EXPERIMENTAL STUDY ON OPTIMUM MIX DESIGN FOR PERVIOUS CONCRETE

Sathish Kumar.K [1], Dr. J. Premalatha[2]

[1](P.G. Student (M.E- Structure), Department of Civil Engineering, Kumaraguru college of Technology, Athipalayam rd, Chinnavedampatti,Coimbatore, Tamil Nadu 641049)
[2](Professor, Department of Civil Engineering Kumaraguru college of Technology, Athipalayam rd, Chinnavedampatti, Coimbatore, Tamil Nadu 641049)

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Abstract - *There is lot of research work is going in the field of pervious concrete. The compressive strength of pervious concrete is less when compared to the conventional concrete due to its porosity and voids. Hence, the usage of pervious concrete is limited even though it has lots of advantages. If the compressive strength and flexural strength of pervious concrete is increased, then it can be used for more number of applications. For now, the usage of pervious concrete is mostly limited to light traffic roads only. If the properties are improved, then it can be used for medium and heavy traffic rigid pavements also. Along with that, the pervious concrete eliminates surface runoff of storm water, facilities the ground water recharge and make the effective usage of available land. In the present research work, an attempt has been made to arrive at the optimum mix proportions for pervious concrete with target strength of 30 MPa and water permeability of 20 to 30%. Along with the cement and coarse aggregates mineral admixtures like flyash, Ground Granulated Blast furnace Slag (GGBS) and silica fume are used in the trial mixes. Chemical admixtures like superplasticizer and viscosity modifying agents also are used in the concrete mixes. In order to enhance the tensile strength of pervious concrete polypropylene fibers are added and they are tested for its mechanical strength. 11 numbers of trial mixes were prepared and tested for its mechanical strength and permeability properties and optimum mix proportion with compressive strength of 30 MPa and 27% water permeability has been arrived and the test results of all trial mixes is presented in this thesis.*

***Keywords**: Permeability, Compressive strength, Flexural strength.*

1. INTRODUCTION

In pervious concrete, carefully controlled amounts of water and cementitious materials are used to create a paste that forms a thick coating around aggregate particles. A pervious concrete mixture contains little or no sand, creating a substantial void content. Using sufficient paste to coat and bind the aggregate particles together creates a system of highly permeable, interconnected voids that drains quickly. Typically, between 15% and 25% voids are achieved in the hardened concrete. Both the low mortar content and high porosity also reduce strength compared to conventional concrete mixtures, but sufficient strength for many applications is readily achieved. Pervious concrete is a mixture of Portland cement, coarse aggregate, water, and admixtures. Because the mix contains little or no sand, the pore structure has many voids, allowing water and air to pass through. Unfortunately, this lack of sand in pervious concrete also results in a very harsh mix that negatively affects mixing, delivery, and placement.

1.1 Benefits of Pervious Concrete

Pervious concrete pavement systems provide a valuable storm water management tool under the requirements of the EPA Storm Water Phase II Final Rule Phase II regulations provide programs and practices to help control the amount of contaminants in our waterways. Impervious pavement particularly parking lots collect oil, anti-freeze, and other automobile fluids that can be washed into streams, lakes, and oceans when it rains. EPA Storm Water regulations set limits on the levels of pollution in our streams and lakes. To meet these regulations, local officials have considered two basic approaches. They are

1) Reduce the overall runoff from an area.

2) Reduce the level of pollution contained in runoff.

1.2 Major applications of pervious concrete

- Low-volume pavements
- Residential roads, alleys, and driveways
- Sidewalks and pathways
- Parking areas
- Low water crossings
- Tennis courts
- Sub base for conventional concrete pavements

1.3 OBJECTIVE

To arrive at the right ingredients and proportions for pervious concrete with a target compressive strength of 30 MPa and water permeability of 25 to 30% through experimental study.

2. MATERIALS USED

2.1 Portland Pozzolana Cement

Portland Pozzolana cement (PPC) is manufactured by combination of pozzolanic materials. Pozzolana is an artificial or natural material which has silica in it in a reactive form. Along with pozzolanic materials in specific proportions, PPC also contains OPC clinker and gypsum. These pozzolanic materials includes volcanic ash, calcined clay or silica fumes and fly ash which make around 15% to 35% of cement weight.(ultra tech cement)

2.2 WATER

While any potable water can be used for mixing, the amount of water is critical for the formation of the voids in pervious concrete. Water-to-cement ratios can range from 0.27 & 0.28. Careful control of water is critical. A mix design with little water can create a very weak binder. This will create a very dry mix that is susceptible to spalling and crumbling.

2.3. SUPPLEMENTARYCEMENTITIOUS MATERIALS (SCMS)

SCM includes fly ash, pozzolans, and slag can be added to the cement. These influence concrete performance, setting time, rate of strength development, porosity, permeability, etc., The key to high-performance concrete is the use of SCMs. Silica fume, fly ash, and blast furnace slag all increase durability by decreasing permeability and cracking

1. **Silica fume** is a by-product of silicone production. It consists of superfine spherical particles which significantly increase the strength and durability of concrete. Used frequently for high-ris buildings, it produces concrete that exceeds 140 MPa compressive strength. Silica fume can replace cement in quantities of 5-12%.

2. **Fly ash** is the waste by-product of burning coal in electrical power plants; it used to be land filled, but now a significant amount is used in cement. This material can be used to replace 5-65% of the Portland cement

3. **Blast furnace** slag is the waste by-product of steel manufacturing. It imparts added strength and durability to concrete, and can replace 20-70% of the cement in the mix.

2.4 SUPER PLASTICIZERS

Super Plasticizers (SP), also known as high range water reducers, are chemical admixtures used where well-dispersed particle suspension is required. These polymers are used as dispersants to avoid particle segregation (gravel, coarse and fine fine sands), and to improve the flow characteristics of suspensions such as in concrete applications. Their addition to concrete or mortar allows the reduction of the water to cement ratio, not affecting the workability of the mixture, and enables the production of Self Compacting Concrete and High Performance Concrete. This effect drastically improves the performance of the hardening fresh paste. The strength of concrete increases when the water to cement ratio decreases.

2.5 VISCOSITY MODIFYING AGENT

Viscosity Modifying admixtures or VMAs are the admixtures used to change the properties such as viscosity, workability, cohesiveness etc. of fresh concrete.

2.6 POLYPROPYLENE FIBER

This material has great flexibility, toughness, high impact strength and low density. It is cheap and has good effects on plastic properties and on post cracking behaviour of hardened concrete. The addition of fibre leads to a heavily air entrained mix containing upto 45% air. This gives the fresh concrete thixotropic properties having zero slump and still flowing and compacting readily under vibration. Further it is resistant to bleeding and segregation. The widest use of this composite is based on impact resistance.

Table-2.1 Physical properties of polypropylene fibre

Appearance	Straight
Length	12mm
Diameter	7.5 µm
Aspect ratio	1600
Colour	White
Specific gravity	0.90gm/cm3
Melting point	165oC

3. MATERIALS TESTING

Table-3.1 Specific gravity results

MATERIAL	OBTAINED VALUE
Fly ash	2.65
Silica fume	2.22
GGBS	2.22
Cement	3.15
M . Sand	2.67
Coarse aggregate	2.85

3.2 Tests on cement

Table-3.2 Properties of Cement Results

S.No	Property	Value
1	Specific gravity	3.15
2	Fineness	225 m2/kg
3	Initial setting time	35 min
4	Final setting time	132 min

Figure 3.1 Specific Gravity Test on Cement

3.3 Tests on Coarse aggregates

12.5mm aggregate: Minimum weight of sample = 12kg

Table 3.3 Sieve analysis result of coarse aggregate

IS Sieve No	Weight retained (g)	Cumulative weight retained (g)	Cumulative percentage retained (%)	Cumulative percentage passing (%)
16mm	20	20	1	99
12.5mm	618	638	31.9	68.1
10mm	1088	1726	86.3	13.7
4.75mm	274	2000	100	0

The values obtained are conforming to Zone II as per IS 383:1970

3.4 Water Absorption Test

Table-3.4 Water absorption test results

Materials	Water absorption (%)
Coarse aggregate	0.5
Fine aggregate	0.5
Fly ash	1
Silica fume	-

4. CONCRETE MIX DESIGN FOR TRIAL MIX

Trial Mix Proportions: (0.5:3) C.A

Binder Content: silica fume, Fly ash (0.5:0.10:0.40:3) Admixtures: Super Plasticizers conplast 430 (2%)

Table-4.1 Trial Mix Proportions

S.No	Age of concrete (days)	Compressive Strength Of Standard Pervious Concrete (MPa)
1	7	15.33
2	14	19.26
3	28	21.06

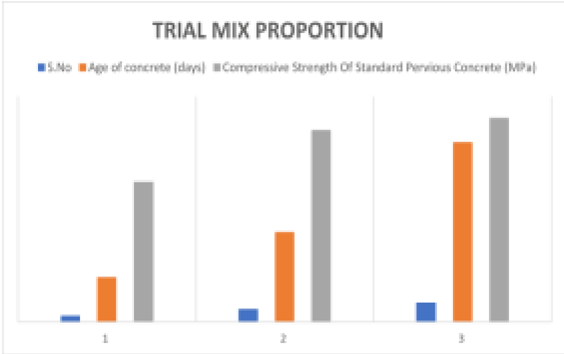

FIG: 4.1 trial mix proportions

5. CASTING OF SPECIMENS

Eleven mixes are casted for this research such as Control mix containing 40% Fly Ash (CM), 10% silica fume. Mix containing all the four mineral admixtures in various proportion. Polypropylene are used in 0.75% and 0.25% respectively.

Figure 5.1 Casting of Specimens

6. CURING OF SPECIMENS

The specimens were left in the moulds undisturbed at room temperature for about 48 hours after casting. The specimens after removing from the moulds were immediately transferred to curing ponds containing clean and portable water. The specimens are then tested accordingly at the end of 7 days and 28 days.

Figure 6.1: curing of cube cylinder and prism

7. TESTING FOR MECHANICAL STRENGTH OF CONCRETE

7.1 COMPRESSIVE STRENGTH OF CONCRETE

Figure 7.1: Compressive Strength test

Figure 7.2 Cube after failure set up

Unit Weight of Cube = 8.29 kg

Table-7.1 MIX PROPORTIONS

Material	Cement	M.Sand	Coarse Aggregate
Trial Mix	0.5	0	3
Mix 1	1	0.1	3
Mix 2	1	0.2	3
Mix 3	1	0.1	3
Mix 4	1	0.2	3
Mix 5	1	0	3
Mix 6	1	0	4
Mix 7	1	0	5
Mix 8	0.5	0	4
Mix 9	0.5	0	4
Mix 10	0.5	0	4

Binder Content:

Table-7.2 Binder Content

Material	Silica fume	Flyash	GGBS	Polypropylene fiber	Super plasticizers	W/C Ratio
Trial Mix	0.10	0.40	0	2	1	0.27
Mix 1	0	0	0	2	1	0.27
Mix 2	0	0	0	2	1	0.27
Mix 3	0	0	0	0	1	0.28
Mix 4	0	0	0	0	2	0.28
Mix 5	0	0	0	2	2	0.28
Mix 6	0	0	0	2	2	0.28
Mix 7	0	0	0	2	2	0.28
Mix 8	0.2	0	0.3	2	2	0.28
Mix 9	0.2	0	0.3	0	2	0.28
Mix 10	0.2	0	0.3	2	2	0.28

8. SPLIT TENSILE STENGTH TEST

Fig 8.1 Cylinder mounted for Split tensile

Fig 8.2 Cylinder after failure

Unit Weight of Cylinder = 13.128 kg

Calculations

Calculate the splitting tensile strength of the specimen as follows: T= 2P/ pi LD Where:

T = splitting tensile strength, MPa

P: maximum applied load indicated by the testing machine, N
D: diameter of the specimen, mm

L: length of the specimen, mm

9. FLEXURAL STRENGTH TEST

Figure 9.1: Flexural strength test setup

Unit Weight of Prism = 12.70 kg

REFERENCE STANDARDS

IS: 516-1959 – Methods of tests for strength of concrete

10. PERMEABILITY OF PERVIOUS CONCRETE

The permeability of pervious concrete was determined using a falling head permeability set up Figure 8. Water was allowed to flow through the sample, through a connected standpipe which provides the water head. Before starting the flow measurement, the samples were wrapped with polythene inside the cylinder. Then the test started by allowing water to flow through the sample until the water in the standpipe reached a given lower level. A constant time of 5seconds was taken for the water to fall from one head to another in the standpipe. The standpipe was refilled and the test was repeated when water reached a lower. The permeability of the pervious concrete sample was evaluated from the expression given below:

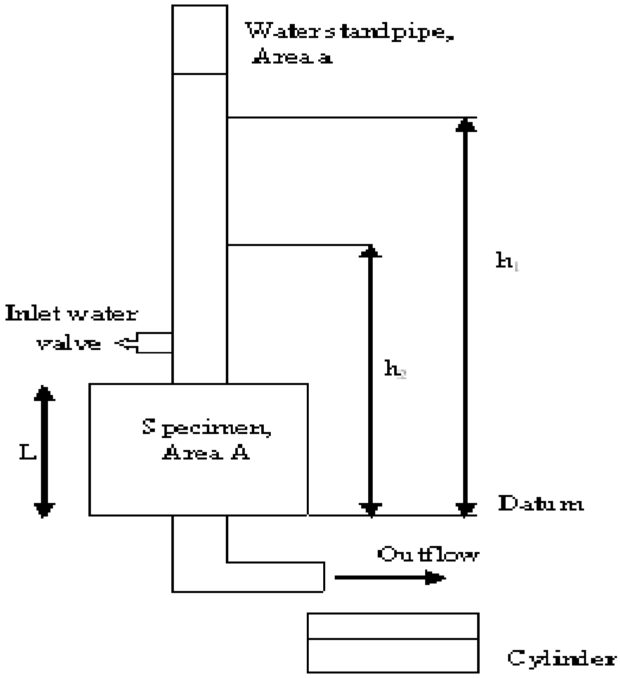

Figure 10.1: Falling head permeability test apparatus

Permeability of Standard pervious concrete with 0% fine aggregates

Quantities of materials: Mix Proportions (1:4) (0.5:0.2:0.3:4)

Cement = 0.5%

Coarse aggregates = 4%

Fine aggregates = 0%

Silica Fume = 0.2%

GGBS = 0.3%

Water = 0.27%

Polypropylene Fibre = 2%

Super Plasticizers = 2%

Table-10.1. coefficient of permeability of standard pervious concrete with 0% fines

Permeability Test for 24 Hours:

S.No	Unit weight of standard pervious concrete (0% fines) after 24 hours (kg/m3)	Coefficient of permeability K (cm/sec)	Coefficient of permeability percentage(%)
1	19.497	0.53	33.4

Table-10.2. coefficient of permeability of standard pervious concrete with 0% fines

Permeability Test for 14 Days:

S.No	Unit weight of standard pervious concrete (0% fines) after 14 days (kg/m3)	Coefficient of permeability K (cm/sec)	Coefficient of permeability percentage (%)
1	**13.12**	**1.314**	**27**

Table 10.3. Coefficient of permeability of standard pervious concrete

Permeability Test for 14 Days:

S.No	Unit weight of standard pervious concrete (0% fines) after 14 days (kg/m3)	Coefficient of permeability K (cm/sec)	Coefficient of permeability percentage (%)
Trial Mix	53.85	4.326	63.6
Mix 1	56.24	4.498	60.5
Mix 2	61.35	4.78	64.23
Mix 3	48.19	4.12	54.63
Mix 4	52.63	4.302	62.5
Mix 5	47.85	4.00	51.76
Mix 6	48.59	4.32	52.08
Mix 7	45.98	4.21	48.79
Mix 8	0	0	0
Mix 9	13.12	1.314	22.8
Mix 10	13.25	1.306	21.86

11. RESULTS AND DISCUSSION

GENERAL

This chapter deals with the mechanical property test result. The hardened properties such as compressive strength, split tensile strength, flexural strength, were determined by conducting suitable tests for Pervious Concrete.

11.1 Compressive Strength

The test results for compressive strength of all the mixes at 7 and 28 days is shown in Table 11.1. The graph for the same is shown in Fig 11.1. Compressive Strength was found maximum for the mix 30Mpa.

Table-11.1 Cube Compressive Strength test results at 7 and 28 day

Material	Compressive Strength Of Standard Pervious Concrete (MPa) 7 days	Compressive Strength Of Standard Pervious Concrete (MPa)14days	Compressive Strength Of Standard Pervious Concrete (MPa)28 days
Trial Mix	15.33	16.3	20.38
Mix 1	8.7	12.5	18.26
Mix 2	14.8	17.69	20.58
Mix 3	18.84	20.75	22.67
Mix 4	16	16.2	16.8
Mix 5	12	13.5	13.78
Mix 6	10	10.6	10.6
Mix 7	0	0	0
Mix 8	23.27	24.23	26.1
Mix 9	21.86	29.89	31.82
Mix 10	22.89	24.3	28.56

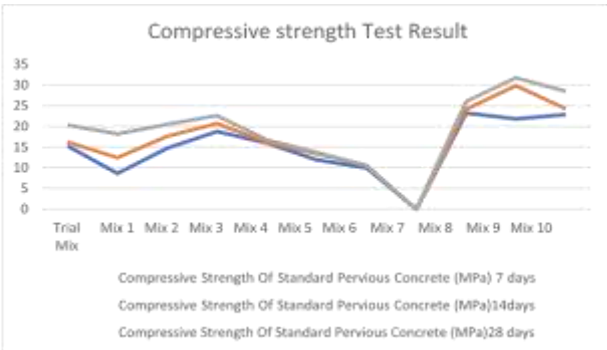

FIGURE 11.1 Compressive strength Test Result

11.2 SPLIT TENSILE STRENGTH

The test results for Split tensile strength of all the mixes is shown in Table 11.2 and graph for the same is shown in Fig 11.2. Split Tensile strength was found for the mix containing mineral admixtures in various proportion and the fibres in 2%(Polypropylene).

Table 11.2 Split Tensile Strength test results at 7 and 28 day

Material	Split tensile Strength (MPa) 7 days	Split Tensile Strength (MPa)28 days
Trial Mix	1.3	1.6
Mix 1	1.24	2.7
Mix 2	1.6	2.81
Mix 3	1.59	2.52
Mix 4	1.38	2.63
Mix 5	1.55	2.53
Mix 6	1.2	1.23
Mix 7	0	0
Mix 8	1.56	2.49
Mix 9	1.6	2.9
Mix 10	1.63	2.59

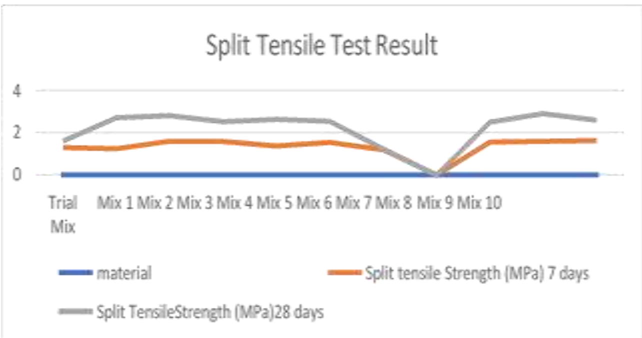

FIGURE 11.2 Split Tensile Test Result

11.3 Flexural Strength

The test results for Flexural strength of all the mixes is shown in Table 11.3 and graph for the same is shown in Fig 11.3.

Table-11.3 Flexural Strength test results at 7 and 28 day

Material	Age of concrete (7 days) load (KN)	Age of concrete (28days) Load(KN)	Flexural Strength (MPa) 7 days	Flexural Strength (MPa) 28 days
Trial Mix	15	15	4.6	7
Mix 1	15	16	5.4	7.2
Mix 2	16	16	5.8	7.2
Mix 3	15	16	6.12	6.4
Mix 4	15	16	6.52	7.32
Mix 5	10	10	3.2	3.68
Mix 6	10	10	3.5	3.56
Mix 7	0	0	0	0
Mix 8	15	25	6.56	7.36
Mix 9	15	15	6.45	7.8
Mix 10	15	25	6.52	7.28

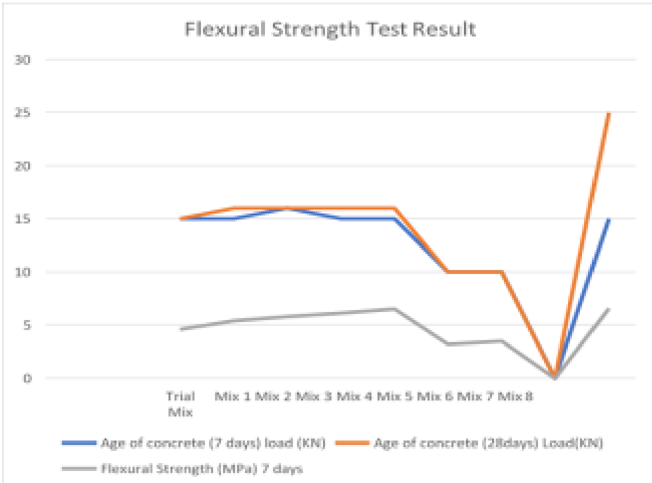

FIGURE 11.3 Flexural Strength Test Result

12. RECOMMENDATION OF OPTIMUM MIX FOR PERVIOUS CONCRETE

12.1 OPTIMUM MIX PROPORTIONS

Optimum Mix Prportions: (0.5:4) C.A

Binder Content: silica fume, GGBS(0.5:0.30:0.20:4) Admixtures: Super Plasticizers conplast 430 (2%)

Table-12.1 Optimum Mix Proportion

S.No	Age of concrete (days)	Compressive Strength Of Standard Pervious Concrete (MPa)
1	7	21.86
2	14	29.89
3	28	31.82

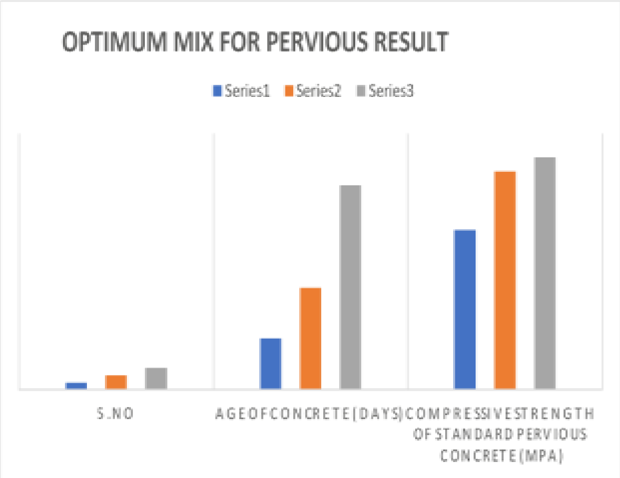

FIGURE: 12.1 Optimum Mix for Pervious Result

13. CONCLUSIONS

Experimental investigation was carried out on 11 numbers of trial mixes of concrete with various proportions of binder content, various contents of cement, fly ash, silica fume and GGBS with different water cement ratio and various % of superplasticizer along with polypropylene fibers to find out their mechanical strength and water permeability properties.

The concrete mix with Binder content: coarse aggregate ratio of 1: 3 at w/c ratio of 0.28 with superplasticizer content of 2% and 1% of polypropylene fibers exhibited maximum compressive strength of 31 MPa and water permeability of 27% and this mix is recommended as the optimum mix proportions for the pervious concrete.

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