An Integrated Study on the Characterization of The Designed Mechanical Properties of The Ecofriendly Porous Concrete

P.Durga Prasad[1], G.Jayatre Sai[2], Shaik Nadhim[3]
[1]Dept of Civil Engineering
[2, 3]Asst. Professor, Dept Of Civil Engineering
[1, 2] Nannapaneni Venkatrao College Of Endgineering And Technology
[3]geethanjali Institute Of Science And Technology

Abstract- *In 1980's the research was started on pervious concrete in developed countries to improve reduction of stagnation of water on the road surfaces. In India it became popular in 2000. Mostly pervious concrete can be used for foot paths and parking areas to control storm water runoff. Because of porous nature the storm water captured and allows infiltrating the soil. An addition of fine aggregates will improve the strength of pervious concrete. The present experimental study concentrate on achieving good compressive strength as well as better permeability. For this in the present study the experimental work followed by two cases. In one case percentage of fine aggregates increased gradually with respect to percentage of coarse aggregates and in another case the percentage of fine aggregates increased gradually with maintained constant volume of coarse aggregates. The design mix prepared for M25 and the w/c ratio was kept 0.35 for both the cases and the compressive strength was found at the age of 3, 7 and 28 days. The size of coarse aggregate was used between 12mm to 20mm. From the results 10% of fine aggregates in both the cases give good compressive strength and permeability.*

I. INTRODUCTION

Pervious cement is a blend of pressure driven concrete, coarse total of littler size, admixtures and water. It is likewise called as no fines concrete or permeable cement. Pervious cement enables the water to permeate through the solid into the sub-base and energize the underground water level. A little measure of sand can be utilized for compressive quality change yet air void substance will be lessened and porousness brought down. It is critical to keep up the correct volume of mortar in the blend outline so the total is similarly covered however the overabundance of mortar does not fill the voids pace inside coarse total. Voids inside the pervious cement ought to be interconnected so they make channels through which water can uninhibitedly stream. Pervious cement is an incredible decision for storm water administration.

As urbanization increments in India and numerous parts of the world the issue of water logging and prerequisite of seepage is likewise increment. This is mostly because of impenetrable nature of the bituminous and solid asphalts. Pervious solid which has an open cell encourages essentially to give high porousness because of its interconnected pores. It is utilized for solid flatwork applications that permits water from precipitation and different sources to go straightforwardly through, in this way decreasing the overflow from a site and permitting groundwater energize. It is principally utilized as a part of asphalts which are in private streets, rear ways and low volume asphalts, low water intersections, walkways, pathways and stopping regions and so forth. Pervious cement has been utilized as a part of the United State for more than 30 years. Pervious cement was first utilized as a part of the 1800'S in Europe as asphalt surfacing and load bearing dividers. It turned out to be progressively practical in Europe after the Second World War because of the shortage of concrete.

Sand is one of the regular assets of the world's surface because of the common breaking down of rocks. The waterway sand still remains the primary wellspring of sand for development industry. The interest for sand has been regularly expanding with the improvement of building industry. Therefore, it has been seen the overexploitation of stream sand causing genuine natural issues. This is one of the motivation to build up the pervious cement in different nations.

Figure 1.1: pervious concrete

1.2. BENEFITS OF PERVIOUS CONCRETE

a) Environmental benefits

- Helps in saving precious water which otherwise goes to drains.
- Helps in keeping earth below wetter, greener and cooler.
- Recharging ground water level.

b) Other benefits

- Eliminates the need of costly water drainage systems.
- Rough texture thus avoiding skidding of vehicles.
- Low maintenance cost.
- Stronger and durable for light traffic loads.
- Use of local building material.
- Use local semi-skilled mason or labor.-

1.3 DISADVANTAGES OF PERVIOUS CONCRETE:

- Difficult in providing the reinforcements.
- Frequent maintenance is required.
- Compressive strength is comparatively less.
- Require more time and experimental works for the construction.
- It can't be used for the construction of bridges, buildings, dams and so on….,
- Limited use in heavy vehicle traffic areas.

II. METHODOLOGY

In this present work mix design had been calculated, after collected the materials. The concrete was produced by partial replacement of fine aggregates and coarse aggregates with cement. We take different proportions of materials in different cases mentioned in the experimental program.

We conducted different tests on cement, river sand, coarse aggregates. We did tests on cement like fineness of cement, specific gravity and setting time. The OPC 43 grade (Maha cement) cement and river sand having the specific gravity of 2.61 was used in this work. The coarse aggregate was obtained from local supplier with a maximum size of 20mm, specific gravity of 2.69. Both aggregates confirm to IS: 383, IS: 10262-2009 respectively. After trail mix is done the water cementitious ratio is considered as 0.35 for better workability of entire experimental work

The fresh water was obtained from bore hole. The concrete cubes were cast and cured for 3, 7 &28 days respectively and another 3 cylindrical specimens were made for permeability test. For each time 3 cubes were tested for compressive strength and another 3 cylindrical specimens were tested for permeability. After getting the results we go through discussion and finally concluded this work.

III. EXPERIMENTAL DETAILS

In the present investigation the following materials were used

- Ordinary Portland Cement of 43 Grade cement conforming to IS:169-1989
- Fine aggregate conforming to IS: 2386-1963.
- Coarse aggregates
- Water.

3.2 CEMENT

The colour of OPC is grey colour and many types of cements are available in market. Ordinary Portland Cement of 43 Grade

Table.1 Properties of Cement

S.NO	Characteristics	Values obtained	Standard values
1	Normal consistency	31mm	33 to 35 mm
2	Initial setting time	130 min	Not be less than 30mins
3	Final setting time	600 min	Not be greater than 600min
4	Fineness Test	1.6%	Not more than 10%
5	Specific gravity	3.16	3.12 to 3.19

3.3 FINE AGGREGATE

Sand is an inorganic material. It consists of small angular or rounded or sharp grains of Silica. Sand is formed by decomposition of sand stone under the effect of weathering agencies.

Table 2 Characteristics of Sand

S.NO	CHARACTERISTICS	VALUE
1.	Specific gravity	2.61
2.	Water absorption	14%@ 8%
3.	Fineness modulus	3.77

3.4 COARSE AGGREGATE

The aggregates are used in concrete for very specific purposes. The use of coarse aggregate in concrete provides significant economic benefits for the final cost of concrete.

Table 3 The Characteristics of Coarse aggregate

S.NO	CHARACTERISTICS	VALUE
1.	Specific gravity	2.69
2.	Water absorption	2%
3.	Impact value	21
4.	Fineness modulus	5.01
5	Crushing strength	17.15%
6	los Angeles	27%

2.4 TESTS ON CONCRETE

Compressive strength of concrete at various ages:

The strength of concrete increases with age. Table shows the strength of concrete at different ages in comparison with the strength at 28 days after casting.

Table 4 Compressive Strength of Cubes to be attained in time

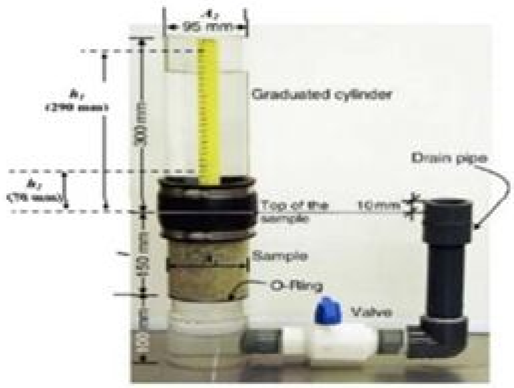
Age	Strength per cent
1 day	16%
3 days	40%
7 days	65%
14 days	90%
28 days	99%

. Slump cone test

Permeability Test:

Sample Preparation:

All samples were prepared as cylindrical specimens. In order to evaluate the size effects of porous concrete samples, three mould sizes were used. The diameters of the sample were 15cm. the specimens were compacted in the mould in either 2 or 3 lifts. To provide uniform compaction in all cylinders, each lift was rodded 25 times with an appropriately sized tamping rod.



Permeameter Appartus

Permeameter specimens

IV. CONCRETE MIX DESIGN

Design Mix for M25 Grade Pervious Concrete (without Sand)

Test data for materials

Cement used = OPC 43 Grade. (Maha cement)

Specific gravity of cement = 3.16 Specific gravity of fine aggregate = 2.61
Specific gravity of Coarse aggregates = 2.69
Minimum cement content = 320 kg/ m3 (as per IS – 456 - 2000)
Maximum cement content = 450 kg/m3
Fine aggregates = Zone - III

Step: 1 Target mean Strength:

Fck = fck +1.65S
S = standard deviation N/mm2 = 4 (table -1-IS 10262)
Fck = target characteristic compressive strength at 28 days in N/mm2
fck = characteristic compressive strength at 28 days in N/mm2
Fck = 25 + 1.65x5
= 31.6 N/mm2

Step: 2 Selection of Water Cement ratio

From IS 10262

From table 5 IS 456 maximum w/c ratio = 0.45

Adopt w/c ratio = 0.35

This water cement ratio is to be selected both from strength consideration and maximum w/c denoted in table -5 of IS 456 and lesser of the two is to be adopted for durability requirement.

Step: 3 Selection of Water content

From table -2 IS10262

Nominal maximum size of aggregates = 20mm Maximum water content per cubic meter of concrete = 186 lit
As per IS 10262 table -4

Estimated water content for 100mm slump = 186x (3/100) +186 (3% increase for every 25mm slump over and above 50mm slump)
=191.58 kg

Step: 4 Calculation of Cement content
W/c ratio = 0.35
Water used = 191.58kg
Cement content = w/c = 0.35
C = 191.58/0.35
Cement = 547.37kg/m3

Step: 5 Calculations of C.A and F.A

From table -3-10262-2009 volume of coarse aggregates corresponding for 20mm size aggregates and fine aggregates and fine aggregate zone-III for w/c ratio = 0.35 is found out to be 0.64

Volume of C.A = 0.64

Since it is angular aggregates and concrete is to be pumped the C.A can be reduce by 10%
Final volume of C.A =0.64x0.9 = 0.576

Step: 6 Calculation of Mix Proportions

Volume of concrete = 1 m3

Absolute volume of cement = (440/3.54) x (1/1000)

= 0.124m3

Volume of water = 0.191m3

Absolute volume of all materials expert total aggregates = 0.124+0.191=0.315m3

Absolute volume of total aggregates = 1- 0.315 = 0.685m3

Weight of C.A = 0.685x0.576x2.74x1000 = 1061.36 kg/m3

Mix Proportions are 1m3 Concrete:

Cement	=	547.37 kg/m^5
C.A	=	1061.36 kg/m^3
F.A	=	0 kg/m^3
Water	=	191.58 kg/m^3

Design Mix for M25 Grade Pervious Concrete (with Sand)

Test data for materials

Cement used = OPC 43 Grade. (Maha cement)
Specific gravity of cement = 3.54
Specific gravity of fine aggregates = 2.61
Specific gravity of Coarse aggregates = 2.69
Minimum cement content = 320 kg/ m3 (as per IS – 456 2000) Maximum cement content = 450 kg/ m3
Fine aggregate = Zone - III

Step: 1 Target mean Strength:

Fck = fck +1.65S
S = standard deviation N/mm2 = 4 (table -1-IS 10262)
fck = target characteristic compressive strength at 28 days in N/mm2 fck = characteristic compressive strength at 28 days in N/mm2
fck = 25 + 1.65x4
= 31.6 N/mm2

Step: 2 Selection of Water Cement ratio

From IS 10262

From table 5 IS 456 maximum w/c ratio = 0.45

Adopt w/c ratio = 0.35

This water cement ratio is to be selected both from strength consideration and maximum w/c denoted in table -5 of IS 456 and lesser of the two is to be adopted for durability requirement.

Step: 3 Selection of Water content

From table -2 IS10262

Nominal maximum size of aggregates = 20mm

Maximum water content per cubic meter of concrete = 186 lit As per IS 10262 table -4

Estimated water content for 100mm slump = 186x (3/100) +186 (3% increase for every 25mm slump over and above 50mm slump)
=191.58 kg

Step: 4 Calculation of Cement content

W/c ratio = 0.35

Water used = 191.58kg

Cement content = w/c = 0.35
Cement = 191.58/0.35
Cement = 547.37kg/m3

Step: 5 Calculations of C.A and F.A

From table -3-10262-2009 volume of coarse aggregates corresponding for 20mm size aggregates and fine aggregates and fine aggregate zone-III for w/c ratio = 0.35 is found out to be 0.64

Volume of C.A = 0.64

Since it is angular aggregates and concrete is to be pumped the C.A can be reduce by 10% Final volume of C.A = 0.64x0.9 = 0.576

Final volume of F.A = 1-0.576 = 0.424

Step: 6 Calculation of Mix Proportions

Volume of concrete = 1 m3

Absolute volume of cement = (440/3.54) x (1/1000) = 0.124m3

Volume of water = 0.191m3

Absolute volume of all materials total aggregates = 0.154+0.191=0.315m3

Absolute volume of total aggregates = 1- 0.315 = 0.685m3

Weight of C.A = 0.685x0.576x2.69x1000 = 1061.36kg/m3

Weight of F.A = 0.685x0.424x2.61x1000 = 758.04kg/m3

Mix Proportions are 1m3 Concrete:

Cement = 547.37 kg/m^3

C.A = 1061.36 kg/m^3

F.A = 724.84 kg/m^3

Water = 191.58 kg/m^3

V. COMPRESSIVE STRENGTH FOR UNMODIFIED PERVIOUS CONCRETE FOR 3, 7 AND 28 DAYS

Table 5 Compressive Strength of unmodified Pervious Concrete for 3, 7, and 28 days

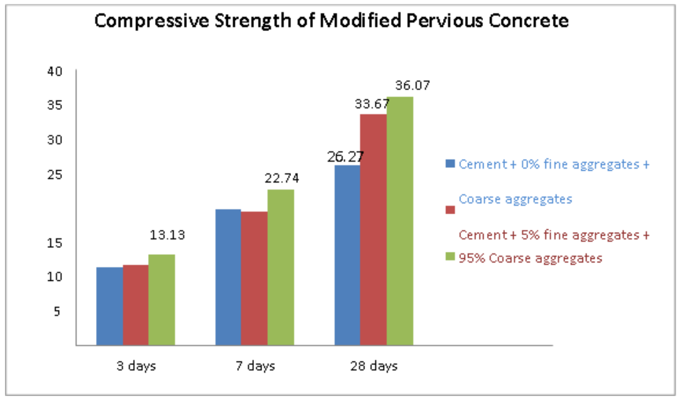
S.NO	Cement + 0% fine aggregates + coarse aggregates	Compressive Strength in N/mm^2		
		3 Days	7Days	28 Days
1	Cube-1	10.89	19.85	25.95
2	Cube-2	10.05	18.00	27.80
3	Cube-3	12.75	23.14	24.88
		11.23	**20.33**	**26.21**

Table 6 Compressive Strength of unmodified Pervious Concrete for 3, 7, and 28 days

S.NO	Cement + 5% fine aggregates + 95% coarse aggregates	Compressive Strength in N/mm^2		
		3 Days	7Days	28 Days
1	Cube-1	9.88	18.86	36.74
2	Cube-2	13.55	17.53	35.31
3	Cube-3	12.85	22.44	28.98
		12.09	**19.61**	**33.67**

Table 7 Compressive Strength of unmodified Pervious Concrete for 3, 7, and 28 days

S.NO	Cement + 10% fine aggregates + 90% coarse aggregates	Compressive Strength in N/mm^2		
		3 Days	7Days	28 Days
1	Cube-1	11.15	20.68	36.15
2	Cube-2	13.76	23.31	34.43
3	Cube-3	14.48	24.24	37.64
	Avg	**13.13**	**22.74**	**36.07**



Compressive Strength of modified Pervious Concrete for case i

5.2 COMPRESSIVE STRENGTH OF MODIFIED PERVIOUS CONCRETE FOR 3, 7, AND 28 DAYS

Table 8 Compressive Strength of modified Pervious Concrete with increase of 2.5% fine aggregates for 3, 7 and 28 days

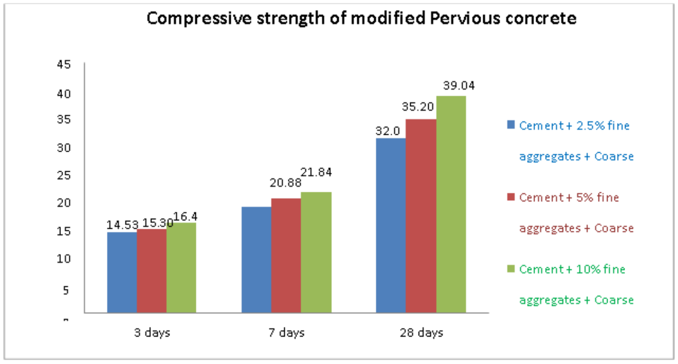
S.No	Cement + 2.5% fine aggregates + 100% coarse aggregates	(3days)Compressive Strength in N/mm^2	(7days)Compressive Strength in N/mm^2	(28days)Compressive Strength in N/mm^2
1.	Cube-1	12.64	18.04	34.85
2.	Cube-2	14.22	19.22	30.12
3.	Cube-3	16.74	20.88	31.11
	Avg	**14.53**	**19.38**	**32.02**

Table 9 Compressive Strength of modified Pervious Concrete with increase of 5% fine aggregates for 3, 7 and 28 days

S.No	Cement + 5% fine aggregates + 100% coarse aggregates	(3days)Compressive Strength in N/mm^2	(7days)Compressive Strength in N/mm^2	(28days)Compressive Strength in N/mm^2
1.	Cube-1	17.64	17.55	35.75
2.	Cube-2	14.55	21.45	34.65
3.	Cube-3	13.72	23.65	35.22
	Avg	**15.30**	**20.88**	**35.20**

Table 11 Compressive Strength of modified Pervious Concrete with increase of 5% fine aggregates for 3, 7 and 28 days

S.No	Cement + 10% fine aggregates + 100% coarse aggregates	(3days)Compressive Strength in N/mm^2	(7days)Compressive Strength in N/mm^2	(28days)Compressive Strength in N/mm^2
1.	Cube-1	17.55	18.86	41.55
2.	Cube-2	16.85	21.55	37.12
3.	Cube-3	14.98	25.12	38.46
	Avg	**16.46**	**21.84**	**39.04**



Compressive Strength of modified Pervious Concrete for case ii

5.3 PERMEABILITY FOR UNMODIFIED PERVIOUS CONCRETE FOR 3, 7 AND 28 DAYS

Table 12 Permeability of unmodified Pervious Concrete for 3, 7, and 28 days

S.No	Cement + 0% fine aggregates + coarse aggregates	(3days) Permeability in mm/sec	(7days) Permeability in mm/sec	(28days) Permeability in mm/sec
1.	Specimen-1	0.46	0.45	0.47
2.	Specimen-2	0.36	0.32	0.42
3.	Specimen-3	0.33	0.49	0.39
	Avg	**0.38**	**0.40**	**0.42**

Table 13 Permeability of unmodified Pervious Concrete for 3, 7, and 28 days

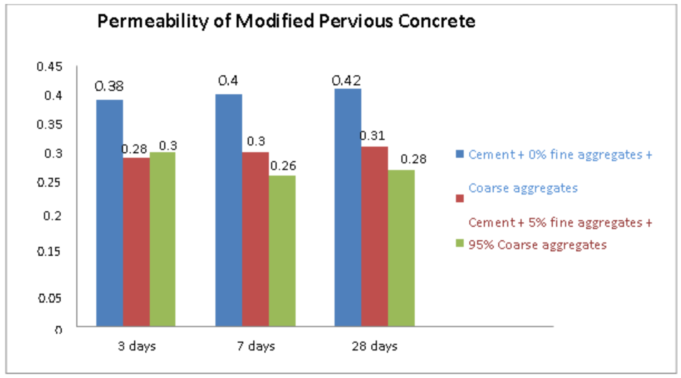
S.No	Cement + 5% fine aggregates + 95% coarse aggregates	(3days) Permeability in mm/sec	(7days) Permeability in mm/sec	(28days) Permeability in mm/sec
1.	Specimen-1	0.26	0.36	0.30
2.	Specimen-2	0.14	0.25	0.33
3.	Specimen-3	0.45	0.32	0.31
	Avg	**0.28**	**0.38**	**0.31**

Table 14 Permeability of unmodified Pervious Concrete for 3, 7, and 28 days

S.No	Cement + 5% fine aggregates + 95% coarse aggregates	(3days) Permeability in mm/sec	(7days) Permeability in mm/sec	(28days) Permeability in mm/sec
1.	Specimen-1	0.26	0.36	0.30
2.	Specimen-2	0.14	0.25	0.33
3.	Specimen-3	0.45	0.32	0.31
	Avg	**0.28**	**0.38**	**0.31**

Table 15 Permeability of unmodified Pervious Concrete for 3, 7, and 28 days

S.No	Cement + 10% fine aggregates + 90% coarse aggregates	(3days) Permeability in mm/sec	(7days) Permeability in mm/sec	(28days) Permeability in mm/sec
1.	Specimen-1	0.28	0.22	0.26
2.	Specimen-2	0.26	0.18	0.24
3.	Specimen-3	0.42	0.38	0.34
	Avg	**0.328**	**0.26**	**0.28**



Permeability of modified Pervious Concrete for case i

5.4 PERMEABILITY OF MODIFIED PERVIOUS CONCRETE (I.E. CASE II) FOR 3, 7, AND 28 DAYS

Table 16 Permeability of unmodified Pervious Concrete for 3, 7, and 28 days

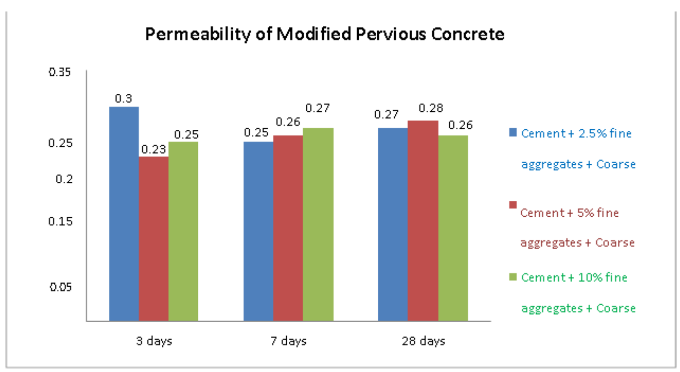
S.No	Cement + 2.5% fine aggregates + 100% coarse aggregates	(3days) Permeability in mm/sec	(7days) Permeability in mm/sec	(28days) Permeability in mm/sec
1.	Specimen-1	0.28	0.24	0.22
2.	Specimen-2	0.30	0.26	0.26
3.	Specimen-3	0.33	0.36	0.30
	Avg	**0.30**	**0.28**	**0.27**

Table 17 Permeability of unmodified Pervious Concrete for 3, 7, and 28 days

S.No	Cement + 5% fine aggregates + 100% coarse aggregates	(3days) Permeability in mm/sec	(7days) Permeability in mm/sec	(28days) Permeability in mm/sec
1.	Specimen-1	0.18	0.26	0.27
2.	Specimen-2	0.26	0.24	0.25
3.	Specimen-3	0.27	0.29	0.31
	Avg	**0.23**	**0.26**	**0.28**

Table 18 Permeability of modified Pervious Concrete with increase of 10% fine aggregates for 3,7 and 28 day.

S.No	Cement + 10% fine aggregates + 100% coarse aggregates	(3days) Permeability in mm/sec	(7days) Permeability in mm/sec	(28days) Permeability in mm/sec
1.	Specimen-1	0.22	0.24	0.26
2.	Specimen-2	0.25	0.26	0.25
3.	Specimen-3	0.29	0.31	0.29
	Avg	0.25	**0.27**	**0.26**



Permeability of modified Pervious Concrete for case ii

5.5 FINAL RESULTS OF COMPRESSIVE STRENGTH & PERMEABILITY FOR BOTH CASES.

Case (i): Cement + % F.A + % C.A + water

• In case (i) the percentage of the fine aggregates is gradually increased to obtain the strength and permeability.

Table 19 Final results of Compressive Strength for 3, 7& 28 days

s.no	Days	0%F.A + C.A + cement(unmodified pervious concrete)(N/mm^2)	5%F.A + 95%C.A + cement (N/mm^2)	10 %F.A + 90% C.A + cement (N/mm^2)
1	3 days	11.23	12.09	13.13
2	7 days	20.33	19.61	22.74
3	28 days	26.21	33.67	36.07

Table 20 Final results of Permeability for 3, 7& 28 days

s.no	Days	0%F.A + C.A+ cement(unmodified pervious concrete) (mm/sec)	5%F.A + 95%C.A + cement (mm/sec)	10 %F.A + 90% C.A + cement (mm/sec)
1	3 days	0.38	0.28	0.32
2	7 days	0.40	0.30	0.26
3	28 days	0.42	0.31	0.28
	Avg	**0.40**	**0.29**	**0.28**

Case (ii): Cement + % F.A + constant volume of C.A + water

• In case (ii) the percentage of fine aggregates is gradually increased with maintaining the constant value of coarse aggregates each time to obtain better strength and permeability.

Table 21 Final results for Compressive Strength test for 3, 7& 28 day

s.no	Days	0%F.A + C.A+ cement(unmodified pervious concrete)(N/mm^2)	2.5%F.A + C.A + cement (N/mm^2)	5%F.A + C.A + cement (N/mm^2)	10 %F.A + C.A + cement (N/mm^2)
1	3 days	11.23	14.53	15.30	16.46
2	7 days	20.33	19.38	20.88	21.84
3	28 days	26.21	32.02	35.20	39.04

Table 22 Final results of Permeability for 3, 7& 28 days

s.no	Days	0%F.A + C.A+ cement(unmodified pervious concrete) (mm/sec)	2.5%F.A + C.A + cement (mm/sec)	5 %F.A + C.A + cement (mm/sec)	10 %F.A + C.A + cement (mm/sec)
1	3 days	0.39	0.30	0.23	0.25
2	7 days	0.40	0.28	0.26	0.27
3	28 days	0.41	0.27	0.28	0.26
	Avg	**0.40**	**0.28**	**0.25**	**0.26**

VI. DISCUSSIONS

From the above mentioned results the following discussions are

- The compressive strength of pervious concrete made by increasing of fine aggregates like 5% and 10% obtained values are 33.98 N/mm2 and 36.14 N/mm2 at the age of 28 days when compared to the control specimen. Due to increasing percentage of fine aggregates take major role for getting good bonding and produce good compressive strength.
- In the same case (i.e. case I) the 3 days compressive strength was decreased by using 5% and 10% fine aggregates in Pervious concrete when compared to control specimen. It may happen due to using different size of coarse aggregates i.e. between 16mm to 25mm. But the 7 days strength was increased by using 10% of fine aggregates i.e. 23N/mm2.
- The 3 and 7 days strength at 2.5%, 5% and 10% of fine aggregates with constant volume of coarse aggregates slightly increased.
- The 2.5%, 5% and 10% of fine aggregates with constant volume of coarse aggregates in pervious concrete produce compressive strength of 31.40N/mm2, 34.81N/mm2 and 39.11N/mm2 respectively when compared to control specimen for 28 days of hydration period.
- In case i and case ii the permeability is decreased from 0.3mm/sec to 0.2 mm/sec and 0.28 mm/sec to 0.26 mm/sec respectively at the age of 3 days to 28 days due to increasing of fine aggregate volume.
- In both case i and case ii the average permeability is almost same i.e. 0.30mm/sec for 28 days but it is slightly decreased when compared to the control specimen. It shows that no fines concrete having good permeability due to porousness

VII. CONCLUSION

Pervious concrete made by 10% of fine aggregates and 90% of coarse aggregates and 10% of fine aggregates and constant volume of coarse aggregates produce high compressive strength and satisfied good permeability condition.

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