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PERFORMANCE ASSESSMENT OF PERVIOUS CONCRETE ROAD ON STRENGTH AND PERMEABILITY BY USING SILICA FUME

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ABSTRACT: Pervious concrete is most sustainable material become more popular due to having some extra ordinary characteristics like permeable concrete, no fine concrete and many more. Pervious concrete is a concrete which allows water pass through its surface due to presence of voids. Generally pervious concrete is made using cement, coarse aggregates, no or little fine aggregates, water and admixture. Pervious concrete can be used for low volume roads, parking lot, tennis court, sidewalk areas etc. As the concrete have high porosity, it has low strength as compared to impermeable concrete. In order to increase the strength some cementitious materials like- Silica fume, fly ash, Metakaolin etc. are used. Silica fume is a high density, high strength and durable cementitious materials which allow to increase strength in pervious concrete. Here the aim of the study is to improve performance of permeability, strength and abrasion resistance of pervious concrete by using silica fume at different percentage. Here a high-performance pervious concrete develops using cement 43 grade, silica fume, different size of coarse aggregate, little fine aggregates, water, superplasticizer (Rheoplast). To achieve higher and better strength and permeability partial replacement of silica fume by cement is done by 0%, 4%, 8%, 12%, and 16%, various sand percentage like- 5%, 7% and 9% with a fixed water cement ratio 0.35. This paper represents a detailed overview of experimental study on compressive strength, split tensile strength, flexural strength and cantabro abrasion resistance test at 7, 14, 28 day. The test result exhibited that use of silica fume in pervious concrete have improve the compressive strength, abrasion resistance and did not have detrimental change on permeability.

Key wards: Pervious concrete, Compressive strength, Flexural strength, Tensile strength Cantabro test, Silica fume etc.

1. INTRODUCTION

Generally normal conventional Portland cement concrete is used for pavement construction with presence of fine aggregates which makes concrete impermeable. The impervious nature of concrete creates a huge environmental issue like increased runoff, reduce ground water level, flooding in buildup areas etc. Pervious concrete is a new type of construction material with lots of environmental and structural advantages. This concrete mainly develops for the drain water from the ground surface so that it reduces runoff, recharge the ground water, increase the buildup area and many more benefits. It also called as Porous concrete, No fine concrete. The concrete which allows water pass through its surface known as porous concrete. As per its name it has large numbers of voids which makes the concrete porous in nature and reduce water pollution. Generally pervious concrete made using coarse aggregates, cement, water and little or no fine aggregates. It is commonly used for parking lot, pedestrian walkway, tennis court, other low volume roads etc.

These are the following benefits of pervious concrete:

Pervious concrete control stormwater runoff. It reduces the stormwater pollution at the source. It increases the parking facilities area by reducing water retention areas. It used for water harvesting. It allows water and air to the ground. It reduces the glare on road surface particularly in night. It has higher number of voids are present which helps less traffic noise. In pervious concrete UV rays get reflected more thus it absorb less heat.

These are the following limitations of pervious concrete:

As we know pervious concrete is high permeable concrete thus this property limits the utilization due to decrease of strength. Limited use in heavy traffic areas due to its low strength. It has less abrasion resistance that is one of the drawbacks. Due to presence of high voids in pervious concrete, it tends to water clogging. It required extended curing time period. This concrete is more sensitive to water content and control in fresh concrete. Lack of standardized test methods in pervious concrete. In Pervious Concrete initial cost higher than Conventional Concrete. The high initial cost of Pervious Concrete is somehow due to the construction of the sub grade.

1.1 OBJECTIVE OF THE STUDY

- Investigate the properties of pervious concrete by using Silica fume at different percentage.
- Experimental procedure to determine strength and water permeability of pervious concrete.
- To provide a sustainable concrete to environment.
- To study which percentage of silica fume achieved high strength and good permeability.

2. LITERATURE REVIEW

2.1 Pervious concrete without additives

Pervious concrete pavement also called "Porous Concrete", "Permeable Concrete", "No Fines Concrete" is a new type of concrete pavement used for high porosity concrete work and passes water directly comes from rainfall, precipitations and from other source to the ground **(Shah.D & Pitroda.J (2016)).** Pervious concrete pavement is mainly known for its storm water management technique that mainly help to reduce water pollution and help to get preserved for future use and also helps to maintain the natural water table. From the past research the use of such kind of pavement is mainly seen in parking places, sidewalks, pedestrian pathways etc. and also in low traffic area. But the use of P.C is not limited here it has also been utilized in structural applications like for greenhouse floors in order to keep water standing in floor, also it is used as wall concrete for effective thermal insulation and as surface course for parking places and many more **(Yang.J & Jiang.G(2003), G.Nader & Shivaji.D (1995)).**

"Pervious concrete" is made up of common materials like coarse aggregate, Portland cement and water and admixture if necessary. It looks different from conventional concrete as it looks like a honeycomb as the concrete mixture contains no fines or a little number of fines in it. The aggregate that are used is of mainly single size and is mixed uniformly with cement to make a homogenous paste. A typical pervious concrete varies in the ranges of 15-25% with a minimum of 15% as prescribed by the National Ready Mix Concrete Association (NRMCA) **(G.Divya & L.Renna (2017)).**The water cement ratio vary a lot as compared to conventional concrete mix and it typically very less and ranges from 0.28 to 0.4, the main motive is to provide adequate coating of cement with aggregates. And ratio of aggregate: cement varies from 4:1 to 6:1**(Deo.O (2011)).** For providing sufficient voids aggregate of single size and round in shape are mainly sued, the aggregate selection is very important in controlling the durability, mechanical property & permeability of pervious concrete and it ranges from 19-9.5mm, however coarse aggregate of size 9.5-2.36mm are also used by some of the researcher in need to improve the strength of pervious concrete **(Baurd.Fet.al (2014), Huang.B (2009)).**

In "Pervious concrete" mix it is nearly very hard to achieve a high strength concrete mix as it contains a huge number of voids in its. Thus, by adding the ordinary materials we can never achieved a mix of very good strength, so we need to modified the proportions of the materials along with that we need to introduced some of the admixtures to it. As we know by using aggregate of smaller in size the strength can be improved but it will simultaneously decrease the permeability rate **(Mahalingam.R & Mahalingam.S (2015), Yang.J & Jiang.G(2003)).**

2.3 Pervious concrete with additives

Pervious concrete is a environment friendly materials. Due to presence in high void in it, it leads to lower compressive strength than normal conventional concrete. Most of the pervious concretes 28day strength is limited to 21 Mpa. In order to increase the strength properties of pervious concrete some cementitious materials or additives are used.

Supplementary Cementitious Materials (SCMS) include fly ash, pozzolans, slag and Silica Fume can also be added to cement. These materials are helpful in developing concrete performance, setting time, rate of strength development, porosity, permeability etc. All these SCMs product are used for developing the durability but it simultaneously decreases the permeability of P.C. Slag is the supplementary waste material required acquired during steel and iron making processes **(Geiseler.J (1999)).** Relaying on the iron and steel making process different type of slag can be found. Blast furnace slag is produced in the time of liquefaction and depletion of iron ore in a blast furnace. Electric arc furnace slag (EAFS) is made in the course of transforming of hot metal crude steel. GGBS are used as aggregate in place of natural aggregate in pervious concrete **(Chini.M (2003)).** Many researchers have studied the performance of pervious concrete by adding Fly ash and GGBS. Fly ash is used as the blending agent to achieve durable concrete, the addition rate of the fly ash is normally 25% to 40% by mass of cement. The effect of the fly ash concrete depends on combinations of paste enhancement, water reduction and Pozzolanic reactivity, resulting in pore refinement in the paste fraction of the concrete. The main beneficial effect of fly ash is related to the refinement of pore structure by Pozzolanic reaction reducing diffusion rate. GGBS has an ability to replace large amounts of Portland cement when early strength is not of serious concern. Pore enhancement is probably more pronounced with GGBS than with pozzolana, this is reflected in excellent performance in seawater **(Jena.A(2017),Yukari.A et al. (2010)).**

"Rice husk ash" (RHA) comes under waste agriculture material. As there are many difficulties involves in its disposal RHA is becoming an environmental hazard for each and every rice producing countries. RHA is produced in large quantities every year all over world. India alone produces 6 million tons of Rice Husk Ash per year. The effect of pervious concrete by partial replacement of cement with 0% to 30% of RHA has been studied by a number of authors. They concluded that the strength of pervious concrete hence by using RHA. The optimum replacement of RHA lies between 10%-12%. More than that will reduce the strength and permeability properties of pervious concrete **(Talsanai.S. et al (2015), Akeke.G et.al (2013)).**

"Silica fume" also named as Micro-Silica. It's a mineral type admixture consisting of very fine particles of silicon dioxide. It produced during manufacturing of ferrosilicon & metallic silicon at very high temperature in electric arc furnaces. Silica fume is used as an additive in "Pervious Concrete" as well as in "Conventional Concrete" mix for improving the strength properties of concrete but it simultaneously decreases the workability and rate of permeability of concrete mix. So sometimes water reducing agent is used along with silica fume in order to maintain its workability **(Vikram & Mahla.P (2015), Pradhan.D & Dutta.D (2013)**, **Amudhavalli .N & Mathew.J(2012))**.By using "Silica Fume" both the flexural strength & compressive strength increases about 20% than that of conventional pervious concrete **(Prakash.V (2018),Yang.J & Jiang.G (2003))**. The recommended dosage of silica fume varies from 0%-15% by partial replacement of cement **(Ghutke.V & Bhandari.P (2014), Amudhavalli.N & Mathew.J (2012), Yang.J & Jiang.G (2003)).**

According to Author **J.D Chaitanayakumar** and **C.H Jyothinikhila in 2015,** Workability of concrete decreases with increase in percentage of metakaolin. Metakaolin powder increases workability of concrete. The compressive strength test ,flexural strength test ,split tensile values are compared with conventional concrete and we get to know that conventional strength is lower than the metakaolin concrete.

The compressive strength, flexural strength and split tensile strength is maximum at 15% replacement of metakaolin. Relationship of conventional concrete and metakaolin concrete for stress –strain is same at 100°c and room temperature. But it will different for other temperature exposure of 200°c to 500°c. The strength increases at 100°c temperature but after that it will start to lose the strength.

Nova John et al. (2013) in her paper "Strength Properties of Metakaolin Admixed Concrete" studies the effect of Metakaolin as mineral admixture in the concrete on its performance. The replacement was done in a pattern of 0, 5, 10, 15 and 20% to cement by Metakaolin. Concrete mix of M30 grade was used for the experimental investigation. The cubes, cylinders and prisms were tested for compressive strength, split tensile strength and flexural strength respectively. The tests are performed after 7 days and 28 days curing of the specimens. The results indicate that the use of Metakaolin in concrete has improved the strength characteristics of concrete. From the results of considered parameters, it is observed that 15% replacement of cement with Metakaolin showed better performance in case of strength parameters such as compressive, flexural and split tensile strength.

3.EXPERIMENTAL INVESTIGATION

3.1 MATERIAL PROPERTIES

3.1.1 Cement: Ordinary Portland cement of 43 grade Conforming to IS:8112-1989 was used in this study. The cement was tested as per IS:4031-1996. The following test of cement were conducted as per IS code. Table 3.1 shows the physical properties of cement.

- **Fineness test:** This test is conducted in order to check the proper grinding of cement. Fineness of cement is measured by sieving cement on standard sieve. IS: 4031 (Part 1)-1996 used for conducting fineness test of cement.
- **Consistency test:** In order to evaluate the minimum amount of water needed to produce a cement paste of standard consistency this test is carried out. IS: 5513-1996 and IS: 4031(Part-4)- 1988 used for conducting consistency test of cement.
- **Specific gravity:** Specific gravity is used for determining the density of any material. In designing of concrete density plays a very crucial role since in concrete mix proportion is done based on the

weight batching not on volumetric, so density is an important factor. IS: 2720(Part-3)-1980 used for conducting specific gravity test for cement.

- **Setting time:** This test is conducted in order to record the "Initial Setting Time" and "Final Setting Time" of cement, as the "initial setting time" has an important role in transportation, placing and compaction of cement concrete. For a perfect casting the setting time is important and without assuming the setting time we can't remove the frames. IS: 4031(Part-5)-1988 used for conducting setting time of cement.

In this study OPC 43 grade cement is used which is collected from Sarang, Dhenkanal.

Table 3.1 Physical properties of cement

Sl. No.	Properties	Test results	Value specified by IS:455-1980
1	Fineness %	1.98%	Not more than 10%
2	Normal consistency %	32.57%	-
3	Specific gravity	3.10	-
4	Setting time Initial setting time Final setting time	 168 min 230 min	 Not less than 30 min Not more than 600 min

3.1.2 AGGREGATE

Generally fine aggregate and coarse aggregate are used for casting of concrete mix. These aggregates must be free from any kind of impurities, hard and well graded as they occupy a large volume in concrete mix hence, they provide stability to it. For better strength of pervious concrete some amount of fine aggerates used as replacement of coarse aggregates. Two sizes of coarse aggregates were used for concrete mix of previous concrete to maintain interlocking between aggregates. Aggregate size of 16mm passing 12.5 retaining and 12.5mm passing 10mm retaining. The aggregates were collected from Sarang, Dhenkanal.

- **Impact value test:** Aggregate impact value test includes Toughness test of aggregate. The main objective of the study is to find ability of aggregate to resist sudden load or impact. The test was conducted as per IS:2386-(Part-IV).
- **Crushing value test:** Crushing value test are performed to find the strength of aggregate that use for road construction. This test gives us idea about strength of aggregate i.e., resistance to gradual loading and also helps us to find compressive stress. IS: 2386(Part-IV) is used for conducting crushing value test of aggregate.
- **Abrasion value test:** Abrasion value test is conducted by using Los Angeles abrasion machine to find hardness characteristics of aggregate. To find the resistance of aggregate towards abrasion. This test is important in order to produce a high quality of road surface.IS:2386 Part-IV is used for conducting Los Angeles Abrasion test.
- **Water absorption test:** These tests are done to find the water carrying capacity of the coarse and fine aggregate. It is defined as the ratio of absorbed water weight to dry sample weight and generally expressed in percentage. It not includes the amount of water adhering to the surface of the particles. IS:2386 (Part-III) is used for conducting water absorption test of aggregate.
- **Specific gravity test:** Specific gravity aggregates test is done to measure the material's strength or quality. Specific gravity can be written as ratio of "weight of given volume of aggregate" to "weight of an equal volume of water". Specific gravity of aggregate is low then they are generally weaker as compared to those with higher specific gravity values. IS:2386 (Part-III) is used for conducting specific gravity of aggregate.

Table 3.2 Physical properties of aggregate

Sl. no.	Property	Test	Test results	Specification as per MORTH
1	Toughness	Impact value test	10.05%	Maximum 35%
2	Hardness	Los Angeles abrasion test	21.35%	Maximum 30%

3	Strength	Crushing value test	20.73%	Maximum 40%
4	Water absorption	Water absorption	0.5%	Maximum 2%
5	Specific gravity	Specific gravity	2.56	-

3.1.3 WATER

For this research work the water that has been used must be clear and free from impurities and from any detrimental contaminants. The portable water is generally preferred for casting as well as for curing purpose. Before using the water, the PH value of water is tested. In case of a conventional concrete the relationship between cement and water and strength are commonly seen as it has very low number of voids in it but in case of P.C it is not the same due to presence of high number of voids in it. Therefore, it is not necessary that stronger paste will leads to increase in strength in case of P.C. so the water content is selected very carefully.

3.1.4 SILICA FUME AS AN ADDITIVE

Silica fume also called as Nano silica, Micro silica which is by product of the carbo-thermic reduction of high purity carbonaceous materials like coal, wood ships, coke etc. Silica fume also named as Condensed silica fume because it is by product if industrial produced during production of ferrosilicon and metallic silicon in electric arc furnace at high temperature. It is an amorphous or non-crystalline in nature. Silica fume is a superfine material which particle size is less than 1micron meter. Generally bulk density of silica fume (SF) varies from 130-600 kg/m^2 and specific gravity range from 2.2 to 2.3. Silica fume is a mineral admixture for high strength concrete. Due to its pozzolanic behavior it can be used as high strength concrete work. It not only increases the strength but also it increases the workability and make concrete impermeable.

Table 3.3 Physical properties of silica fume (HINDALCO, Berhampur)

Sl. no	Properties	Observed values
1	Colour	Light grey
2	Fineness	Below 45 microns
3	Specific gravity	2.15
4	Bulk density	550-700 kg/m3
5	Moisture content	0.1-3.0%

Table 3.4 Chemical properties of silica fume (HINDALCO, Berhampur)

Sl. no	Chemical properties	Quantity
1	Sio_2	90.12
2	Al_2o_3	0.94
3	Cao	0.87
4	Fe_2o_3	1.62
5	So_3	0.29
6	MgO	-
7	K_2O	1.21
8	LOI	2.87

3.2.5 RHEOPLAST AS SUPERPLASIZER

Generally, Superplasticizer (SP) known for high range water reducer which is used for developed high strength concrete. Superplasticizer 15-30% of water content can reduce and it do not affect strength and workability of concrete mixes. As water cement ratio reduced it tends to increase of strength of concrete. Here Rheoplast is used for producing extremely workable concrete. Rheoplast is a water reducer superplasticizer. It is retarder in nature hence it delays initial setting time of concrete. 1% Rheoplast can reduce water quantity up to 20%.

3.3 TRIAL MIX DESIGN USING DIFFERENT % OF SAND

Pervious concrete has no such perfect mix design till now. So the mix design is prepared by using ACI-552, NRMCA guidelines and Indian standard mix as per IS:10262-2009. Porosity in pervious concrete depends on the volume of voids between aggregates and volume of mortar. Due to presence of high volume of voids it leads to decreases the strength of pervious concrete. In order to increase the strength some little amounts of fine aggregates were used. Here the trial mix were done using different percentage of fine aggregates like 5%, 7%, 9% with a predefined void ratio of 20% and fixed water cement ratio of 0.35.

Table 3.5 Trial mix proportion for $1m^3$ pervious concrete

Mix	Coarse aggregate (kg)	Cement (kg)	Sand (kg)	Water-cement ratio
OPC1	1774.60	425.14	93.40 (5%)	0.35
OPC2	1737.24	425.14	130.76 (7%)	0.35
OPC3	1699.88	425.14	168.12 (9%)	0.35

3.4 TEST ON TRIAL MIX SPECIMEN

3.4.1 Porosity: Permeability, compressive strength of pervious concrete are directly related to porosity of the pervious concrete. So, porosity is important parameter to determine. Porosity was measured on cube specimens, using the method developed by **Matsuo** et. al. which is recommended by Japan Concrete Institute (JCI). The porosity calculated using following equation:

$$P = 1 - \frac{(M2-M1)}{V1*\rho_w} \times 100$$

Where, P = Porosity of porous concrete

M1 = buoyant mass of the saturated specimens in water

M2 = dry mass in the air for 24 hours

V1 = total volume of specimens

ρ_w = density of water

3.4.2 Compressive strength test

For studying the strength criteria of pervious concrete, compressive strength test is done. For testing procedure first of all we casted the cubes of size 150mm*150mm*150mm for various mix proportion. Each composition or for each percentage of sand used 3 cubes are casted. The "compressive strength" was done after 7 days of curing and the test result are recorded.

Fig 3.3 Compressive strength on trial mix specimen

3.4.3 Permeability test: For permeability test of pervious concrete, Constant head method was adopted shown in Fig 3.4. In this test three water head was considered that is 100mm, 150mm. Permeability measured on concrete casted cylinder specimen. Matsuo et. al. conducted constant head method which is recommended by Japan concrete institute (JCI). By using Darcy's first law Matsuo et al. calculated permeability of pervious concrete. In this experiment permeability calculated using the equation shown in below,

$$K_T = \frac{l}{h} \times \frac{Q}{A\,(t_2 \times t_1)}$$

Where K_T = water permeability at Tc°

l = length of specimen

Q = quantity of water

h = head difference

t2 – t1 = time

A = cross sectional area of specimen

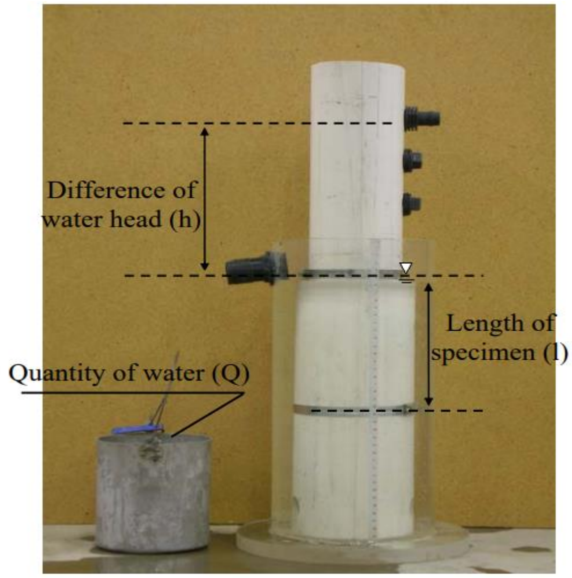

Fig 3.4 Constant head method for permeability test

3.5 CASTING OF SPECIMEN USING SILICA FUME

As a cement replacement Silica fume (SF)was used in concrete mixes at 0%, 4%, 8%, 12% and 16%. The mixing of all materials done in mixture machine. For compressive strength test 150mm x 150mm x 150mm size of cubes were used for test specimen. For Split tensile strength 150mm x 300mm size of cylinder were used for test specimen. For Flexural strength 450mm x 100mm x100mm size of beam were used test specimen. For the Cantabro abrasion resistance test 70mm x 70mm x 70mm cube were casted for test specimen. All specimen were casted as per IS: 516-1959. For strength calculation specimen were tested at the age of 7d, 14d, 28d. For Cantabro test specimen were tested at the age of 28d.

3.6 MIXING AND PROPERTION

The aim of the final mix design is to create strong and durable pervious concrete by replacing cement by silica fume that not only have water permeability but also have sufficient strength. By adjusting sand percentage in trial mix and fixed water cement ratio of 0.35 make pervious concrete that totally different from conventional concrete. All materials were weighed on the weighing machine. All mixes were done by Mixture machine. Cement, Fine aggregates (9%), silica fume, coarse aggregates and water were thoroughly mix to form uniform mixes. All mix proportion shown in table 3.6. The specimens were casted as per IS:

516-1959. The most important thing compaction was done at two layer using Tamping rod each layer 15 blows. The concrete specimen was removed from the moulds after 24 hour. The concrete specimen kept in fresh water for curing at the age of 7d, 14d, 28d.

Table 3.6 Mix proportion with silica fume for $1m^3$ of pervious concrete

Sl. no	Coarse aggregate (kg)	Cement (kg)	Silica fume (%)	Fine aggregate (9% sand) (kg)	Water-cement ratio
SFPC 1	1699.88	425.14	0%	168.12	0.35
SFPC 2	1699.88	408.13	4%	168.12	0.35
SFPC 3	1699.88	391.13	8%	168.12	0.35
SFPC 4	1699.88	374.12	12%	168.12	0.35
SFPC 5	1699.88	357.12	16%	168.12	0.35

3.7 TEST CONDUCTED ON SPECIMEN

3.7.1 Compressive strength test: Compressive strength test is done to determine strength of pervious concrete. For each composition 3 cubes were casted. The specimens were tested at 7, 14 and 18 days as shown in fig.3.5. All cubes were tested on Universal compression testing machine as per IS: 516-1959. The load was applied continuously @ 140N/ min. Load continued till the specimens were crack or fail and maximum load was noted down. The compressive strength value was obtained by taking average value of three specimen.

Fig. 3.5 Compressive strength of cube

3.7.2 Split tensile strength test: Split tensile strength test is done to determine tensile strength of pervious concrete. For each composition 3 cubes were casted. The specimens were tested at 7, 14 and 18 days as shown in fig.3.6.

Fig.3.6 Split tensile strength of cylinder

3.7.3 Flexural strength test

From nine beam for each composition, three similar beams were crushed at 7days, 14days, and 28days. The flexural strength is evaluated by using the following formula. And the average of 3 similar beams for each composition gives the flexural strength or modulus of rupture of pervious concrete for a particular composition. This test is carried out with accordance to IS: 516-1959.

Modulus of rupture=PL/BD^2 If $\begin{bmatrix} \text{A} > 20\text{cm for }15\text{cm specimen} \\ A > 13.3cm\ for\ 10cm\ specimen \end{bmatrix}$

Modulus of rupture=3PA/BD^2 If $\begin{bmatrix} \text{A17cm for 15cm specimen} \\ \text{A11cm for 10cm specimen} \end{bmatrix}$

Where, A=the distance between the line of facture and the nearer support, measured on center

line of tensile side of sample in cm

B=width of prism in cm

D=depth of failure point in cm

L=length of prism in cm

P=load in kg

Fig.3.7 Flexural strength test

3.7.4 Cantabro Abrasion resistance test

Generally pervious concrete used in road pavement so Abrasion resistance should be checked. The Cantabro test conducted using Los Angeles Abrasion Machine. The Cantabro test were conducted by two sets of samples and each set of sample contains three specimens. 70mm x 70mm x 70mm size of mortar casted for 28days of curing. The test procedure was beginning by measuring initial mass M1 of three sets of specimens. Then we placed the specimens inside the drum of abrasion machine. Then the machine was rotated up to 30 revolution per minute. In this test no steel balls were used. After that specimens were passing through 25mm sieve and the final mass of specimen M2 was measured. The percentage of mass loss was calculated by the given formula:

$$\text{Mass loss } (\%) = \frac{(M1-M2)}{M1} \times 100$$

Fig.3.8 Los Angeles Abrasion Machine

Fig.3.9 Specimen for Cantabro test

4.1 RESULTS OF TRIAL MIX DESIGN

In table 4.1 shown the results on trial mix of pervious concrete which was done with 5%, 7%, 9% of sand without superplasticizer. The average value of three specimen were taken as result for all properties.

4..1 Porosity and Permeability: The results of Porosity and Permeability of all mixes of pervious concrete were shown in Table 4.1 and Table 4.2. Water permeability coefficient under the water head of 100mm and 150mm for pervious concrete with 5%, 7% and 9% of fine aggregates.

Table 4.1 Porosity of pervious concrete

Mix type	**Fine aggregates (%)**	**Porosity (%)**
OPC 1	5%	25.45
OPC 2	7%	23.74
OPC 3	9%	21.37

The typical analysis of fine aggregate percentage in pervious concrete indicated that porosity was closed to target 20%. All three-percentage sand satisfied the target of porosity. But here we were taken OPC 3 mix type for further analysis because OPC 3 has more compressive strength which was shown in table 4.3.

Table 4.2 Permeability of pervious concrete

Mix type	Fine aggregates (%)	Permeability for 100mm water head	Permeability for 150mm water head
OPC 1	5%	15.7 mm/sec	14.9 mm/sec
OPC 2	7%	13.6 mm/sec	12.9 mm/sec
OPC 3	9%	12.5 mm/sec	11.7 mm/sec

Water permeability of pervious concrete of all mixes for water head due to the sensitivity of permeability to pore structure and size. Table 4.2 shows that the water permeability was decreased with adding of fine aggregates. For 5% of fine aggregate the water permeability was 15.7 and 14.9 mm/sec while 9% of fine aggregate the permeability is 12.5 and 11.7 mm/sec. As per test the water permeability was decreased while water head changed from 100mm to 150mm due to change in water flow.

4.1.2 Compressive strength test: Three specimens or cubes were casted for each type of composition. Here in trial mix different percentage of fine aggregates were taken as 5%, 7%, 9%. Each specimen was tested for compressive strength test on Compressive testing machine. The value of compressive strength was taken average of three specimen. The results of compressive strength test were shown in Table 4.3.

Table 4.3 Compressive strength of pervious concrete

Mix type	% of fine aggregates	Compressive strength of 7day
OPC 1	5	12
OPC 2	7	16

OPC 3	9	18

4.2 DISCUSSION FOR TRIAL MIX DESIGN

From the above all test results, we can clearly see that the porosity value was lies between 21-26%, permeability lies between 11-16 mm/sec and compressive strength test value lies between 12-18Mpa. All mixes were satisfied its conditions and test results were lies within the limits. As we had to choose one percentage of fine aggregates for future analysis which satisfy all properties. Here we choose 9% of fine aggregates for future work analysis because 9% of fine aggregates gives maximum compressive strength and also satisfy porosity and permeability parameter.

4.3 RESULTS OF MIX DESIGN USING SILICA FUME

Various pervious concrete mix proportions were subjected to destructive testing to evaluate the effects of silica fume at different percentage and super plasticizers (1%) on the various mechanical properties of the concrete such as compressive strength, split tensile strength, flexural strength and Cantabro test. Results of each test have been mentioned in Tables 4.4 to 4.7. The variation of compressive strength, split tensile strength, flexure strength of different concrete mix with age have been shown in fig.4.1 to 4.5 respectively.

4.3.1 Compressive strength test

The cubes 150 mm x 150 mm x 150 mm were tested in the Compression Testing Machine (CTM). During Initial loading, cubes were uncracked and stiff. With further loading, cracks occurred at the edges. As the applied load is further increased, the cracks were also increased. The results of compressive strength of cubes of all mix proportions with water-cement ratio 0.34 have been shown in Table 4.4 and Fig 4.1. All the values are the average value of these three identical cubes of each type of composition.

Table 4.4 Compressive strength (N/mm2) of PC using silica fume

Mix type	Compressive strength of 7day	Compressive strength of 14day	Compressive strength of 28day
SFPC 1	18	20	21
SFPC 2	23	27	32
SFPC 3	26	29	36
SFPC 4	20	21	25
SFPC 5	18	19	21

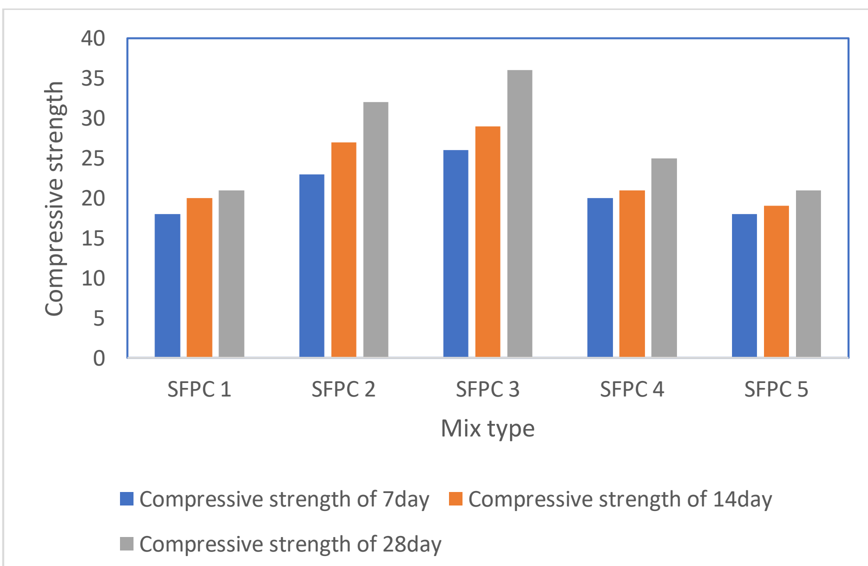

Fig. 4.1 Comparison of Compressive strength on different % of silica fume on pervious concrete

The mix type SFPC1, SFPC2, SFPC3, SFPC4, SFPC5 represents the replacement of silica fume of 0%, 4%, 8%, 12%, 16%. The compressive strength results of all the mix proportion with constant water cement ratio 0.35 at 7, 14 and 28 days has been shown in fig.4.1 From the above results we conclude that the compressive strength of PC is increase with addition of silica fume. As we mix different percentage of silica fume, the 8% replace of cement by silica fume give maximum strength with addition of 9% of fine aggregates and water cement ratio of 0.35. We archive maximum strength of 36 N/mm2 at 28days of pervious concrete with silica fume. Further addition of silica fume tends to decrease of strength.

4.3.2 Split tensile strength:

The cylinders 300 mm x 150 mm were tested in the Compression Testing Machine (CTM). During Initial loading, cubes were uncracked and stiff. With further loading, cracks occurred at the center which is shown in fig.4.1. Results of split tensile strength of various pervious concrete mix proportions have been shown in Table 4.5 and Fig 4.2.

Fig. 4.2 Failure of split tensile strength

Table.4.5 Split tensile strength (N/mm2) using silica fume

Mix type	7day	14day	28day
SFPC 1	1.1	1.24	1.38
SFPC 2	1.24	1.38	1.94
SFPC 3	1.66	1.80	2.08
SFPC 4	1.38	1.52	1.66
SFPC 5	1.24	1.32	1.38

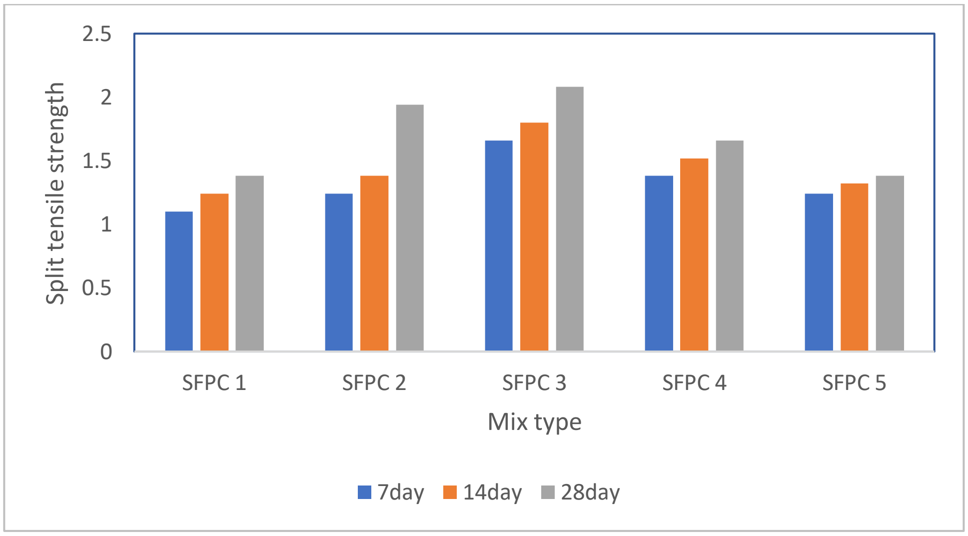

Fig. 4.3 Comparison of Split tensile strength on different % of silica fume on pervious concrete

The mix type SFPC1, SFPC2, SFPC3, SFPC4, SFPC5 represents the replacement of silica fume of 0%, 4%, 8%, 12%, 16%. The Split tensile strength results of all the mix proportion with constant water cement ratio 0.35 at 7, 14 and 28 days has been shown in fig.4.2. The split tensile strength of pervious concrete decreased with silica fume. As we mix different percentage of silica fume, the 8% replace of cement by silica fume give maximum tensile strength with addition of 9% of fine aggregates and water cement ratio of 0.35. We archive maximum tensile strength of 2.08 N/mm2 at 28days of pervious concrete with silica fume. Further addition of silica fume tends to decrease of strength.

4.3.3 Flexural strength

The results of compressive strength of cubes of all mix proportions with water-cement ratio 0.34 have been shown in Table 4.4 and Fig 4.1. All the values are the average value of these three identical cubes of each type of composition.

Table 4.6 Flexural strength test

Mix type	At 28day
SFPC 1	1.26
SFPC 2	1.79

SFPC 3	2.40
SFPC 4	2.11
SFPC 5	1.65

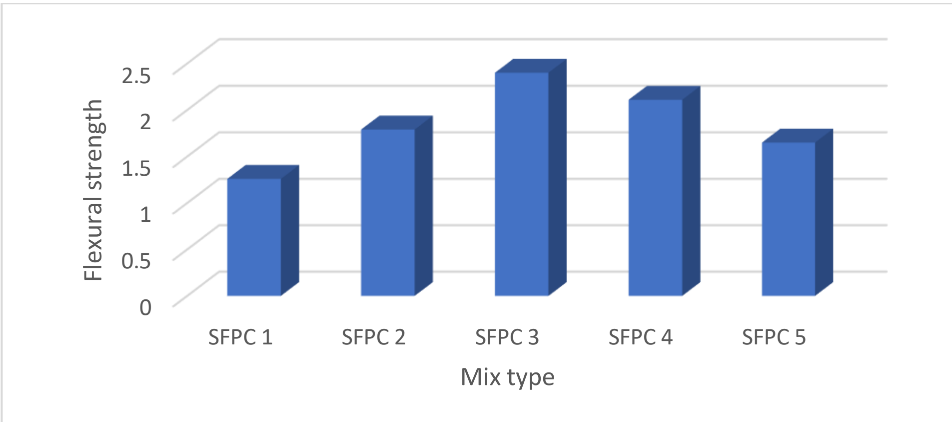

Fig4.4 Flexural strength at 28day

The mix type SFPC1, SFPC2, SFPC3, SFPC4, SFPC5 represents the replacement of silica fume of 0%, 4%, 8%, 12%, 16%. The Flexural strength results of all the mix proportion with constant water cement ratio 0.35 at 28 days has been shown in fig.4.4. The split tensile strength of pervious concrete decreased with silica fume. As we mix different percentage of silica fume, the 8% replace of cement by silica fume give maximum tensile strength with addition of 9% of fine aggregates. We archive maximum tensile strength of 2.40 N/mm2 at 28days of pervious concrete with silica fume. Further addition of silica fume tends to decrease of strength.

4.3.4 Cantabro test

The cantabro test conducted on two sets of samples. Each sample contains three specimens. The mass loss of all mix proportion was shown in Table 4.7 and Fig. 4.5.

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Table 4.7 Cantabro abrasion resistance test

Mix	Mass loss (%)
SFPC 1	42.45
SFPC 2	30.94
SFPC 3	24.91
SFPC 4	25.67
SFPC 5	26.5

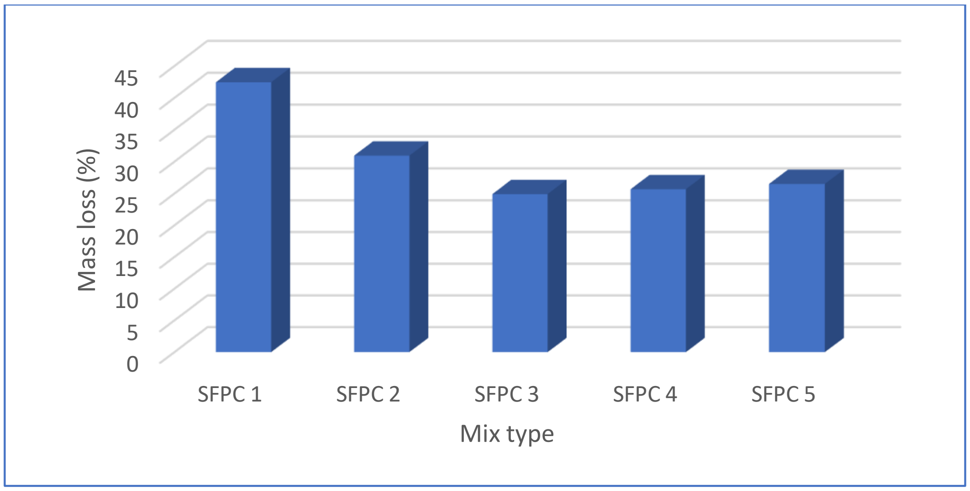

Fig. 4.5 Cantabro mass loss of pervious concrete

The mix type SFPC1, SFPC2, SFPC3, SFPC4, SFPC5 represents the replacement of silica fume of 0%, 4%, 8%, 12%, 16%. The mass loss of pervious concrete were between 25-45%. Interlocking of aggregates voids by sand particles was the reason for mass loss. Experimental results indicates that addition of silica fume reduced the percentage of mass loss. Here we got 8% replacement of silica fume had less percentage of mass loss which have high resistance to abrasion effect.

5. CONCLUSION

Basically, pervious concrete is environment friendly because it allows water to drain in to the subgrade directly. As pervious concrete is open cell structure it does not absorb heat and radiate heat back to the environment. No need to install drainage pipe in pervious concrete. Due to low compressive strength, it limits the usage of pervious concrete. Cement is main ingredient in pervious concrete. Production of cement deliver the maximum carbon dioxide to environment. In order to minimize environment pollution here we use silica fume as partial replacement of cement. In this paper we studied about effect of fine aggregate on pervious concrete. Trial mix carried out by using 5%, 7%, 9% fine aggregates. We get 9% fine aggregate gives maximum strength and satisfy all parameter. Then after replacement was done with silica fume at different percentage like 0%, 4%, 8%,12%, 16%. From the above investigation we conclude the following:

- Pervious concrete has low strength as compare to conventional concrete. In order to increase strength silica fume is added to it.
- Strength parameters are increases in pervious concrete by using admixtures like silica fume.
- We archive maximum compressive strength of 32 N/mm2 and satisfy porosity and permeability at 8% replacement of silica fume Further increase of silica fume tends to loss of strength.
- So therefore, silica fume as a additive can be used to increase the strength of pervious concrete by adding 8% of silica fume.

5.2 SCOPE OF FFUTURE WORK

All characteristics of pervious concrete can be further studied by taking following parameters:

- By varying the water-cement ratio of pervious concrete.
- By varying different size of coarse aggregates.
- By using recycled coarse aggregates in pervious concrete mix.
- By using different types of admixtures like Metakaolin, Fly ash, Rice husk ash etc.
- Other properties like Bond strength, hydraulic conductivity etc. can also be studied.
- The pore structure should be studied due to its effect on permeability of pervious concrete.
- A detailed study needed for combination of pervious mortar and pervious concrete and its application.

5.3 FUTURE SCOPE OF PERVIOUS CONCRETE

The future scopes of the study are given below:

- For building cooling and rainwater harvesting purpose pervious concrete can be used by simply giving a permeable wall to it.
- Water can be passing through providing borehole at every 1Km to 2Km with the help of drainage system if clayey soil is present.
- Pervious concrete need pressure washing for every 1-2 times a year.
- Water can be filtered through pervious concrete and stored then can be stored as fresh water below the ground thus eliminating the shortage of drinking water and reduce water pollution.
- Flaky aggregate have more strength and thus can be used to provide easy passes of water without providing any extra drainage system.
- Research should be done in order to increase the strength of pervious concrete so that it can be used for high volume road.
- However more research work needed to be done to study that how this pervious concrete can be broadly used to increase the storage of ground water table by studying the nature of soil, properties of different type of soils, effect of different types of admixture etc. which can be helpful to meet the water demand and to overcome water crisis which is a growing and important problem all over the world to be solved.

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