly ash

From above values it is observed that densities of mixes increased with increase in content of fly ash as replacement of cement, it also increased with increase in curing days. Concrete mix having more density is more compacted i.e. no. of pores decreased with increase in density. It is concluded that concrete mix with less density i.e. Mix D is suitable for construction.

4.2.2 Porosity

Porosity of concrete mixes is calculated with standard method. Porosity of concrete shows it's water/air permeability. Porosity generally means no. of pores per cubic meter concrete. Porosity has great influence on concretes strength and durability. Porosity of different concrete mixes prepared with different fly ash replacement is calculated. Table 4.2 presents the porosity of all pervious concrete with and without cement replacement with fly ash at 7, 14 and 28 days.

The highest mean porosity of concrete mixes is of Mix B and Mix D i.e. 0.33, lowest mean porosity of concrete mix is of Mix E i.e. 0.31. Porosity of mix increased with increased in curing days in Mix A, but by adding fly ash in mixes porosity of mixes i.e. in Mix B, Mix C and Mix D are decreased with increase in curing days. The porosity of pervious concrete are relatively high and they are not affected by age. The coefficient value ranges from 0.56% to 15%. This is also caused by the porosity structure. The porosity is depended on more likely construction methodology such as compaction energy rather than mix properties. Thus, it can be concluded that the partial cement replacement up to 50% with fly ash does not influence the porosity of pervious concrete.

Fig 4.1 shows that porosity of the various Mix design. Mix A shows more porosity than the other Mix.

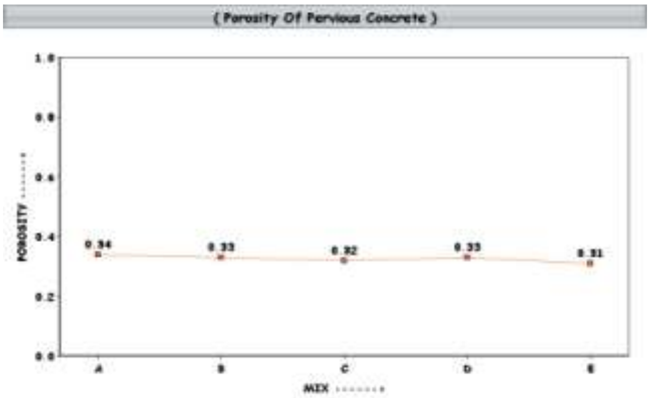

Figure 4.1 Porosity of pervious concrete of different mixes

4.2.3 Compressive strength

Compressive strength for pervious concrete mixes at 7, 14and 28 days are calculated by using compression testing machine. Compressive strengths of concrete mixes are varied with addition of fly ash as replacement of concrete. Pervious concrete having 40% cement replacement with fly ash (Mix D) showed the lowest compressive strength among the all pervious concrete. The mean compressive strength was 5.65 MPa at 7 days and 11.04 MPa at 28 days. Pervious concrete with 100% cement (Mix A) presented the highest compressive strength at both ages, namely 6.67 MPa at 7 days and 14.47 MPa at 28 days. Pervious concrete having 20% cement replacement with fly ash showed marginally lower compressive strength than pervious concrete with 100% cement. The strength was 4.88 MPa at 7 days and 11.55 MPa at 28 days. Thus, it is clear that increased cement replacement with fly ash had reduced the compressive strength of pervious concrete.

Mix Design	DAYS	Compressive strength (MPa)	Mean Compressive strength (MPa)
100% Cement (Mix A)	7 14 28	6.67 10.01 14.47	9.55
80%cement+ 20% fly ash (Mix B)	7 14 28	4.88 5.77 11.55	7.44
70%cement+ 30% fly ash (Mix C)	7 14 28	6.67 8.88 10.66	7.40
60%cement+ 40% fly ash (Mix D)	7 14 28	4.26 6.67 8.89	6.60
100%cement+5%fine aggregate (Mix E)	7 14 28	5.78 13.33 14.00	11.04

Table 4.3: Compressive strength of Mix Design

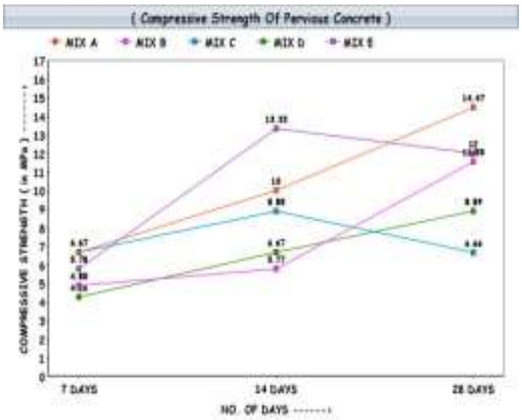

Figure 4.2: Compressive strength of Mix design

The Fig 4.2 shows the compressive strength of the various mix design in which Mix A clearly shows a Maximum compressive strength among all these Mix design.

4.2.4 Water permeability

Water permeability of pervious concrete is calculated for all mixes with different fly ash replacement for cement under all three water heads used i.e. 100mm, 150mm and 200mm. Water permeability under 100 mm,150mm and 200mm water heads for Mix A pervious concrete is 13.7 mm/s, 19.2mm/s and 14.47mm/s respectively. Water permeability under 100 mm, 150mm and 200mm water heads for Mix B pervious concrete is 8.0 mm/s, 6.3mm/s and 5.9mm/s respectively. Water permeability under 100 mm, 150mm and 200mm water heads for Mix C pervious concrete is 10.0mm/s, 9.70mm/s and 6.3mm/s respectively. Water permeability under 100 mm, 150mm and 200mm water heads for Mix D

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pervious concrete is 12.7 mm/s, 14.4mm/s and 13.4mm/s respectively. Water permeability under 100 mm, 150mm and 200mm water heads for Mix E pervious concrete is 12.8mm/s, 11.4mm/s and 10.3mm/s respectively. Water permeability of pervious concrete is significantly influenced by pore structure which is affected by compaction and grading. Mean water permeability under different water heads for each pervious concrete mixes i.e. Mix A, B, C, D and E are 16.02, 15.79, 14.67, 13.5 and 11.5 respectively. Water permeability of different mixes under different water heads are given in table 4.4.

Table 4.4: Water permeability of different Mix Design

Mix design	DAYS	Water head (mm)	Permeability (mm/s)	Mean
100% Cement (Mix A)	28	100 150 200	13.7 19.2 14.47	16.02
80%cement+ 20% fly ash (Mix B)	28	100 150 200	8.0 6.3 5.9	15.79
70%cement+ 30% fly ash (Mix C)	28	100 150 200	10.0 9.70 6.3	14.67
60%cement+ 40% fly ash (Mix D)	28	100 150 200	12.7 14.4 13.4	13.5
100%cement+5%fine aggregate (Mix E)	28	100 150 200	12.8 11.4 10.3	11.5

Water permeability of pervious concrete is relatively high, especially for Mix A and Mix D pervious concretes. Water permeability coefficient under 200 mm water head showed the lowest value for all pervious concrete mixes, while the water permeability under 150 mm water head had the highest value for Mix A and Mix D pervious concrete. This is an unexpected result, since higher water permeability is expected under the highest water head of 200 mm. This is probably caused by change in water flow pattern from steady to turbulent. The sizes of pores in pervious concrete are large; hence high water head may lead to turbulent. Various figures shown below the permeability of the pervious concrete at various water heads and mix design.

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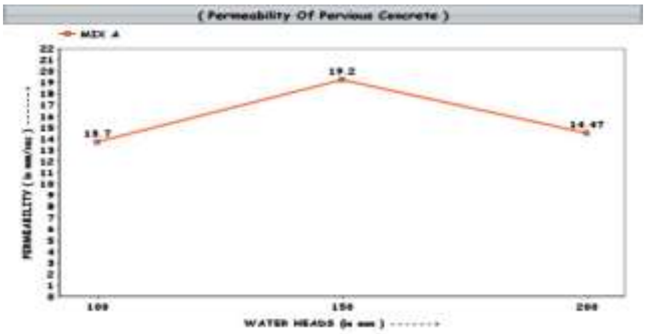

Figure 4.3 Permeability of pervious concrete of Mix A at 100,150,200 heights

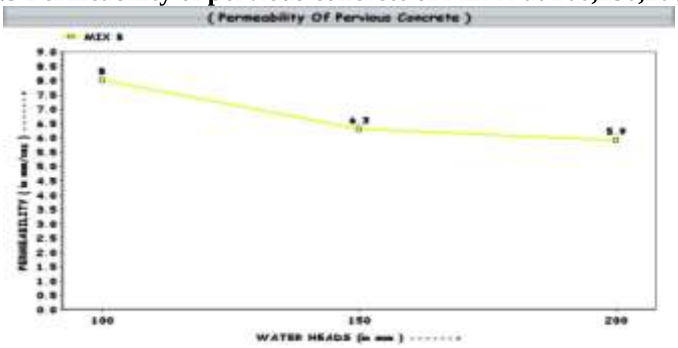

Figure 4.4 Permeability of pervious concrete of Mix B at 100,150,200 heights

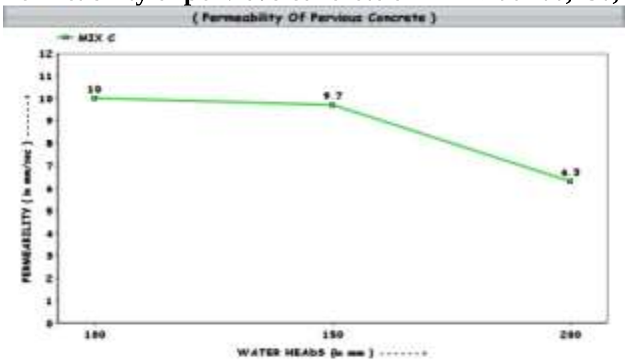

Figure 4.5 Permeability of pervious concrete of Mix C at 100,150,200 heights

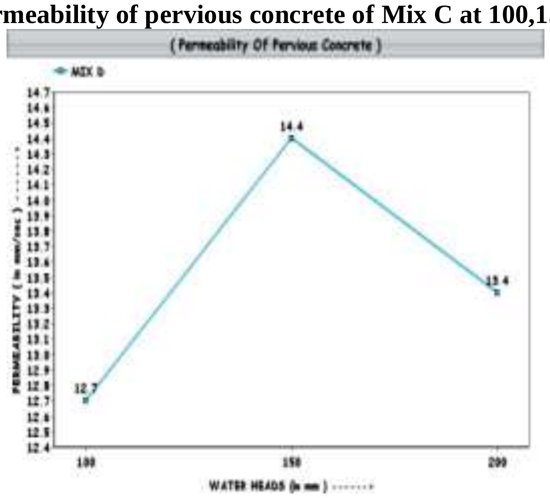

Figure 4.6 Permeability of pervious concrete of Mix D at 100,150,200 heights

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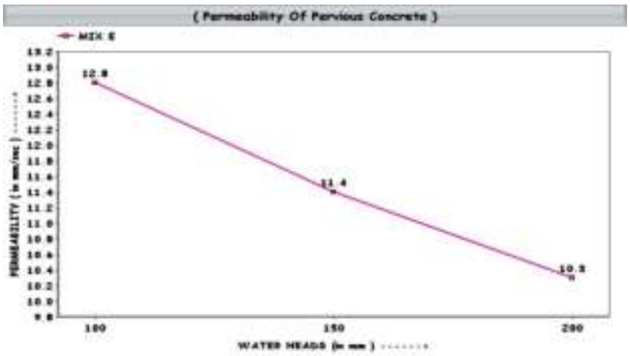

Figure 4.7 Permeability of pervious concrete of Mix E at 100,150,200 heights

4.3 ASSESSMENT ON CARBON EMISSION

According to M20 mix design proportion of the coarse aggregate (CA), fine aggregate (FA) and cement are used in one cubic meter are as given below.

Table 4.5 Quantity of material used in one cubic meter

Items	Cement	FA	CA
In (kg)	360	584	1223.8

Mathematical calculation of carbon emission for different concrete raw materials are as below:

Total CO_2 emitted by Coarse Aggregate is = 25.47 kg/m^3

Total CO_2 emitted by Fine Aggregate is = 6.38 kg/m^3

Total CO_2 emitted by cement is = 417.6 kg/m^3

Thus, the sum total CO_2 emission of all the raw materials for conventional concrete is is equal to 449.5 kg/m^3. In the next step, analysis of CO_2 emission by the pervious concrete is calculated. Total material used in one cubic meter of pervious concrete as given below

Table 4.6 Items used in pervious concrete

Item	Cement	CA	Fly ash (20% replace by cement)
Quantity(kg)	285	1422	71

Mathematical calculation of carbon emission

Total CO_2 emitted by Coarse Aggregate is = 29.60 kg/m^3

Total CO_2 emitted by Fly Ash is = 0.072 kg/m^3

Total CO_2 emitted by cement is = 330 kg/m^3

Sum of all the CO_2 emission is equal to 359.61 kg/m^3. As per the above result, the CO_2 emission is reduced by the pervious concrete

V. SUMMARY AND CONCLUSIONS

5.1 GENERAL

The present study was undertaken to investigate the potential of pervious concrete to storm water management in areas where rainfall occurs at a very high rate. Based on result obtained from the present study, the following conclusions have been drawn and are reported in this chapter.

5.2 SUMMARY

Pervious concrete is a special type of concrete that is used for flatworks and allow water to seep through the concrete due to its high permeable structure. In present study we have several objective such as compressive strength, permeability, reduced the carbon emission and find out the best mix design in performance wise. Therefore we did various experiment and survey to find out the best one. The main thing is that we use fly ash in the mix design which was the main work because fly ash gives a better final product but also it is a sensible way to control the pollution. The overall performance of pervious concrete can be enhanced by using fly ash as a mineral admixture. CO_2 emissions created during cement production are greatly reduced by using fly ash as a partial replacement of cement, which decreases the negative effect on our atmosphere. In addition of second thing was that reducing the carbon emission by minimizes the use of cement in now days cement widely use product in world wide. In this section we summarize the whole research briefly. Firstly we describe the general introduction about pervious concrete, their use in previous times, advantages and disadvantages. These information are described in first chapter, from these information we know enough about pervious concrete. We study some relevant previous literature of pervious concrete and describe them in second chapter. We also study carbon footprint relevant literature and described them in second chapter. These literature studies helped us in experiment conducting. After this we select the materials which we used in conducting experiment. After material selection we estimated their properties so that they significantly used for mix design. Properties of materials describe whether they produce suitable mix or not. In this study we use materials having significant properties. All tests are conducted in this study as per standard methods. Pervious concrete mix is designed as per Indian standard with partial replacement of cement with fly ash and some mixes having fine aggregates. Tests conducted on these concrete mixes are described in chapter third. After conducting tests, results are mentioned in forms of table and graphs. Discussions of graphs and tables are described properly in chapter fifth. Discussions of results include comparison of mixes with each other, so that we can easily find which mix gives best results. We also calculated carbon footprints of different concrete mixes mathematically. Pervious concrete reduced carbon emission of concrete by replacing cement with fly ash. Pervious concrete with 20% fly ash replacement gave 30% less carbon emission than conventional pervious concrete. Compressive strength of pervious concrete with 0% of fine aggregates was approximate 14MPa and by varying percentage of fine aggregates from 0-10% and fly ash 20%-40% the compressive strength was increased up to 16MPa. Permeability of pervious concrete was estimated in range of 0.6 -1.3cm/s. We study storm water management using pervious concrete from which it concluded that storm water provided is not sufficient for maximum intensity. We also calculated performance analysis of pervious concrete mixes from which it concluded that Mix B has better performance in comparison of other mixes. All results and discussions are described in chapter fourth. At last we made conclusions from our study and presented in this chapter, we analyzed some recommendations for future work.

5.3 CONCLUSIONS

- From the results obtained it can be concluded that with increment in water cement ratio there was decrement in compressive strength of pervious concrete.
- Compressive strength of pervious concrete with 0% of fine aggregates was approximate 14MPa and by varying percentage of fine aggregates from 0-10% and fly ash 20%-40% the compressive strength was increased up to 16MPa.
- Permeability of pervious concrete was found in between 0.6 -1.3cm/s.
- It was found that the storm water drains that provided are not sufficient for maximum intensity.
- After calculating and comparing runoff it can concluded that from 6-15% of runoff will be decreased by providing pervious concrete in parking area, footpaths and low traffic roads.
- We reduced the carbon emission up to 30% in compare to conventional concrete
- Performance of Mix B (20% fly ash replace with cement) gives the better result in all aspects.
- In this study, Co2 emission of raw material was highest for cement, followed by aggregate and fine aggregate. The emission is very low in the fly ash. In the future we used the fly ash for the low carbon emission.
- Transportation of raw material is also play a vital role in the co2 emission, so we can avoid the more transportation of raw material.

5.4 Limitations of the Study and Future Scope

The research on pervious concrete are still limited, only up to 25MPa strength were observed. But it promises a great scope for future studies. Following aspects can be investigated in future.

- For achievement of higher strength and workability in pervious concrete, it is not possible to get higher strength with conventional concrete mix. Modification is necessary in design. With use of fly ash and silica fume, it can be possible to increment in strength of pervious concrete.
- For achievement of more water-management through pervious concrete it can be possible to construct major roads and pavements by increasing strength of pervious concrete at desired permeability.

5.5 SOCIAL IMPACT OF PROJECT

- Parking areas paved with pervious concrete reduce the need for large detention ponds, because the pavement itself acts as a detention area. Parking lot owners that use pervious will spend fewer dollars on the labor, construction, and maintenance of detention ponds, skimmers, pumps, drainage pipes, and other storm water management systems. Expensive irrigation systems can also be downsized or eliminated.
- Many government agencies are now implementing storm water impact fees for all impervious areas.

As regulations further limit storm water runoff, it is becoming more expensive for property owners to develop real estate, due to the size and expense of the necessary drainage systems. Pervious concrete can reduce these fees for the property owner by helping to minimize demands upon sewer systems.

- Concrete pavements have a significantly lower life-cycle cost than alternatives such as asphalt. Although the initial cost of pervious installation may be slightly higher, concrete saves money in the long run due to its superior durability and strength. It requires fewer repairs than asphalt, and has a longer overall lifespan as well

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