A Project Report

On

Pervious Concrete Using Fly Ash, Silica Fumes, GGBFS And Metakaolin : A Review

Submitted in partial fulfillment of the requirements of the degree of

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In

Civil Engineering

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Certificate

This is to certify that the project entitled **"Pervious Concrete Using Fly Ash, Silica Fumes, GGBFS And Metakaolin : A Review"** is a bonafide work of **Khan Abubakar, Khan Ubaidullah, Baig Abdul Samad, Hodekar Nujaid** submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of

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This dissertation report entitled **"Pervious Concrete Using Fly Ash, Silica Fumes, GGBFS And Metakaolin : A Review"** by **Khan Abubakar, Khan Ubaidullah, Baig Abdul Samad, Hodekar Nujaid** is approved for the degree of "**Bachelor Of Engineering**" in "**Civil Engineering**"

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Abstract

Pervious concrete is a special type of concrete which consist of cement, coarse aggregate, water and if required admixtures and other cementitious materials. As there is no fine aggregate present in the matrix, the void content is more which allows the water to flow through it. Therefore, the pervious concrete is called as permeable concrete or porous concrete.

Considering the high porosity and high permeability of pervious concrete, it is capable of various environmental benefits such as reduction in stormwater runoff, reduction in urban heat island effect and recharge of ground water. Cement being one of the major source of CO_2 emission, it is replaced by some proportion of SCMs.

This study shows the effects of replacement of SCMs such as Silica fumes, fly ash, ggbfs and metakaolin with Cement. By adding 5-10% silica fumes, void ratio is decreased to 25% and compressive strength increased significantly.Highest compressive strength was achieved at 50% replacement of cement, upto 17% more than normal pervious concrete. When the cement is replaced by 2% of metakaolin porosity decreased and density increased significantly. Optimum level of replacement for cement with fly ash was seen to be 5-15%. While fly ash's replacement with cement shows the similar behavior as that of metakaolin.

KEYWORDS: Pervious concrete, porous concrete, permeable concrete, silica fumes, fly ash, ggbfs, metakaolin

Contents

Abbreviation Notation and Nomenclature

SCM	Supplementary cementitious material
OPC	Ordinary Portland cement
PC	Pervious Concrete
FA	Fly ash
HVFA	High volume fly ash
GGBFS	Ground granulated blast furnace slag
IS	Indian standard
ASTM	American Society For Testing And Materials

INTRODUCTION

Pervious concrete also known as permeable concrete, is a special type of concrete with high porosity used for concrete flat work. It is characterized as a sustainable pavement concrete with high water permeability and porosity. High latent heat capacity of pervious concrete also leads to the reduction in urban heat island effect. This kind of permeability helps in reduction of stormwater run-off and also recharges the ground water. Therefore, the application of pervious concrete payments are limited to low- volume roads, parking lots, cycle tracks, pedestrian walkways, residential streets, where all these classes of roads constitute major portion of payment network in urban areas. Generally, the porosity of pervious concrete ranges between 15% to 35% by volume.

On the other hand, cement been one of the most widely used construction material has led to the release of large content of CO_2 in the atmosphere which in turn affects the global environment. Statistical results shows that over 3000MJ of energy is consumed to produce 1 ton of cement, even if the best available technique is used. Around 0.82 KG of CO_2 is emitted in the production of per KG cement, which almost accounts for five percentage of global CO_2 emission. In a view to reduce greenhouse gas emission for sustainable development of road, efforts have been taken from a long period. So, the most effective practice to reduce the use of cement clinkers is by blending supplementary cementitious materials in replacement to cement. Fly ash, silica fume, ground granulated blast furnace

Slag (GGBFS), Metakaolin are the most commonly used SCMs. Supplementary cementitious material (SCM) reacts with calcium hydroxide and water and further produces calcium silicate hydrates (CSH) as similar as in cement hydration.

Silica fume is an ultrafine, non-crystalline material formed as by-product during the production of silicon and ferrosilicon alloys. It is an highly reactive pozzolana comprised of amorphous silicon dioxide. It can be replaced with cement to achieve economy as well as it provides more strength. From various experiments performed earlier it is reported that it can be replaced with cement quantity by 15 to 20% for best results. Being an ultrafine material it densifies the ITZ leading to better paste to aggregate bonding and thus increased durability. Freeze-thaw is a major problem in pervious concrete. An experiment performed by Cwirzon and Penthala showed that replacing silica fume with cement improves the performance of Pervious Concrete against freezing and thawing cycles.

GGBS is a by-product from the Limestone, Iron-ore, coke and iron manufacturing at a temperature of about 1500°C to 1600°C.The chemical composition is similar to Portland Cement. The molten slag after the tapping of the molten iron is water-quenched rapidly resulting in the formation of a glassy granulate which is further dried and ground to the required size. When the experimental study was carried out on GGBS concrete with 20%, 30%, 40% and 50% replacement of the cement with GGBS.

MATERIALS

PHYSICAL PROPERTIES:

Physical properties of metakaolin:

Metakaolin is generally found in powdered form in white/grey color. The metakaolin has a surface area of 14300 m2/kg. Its specific gravity is 2.54 and Strength activity index is 113. The uncompacted weight density of metakaolin is 890kg /m3, While the compacted weight density of metakaolin is 1005kg/m3.

Physical properties of GGBS:

It's specific gravity is 2.90 and it's specific area (cm2 g−1) is 4550 Bulk Density of GGBS is 1000-1100 kg/m^3 (loose) 1200-1300 kg/m^3 (vibrated). The colour of GGBS is off white. Fineness is less than 350 m^2/kg.

Physical properties of silica fumes:

The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 (undensified) to 600 kg/m3. The specific gravity of silica fume is generally in the range of 2.2 to 2.3. The specific surface area of silica fume can be measured with the BET method or nitrogen adsorption method. It typically ranges from 15,000 to 30,000 m2/kg. Silica fume has a greyish black colour.

Physical properties of fly ash:

Specific gravity of fly ash varies in the range 2.1-2.6, while bulk density ranges from 1 to 1.8 g/cm3. The specific surface area of the fly ash used in current practical engineering is between 300 and 400 m2/kg. Fly ash with a specific surface area of 600 to 700 m2/kg can be obtained from grinding.

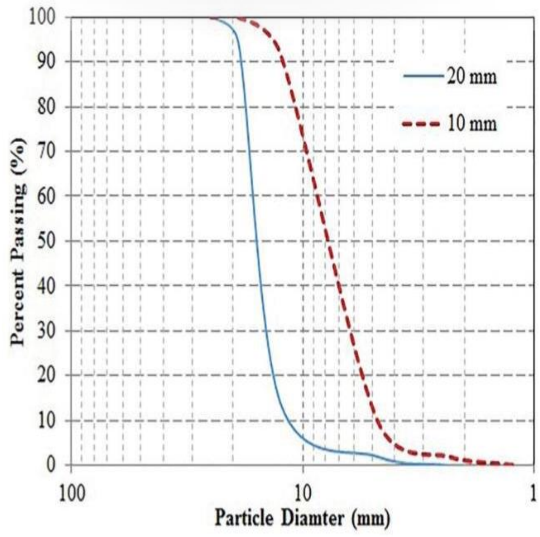
CHEMICAL COMPOSITIONS:

Chemical composition of metakaolin:

Chemical	Wt (%) Metakaolin
SiO_2	55.7
Al_2O_3	38.6
Fe_2O_3	2.03
TiO_2	0.78
CuO	0.03
ZrO_2	0.04
K_2O	2.43
MnO_2	0.04
LOI	1.74

Chemical composition of GGBS:

	Chemical composition (%)								Physical properties	
Material	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	NaO	SO_3	LOI	Specific gravity	Surface area ($cm^2\ g^{-1}$)
Cement	63.2	19.9	4.9	2.3	2.5	0.8	3.8	2.6	3.14	3670
GGBS	42.1	35.4	10.6	0.4	8.1	–	0.3	3.1	2.90	4550



Chemical composition of silica fume:

Element	%
SiO_2	94.10
Al_2O_3	0.47
CaO	0.92
Fe_2O_3	0.25
MgO	1.18
Na_2O	0.40
K_2O	1.22
SO_3	0.26
L.O.I	0.90

Chemical composition of fly ash and metakaolin

Particles	FA % by mass	MK % by mass
SiO_2	35.91	31
Al_2O_3	16.02	53.5
CaO	14.43	1.1
Fe_2O_3	12.34	6.58
K_2O	1.28	5.79
MgO	9.09	0.12
Na_2O	5.87	0.04
TiO_2	0.66	0.919

METHODOLOGY

a) Preparation and curing of specimen:-

Cylindrical pervious concrete sample having radius of 50mm and height of 200mm with aspect ratio of 1:2 were prepared in laboratory.Two layer compaction were done with 20 blows per layer with 2.5kg standard proctar hammer.Two batches of samples were prepared and left in the mould for 24 hours.Plastic membrane curing method was adopted for a batch while wet curing method was adopted for another batch.Both curing process were done for 28 days.

b) Density and porosity determination:-

These are the main factors that strongly influence the functional and structural properties of PC.

ASTM C1754 was adopted for determination of density and porosity if both the samples.For density determination the cured sample is placed in oven at 50.C for 7 days and its hardened weight is noted down.

While to determine the porosity the samples are kept submerged in water for 30 minutes and weight under water is measured .The weight of submerged sample and oven dried sample of PC samples are used in relationshipas given in ASTM C1754 for calculating porosity.

c) Permeability:-

To conduct permiability test,falling head lermeameter was used in this test. To prevent any leakage of water, the sides of the specimens were tightly wrapped with duct tape,which ensure the water to enter through top surface and exit only through bottom surface.Then the specimen is placed inside the bottom stand pipe and to seal the gaps between the standpipe and specimen silicone gel was used.One end of standpipe is placed on the top of the specimen witb due precautions.The time taken for water level to drop from h1 to h2 is noted.Then with the help of formula:-

Permeability={(aL/At)*ln(h1/h2)}

where,a=top standpipe area(cm2);

L=sample height(cm)

A=sample crosssectional area(cm2);

t=time taken by water to fall from h1 to h2(sec); h1=initial water head(cm), h2=final water head(cm). The resulting permeability(cm/sec) is converted to (mm/sec).

d) Compressive strength:-

Displacement controlled(1mm/minute) compressive strenght test was adopted for all samples.

e) Unit weight:

The unit weight is calculated according to ASTM C138

f) Porosity:

For the Porosity test, the length, width and height of the specimen is measured. Then the specimen is immersed in water and its buoyant weight is measured when the specimen is filled with water. After that, the specimen isdried in 105 ± 5 °C oven until the weight is constant. The Porosity P is calculated by

$$\left[1 - \frac{(W_2 - W_1)}{(\rho_w V)}\right]$$

where P is the Porosity of pervious concrete.

W1 is the constant weight of specimen dried under 105 °C.

W2 is the buoyant weight of specimen in water.

ρw is the density of water.

And V is the volume of specimen.

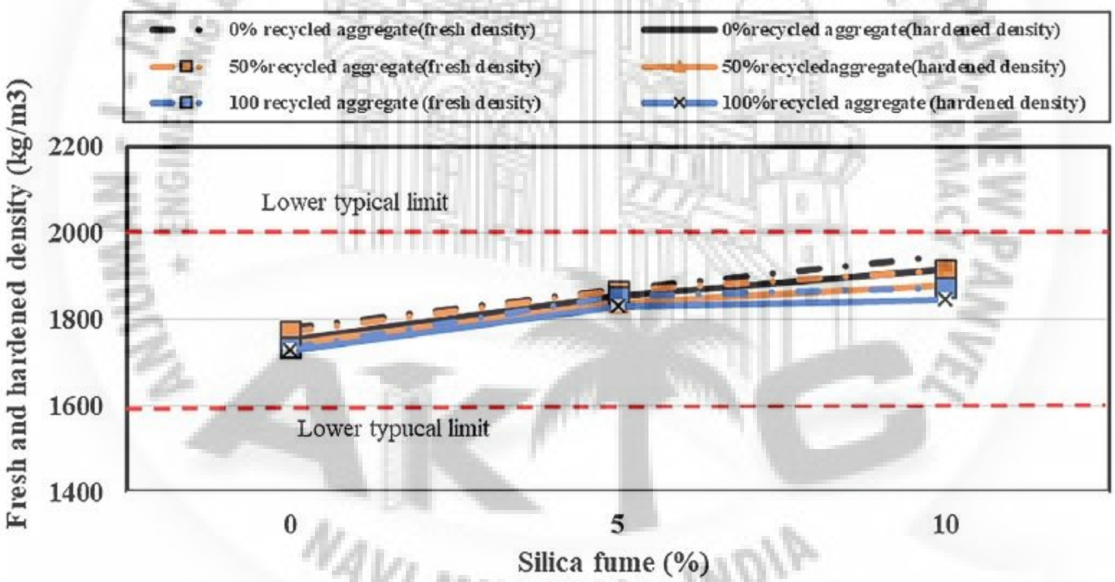
RESULT

Effect of silica fume on:

1. Fresh and hardened density of pervious concrete:

The effect of silica fume on density is shown in fig below. From the fig. it can be seen that the increase of silica fume content, increases the density of fresh and hardened pervious concrete.

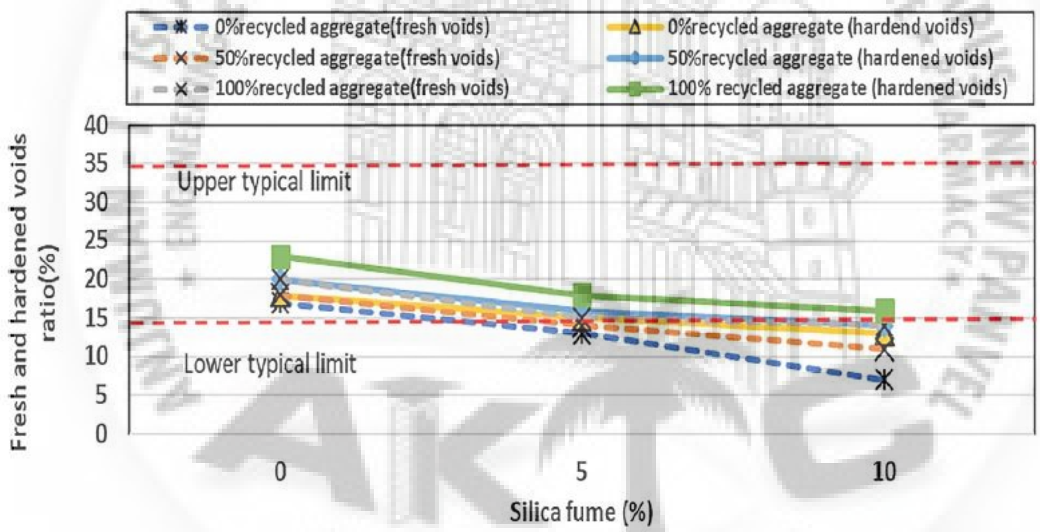
This observation is the same for concrete with and without recycled aggregate. The increase in fresh pervious concrete density is 5.1% and 8.9% for 5%, and 10% silica fume content, respectively. This increase in hardened density is 5.3% and 8.4%, for pervious concrete with 5% and 10% silica fume, respectively.



2. Voids ratio for pervious concrete:

The influence of using silica fume on voids ratio of pervious concrete is shown in the fig below. The increase of silica fume levels decreases the resulting voids ratios. From the test results, the decrease in hardened pervious concrete voids ratio is 16.7% and 27.7% for 5% and 10% silica fume.

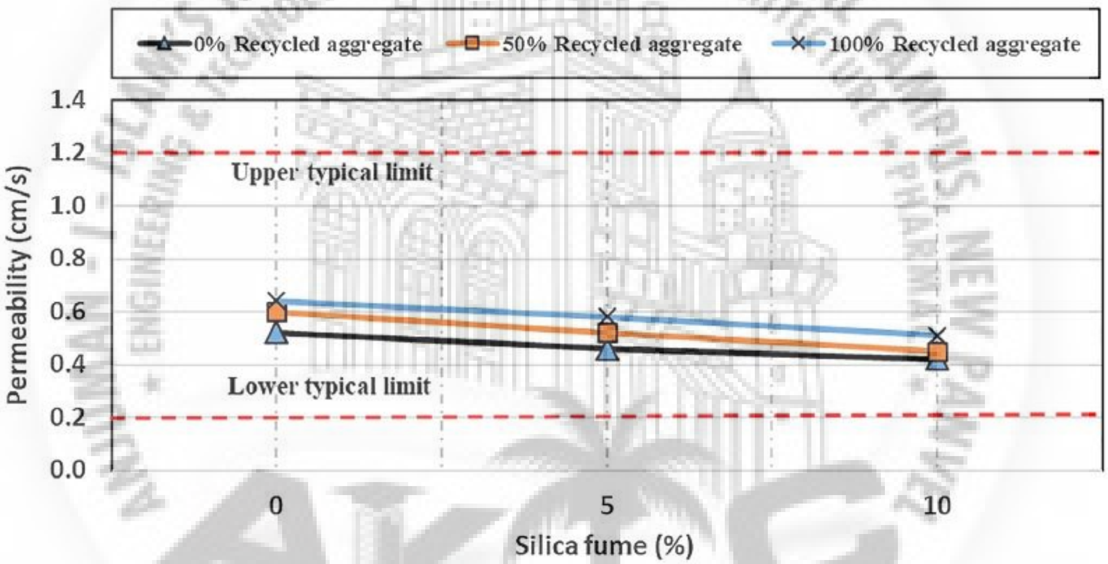
This behavior may be attributed to the filling effect of silica fume in addition to the good ability of compaction in the presence of very fine silica fume. This trend is also concluded by Raghwani. Also, it is obvious that the use of 10% silica fume decreases the voids ratio to limits out of the typical ranges recommended by ACI 52



3. Water permeability coefficient:

The influence of silica fume on water permeability is shown in fig below. From the test results either for concrete with and without recycled aggregate, the increase of the silica fume decreases pervious concrete permeability.

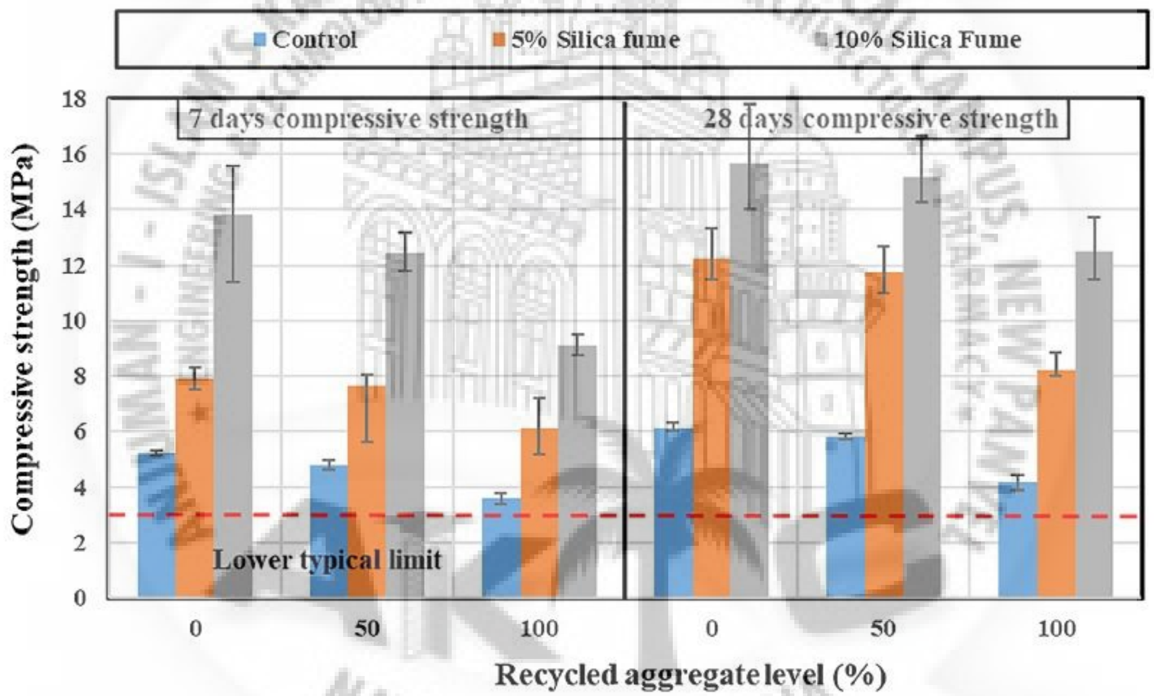
These results may be due to the enhance of pervious concrete density as the result of adding silica fume. The decrease in pervious concrete permeability is 11.5% and 19.2% for 5% and 10% silica fume, respectively compared with control mix without silica fume.



4. Compressive strength of pervious concrete:

The influence of silica fume on pervious concrete compressive strength is presented in fig below. From this figure, it can be noted that the use of silica fume enhances pervious concrete compressive strength. This increase on 28 days compressive strength for pervious concrete with and without recycled aggregate is 49% and 61% for 5% and 10% silica fume, respectively.

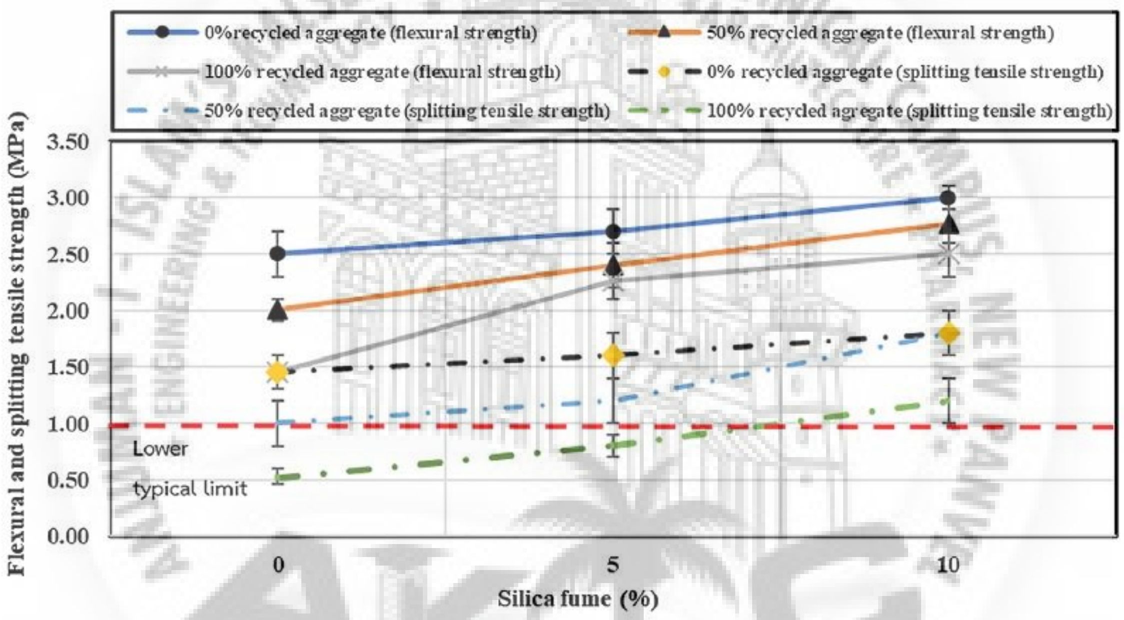
This enhancement may be attributed to the improvement of cement matrix as a result of filling effect and pozzolanic reaction of silica fume



5. Flexural and splitting tensile strength:

Figure below shows the influence of silica fume on 28 days pervious concrete flexural and splitting tensile strength. From this figure, it is clear that the silica fume slightly improves pervious concrete flexural and splitting tensile strength. This results agrees with pervious concrete with and without recycled aggregate.

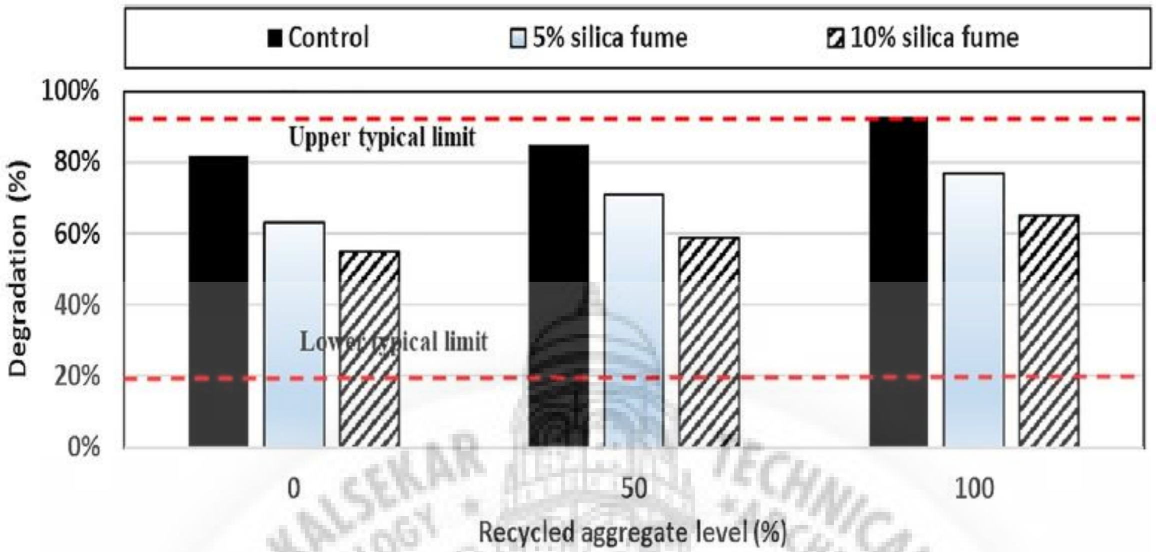
This improvement may be attributed to the enhancement of cement matrix and transition zone as a result of using very fine silica fume. For example for concrete without recycled aggregate, the increase in pervious concrete 28 days splitting tensile strength is 7.5% and 17.7% for 5% and 10% silica fume



6. Pervious concrete degradation:

Influence of silica fume on pervious concrete degradation is presented in below fig. It can be observed that the increase of silica fume levels decreases the degradation for pervious concrete.

For concrete without recycled aggregate, the decrease in pervious concrete degradation is 23% and 32.9% for 5% and 10% silica fume, compared with control mix with recycled aggregate.



Effect of GGBFS on pervious concrete:

The experimental results are presented and discussed. The com- pressive strength, permeability, Elasticity test results are tabulated.

Coefficient of Permeability

The 28-day Coefficient of Permeability of various Pervious Concrete specimens were calculated using falling head method by using conventionally made permeability apparatus.

Modulus of Elasticity

The 28- day Young's Modulus of various Pervious Concrete specimens were obtained.

Comparison of Compressive Strength

The Compressive strength of mixes with Cellulose fiber, GGBS and both GGBS and Cellulose fiber are tabulated and compared with that of the Pervious Concrete mix with no additives.

Table 4.2 Modulus of Elasticity for various mixes

Type of Mix	Permeability(cm/sec)
PC	20.00
PC+CF	20.34
PC+GGBS	30.64
PC+CF+GGBS	31.11

Coefficient of Permeability of various mixes

Type of Mix	Permeability(cm/sec)
PC	0.865
PC+CF	0.824
PC+GGBS	0.846
PC+CF+GGBS	0.816

Table 4.3 Compressive Strength for various mixes with curing periods

Curing Period (Days)	PC MPa	PC+CF MPa	PC+GGBS MPa	PC+CF+GGBS MPa
7	12.33	13.563	14.432	14.16
14	17.66	18.832	20.295	20.33
28	24.695	25.66	26.279	27.66

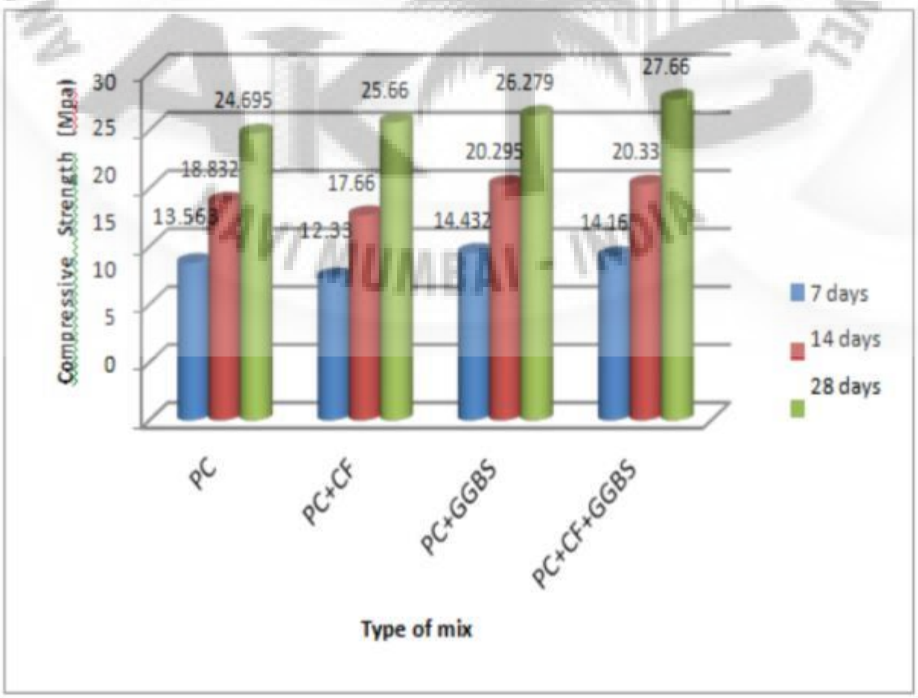


Fig 4.1 Comparison of Compressive Strength

Effect of fly ash and metakolin on pervious concrete:

1.SCATTER PLOT:-

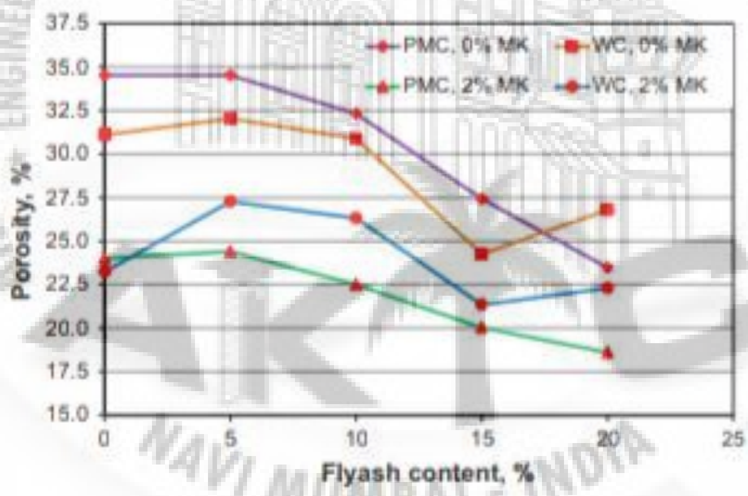
Scatter plot graphs shows the obtained values for different properties and their characteristic relationship with each other.

It clearly depicts that with the increase in porosity compressive strenght decreased,density reduced and permeability increased significantly.

2.Effect of fly ash and metakaolin:-

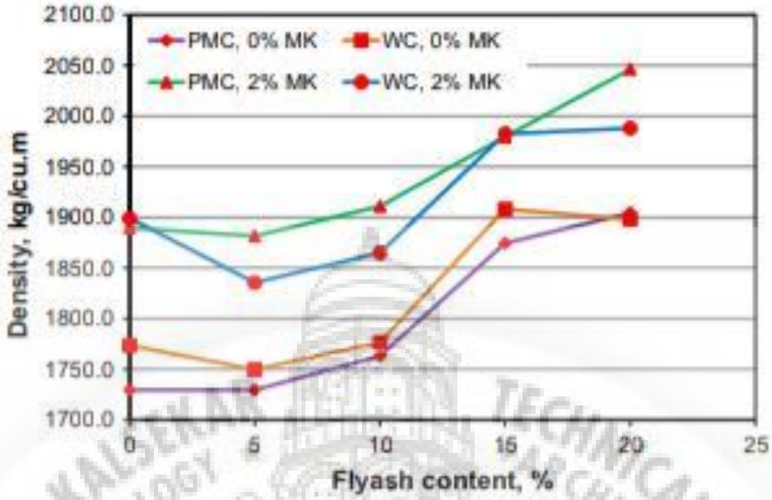
Fly ash alone and with addition of metakaolin was added as partial replacement of OPC.

Fig. below shows the porosity intersection plot.



It is seen that with the increase in content of fly ash and metakaolin,the porosity decreases.It shows large decrease in porosity when metakaolin content was increased from 0-2%.With plastic membrane curing and no fly ash,approximately 10% decrease in porosity was observed,indicating the impact of replacing cement by 2% metakaolin.Further addition of metakaolin may lead the concrete to become impermeable.

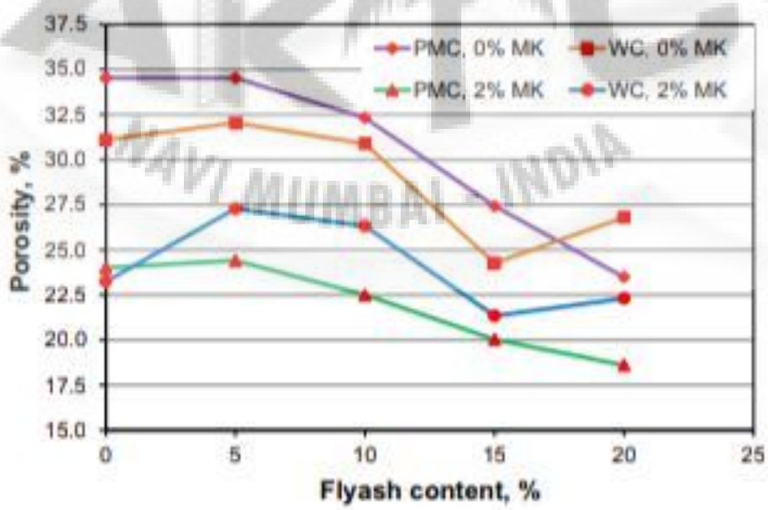
Fig. below shows intersection density intersection plot.



It can be observed that for mixture with addition of 2% metakaolin without any fly ash,density increased by approximately 6.5%.

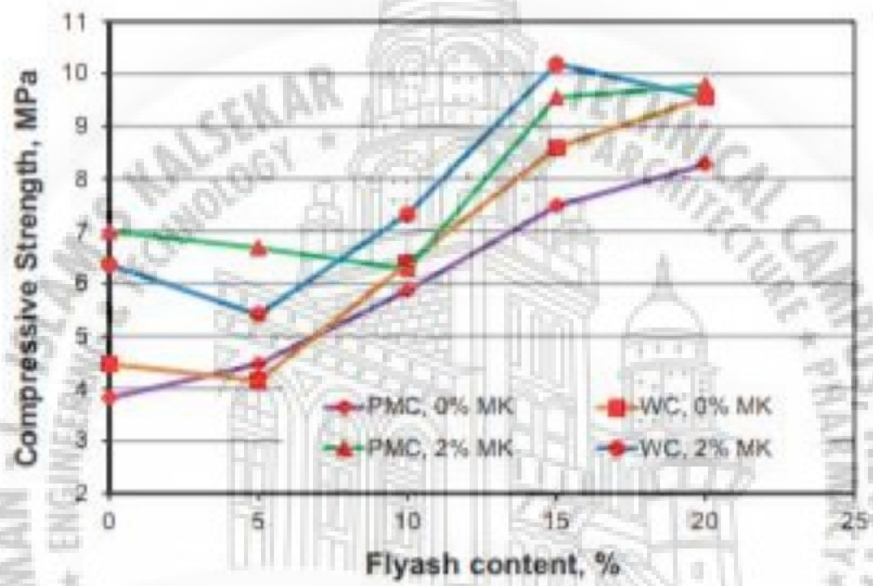
With further increment of fly ash from 0-20%,density increased proportionaly for all curing conditions.After 20% addition of fly ash no changes in density was observed.

Fig. below permeability intersection plot.



At 2% metakaolin content,the permeability decreased with increase in fly ash content and with increased density and resuced porosity.Clear trends can be seen with fly ash percentage of 5-15%.

Fig below shows compressive strenght intersection plot.



Wet curing method is observed to be showing slightly more compressive strenght.Further with increase in fly ash content and metakaolin content ,compressive strenght increased.

Rate of increase was higher fir fly ash content of 5-15%.

But the rate decreased later on.

Further increase in fly ash after 20% may lead to decrease in porosity without any increase in compressive strenght.

CONCLUSION

From various research papers, it can be concluded that by adding 5-10% silica fumes, hardened density of pervious concrete is increased significantly also it is noted that void ratio is decreased upto 25% leading to decrease in permeability of pervious concrete. Therefore it is recommended by ACI to not use silica fumes more than 10%. Further it is concluded that silica fumes enhances the compressive strength of pervious concrete significantly. Flexural and spliting strength is also seen to increase slightly by adding silica fumes.

From the interaction plots it can be concluded that,with the addition of 2% metakaolin, porosity decreases and density increased significantly. Similar behavior was observed with the addition of flyash,as porosity decreases and density increases significantly. Rate of change in properties of pervious concrete was higher for the replacement level 5-15% for fly ash .

The workability of concrete increases with increase in replacement of cement by GGBFS. Highest compressive strength was achieved at 50% replacement of cement, upto 17% more than normal pervious concrete. By adding GGBFS it is also noted that sulphate resistance is increased upto 18% than normal pervious concrete.

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