Experimental Study On Pervious Concrete Using Different Size Of Coarse Aggregate

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Abstract: ***Concrete is a widely used structural material consisting essentially of a binder and a mineral filler. Concrete has been the leading material since it was used and is bound to maintain its significant role in the upcoming future due to its durability, adaptability to any shape and size and many other applications. It is a composite material produced by mixing cement, inert matrix of sand and gravel or crushed stone. Pervious concrete is a type of concrete that has a low water-cement ratio and contains none or very little amount of sand. This concrete has a light colour and open-cell structure because of which they do not absorb heat from the sun; they also do not radiate the heat back into the atmosphere, which reduces heating in the environment. Pervious concrete has low installation costs. 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. In the present study the behaviour of pervious concrete has been studied experimentally. Various mix proportions were prepared by replacing cement with silica fume (10% by the weight of cement), by adding super plasticizers (0.3%). Different properties of pervious concrete e.g. compressive strength, split tensile strength, permeability test at 7, 14 & 28 days have been studied experimentally.***

Keywords: Experimental Study, Pervious Concrete, Different Size, Coarse Aggregate

1. INTRODUCTION

The concrete technology has made tremendous strides in past decade. Concrete is now no longer a material consisting of cement , aggregates , water and admixtures but it is an engineered material with several new constituents. The concrete today can take care of any specific requirements under most different exposure conditions. The concrete today is tailor made for specific applications and it contains several different materials. The development of specifying the concretes as per its performance requirements rather than the constituents and ingredients in concrete has opened innumerable opportunities for producer and user of concrete to design concrete as per specific requirements.

Pervious concrete is a special type of concrete which is also known as porous, no fines or permeable concrete. Pervious concrete was first used in 1800's in Europe as a pavement surfacing and load bearing wall. It is made using large aggregate with little to no fines also it's cost effective way to reduce use of river sand. Pervious concrete contains open cells which help in high permeability due to the porous structure. The use of the storm water is the Best Management Practice (BMP) recommended by the Environmental Production Agency (EPA) and Geotechnical engineers. As urbanization increase in India and many part of the world the problem of water logging and requirement of drainage is also increased. India is facing a typical problem of ground water table falling at a fast rate due to reduce recharge of the rainwater into the subsoil and also solid waste like scrap rubber facing a major environmental problem. The European Union countries which took this problem in charge, through legislation, recycling companies, research, we can say that many countries are postponing the solution to this problem, and the mass of worm tyres can only considerable. One of the recommended solutions to solve this environmental problem is to incorporate rubber aggregates resulting from cutting worm tires in cement concrete .pervious concrete can also reduces the impact on the development of the trees. Pervious concrete has water cement ratio of 0.35-0.45, with void content of about 15-25%. Both low mortar and high porosity also reduces the strength of concrete. Addition of some amount of fine aggregate will enhance the strength, thereby reduces the void content. Hence sufficient strength for many applications is readily achieved by carefully controlled amounts of water, cement and fine aggregate to prepare the paste which forms a thick coating around the aggregate particles.

The annual rainfall in India, according to 2015 report is 1,204mm. From this only 5-10% of water is being recharged as ground water. As the land usage is being increased tremendously, the Rainwater Harvesting pits are not that much effective in collecting rainfall2,6. In order to overcome this situation, "Pervious Concrete" should be provided to harvest the storm run-off. Pervious concrete is a permeable concrete which allows to penetrate the water to the sub-surface, so that water table level may increase.

Since porosity of concrete will reduce the strength of concrete, an attempt will be made to increase the strength of concrete by adding grading of aggregates to it.

1.1 Pervious Concrete

It is define the term “pervious concrete” typically describes a near-zero-slump, open-graded material consisting of Portland cement, coarse aggregate, little or no fine aggregate, admixtures, and water. It is such a concrete that has high porosity and allows draining freely unlike dense, high strength concrete. Its applications are therefore in conditions where water from precipitation or other sources needs to be drained. The high porosity is achieved by the absence or very low content of fine aggregates. Pervious concrete is also known as no-finesconcrete, gap graded concrete or porous concrete. It essentially consists of cement, coarse aggregate, water and little or no fine aggregate. In normal concrete, the fine aggregates typically fill in the voids between coarse aggregates. But in pervious concrete fine aggregate is non-existent or present in very small amounts. Moreover, there is globally considerable research is being done on pervious concrete that can be used for concrete flatwork applications.

1.2 Applications of Water Absorption Concrete Road

It is mostly applied in roads with low traffic usage, parking and sidewalks. It can serve as the surface course in such sites. Reports indicate that since 1970 pervious concrete has been utilized as the material for paving in Florida. It has also been applied in permeable drainages in water and power recourses, noise barriers, wall building, systems of thermal storage in greenhouses, decks of swimming pools, sludge beds in sewage treatment plants, bridge tennis courts, embankments and wall lining in water wells. Presently, substantial level of interest has existed regarding the application o pervious concrete in the alleviation of noise from tire-pavement interaction in concrete pavements. Pervious concrete possesses an excellent acoustic absorption capacity because of its extensive porosity. Acoustic absorption takes place in the material when sound waves are transmitted via a series of interconnected pores present in the material.

1.3 Construction Process

Pervious concrete consists of cement, coarse aggregate and water with little to no fine aggregates. The addition of a small amount of sand will increase the strength. The mixture has a water-to-cement ratio of 0.28 to 0.40 with a void content of 15 to 25 percent. The correct quantity of water in the concrete is critical. A low water to cement ratio will increase the strength of the concrete, but too little water may cause surface failure. A proper water content gives the mixture a wet-metallic appearance. As this concrete is sensitive to water content, the mixture should be field checked. Entrained air may be measured by a Rapid Air system, where the concrete is stained black and sections are analyzed under a microscope.

A common flatwork form has riser strips on top such that the screed is 3/8-1/2 in. (9 to 12 mm) above final pavement elevation. Mechanical screeds are preferable to manual. The riser strips are removed to guide compaction. Immediately after screeding, the concrete is compacted to improve the bond and smooth the surface. Excessive compaction of pervious concrete results in higher compressive strength, but lower porosity (and thus lower permeability). Jointing varies little from other concrete slabs. Joints are tooled with a rolling jointing tool prior to curing or saw cut after curing. Curing consists of covering concrete with 6 mil. Plastic sheeting within 20 minutes of concrete discharge. However, this contributes to a substantial amount of waste sent to landfills. Alternatively, preconditioned absorptive lightweight aggregate as well as internal curing admixture (ICA) have been used to effectively cure pervious concrete without waste generation.

1.4 Applications

Although not a new technology, pervious concrete is receiving renewed interest, partly because of federal clean water legislation. The high flow rate of water through a pervious concrete pavement allows rainfall to be captured and to percolate into the ground, reducing storm water runoff, recharging groundwater, supporting sustainable construction, providing a solution for construction that is sensitive to environmental concerns, and helping owners comply with EPA storm water regulations. This unique ability of pervious concrete offers advantages to the environment, public agencies, and building owners by controlling rainwater on-site and addressing storm water runoff issues. This can be of particular interest in urban areas, or where land is very expensive. Depending on local regulations and environment, a pervious concrete pavement and its sub base may provide enough water storage capacity to eliminate the need for retention ponds, swales, and other precipitation runoff containment strategies.

This provides for more efficient land use and is one factor that has led to a renewed interest in pervious concrete. Other applications that take advantage of the high flow rate through pervious concrete include drainage media for hydraulic structures, parking lots, tennis courts, greenhouses, and pervious base layers under heavy-duty pavements. Its high porosity also gives it other useful characteristics: it is thermally insulating (for example, in walls of buildings) and has good acoustical properties (for sound barrier walls).All of these applications take advantage of the benefits of pervious concrete’s characteristics. However, to achieve these results, mix design and construction details must be planned and executed with care.

1.5 Research Objectives

The use of pervious concrete to date has been limited to low volume and low speed traffic areas such as parking lots and sidewalks. These facilities are not typically subjected to high volume and standard wheel loads. Many jurisdictions are now considering the use of pervious concrete on low volume roads such as residential streets and alleys.

- To study about properties of Pervious concrete.
- Creating an eco-friendly pavement.
- To provide a sustainable environment.
- Result analysis in the strength and permeability.

It is an important application for sustainable construction and is one of the techniques used for ground water recharge. 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. It also reduces the bad impact of urbanization on trees. A pervious concrete ground surface allows the transfer of water and air to root systems allowing trees to flourish. Pervious concrete demonstrate the following advantages, benefiting the environment.

1. Decreasing flooding possibilities, especially in urban areas
2. Recharging the groundwater level
3. Reducing puddles on the road
4. Improving water quality through percolation
5. Sound absorption
6. Heat absorption
7. Supporting vegetation growth

1.6 Advantages

- **Environmental** - reduced storm water runoff, recharge groundwater, efficient land use by reducing the need for retention ponds.
- **Economic** - the management effort made in preventing excess runoff during heavy rainfall is prevented. Reduces cost to maintain large detention ponds.
- **Safety** - increased safety for drivers, improves driving in wet weather conditions, reduces night time glare and lessens the risk of hydroplaning
- Reduced Surface Temperatures, Minimizes the Urban Heat Island Effect
- Extended Pavement Life Due to Well Drained Base and Reduced Freeze-Thaw
- Less Lighting Needed Due to Highly Reflective Pavement Surface.

1.7 Limitations

The following are the limitations of the pervious concrete pavement:

- Requires Routine (Quarterly) Vacuum Sweeping
- Requires a Certified Pervious Concrete Craftsman On-site During Installation
- Proper Soil Stabilization and Erosion Control are required to Prevent Clogging
- Quality Control for Material Production and Installation are Essential for Success.

2.METHODOLOGY

Figure 1. Shows the methodology adopted in this study

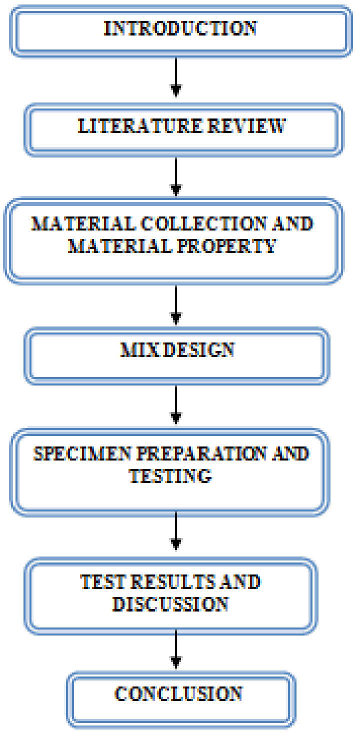

Figure 1 Methodology

3. MATERIALS PROPERTIES

3.1 Cement

The cement used was ordinary Portland cement 53 (OPC 53).All properties of cement were determined by referring IS 12269 - 1987. The specific gravity of cement is 3.15. The initial and final setting times were found as 55 minutes and 258 minutes respectively. Standard consistency of cement was 30%.

Different types of cement also will produce concrete have a different rates of strength development. The choice of brand and type of cement is the most important to produce a good quality of concrete. The type of cement affects the rate of hydration, so that the strengths at early ages can be considerably influenced by the particular cement used. It is also important to ensure compatibility of the chemical and mineral admixtures with cement. Test which had been carried out to find the properties of cements are

- specific Gravity
- Fineness (By Sieve Analysis)
- Consistency
- Initial Setting Time

3.2 Fine Aggregate

The sand which was locally available and passing through 4.75mm IS sieve is used. The specific gravity of fine aggregate was 2.60.

Locally available river sand conforming to Grading zone I of IS: 383 –1970.Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm Sieve will be used for casting all the specimens.

3.3 Coarse Aggregate

20mm size aggregates-The coarse aggregates with size of 20mm were tested and the specific gravity value of 2.78 and fineness modulus of 7 was found out. Aggregates were available from local sources.

- Specific Gravity
- Bulk Density
- Surface Moisture
- Water Absorption
- Fineness Modulus

3.4 Water

The water used for experiments was potable water.Water used for mixing and curing shall be clean and free from injurious amounts of Oils, Acids, Alkalis, Salts, Sugar, Organic materials Potable water is generally considered satisfactory for mixing concrete Mixing and curing with sea water shall not be permitted. The pH value shall not be less than 6.

3.5 Silica Fume

Silica fume is a by-product in the carbon-thermic reduction of high-purity quartz with carbonaceous materials like coal, coke, wood-chips in electric arc furnaces in the production of silicon and ferrosilicon alloys. Silica fume is also Known as micro silica, is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. Silica fume is an ultrafine material with spherical particles less than 1µm in diameter, the average being about 0.15µm. This makes it approximately 100 times smaller than the average cement particle. The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 to 600 kg/m3. The specific gravity of silica fume is generally in the range of 2.2 to 2.3.

Figure 2 Silica Fume

Silica Fume also referred to as silica dust, condensed Silica Fume, Micro Silica, and Fumed Silica. Silica fume imparts betterment to rheological, mechanical and chemical properties. It increases the durability of the concrete by reinforcing the microstructure through filler effect and consequently reduces segregation and bleeding. The powdered form of Silica fume with the specific gravity of 2.25. By adding the superfine particles of silica fume to cement and other materials, the gaps between the particles are filled. This effect achieves the production of dense, high-strength products.

Table 1: Physical properties of Silica Fume

S.NO	CHARACTERISTIC	OBSERVED VALUE
1	Colour	Light grey
2	Fineness%	Below 45 microns
3	Specific gravity (Le-Chatelier's Method	2.17
4	Bulk Density	550 to 700 kg/m3
5	Moisture content	0.1 to 3%

Silica fume improves the flow ability and workability of cement. This effect reduces the unit water amount required for achieving the specific flow ability. Soluble silica reacts with calcium hydroxide to produce a water-insoluble, curable siliceous compound. The main ingredient of silica fume is non-crystalline SiO2, which reacts with $Ca(OH)_2$ produced by hydration of the cement and produces calcium silicate hydrate.

Table 2:Chemical Properties of Silica Fume

S.NO	CHARACTERISTIC	TEST REPORT (%)
1	SiO_2	93
2	CaO	0.10
3	MgO	1.50
4	Fe_2O_3	1.0
5	Al_2O_3	1.40
6	Alkalis	2.50
7	Sulphide Sulphur as SO_3	0.50
8	Fineness	2250
9	Specific Gravity	2.23

By this reaction, the intensity and the water-tightness of the cement are improved. It is used in concrete products to improve water tightness, higher-mechanical strength and reduce rebound amount when spraying.

3.6 Super Plasticizers

Super plasticizers, also known as high range water reducers, are chemicals used as admixtures where well-dispersed particle suspensions are required. These polymers are used as dispersants to avoid particle aggregation and to improve the flow characteristics of suspensions such as in concrete applications. This effect drastically improves the performance of the hardened fresh paste (Wikipedia, the free encyclopedia). Cico plast super is used for producing extremely flow able concrete, pumped concrete, pre-stressed and denser concrete as well as in industrial commercial flooring and floor toppings. Cico plast super is new generation concrete admixture based on modified Sulphonated naphthalene formaldehyde, combining the properties of super plasticizers with high degree of slump retention characteristics, high range water reducer and also acts as water proofers for concrete, conforms to ASTM C-494.

3.6.1 Features

- Improves workability and flow properties without any increase in water.
- Increase in bond strength of concrete to reinforcing steel.
- Reduction of internal friction and thixotropy without the risk of segregation and making concrete workable.
- Minimize shrinkage or cracking.
- Suitable for use in concrete above and below ground.

3.6.2 Uses

- It produces extremely workable and flowing concrete without loss of strength.
- It can be used to produce pumpable concrete or at locations where flowable or high strength concrete is needed.

4. Mix Design

Design Stipulations

- Grade Designation M-30
- Type of cement O.P.C-53grade
- Fine Aggregate Zone-I
- Sp. Gravity Cement 3.15
- Sp. Gravity Fine Aggregate 2.65
- Sp. Gravity Coarse Aggregate 2.68

Mix Proportion shown in Table.3

Table 3: Mixproportion

Cement (kg)/m³	FA (kg)/m³	CA (kg)/m³	Water (liter)/m³
531.43	604.8	1064	186

5. TESTING PROCEDURE

5.1 Compressive Strength Test

The main aim is to determine the compressive strength of concrete specimen. The test specimens, cubical in shape of size 150x150x150 mm are used. Compression tests are conducted at 28 days of the casting of specimens. Specimens cured in the water where tested immediately on removal from water and while they are still in wet condition.

The load applied Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. Compression test is carried out on specimens cubical in shape. Sometimes, the compression strength of concrete is determined using parts of beam tested in flexure. The maximum load applied to the specimen until a failure recorded. Then based on the load value the compressive strength of the concrete specimen calculated as follows.

Compressive strength=ultimate load/contact area of the cube

5.2 Split Tensile Test

Take the wet specimen from water after 7 days of curing .Wipe out water from the surface of specimen Draw diametrical lines on the two ends of the specimen to ensure that they are on the same axial place. Note the weight and dimension of the specimen. Set the compression testing machine for the required range. Keep are plywood strip on the lower plate and place the specimen. Align the specimen so that the lines marked on the ends are vertical and centered over the bottom plate. Place the other plywood strip above the specimen. Bring down the upper plate to touch the plywood strip. Apply the load continuously without shock at a rate .Note down the breaking load(P).

5.3 Permeability Test on Concrete

The permeability of concrete to liquids, ions and gases is of direct relevance to both durable concrete and to leak-resistant concrete for containment. Analytical models used to predict the age at which corrosion of the reinforcement will be initiated require a detailed knowledge of the transport mechanisms involved and the permeability of the concrete. Some specifications for projects in extreme environments (e.g. the Middle East) or requiring very long lives (e.g. railway tunnels) have specified permeability criteria, based on some form of analytical durability model, to be verified by testing the supplied concrete or precast concrete elements. A simple permeability test could form part of the quality assurance (QA) scheme for any precast concrete element, to check on the variability of standard units.

6. TESTING RESULT

6.1 Ratios for Special Concrete (Extra Ingredients) Ratio –I

Cement Replacing 10 % of silica fume

10mm coarse aggregate Replacing 10 % of coarse aggregate

Super Plastizeraddin of water 0.3 %

6.2 Compressive Strength of Cube

Compressive strength results are shown in Table 4

Table 4: Compressive strength test result

MIX DESIGN	% OF REPLACEMENT	COMPRESSIVE STRENGTH(N/mm²)		
		7DAYS	14 DAYS	28DAYS
M_{35}	0	19.5	29.5	33.65
	10	23.5	32.5	36.6

Figure 3 shows the compressive test graph results

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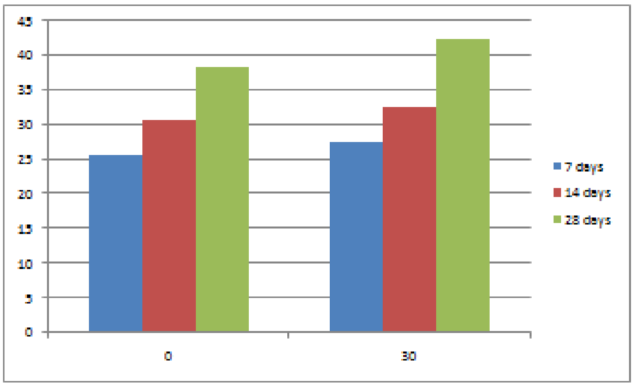

Figure3 Compression test graph result

6.3 Split Tensile Test for Cylinder

Split tensile test results are shown in Table 5

Table 5: Split tensile test result

MIX DESIGN	% OF REPLACEMENT	SPLIT TENSILE TEST (N/mm²)		
		7 DAYS	14 DAYS	28 DAYS
M_{35}	0	1.88	2.5	3.38
	10	1.96	3.15	3.89

Figure 4 shows the split tensile graph results

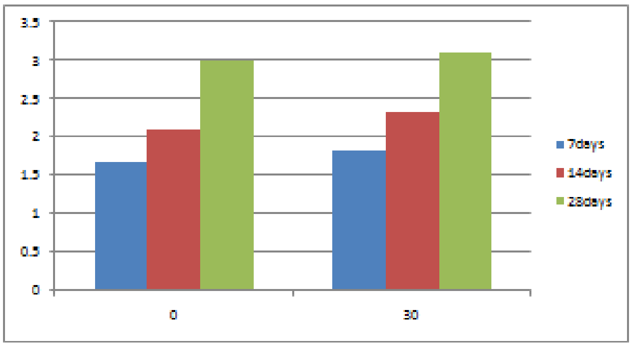

Figure 4 Split tensile graph result

6.4 Permeability Test

Permeability test results are shown in Table 6

Table 6: Permeability test

Time	Permeability (cm/sec)
15	0.17
20	0.165
25	0.15
30	0.13

Figure 5 shows the permeability test results

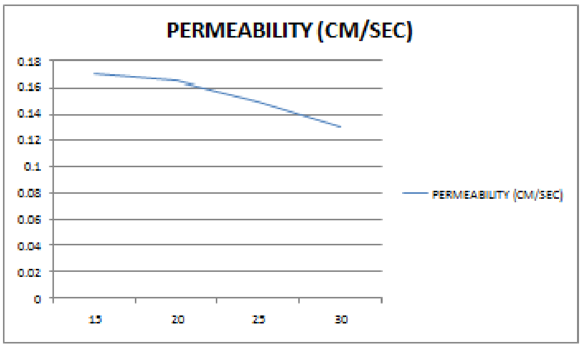

Figure 5 Permeability test results

7. CONCLUSION

1) Pervious concrete mix proportions increased with addition of 0.3% of super plasticizers and increases with addition of 10 mm coarse aggregate.
2) The compressive strength of pervious concrete increases by 10% with the addition of silica fume in concrete.
3) Compressive strength of conventional concrete is 33.65 MPa at 28 days, and pervious concrete is 36.6 MPa, which is greater than conventional concrete.
4) Split tensile strength of conventional concrete is 3.3 MPa at 28 days, and pervious concrete is 3.89MPa, which is greater than conventional concrete
5) The experimental observations have shown an average Co-efficient of permeability as 0.165 cm/sec.

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