# Application of porous concrete in pavement

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**Abstract**—To develop smart and sustainable cities in India, we need to develop smart technologies and sustainable construction materials and also to focus on minimizing our defects. In India, the groundwater table is decreasing at a faster rate due to a reduction in groundwater rechargers. As rapidly growing and uncontrolled changes within the natural landscape thanks to human intervention have created a significant problem of rainwater harvesting in many Indian cities. Rainwater is seen getting wasted in the city because of a lack of proper arrangement of drainage systems. Nowadays, the vegetation cover is supplanted by foundation hence the water gets very little opportunity to infiltrate itself into the soil. If the porous concrete which has a high porosity is utilized for the development of pavements, strolling tracks, parking areas, well coating, and so forth then it can reduce the runoff from the site and help in the groundwater recharge. This lessens the potential for downstream sewer overcharging and flooding, decreases downstream contamination stacking, and accommodates groundwater to re-energize. The construction of Porous concrete pavement (PCP) is also one of the best methods to solve this problem. Such types of smart materials will play an important role in Indian conditions where the government is putting a lot of effort to implement groundwater recharging techniques. However, the use and implementation of porous concrete pavements in India are exceptionally negligible because of a shortage of involvement and experienced laborers, and accordingly, the structure of porous concrete makes limits to its mechanical strength and difficulties in its maintenance to accomplish the expected lifetime. This research aimed to work out the properties of porous concrete-supported trials within the laboratory and on sites. We have also studied some important factors to implement porous concrete like where it can be used over an existing road, the maintenance schedule prepared for the supervision of PCP, to measure the infiltration rate at different intervals to determine if there was clogging in the PCP, the mix design for the porous concrete which was completed dependent on its permeability and characteristics strength, different geographical provisions, the traffic intensity and the precipitation for that particular region the concrete was designed. In some research, it's seen that there's effective seepage execution of the PCP, showing the probability of development of such pavements within the waterlogged areas of India. This research paper also examines the planning and technical details related to the implementation of the pavement system including an examination of regulatory requirements concerning stormwater management that applied to the development project. Pavement system costs including ongoing maintenance costs are also evaluated and compared to costs associated with a more conventional pavement and stormwater management.



**Index Terms**— Porous Concrete Pavement(PCP), sustainable construction material, ground water recharge, rain water harvesting, water logging, maintenance, effective seepage execution.

## 1 Introduction :-

### 1.1 Introduction :-

To develop smart and sustainable cities in India, we need to develop smart technologies and sustainable construction materials and also to specialize in minimizing our defects. In India, the groundwater table is decreasing at a faster rate as India is an underdeveloped country and goes through drastic changes to develop its infrastructure which results in the reduction of groundwater rechargers. Nowadays, Paved surfaces have become quite common everywhere around the globe because of urbanization. As urbanization increases in India and lots of parts of the world, the problem of waterlogging and also the requirement of drainage are additionally increased, this can be partly due to the imporous nature of the bituminous and concrete pavements. The rainwater that might have earlier been percolated into the ground has now become a runoff, which needs proper stormwater management to make sure adequate groundwater recharge. The use of porous concrete as pavement material with little or no fine aggregate and only enough cement paste to bind together the coarse aggregate has been recognized as Best Management Practice (BMP) by the US Environment Protection Agency (EPA) for providing pollution control, stormwater management, and for sustainable development.

Porous concrete is also called permeable concrete, no-fines concrete, and Pervious concrete. In recent years, porous concrete has become popular as an efficient stormwater management device in a region that receives frequent and sometimes extensive rainfalls. Also, because the metropolitan regions extend, the vegetation cover is being replaced by infrastructure hence the water gets little or no opportunity to infiltrate itself into the soil. If the porous concrete which contains a high porosity is used for the development of pavements, strolling tracks, parking areas, well coating, so forth then it can reduce the runoff from the location and help in the groundwater recharge. This lessens the potential for downstream sewer overcharging and flooding, decreases downstream contamination stacking, and accommodates groundwater to re-energize. The construction of Porous concrete pavement (PCP) is additionally one of the most effective methods to resolve this problem. Such types of smart materials will play a crucial role in Indian conditions where the govt is putting tons of effort to implement groundwater recharging techniques. Porous concrete pavement (PCP) is an alternate to traditional concrete and asphalt in the roadway and pavement design which contributes to enhancing society benefits the environment and promotes the economy while also presenting a number of the prevailing challenges that limit its application. Porous concrete pavement is one of the quickest developing technologies in sustainable roadway engineering. However, the utilization and implementation of porous concrete pavements in India are exceptionally negligible due to a shortage of involvement and experienced laborers, and accordingly, the structure of porous concrete makes cutoff points to its mechanical strength and has many troubles in its maintenance to accomplish the expected lifetime. Additionally, costly stormwater structures like piping, inlets, and ponds are eliminated. Construction schedules also will be improved because the stone recharge bed is going to be installed at the beginning of construction, which helps in enhancing erosion control measures and preventing rain delays thanks to harsh site conditions. There are several benefits for using porous concrete in sidewalks as below the sidewalks there's not any foundation or any concrete structure which will get affected by seepage of water, therefore the seeped water will directly contribute to the groundwater level without affecting any structure. One of the foremost significant advantages is its adequacy for stormwater management; reduces puddling, reducing Stormwater runoff, Helpful in reducing surface runoff, it's eco-friendly, it keeps roads surface cool and clean, Effective utilization of waste, it'll help to protect trees and increases the extent of groundwater level. It also can filter contaminants thus improving water quality. Many types of research have shown high removal rates of Total Suspended Solids (TSS), metals, oil, and moderate removal rates for phosphorous from utilizing porous Concrete.

### 1.2 Background :-

Pervious concrete was first used in the 1800s in Europe as pavement surfacing and load bearing walls. Cost efficiency was the main motive due to a decreased amount of cement. It became popular again in the 1920s for two storey homes in Scotland and England. It became increasingly viable in Europe after WWII due to the scarcity of cement. It did not become as popular in the US until the 1970s. In India it became popular in 2000. [1]


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## 2 Literature Review

### 2.1 Material Used:-

#### 2.1.1 Cementitious Material

Type 1 to 4 grade Portland cement is commercially available and used for sustainable concrete production. (ATM 150). Cement Cement (Plastic Plastic Cement, also known as GGBFS) is a concrete material used in concrete production. (TSMS 989) Fly ash is commercially available and used in sustainable concrete production. (SCM 618). Many types of ash and fly are additional cement materials, which are often used to replace the amount of cement. Both provide good benefits for durable concrete and provide increased performance, which means they add durability and compressive strength in the long run. Both require longer healing time so that the first resistant concrete can stand and gain strength. Additional cement materials (SMS) can be added to cement such as flies, pets and moss. SME affects concrete performance, deadlines, toughness, fragility and more. Silica smoke, ashes, and ashes will increase resilience by reducing fragility and cracks.
Ash is a waste product of burning coal in the power plant used for landfill, but now large quantities are used in cement to increase strength. This material can be used to replace 5-60% Portland cement cement. The blast furnace is a product made of steel. It is added to the concrete and the strength and durability are higher and can replace 20-70% cement in the mix.
Silicone smoke is a product of silicone production. Silicon fumes are good spherical particles and increase the strength and toughness of concrete. It is often used for high-rise buildings and produces concrete that exceeds the compressive strength of 20000P. Silica fume can replace cement in 5-11% volume. [3]

#### 2.1.2 Aggregates

The content of the aggregate is limited to concrete and gravel, including an important role in sustainable concrete. The most commonly used aggregate (19.0 - 4.75 mm), (9.5-2.36 mm). A single unit up to 1 inch (25 mm) is also used. Large units provide rough surfaces. Round and angular summation is used in solid concrete, and generally higher strength is achieved with rounded aggregates. Incorporating physical characteristics such as size, shape and distribution play an important role in the management of mechanical processes, stability, and sustainability of concrete floors. In addition to the size of the aggregate, the total type has a significant effect on the properties of the resistant concrete. Although limestone assemblages are commonly used to produce resistant concrete, there are a number of other studies that show that the sedimentary, sedimentary, sedimentary, sedimentary rocks are replaced by convection. In this diatomite, the concentration provides a higher compressive strength at higher porosity levels than the similar mixture. In another study, natural limestone aggregate (NN) and two types of recycled aggregates: recycled concrete aggregate (RBA) and recycled concrete aggregate (RCA) were the materials used. The water uptake of RBA and RCA was approximately ten-fold higher than that of NA. In other studies, coarse aggregates, such as dolomite, cheddar, steel, were used to drain the leakage capacity of concrete. The best type of aggregate for the preparation of hydropower concrete from a biological point of view is the daisy. For lightweight concentrations of stable concrete, coconut kernel bark is used as an alternative to inertia. [3]

### 2.1.3 Admixtures

For concrete properties, chemical impurities are used like ordinary concrete. Due to the faster repair time in the concrete, added fluid stabilization or hypothermia are usually used. The use of chemicals should be strictly followed by the manufacturer's recommendations. Air impurities, which can reduce cold water damage in ductile concrete, are used when freeze-thaw is a problem. This code regulates ASTM C 494 - Chemical impurities and S-260 - impurities for air concrete. Water reduction impurities are also used. The dose for resistant concrete may exceed the range commonly used for conventional concrete. A threshold of 6 oz / cyl is recommended for this type of concrete. The fluid stability is also known as advanced control and viscosity additives (VMAs). Every day, new impurities for sustainable concrete are discovered e. More recently, the company has teamed up with water manufacturers, fluid stabilizers and recyclers to create a product in the market for sustainable concrete. [3]

### 2.1.4 Water

A W / C ratio of 0.20 to 0.35 is routinely used with a high concentration of chemical impurities into the concrete, with a maximum of 0.40 in the concrete. The relationship between strength and water / cement ratio is not clear for resistant concrete, unlike conventional concrete, the total paste content of concrete is less than the void content of the aggregate. Therefore, reinforcing the paste may not always lead to an increase in the overall strength of the concrete. Water content should be strictly controlled for these species. The correct amount of water should be poured into the concrete for good results if the water level is high and no gaps are present. Water quality is discussed in AIA 301. As a general rule, drinking water is suitable for use in concrete. Recycled water from the use of concrete may be used in the well if it complies with the provisions of SMSAAAA or 157. [3]

## 2.2 Mix Design Components

### 2.2.1 Cement Content

For compressive strength and void content, the general concrete material of ductile concrete is important. The compressive strength will be reduced when inadequate cement material is formed improperly. The size and degree of convection depends on the optimum context of the cement material and usually ranges between 265 and 417 kg / m3. The above guidelines can be used to develop a batch.

The ASTM C1688 test can be performed in the laboratory to determine if the target deletion content is achieved correctly. [3]

### 2.2.2 Void content

There was no significant leakage through the concrete due to insufficient coupling of the gaps to allow rapid colorization at less than 15% of the void content. Therefore, concrete mixes are usually designed for 20% void content to achieve sufficient strength and penetration. [3]

### 2.2.3 Water cement ratio

The water cement ratio ($W/C$) is important for obtaining the desired strength and improper structure in the resistant concrete. A high $W/C$ ratio reduces the adhesion of the paste to the unit and causes the paste to flow and fill the gaps even when compacted. A low $W/C$ ratio will prevent good mixing and may result in the formation of beads in the mixer and prevent even sealing of cement paste thus reducing the maximum strength and durability of the concrete. The $W/C$ ratio between 0.25 and 0.40 provides the best overall coverage and stability. The simple ratio $W/C$ to increase the strength for ordinary concrete does not apply to resistant concrete mixtures. Careful control of the moisture ratio $W/C$ is essential to obtain a stable and stable concrete. [3]

## 2.3 Different Properties

### 2.3.1 Hardened Properties :-

#### 2.3.1.1 Density And Porosity

The properties and proportions of the materials as well as the sealing procedures used in the installation depend on the density of the concrete. General densities ranging from 100 lbs / ft / to 127 lbs / ft (1610 kg / m to 2010 kg / square foot) are in the upper range of lightweight concrete. A 5-inch slab with 25% spacing will allow 1-inch of rain to cover most of the rainfall. When placed on a 6-inch (150 mm) layer with thick gravel or crushed stone, the load capacity increases to 3 inches (75 mm). [3]

#### 2.3.1.2 Compressive strength

In the laboratory, the development of compacted concrete resistant concrete mixes ranges from 3.5 MPa to 28 MPa, which is suitable for many types of applications. About 17 MPa is the normal compressive strength value. Specific material properties and combinations as well as placement techniques and environmental conditions will determine the strength. However, there is currently no ASTM test standard for the compressive strength of resistant concrete, test differentials measured by various test methods have been found to be high. Instead, it is recommended to specify null content between 15% and 25% as measured by MSM 1688: Standardized test method for density and blank content of mixed primary summary for quality assurance and reception. Take. [3]

#### 2.3.1.3 Permeability

Permeability was used to measure the resistance to a permanent nozzle designed in the laboratory. Samples were placed in the apparatus for maintaining a vertical water column above the surface of each sample. The apparatus tightens around each sample and seals and restricts the flow of water so that water enters and exit only through the top and bottom of the sample. The water level was maintained at 75 mm above the sample surface. This ensures that the surface turbulence will not affect the flow of water in the sample. Flow rates were measured using a measuring device (ISCO UniMag 4401 magnetic flux) in a water main. Adjust flow rate while keeping a fixed head 75 mm above the sample for 10 minutes. Once the flow equilibrium is reached, the flow rate through the sample is recorded. The resistance of each sample was calculated by dividing the flow rate recorded by the surface area for each sample. [3]

#### 2.3.1.4 Flexural strength

In a continuous summary, the flexural strength usually varies between 150MPa and 550MPa. Many factors affect flexibility, especially the degree of compactness, roughness, and aggregation to the cement ratio. For design, measurements of flexural strength are not required in the application of resistant concrete. [3]

#### 2.3.1.5 Shrinkage

Degradation of resin-resistant concrete develops faster but less than normal concrete. The specific compaction values will depend on the mixture and the material used, but the order values of .002 are reported for precast concrete, which is about half of the typical concrete mix. The low content of the paste and the solution of the material is explainable. In the first 10 days, a shrinkage of 50 to 80% occurs for resistant concrete compared with 20% to 30% over the same period for regular concrete. Due to its low contractility and surface texture, many resistance materials are manufactured without the control joints and allow for accidental cracking. [3]

### 2.3.2 Durability Properties :-

#### 2.3.2.1 Freeze thaw resistance

It seems that the cold resistance and melting of the resistant concrete depend on the degree of saturation of the gaps in the concrete when cooled. This field will have a fast drainage feature that prevents saturation. The corroborative evidence also suggests that snow-covered concrete is being cleaned faster because the void content allows the snow to melt faster than normal flooring. In fact, many concrete floors in North Carolina and Tennessee have been in service for more than 10 years. Studies show that the air entering the pots improves protection against freezing and melting of resistant concrete. The use of air retention agents in cement paste will be a minimum of 6 inches and often up to 12 or 18 inches in sand dunes such as 1-inch stones are usually recommended in cold-weather conditions. Melt where the cold period receives considerable moisture. [3]

#### 2.3.2.2 Sulphate resistance

Aggressive chemicals such as acid and sulfate in soil and water are a concern for conventional and resilient concrete. Both have similar mechanisms of attack. The open structure of concrete slab may be more attack than closed in large areas. In soils with high sulfate content and Pervious concreteground-water can be used if insulated. Maximum 6-inch, 1-inch-thick concrete provides concrete slab foundation and rainwater insulation. These precautions are taken in the aggressive environment as recommended by ACI 201 for W / C ratios, and the type of material and the ratio should be strictly observed. [3]

#### 2.3.2.3 Abrasion Resistance

Due to the coarser surface texture and the open structure of the concrete, the removal and removal of aggregate particles can be problematic, especially when snow plows are used to clean floors. This is the main reason why applications such as highways are generally unsuitable for tubular concrete. Evidence that a sealed concrete floor allows the snow to melt faster and requires less plowing. Most soluble concrete flooring will have some loose accumulation on the surface at the beginning of the first week.

These concentrations initially were poorly bonded to the surface and appeared to be due to the charge load. The surface sliding speed decreases after the first few weeks and the pavement surface becomes more stable. Proper compression and healing techniques reduce the appearance of sealing on a durable concrete surface. [3]

## 3 Mthododlogy

### 3.1 Experimental materials and mix proportion:-

#### 3.1.1 Cement, Aggregate & Water

In this 53 grade Deccan Cement (OPC) is used. The color of cement is gray and free from lumps as per IS: 12269:2013.
Tests are performed for cement and are according to standards. [2]

#### 3.1.2 Mix Proportion.

| Mix | Cement (kg/cu.mt) | Aggregate (kg/cu.mt) | Water (lit/cu.mt) |
|---|---|---|---|
| Ratio | 1 | 4 | 0.32 |
| Quantity | 450 | 1800 | 144 |

**Mix proportions**

### 3.2 Preparation of Sample and Testing:

Mechanical properties of Porous concrete are found out by performing tests of compressive strength, flexural strength, porosity, and permeability. [2]

#### 3.2.1 Compressive strength test :-

*Test Procedure:*

1. In order to calculate the compressive strength, cylinders of dimensions 100x200 mm are used.
2. 2. The proportions are then mixed and placed in the cylinder in two layers by giving 25 blows with a mod-

ified proctor hammer for each layer and is then kept for curing for about 7,14,28,56,91 days.

3. After the curing period, the compression strength of the specimen is found out by testing it in the Compression Testing Machine CTM. [2]

### 3.2.2 Flexural strength test :-

Test procedure:

The following testing procedure was undertaken during the flexural strength testing:

1. The specimens for testing are prepared by moulding the concrete into beams, with dimensions500mm×15mm×15mm,support and loading has done as per IS 456-2000.
2. The specimens which are cured in water are tested immediately after taking out of water; while they are still wet. The test specimen should be placed in the machine correctly by centering with the longitudinal axis of the specimen at 900 to the rollers. The loading direction should be normal to mould filling direction in case of molded specimens.
3. The load should be applied slowly without sudden loads at a rate so as to increase the stress at a rate of 0.06 + 0.04 N/mm2 per second.
4. The Flexural Strength (Fb) is given by,

$$F_b = P \times L/(b \times d^2)$$

Where,

Fb = Flexural strength (N/mm2),

P = maximum load in kg applied on the specimen,
L = length in cm of the span of the support.
b = width of specimen(cm),
d = depth of the specimen(cm). [2]

### 3.2.3 Density and void content :-

*Test Procedure:*

1. Calculate the mass of each sample core to the nearest 0.1 g, and record it as "Initial Mass."
2. Initially dry the sample for 24 h ± 1 hour, and find this mass ($W_D$), to the nearest 0.1 g. Place the specimen in the oven for about one hour and note the mass again. When the difference in mass is less than 0.5 %, then constant mass is achieved. Drying in the oven should be continued until a constant mass is achieved.
3. In a bulk density tank-scale measuring system is filled completely with tap water, specimens are submerged completely, and place them straight for 30 minutes underwater.
4. After 30 minutes, keeping the specimen submerged in water, the side of the specimen is tapped 10 times with a rubber mallet. Rotate the specimen slightly after each tap so that they are equally spaced around the circumference of the core.
5. The mass of the specimen is measured to the nearest 0.1 g by submerging the specimen under water, and record it as the "Submerged Mass" ($W_S$) Calculate the Porosity as follows:

$$P = [1 - ((W_D - W_S) / \rho_w) / V_T] \; x \; 100 ].$$

Where,
P = Porosity of the concrete,

$W_D$ = Dried mass of the given concrete,
$W_S$= Submerged Mass of the given concrete,
$V_T$= Total Volume. [2]

### 3.2.4 Water permeability test :-

Test procedure:

1. Measurement of water permeability: As pervious concrete contains large interconnected pore network, the methods that are used to evaluate the hydraulic conductivity of normal concrete are not applicable directly. In order to estimate the hydraulic conductivity of pervious concrete, a falling head permeability cell has been designed.
2. The permeability cell has a 300 mm long acrylic tube with an inner diameter of 110 mm. The specimen is closed in a sponge type membrane which does not absorb water. After placing the specimen in the permeability setup water will be allowed until the taken head level has filled in the graduated cylinder by closing the out let value. The head levels 22 cm difference has taken. Out valve should be released to check the time (t) taken for the water filled between head levels and measured coefficient of permeability (K).

$$K = A_1 l/A_2 \; x \; log(h_2/h_1)$$

Where,

$K$ = Coefficient of permeability,
$A_1$ & $A_2$ are cross-section areas of the sample and the tube,
**L** is length of the specimen,
**h1 & h2** is initial and final heads.

Flow rate is calculated by:
$Q = KIA$
$K$ = permeability m/s,
$I$ = hydraluic gradient,
**A** = cross sectional area ($m^2$). [2]

## 4 Advantages,Disadvantages & Limitation

### 4.1 Advantage Of Pervious Concrete:

#### 4.1.1 Environmental benefits:- [13]

1. It reduces stormwater runoff replenishes water tables and aquifers.
2. It eliminates detention ponds that are costly for stormwater management practices.

3. Also permits for extra environment-friendly land growth.
4. It prevents warm and polluted water from getting into streams.

#### 4.1.2 Safety benefits: [13]

1. It minimizes flash flooding and standing water.
2. Skidding is lowered.
3. Light reflectivity is greater than asphalt surfaces, therefore reduce the heat island effect.
4. Glare from the wet pavement is virtually eliminated.

### 4.2 Disadvantages Of Pervious Concrete: [13]

1. Runoff from adjacent areas onto pervious concrete needs to be prevented.
2. The parking areas are generally limited to auto parking and occasional trucks.
3. If reinforcement is required, epoxy-coated bars should be used.
4. Concrete has variable permeability.
5. Over-vibration significantly reduces permeability.

### 4.3 Limitations

The main limitations are,

#### 4.3.1 Maintenance considerations

The required maintenance schedule must be followed for a pervious concrete pavement to function as planned.
In addition to owners not being aware of the existence of pervious concrete pavement on a property, the primary explanation for premature prior concrete pavement failures is the negligence of necessary maintenance activities and schedules.

#### 4.3.2 Effectiveness

To greatly reduce the volume of runoff, to provide groundwater recharge, and to reduce pollutants in stormwater runoff, perennial concrete pavement can be used. Research shows that current concrete pavement structures support up to 80% of the annual rainfall to recharge groundwater.

## 5 COMPONENT OF DIFFRERNT CASE SYUDIES

**Tab 1: Important points of Different case studies on Porous Concrete**

| Sr. no | Title of paper | Important data from the paper |
|---|---|---|
| 1. | THE USE OF PERMEABLE CONCRETE FOR GROUND WATER RECHARGE. [5] | 1.Moreover as the urban areas expand, the vegetation cover is being replaced by infrastructure hence the water gets very less opportunity to infiltrate itself into the soil.<br>2.As urbanization increases in India and many parts of the world the problem of water logging and requirement of drainage is also increased. |
| 2. | FEASIBILITY OF PERVIOUS CONCRETE PAVEMENT. [4] | 1.It can still have application in vehicle parking areas, pathways, driveways, sidewalks, alleys, and low volume roads.<br>2.It also serves environment-friendly benefits such as stormwater reduction, groundwater recharge, pollutant dwindling, reduces river peak flow, heat island reduction, noise reduction, and skid Reduction. |
| 3. | THE USE OF PERVIOUS CONCRETE IN RAINWATER MANAGEMENT. [6] | 1.PAVED surfaces have become very common all over the world due to urbanization. The rainwater that would earlier percolate into the ground is now turned into runoff, which requires proper storm water management to ensure adequate ground water recharge.<br>2.The use of pervious concrete as pavement material with little or almost no fine aggregate and just enough cementations paste to bind together the coarse<br>aggregate has been recognized as Best Management Practice<br>(BMP) by the US Environment Protection Agency (EPA). |
| 4. | EXPERIMENTAL STUDIES ON PERVIOUS CONCRETE. [7] | Indian Institute of Technology Kharagpur (IIT Kharagpur) team has been developing the material customised for<br>Indian conditions, which is still not used in India. It could be tested commercially on PPP basis in upcoming<br>residential complexes and multiplexes, parking lots, parks, etc. This will not only reduce water logging owing to impervious land cover, but also reduce heat in the surrounding environment. Also, such places encounter less dust in comparison to busy roads. Hence, it is hypothesised that the wear and tear of pervious concrete pavements will be comparatively less, thus ensuring longer pavement life. |
| 5. | A REVIEW ON VARIOUS CASE STUDY OF PERVIOUS CONCRETE USING INDUSTRIAL WASTE. [3] | 1.Instead of preventing water entry into the soil, sidewalks help with the process by putting rainwater into a network of gaps that allow it to penetrate the lower soil. In many cases, separated concrete pavement and parking can double water retention structures and reduce or eliminate the need for traditional rainwater management systems such as ponds, water retention and sewer.<br>2. IS CODES For Pervious Concrete. |
| 6. | CONSTRUCTION OF PERVIOUS CONCRETE PAVEMENT STRETCH, AHMEDABA, INDIA. [8] | 1.Rapidly growing and uncontrolled changes in the natural landscape because of human intervention has created a serious problem of rainwater drainage in many Indian cities. With natural disasters like floods increasing every year, there is a need to set up specific water disposal systems in urban and semi-urban areas. This problem is increasing day by day due to lack of modern drainage infrastructure in most of the cities of India.<br>2.During rains, road water remains stagnant for hours at a time causing erosion of the road and decrease in lifespan of the road. |
| 7. | A STUDY ON WATER ABSORBING ROAD BY | *Environmental Benefits of Porous Concrete:-<br>1. Helpful in reduce the surface runoff.<br>2. It is eco-friendly as well as, it keeps roads surface cool and clean. |

| | | |
|---|---|---|
| | PERVIOUS CONCRETE. [9] | 3. Effective utilization of waste material.<br>3. It will be helpful in protecting trees.<br>4. Rainfall water allows infiltrating ground water, aquifer recharge and increases the level of water table. |
| 8. | CASE STUDIES ON THE CONSTRUCTION OF PERVIOUS CONCRETE PAVEMENTS IN INDIA. [10] | Pavements form an impervious layer against the natural ground and are known to cause two major changes in the urban environment. The impervious layer increases the stormwater runoff and reduces the groundwater recharge, which leads to increased flash flood occurrences. Further, pavements store heat within the surface layer due to lower thermal conductivity and latent heat capacity, and transfer back to the atmosphere during evening time, increasing the local temperature with reference to rural areas. This phenomenon is termed as urban heat island (UHI) effect, which is known to cause thermal discomfort to dwellers and also increases the consumption of electricity for cooling purposes. |
| 9. | EFFECTIVE STRENGTH OF POROUS PAVEMENT AT GLOBAL CITY. [11] | 1.Transportation plays an important role in development and growth of living standard of the human society.<br>2.Porous concrete contains almost 20-30% or up to 30% of the voids. The voids present in the concrete will allow the water to penetrate through it. Penetration of water through voids will lead to increase in the level of ground water table and also the storm water gets filtered through it so that the amount of the contamination is less. |
| 10. | The Effect of Pervious Concrete on Water Quality Parameters. [12] | 1.Stormwater is a leading source of pollutants that when transported to surface waters may damage aquatic habitat, decrease reservoir capacity, and contaminate drinking water.<br>2.In order to evaluate whether a pervious concrete detention system can remove stormwater pollutants from the runoff, water quality was monitored at a site with both impervious asphalt and pervious concrete. |
| 11. | Compressive strength of pervious concrete. [1] | Pervious concrete was first used in the 1800s in Europe as pavement surfacing and load bearing walls. Cost efficiency was the main motive due to a decreased amount of cement. It became popular again in the 1920s for two storey homes in Scotland and England. It became increasingly viable in Europe after WWII due to the scarcity of cement. It did not become as popular in the US until the 1970s. In India it became popular in 2000. |
| 12. | Experiment on Mechanical Properties of Pervious Concrete. [2] | EXPERIMENTAL MATERIALS AND MIX PROPORTION.(2.)<br>FLEXURAL STRENGTH TEST.(3.)<br>DENSITY AND VOID CONTENT.(4.)<br>WATER PERMEABILITY TEST.(5.). |

**Table 2: Mix Proportion of Different Mixture of Pervious Concrete.**

[3]

| CEMENT kg/m³ | AGGREGATE kg/m³ | W/C Ratio | C/A Ratio | ADMIXTURES | AUTHOR |
|---|---|---|---|---|---|
| 316 | 1435 | 0.22 | 1 : 4.5 | - | Construction and Building Materials 111 (2016) 15–21 |
| 210 – 421 | 1565 – 1672 | 0.25 – 0.35 | 1 : 7.4 & 3.9 | - | Construction and Building Materials 101 (2015) 317–325 |
| 266.97 | 1541.93 | 0.39 | 1 : 5.7 | Viscosity modifier | Civ. Eng. 2007.19:561-568. |
| 314.8 – 352.6 | 1416.6 – 1486.9 | 0.35 | 1 : 4.5 & 4.2 | SBR & Latex polymer | Construction and Building Materials 24 (2010) 818–823. |
| 400 | 1916 | 0.34 | 1 : 4.7 | - | Procedia - Social and Behavioral Sciences 104 ( 2013 ) 198 – 207 |
| 356 | 1540 | 0.35 | 1 : 4.3 | AEA , HRWR , VMA | Cem Concrete Res, 37 (2007), pp. 735– 742. |
| 450-700 | 2000-2500 | 0.27 - 0.4 | 1 :4 to 4.5 | AEA, HRWR | Journal of ASTM International, Vol. 5, No. 2 Paper ID JAI101434. |
| 355 | 1513 | | 1 : 4.2 | Hydration stabilizer | ACI Materials Journal/November-December 2009 Title no. 106-M58 |
| 345 | 1425 – 1525 | 0.27 | 1 : 4.1 & 4.4 | HRWR | Journal of ASTM International, Vol. 5, No. 2 Paper ID JAI101434. |
| 270 – 415 | 1190 – 1480 | 0.27 – 0.34 | 1 :4 – 4.5 | Hydration stabilizer | EB302.02, Portland Cement Association |
| 300 | 1783.7 – 2053.3 | 0.33 | 1 : 5.9 & 6.8 | - | Construction and Building Materials 169 (2018) 252–260. |
| 651 – 349 | 1621 – 1688 | 0.35 | 1 : 2.4 & 4.8 | Alkali activator | Construction and Building Materials 109 (2016) 34–40 |
| 269 – 448 | 565 – 740 | 0.24 | 1 : 2.9 & 1.6 | Superplasticizers | Construction and Building Materials 48 (2013) 585–591 |
| 320 | 1175 | 0.30 | 1 : 3.6 | - | Construction and Building Materials 96 (2015) 289–295 |
| 339.5 | 1459.8 | 0.32 | 1 : 4.2 | - | Civ. Eng. 2007.19:561-568. |

- **Refered CODES For Pervious Concrete**

1. **IS: 9399:1979**, Specification for apparatus for flexural testing of concrete.
2. **IS:516:1959**, Method of test for strength of concrete
3. **IS:8112:1989**, Specification for 43 grade ordinary Portland
4. **IS:12269:1987**, Specification for 53 grade ordinary Portland
5. **IS:456 -2000**, for durability of concrete
6. **IS:10262 : 2009**, for water cement ratio
7. **ISO: 17785-1:2016**, Testing methods for pervious concrete.
8. **IS: 383 (1970)**, 'Code of practice for the Specification for coarse and fine aggregate from natural source for concrete', Bureau of Indian Standards, New Delhi.

9. **IS: 456 (2000)**, 'Code of practice for Plain and Reinforcement concrete', Bureau of Indian Standards, New Delhi.
10. **IS: 1199 (1959)**, 'Code of practice for Methods of sampling and Analysis of concrete', Bureau of Indian Standards, New Dehi.
11. **IS: 2386 (part 1), (part 2), (part 3) (2002)**, 'Methods of test for aggregate for concrete', Bureau of Indian Standards, New Delhi.
12. **IS: 10262 (2009).** "Concrete Mix Proportioning Guidelines", Bureau of Indian Standards, New Delhi.

## 6 Results and Analysis

### 6.1 Compressive Strength:

| C/A ratio | W/C ratio | CA (mm) | curing period (days) | compressive strength (N/mm2) |
|---|---|---|---|---|
| 1:4 | 0.32 | 6.3-4.75 | 28 | 8.14 |

**Table I: Compressive strength of pervious concrete 06 4.75mmCA**

| C/A ratio | W/C ratio | CA (mm) | curing period (days) | compressive strength (N/mm2) |
|---|---|---|---|---|
| 1:4 | 0.32 | 12.5-10 | 28 | 9.68 |

**Table II: Compressive strength of pervious concrete of 10mm CA**

| C/A ratio | W/C ratio | CA (mm) | curing period (days) | compressive strength (N/mm2) |
|---|---|---|---|---|
| 1:4 | 0.32 | 12.5-11.2 | 28 | 5.83 |

**Table III: Compressive strength of pervious concrete of 11.2mm CA**

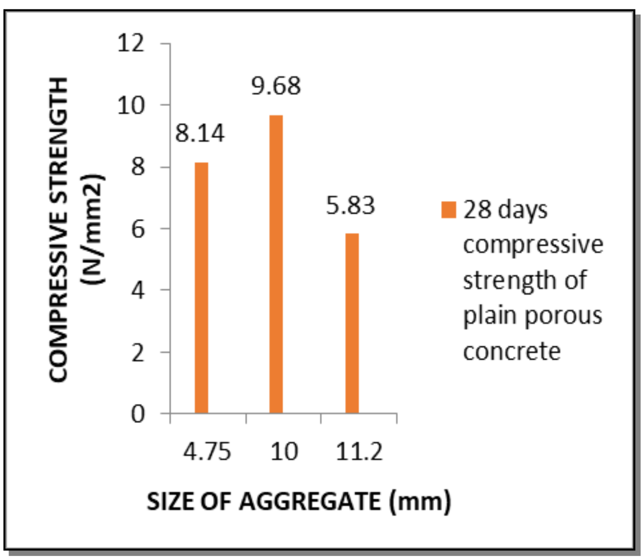


**Fig 1: compressive strength of pervious Concrete of 3 set of aggregate sizes**

### 6.2 Flexural Strength:

| Cement – aggregate ratio | Water-cement ratio | Size of aggregate (mm) | Curing period (days) | Flexural strength (N/mm2) |
|---|---|---|---|---|
| 1:4 | 0.32 | 4.75 | 28 | 3.23 |

**Table IV: Shows flexural strength of 4.75 mm plain pervious concrete**

| Cement – Aggregate Ratio | Water-Cement Ratio | Size Of Aggregate (mm) | Curing Period (Days) | Flexural Strength (N/mm2) |
|---|---|---|---|---|
| 1:4 | 0.32 | 10 | 28 | 2.78 |

**Table V: Shows flexural strength of 10 mm plain pervious concrete**

| Cement – Aggregate Ratio | Water-Cement Ratio | Size Of Aggregate (mm) | Curing Period (Days) | Flexural Strength (N/mm2) |
|---|---|---|---|---|
| 1:4 | 0.32 | 11.2 | 28 | 2.53 |

**Table VI: Shows flexural strength of 11.2 mm plain pervious concrete**

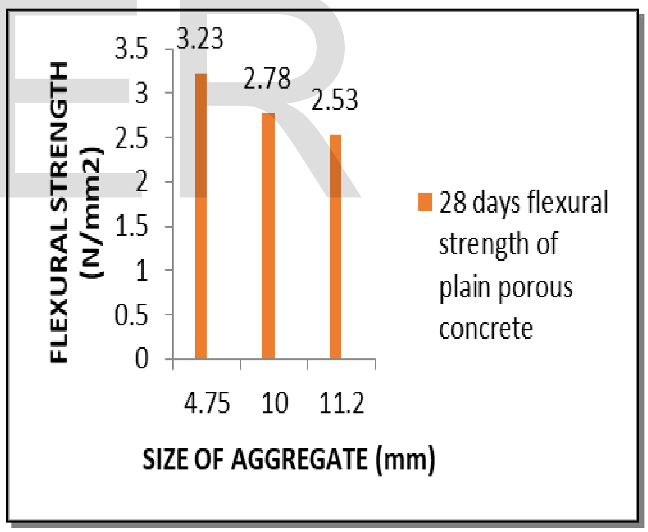


**Fig 2: Flexural strength of pervious Concrete of 3 set of aggregate sizes**

### 6.3 Permeability:

| Size Of Aggregate (mm) | Curing Period (Days) | Permeability (m/s) | Flow Rate($m^3$/s) |
|---|---|---|---|
| 4.75 | 28 | 0.000896 | 0.00000827 |
| 10 | | 0.00203 | 0.00001723 |
| 11.2 | | 0.000942 | 0.0000086 |

**Table VII: Permeability of plain pervious concrete**

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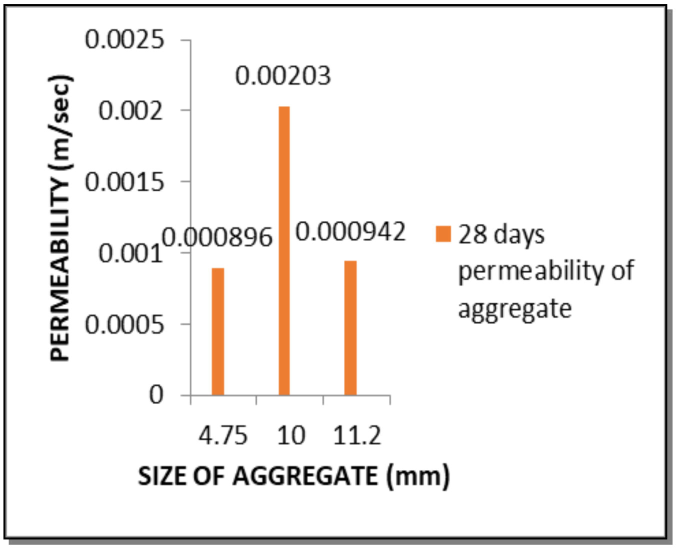


**Fig 3: permeability of aggregate**

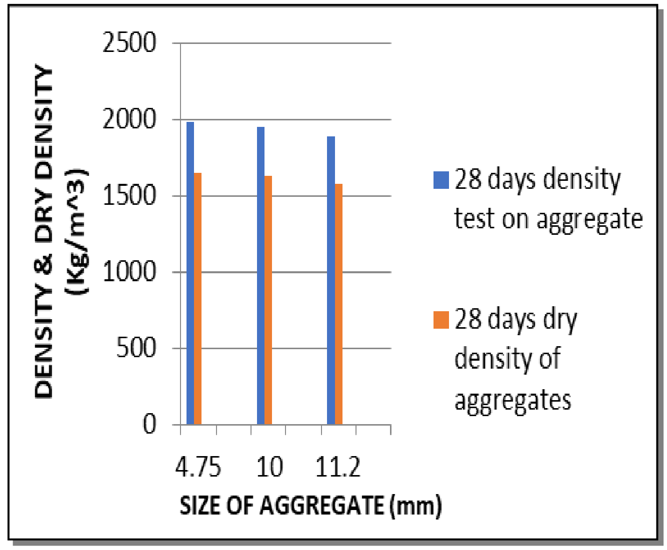


**Fig 5: shows 28 days density test**

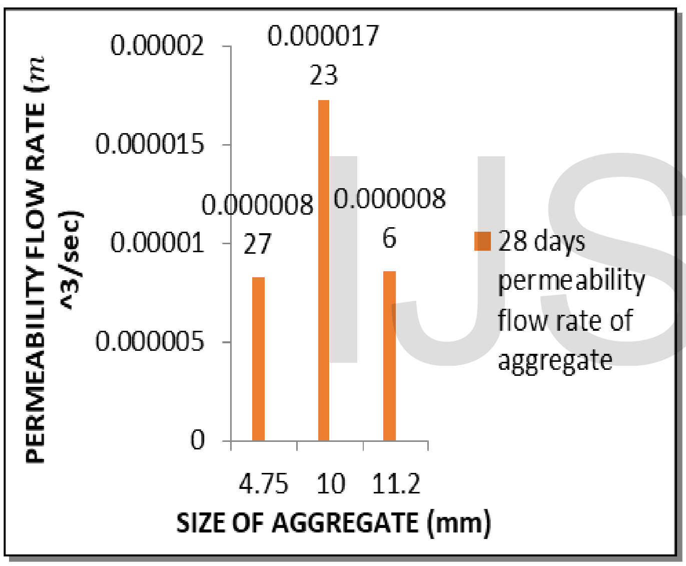


**Fig 4: permeability flow rate of aggregate**

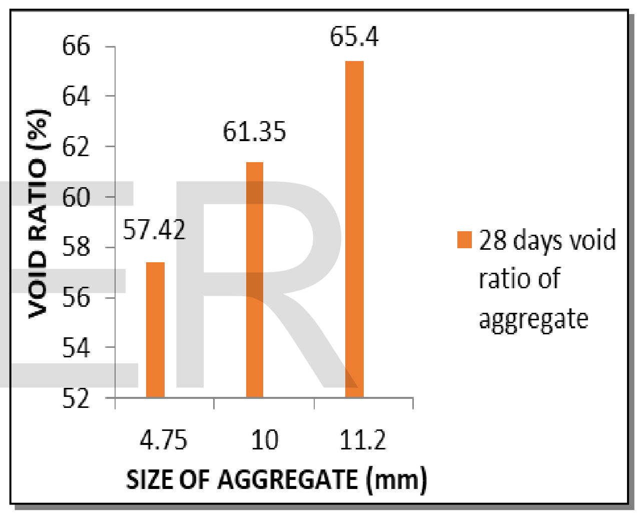


**Fig 6: shows 28 days' void content**

## 6.4 Density & Void Ratio:

| Size Of Aggregate (mm) | Initial Weight of mould (Kg) | Total Weight (Kg) | Compacted Weight (Kg) | Density (Kg/m³) | Dry Density (Kg/m³) | Void Ratio (%) |
|---|---|---|---|---|---|---|
| 4.75 | 1.5 | 3.4849 | 1.9849 | 1984.9 | 1651.61 | 57.42 |
| 10 | 1.5 | 3.4472 | 1.9472 | 1947.2 | 1622.67 | 61.35 |
| 11.2 | 1.5 | 3.3863 | 1.8863 | 1886.3 | 1571.92 | 65.40 |

**Table VIII: shows 28 days' density and void ratio**

## 6.5 Summary Of Results:

The compressive strength of plain pervious concrete for 10mm size is more than 4.75mm and 11.2mm. This shows that the compressive strength depends on size of aggregate. when we observe for flexural strength in the investigation above, for 4.75mm of aggregate it is higher than 10 mm and 11.2 mm. The flexural strength is increased for 4.75 mm due to its bonding between cement and aggregates. As it is a low grade aggregate, the binding nature will be high when compared to other. In permeability test, it is observed that the permeable nature will be high in 10 mm than 4.75 and 11.2mm aggregates. For 10 mm & 11.2 aggregate, in the observed study the voids between the aggregates are higher than 4.75mm which is bonded packly. When coming to density and void ratio, density for 4.75 mm aggregate is higher than 10mm and 11.2 mm aggregates. Density for 4.75mm>10mm>11.2mm aggregate which symbolizes the bonding strength of 4.75mm is high when compared to other but also have comparative low void ratios between the aggregates. The void ratios of 11.2mm and 10mm aggregates show higher values than 4.75mm. As void ratio is high then the permeable nature will be high due to more void content. However, after comparaing values of the compressive strength, flexural strength, permeability, density and void ratio of plain pervious concrete are satisfying the standards.

## 7 Conclusion

We carried out research on the Design of eco-friendly pervious concrete in sidewalks, parking lanes, compound walls, well lining, etc. From the test results, we have taken the mix design with a cement aggregate ratio of 1:4 which has given the required strength to the member. This mix design gives us the required strength of M20 grade concrete and this mix design has the required void ratio for the water seepage. We studied the effect of different aggregate sizes (4.75mm, 10mm & 11.2mm) on hardened properties of porous concrete like compressive strength, flexural strength, permeability, Density & Void Ratio, and the results showed that compressive strength reduces with an increase in aggregates size and as density of aggregate increase, void ratio decreases. It claimed that 10mm aggregate size led to nominal porous concrete strength, flexure, permeability, density, and void ratio, resulting in the increase of the interface strength between the aggregate and cement paste.

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