POROUS CONCRETE & ITS CHARACTERISTICS WITH MINERAL ADMIXTURES

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Abstract: *The advantage of a pervious or porous concrete pavement is to allow the runoff water to its below layers effectively, this characteristic of the pavement is usually dependent on the pore size, geometry & connectivity of the materials. The functional benefits of porous pavements are improved wet-weather driving safety, reduced tire pavement noise and replenishing of groundwater supplies, Porous concrete is an eco friendly pavement is also known as a no fine aggregate or zero slump concrete. This paper presents a study in which the effects of aggregate gradations on the permeability and mechanical properties of pervious concrete were investigated. Concrete mix with aggregate gradation of 20mm & 10mm size with fly ash as an admixture are tested for 7 days & 28 days compressive & split tensile strength for obtaining the optimum gradation mix for the porosity level varying from 15 to 35% by keeping 0.35 as water cement ratio.*

It has been found that There is a reduction in percentage of porosity in the concrete mix with the increase of fly ash at a percentage of 15 & 25 percent of weight in concrete mix for all the specimens tested under 7 days & 28 days & also when the finer aggregate (Fly ash) to coarse aggregate ratio is increased up to 10 % & 20%, there is a considerable increase in compressive & split tensile strength of the concrete specimens. The efficiency of pervious concrete will depend on amount of porosity & co efficient of permeability of mix where the co efficient of permeability had been tested for 7 days & 28 days concrete specimens by allowing the water to flow inside the concrete specimens where as there is considerable variation of flow with respect to the concrete specimens which are tested by Darcy's law of permeability.

Key words: ***Porous concrete, permeability, mix design, compressive strength, admixtures.***

I.INTRODUCTION

Pervious concrete is also termed as porous concrete with no or less finer materials is a mixture of coarse Aggregates, mineral admixtures & water, the mix constitutes high porosity that allows run off water from precipitation and other sources from the surface layer of pavement to enter in to the below layers directly thereby reducing runoff and increase in groundwater recharge with lesser damage to the pavements. Pervious concrete is traditionally used in parking areas, areas having Light or Low traffic volume roads, Residential streets, in Sub base for conventional concrete pavements & Pedestrian walkways. It is an important technique that leads to sustainable construction & low impact on environment. The porous aggregate structure allows run off water in to the concrete surface layer & to below layers of pavement without compromising its durability or integrity.

Voids to mineral aggregate ratio will vary in between 15 to 35% for the pervious mix with a suitable amount of sand or fine mixture to increase the compressive strength of concrete mix & also to reduce air voids content in the mixture. The proper volume of mortar mix design leads to coating of binding material equally to an individual aggregates which will also increase the durability of concrete mix & they create proper channel through which the run off can be drained off effectively in to the below layers. Other benefits of using pervious concrete are reduction of downstream flows, erosion and sediment reduction of large volumes of surface pollution flowing into rivers; decrease of urban heat island effect; eliminating traffic noise; and enhancing safety of driving during rainy seasons. The characteristic of high permeability of pervious concrete contributes to its advantage in storm water management. However, the mechanical properties such as compressive strength are reduced due to this character, limiting the application of pervious concrete to the roads that have light volume traffic. The advantage of pervious concrete can be enhanced by substituting some of the cement with other materials such as fly ash, glass fibres & so on. Fly ash is one of the by-products of coal combustion in power generation plants. Large amount of fly ash are discarded each year, increasing costs for disposal. On the other hand, fly ash has been shown to improve the overall performance of concrete, when substituted for a portion of the cement. Hence, when fly ash is used in pervious concrete, the occupation of landfill space can be reduced and CO2 emissions generated during cement production can be decreased, improving the sustainability of pervious concrete.

Due to an open graded interconnected air void structure porous concrete has been found that it acts as an effective noise absorbent during the movement of vehicular wheels whereas the tyre noise generated by conventional concrete pavement is more when compared to open graded porous concrete pavements. The sub base layer below Pervious concrete pavement can also be provided with enough water storage capacity as a reservoir so as to eliminate the need for retention of ponds, swales and other precipitation runoff containment strategies which also leads to the natural treatment of polluted water by soil filtration and longer service life for the pavements.

II.REVIEW OF LITERATURE

There is a considerable variation of properties of concrete mix due to the influence of coarse & fine aggregate quantities in the mix ratio. The materials used for mix are ordinary Portland cement, fine aggregate corresponding to grading II and four sizes of coarse aggregate namely, 4.75 mm to 9 mm, 9 mm to 12.5 mm, 12.5 mm to 16 mm, 16 mm to 19.5 mm. Mixes were prepared with the water cement ratio of 0.34, fine aggregate was replaced with coarse aggregate in the range of 50 - 100% by its weight & Coefficient of permeability was determined by using falling head permeability test [1].

Presence of air voids in the concrete mix will affect the performance characteristics of concrete where a void ratio from 15 to 35% will increase the strength & durability of concrete. Use of pervious concrete in pavement industry will give an expansive scope for further research of characteristics & sustainable roadway material in future [2].

The physical & engineering characteristics of no-fines concrete mix are investigated where it is subjected to unconfined compression, indirect tension & static modulus of elasticity, the effect of these properties on aggregate mix is tabulated. It was found that the strength of no-fines concrete is strongly related to its mixture proportion and compaction energy, a sealed compressive strength of 20.7 MPa can readily be achieved with an aggregate cement ratio of 4.5:1 [3].

Voids in a concrete mix will reduce the strength of concrete mix so a balanced aggregate & cement ratio should be provided. The traffic wheel loads & volumes also will also leads to structural dis integrity of pavements, a proper compaction is also necessary to maximise compressive strength without having detrimental effects [4].

Due to impermeable layers on the top surface, run off water is not infiltrated in to the ground which leads to improper supply of water in to underground level & also is difficult for soil beneath the ground surface for exchange of heat & moisture with air. In the analysis 10 various concrete mixes were tested by varying Cement content & the effects of such variation on the properties of pervious concrete mixes were studied [5].

The porosity of concrete pavement will be depending on design & interlocking of concrete block pavements, recent innovations like development of combined geothermal heating & cooling, water treatment & recycling of pavement systems are outlined in brief [6].

Investigations on mechanical-hydrological & durability properties of pervious concrete has shown in the analysis that pervious concrete as a pavement material on low volume traffic roads has gained a huge importance due to its positive environmental aspects. The efficiency of pervious concrete with respect to storm water runoff has been done by investigating few test sections & the porous concrete pavements are more suitable in the heavy rainfall areas to reduce storm water runoff & to recharge ground water level [7].

Pervious concrete pavement is an open graded pavement which has an underlying stone reservoir which will capture run off & stores it before it infiltrates in to the sub grade soil. This sub base reservoir replaces the traditional pavement which allows storm water to infiltrate directly in to the below layers. The sub base layer when properly designed & installed where the air voids percentage is more than 15%, pervious concrete can be used substantially applied to reduce the volume of run off & to reduce pollution of storm water runoff [8].

After the construction of pavements, during the design service life maintenance is a major issue where the surface & below layers has to be maintained to avoid structural & non-structural deficiencies. The cause & identification of pavement distresses related to porous concrete pavements & their remedial techniques has been discussed [9].

The effect of urbanisation will lead to global warming, Pervious concrete has a good characteristics with respect to drainage & absorption of solar radiations by which we can reduce the effect of global warming. Porous concrete can also minimize storm water runoff by allowing it to percolate in to below layers which will constitute in recharging of ground water table however if the pavement is not maintained correctly that leads to the clogging of pores & decrease in storm water carrying capacity, periodic maintenance is very much necessary throughout the design life for effective utilisation of pavements[10].

By using different types of admixtures many investigations such as density, void content, compressive strength, split tensile strength, permeability , freeze & thaw ability has been conducted to enhance the structural & durability characteristics of pervious concrete pavements[11].

III.MATERIALS & METHODOLOGY

1. Materials

a) Ordinary Portland cement of 53 grade.

b) Coarse aggregates of 100% pertaining to sieve sizes passing 12.5 mm sieve & retaining on 10 mm sieve as per IS standards.

c) Fly ash as a mineral admixture.

d) Potable water for mixing the constituents.

2. Methodology

Preliminary tests were conducted on the materials as per IS standards & specifications, cubes were casted in the standard metallic moulds & vibrated to obtain the required sample size of specimen. The moulds were cleaned initially and oiled on all the sides before concrete sample is poured in to it. Thoroughly mixed concrete is poured into the moulds in three equal layers and compacted using vibrating table for a small period of 5 minutes. The excess concrete is removed out of the mould using trowel and the top surface is finished with smooth surface.

After 24 hours the samples were demoulded and put in curing tank for the respective periods of 7and 28 days characteristic strength with a set of 5 samples were prepared in each stage for curing. The temperature of curing tank was maintained about 25 degree during the analysis of compressive strength, split tensile strength & permeability (Constant head method) is checked for the casted specimens & the results are tabulated.

3. Tests conducted for coarse aggregates

1. Sieve analysis
2. Specific gravity and Water absorption test
3. Aggregate crushing test
4. Aggregate impact value test

The aggregate gradation was continuous with the maximum aggregate size of 12.5mm passing & retaining on 10 mm sieve. The gradation & other tests were performed as per ASTM standards with 5 trials on each test & the below table represents the physical properties of materials.

TABLE-1 Test on coarse aggregates

Si no	Test	Method of test	Average Result	Permissible value
1	Sieve analysis	IS:2720-Pt-4	Fineness modulus = 2.80	2.3 to 3.1
2	Specific gravity	IS:2386-Pt-3	Bulk specific gravity = 2.61	2.5 to 3.2
			Apparent specific gravity = 2.5	
3	Water absorption	IS:2386-Pt-3	0.51	<2%
4	Aggregate crushing test	IS:2386-Pt-4	16.44%	<30%
5	Aggregate impact test	IS:2386-Pt-4	12%	<24%

4. Tests conducted for cement (53 grade cement)

1. Specific gravity test
2. Soundness test
3. Normal consistency of cement

TABLE-2 Test on Cement

Si no	Test	Method of test	Average Result	Permissible value
1	Specific gravity	IS:2720-Pt-3	3.15	3.12 to 3.19
2	Soundness	IS:4031-Pt-3	4 mm	< 10mm
3	Normal consistency	IS:4031-Pt-4	29%	26 to 33%

5. EXPERIMENTAL DESIGN

5.1 MIX DESIGN

Volumetric batching is done for the material mix to analyse the amount of quantity required for casting each cube specimen of size (150*150*150) mm considering the design mix as M25 grade as per IS 383-1970 specifications. The aggregates mix are varied up to 35% of porosity by varying the materials having minimal or zero number of fine aggregates & is mixed with cement to cast the moulds for analysing the compressive & split tensile strength along with permeability test for 7 days & 28 days strength.

5.2 PERMEABILITY TEST

After the specimens are casted for calculating compressive strength, the same has to be measured for Darcy's co efficient of permeability. The casted specimens of 7 days & 28 days are tested for permeability co efficient covering it by epoxy resins & the water is allowed to flow inside the specimen & noting down the time required for quantity of water to percolate inside the porous specimens at a standard temperature between 21 to 25 degrees.

5.3 COEFFICIENT OF PERMEABILITY

1. Determine the cross sectional area (A) in square metres of the test sample using the following formula:

$$A = (\pi/4) * D^2 \quad \text{…………(1)}$$

where D = Diameter of test sample, to the nearest 0.001m.

2. Determine the applied pressure head (h) in metres of water.

3. D'Arcy Coefficient of Permeability is calculated using the following formula: $k = \{(QL) / (tAh)\}$ ………..(2)

where k = D'Arcy Coefficient of Permeability (m/s), Q = Volume of water in m^3, L = Length of the test sample in metres, to the nearest 0.001m, t = Elapsed time in seconds, h = Applied pressure head in metres of water, A = Area of the test sample in m^2.

IV.RESULTS & DISCUSSION

1.Relationship between Coarse aggregates and Fly ash with Compressive Strength

The pores of coarse aggregates will be filled by finer aggregates & the voids of finer aggregates will be occupied by cement particles initially by trial runs optimum water cement ratio is calculated & by the experimental analysis water cement ratio of 0.35 is considered & the values are tabulated for both 7 days & 28 days of compressive & split tensile strength values.

TABLE-3 Compressive strength in N/mm^2 for different % of fly ash in the mix for 7 days

Si no	% Fly ash	Compressive strength in N/mm^2	Co efficient of permeability
1	0	22.01	0.008465 cm/s
2	5	21.21	0.008445 cm/s
3	10	23.35	0.008425 cm/s
4	15	24.85	0.008365 cm/s
5	20	26.64	0.008265 cm/s
6	25	27.14	0.008165 cm/s
7	30	27.90	0.008115 cm/s

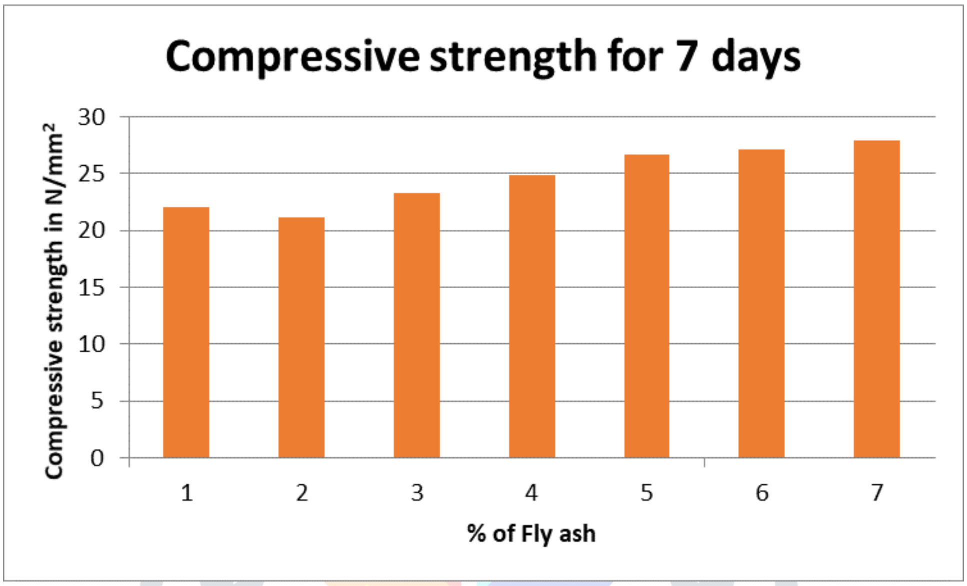

Fig – 1 Comparison between compressive strength VS % of fly ash in the mix for 7 days

TABLE-4 Compressive strength in N/mm^2 for different % of fly ash in the mix for 28 days

Si no	% Fly ash	Compressive strength in N/mm^2	Co efficient of permeability
1	0	32.34	0.008115 cm/s
2	5	33.32	0.007985 cm/s
3	10	35.28	0.007865 cm/s
4	15	33.26	0.007795 cm/s
5	20	36.56	0.007715 cm/s
6	25	35.12	0.007675 cm/s
7	30	37.22	0.007594 cm/s

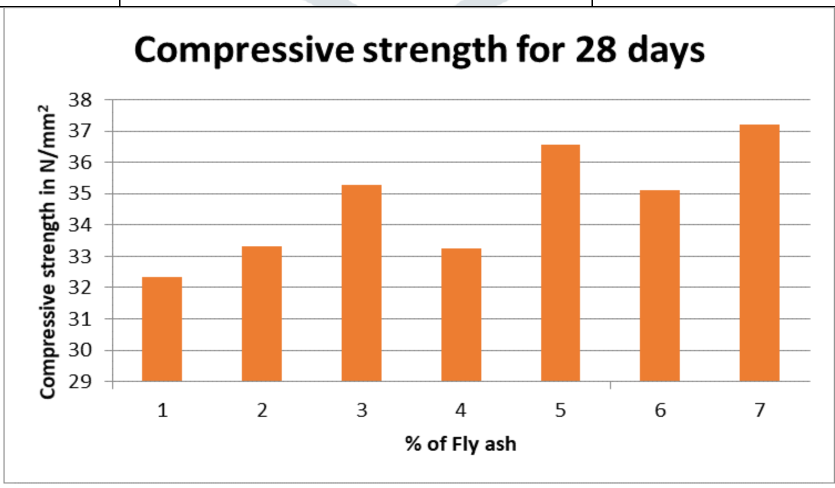

Fig – 2 Comparison between compressive strength VS % of fly ash in the mix for 28 days

2. Relationship between Coarse aggregates and Fly ash with split tensile Strength

TABLE-5 Split tensile strength in N/mm^2 for different % of fly ash in the mix for 7 days

S i no	% Fly ash	Split tensile strength in N/mm^2
1	0	2.18
2	5	2.32
3	10	2.25
4	15	2.44
5	20	2.31
6	25	2.63
7	30	2.83

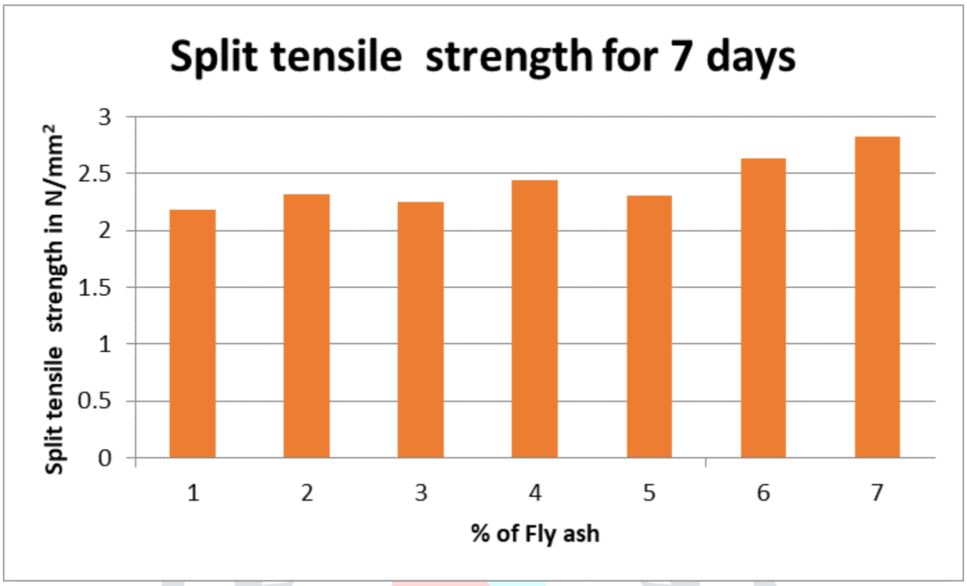

Fig – 3 Comparison between split tensile strength VS % of fly ash in the mix for 7 days

TABLE- 6 Split tensile strength in N/mm^2 for different % of fly ash in the mix for 28 days

S i no	% Fly ash	Split tensile strength in N/mm^2
1	0	3.3
2	5	3.1
3	10	3.29
4	15	3.3
5	20	3.45
6	25	3.7
7	30	3.92

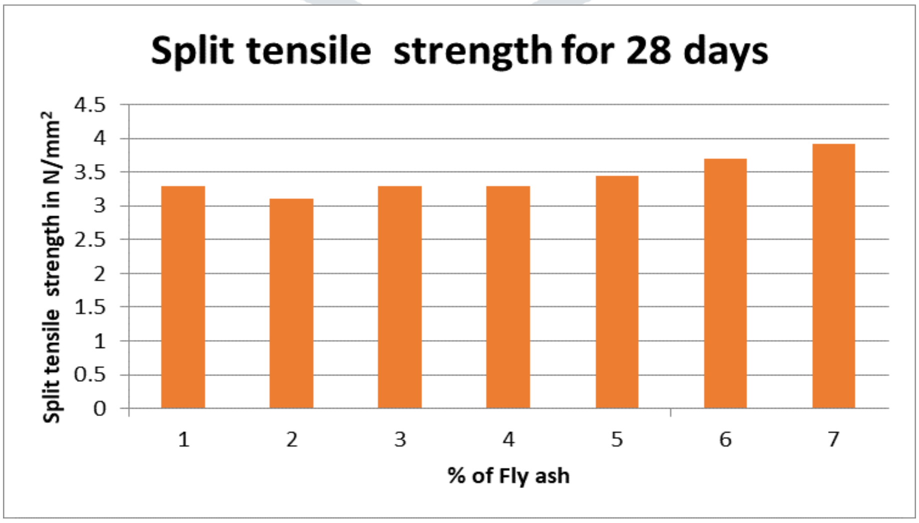

Fig – 4 Comparison between split tensile strength VS % of fly ash in the mix for 28 days

CONCLUSION

Based on the various laboratory tests as per IS standards for the porous concrete by varying the composition the following conclusions are drawn:

1.The compressive strength of pervious concrete with larger size aggregate was lesser, when compared to finer mix which constitutes smaller air voids and better binding between the aggregates.

2.There is a reduction in percentage of porosity in the concrete mix with the increase of fly ash at a percentage of 15 & 25 percent of weight in concrete mix for all the specimens tested under 7 days & 28 days.

3.It has been observed that when the finer aggregate (Fly ash) to coarse aggregate ratio is increased up to 10 % & 20%, there is a considerable increase in compressive & split tensile strength of the concrete specimens.

4. The co efficient of permeability had been tested for 7 days & 28 days concrete specimens by allowing the water to flow inside the concrete specimens where as there is considerable variation of flow with respect to the concrete specimens.

5. A mix design with little water can create a very weak binder. A mix design with too much water can collapse the void space, making an almost impenetrable concrete surface.

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Bibilography

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