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Effect of Mix Proportions on Strength and Porosity of Pervious Concrete

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Abstract—Pervious concrete, also known as permeable concrete, no-fines concrete, or porous asphalt, is a specialized type of concrete characterized by high porosity, allowing water from precipitation and other sources to pass directly through. This reduces surface runoff and supports groundwater recharge, making it a sustainable material choice for low-impact development. Typically composed of coarse aggregates with little to no fine aggregates, the cement paste coats the aggregates, creating interconnected voids that enable water permeability. This study focuses on evaluating the effect of different mix proportions specifically the variations in water-to-cement (w/c) ratios and coarse-to-fine aggregate (CA:FA) ratios on the mechanical properties and porosity of pervious concrete. Mix designs were developed with w/c ratios ranging from 0.40 to 0.50, and coarse aggregates were varied in proportion to study their impact on compressive and flexural strength. The cement used was OPC 43 grade, with specific gravities of cement, coarse aggregate, and fine aggregate being 3.15, 2.68, and 2.65 respectively. Crushed stone and river sand were used as aggregates. The results aim to identify an optimum mix proportion that ensures both adequate strength and desired porosity. Balancing mechanical strength with permeability is a major challenge in pervious concrete, especially for applications in road pavements. This research contributes to developing a structurally viable and environmentally friendly pavement solution through the proper selection and proportioning of materials.

***Index Terms*—Pervious Concrete, Mix Proportions, Porosity, Compressive Strength, Flexural Strength, OPC, Crushed Stone, River Sand.**

1. Introduction

A. General

Pervious concrete is a mixture of coarse aggregate, cement, water, and little to no sand, creating an open-cell structure that allows water and air to pass through. According to the EPA, stormwater runoff can carry up to 90% of pollutants like oil, but pervious concrete helps recharge groundwater and reduce surface runoff and pollution.

Benefits of Pervious Concrete Pavement:

a) Allows fast water infiltration, recharges groundwater, and keeps the subsoil moist.
b) Absorbs traffic noise, creating a quieter environment.
c) Reduces water splash during rain, improving safety and driving comfort.
d) Helps regulate surface temperature and humidity, mitigating urban heat islands.

Proper installation is crucial. The subgrade must be well-compacted 92-96% for sandy soils, with a gravel layer needed for silty/clayey soils. Pervious concrete has 18-35% voids and compressive strength between 10-30 MPa. Mixes typically have a water/cement ratio of 0.25-0.45 and cement/aggregate ratio of 1:3.5-1:6. Small amounts of fine aggregate can improve strength but reduce permeability. Correct water content is essential to avoid segregation or poor mixing.

B. Material Required

Fig. 1. Sample of coarse aggregate and fine aggregate along with crushed stone and river sand

Fig. 2. Sample of Portland cement

Water is a vital component in concrete, essential for both

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hydration of cement and achieving workability. Proper water-cement (W/C) ratio is critical—too little water impedes hydration, while excess water increases porosity, reducing strength. For full hydration, a W/C ratio of 0.42 is ideal. Extra water is needed for workability due to cement particle flocculation, but admixtures can help reduce this need. In pervious concrete, the right amount of water is crucial to maintain strength and permeability, as excessive water may clog pores.

Aggregate type and size also influence concrete strength, especially in pervious concrete, where bonding between aggregate particles is key. Harder aggregates like granite or quartz yield better strength, while limestone, though weaker, is used in this study. Aggregate sizes of 3/8" are preferred for workability and surface finish.

The aggregate-cement (A/C) ratio affects compressive strength; more cement paste increases strength but may reduce permeability. Therefore, balanced A/C ratios are selected based on prior research.

Ordinary Portland Cement (OPC) is used in this study for its availability and its primary role in providing strength and durability to concrete. Overall, careful control of mix components ensures optimal performance of pervious concrete.

C. *Problem Statement*

Flooding in India is a recurring issue, especially during monsoons, due to inadequate drainage systems and unchecked urban development. Cities like Mumbai and Chennai frequently suffer from waterlogged roads, leading to significant property damage and economic loss. A viable solution is the use of pervious concrete, which allows rainwater to infiltrate through surfaces. This not only reduces surface runoff and flood risks but also recharges groundwater and prevents pollutants from entering natural water sources.

D. *Objective of Study*

- The principal target of this examination is to build up a solid and tough pervious bond concrete (PCC) blend utilizing distinctive kinds of fine aggregates with changing the amount of fine aggregates. Moreover, it is likewise expected to think about the properties of these PCC blends.
- The level of fine aggregates to be utilized as a part of PCC blend is set to 30%max.
- The properties of PCC mixes to be looked into are compressive quality and flexural quality.

E. *Scope of the Project Work*

- The present examination tended to the strength and seepage parts of pervious concrete blends and furthermore the impact of CS as a FA.
- A definite report is required to know the impacts of aggregate gradation with different sorts of aggregate to get higher strength and satisfactory building properties of pervious concrete.

2. Methodology

After distinguishing proof of issue and setting the targets of the research, the research methodology has carefully design to accomplish these destinations.

- Accumulation and investigation of writing relating to the exposition work.
- Decide the building properties of pervious concrete and contrast them with ordinary concrete.
- Cast different trial blends with changing rates of pervious concrete and analyze for the compressive quality.
- Get ready test tests with the rate esteem and test these examples for the different properties.
- To remark on the reasonableness and confinements of pervious concrete with traditional concrete.

A. *Planning Schedule*

Collection of Material

a) Collection of OPC Cement
b) Preparation of Mould for casting of cubes and beams
c) Collection of CA and FA

- *Creating Test Mixes with varied percentage of CA and FA*: Commercially available CA and FA will be collected and suitable percentages of both the aggregates will be fixed for e.g. NFA, 4:1, and 3:2.
- *Finding out Optimum Cement Content*: Mixes will be created by varying cement content from 350kg/m3 to 480kg/m3
- *Casting of Cubes and Curing*: Sets of three cubes will be casted having different mix proportion. After 24 hours of casting, cubes will be de moulded and water cured for several days.
- *Laboratory Testing*: Each set of cube will be tested for its mechanical properties at the end of 3, 7 and 28 days.

After making the three-mix design at three different cement content and making proportion at 5:0 of coarse aggregate and fine aggregate, we will choose the mix design with lower cement content and with lower concrete density. Mix design 5.3 having the lower concrete density as compare to mix design 5.1 and 5.2. Therefore, after choosing mix design 5.3 with minimum cement content i.e. 384 kg/m^3 and lower concrete density, we will make further two more mix proportion at ratio 4:1 and 3:2 of coarse aggregate and fine aggregate at cement content 384 kg/m^3. We will use little fine aggregate to increase

Table 1
Mix proportion for cube using no fine aggregate at cement content 479kg/m^3 (w/c = 0.40) (CA: FA = 5:0)

S. No.	Material	Quantity per m^3 (kg)	For 1 Cube (150*150*150mm) (kg/mm^3)	For 4 Cubes (kg/mm^3)	Percentage Proportion (%)
1.	Cement	479	1.6166	6.466	19.72
2.	Water	191.60	0.6466	2.5864	7.88
3.	CA	1758.88	5.9362	23.744	72.40
4.	FA	Nil	Nil	Nil	Nil
5.	Yield	2429.48	8.1994	32.797	-------

Table 2
Mix proportion for cube using no fine aggregate at cement content 446kg/m^3 (W/C = 0.43) (CA: FA = 5:0)

S. No.	Material	Quantity per m^3 (kg)	For 1 Cube (150*150*150mm) (kg/mm^3)	For 4 Cubes (kg/mm^3)	Percentage Proportion (%)
1.	Cement	446	1.5052	6.0208	18.39
2.	Water	191.60	0.6466	2.5864	7.90
3.	CA	1787.024	6.0312	24.124	73.70
4.	FA	Nil	Nil	Nil	Nil
5.	Yield	2424.62	8.1831	32.732	-------

Table 3
Mix proportion for cube using no fine aggregate at cement content 384kg/m^3 (w/c = 0.50) (CA: FA = 5:0)

S. No.	Material	Quantity per m^3(kg)	For1Cube (150*150*150mm) (kg/mm^3)	For10 Cubes (kg/mm^3)	Percentage Proportion (%)
1.	Cement	384	1.2960	12.960	15.89
2.	Water	191.60	0.6466	6.466	7.93
3.	CA	1839.82	6.2093	62.093	76.16
4.	FA	Nil	Nil	Nil	Nil
5.	Yield	2415.42	8.1519	81.519	-------

the strength of pervious concrete.

B. Casting Process

1) Size of Test Specimens

Test specimens cubical in shape shall be 15 X 15 X 15 cm. If the largest nominal size of the aggregate does not exceed 2 cm, 10 cm cubes may be used as an alternative. Similarly, for beams the size of moulds used was 50 cm X 10 cm X 10 cm. Cubes were casted to perform check on compressive strength of pervious concrete while beams were casted to check the flexural strength of pervious concrete.

2) Preparation of Moulds

Prior to mixing and casting of specimen one of the most important and time-consuming work is preparation of moulds. Moulds should be prepared such that all surfaces of moulds are cleaned and oiled properly and all the bolts are tightened so that it shall not allow any leakage of mortar.

Fig. 3. Surface cleaned and oiled moulds

Special care should be taken while applying oil. Excessive amount of oil can lead to presence of bug holes on the surface of concrete after demoulding. A suitable brush or cloth should be used while applying oil on the surface of moulds. Also type of oil used is very important as the purpose of oil is to provide necessary lubrication so that concrete may not stick to the surface of moulds and it should be easy to demould the specimen. If suitable oil is not used then it may break your specimens and whole procedure is to be repeated again. The oil used in this study was Waste Black Oil easily available at any workshop at no cost or very minimal charges.

3) Mixing

All of the mixing of concrete was done by hand mixing only. All of the ingredients of Pervious Concrete like cement, coarse aggregate and fine aggregate were first weighed as per mix design proportion and then mixed on floor which was prepared for saturated surface dry condition so that floor shall not absorb any water from the mix neither shall it release more water into the mix. All 3 ingredients of Pervious Concrete were first mixed in dry condition so that all aggregates were properly mixed with cement in order to have homogeneous mixture as shown in figure 4.

Fig. 4. Homogeneous dry mix

After the homogeneous dry mix was obtained, water was added into the mix. It was kept in mind that all of the water was added within 1/3rd of the total mixing time. Again, further mixing was carried out in order to obtain homogeneous mixture.

Fig. 5. Homogeneous wet mix after adding water

After the mixing of concrete, well cleaned and oiled moulds were filled with concrete and hand compacted. Here, Table Vibrator is not recommended as it was noted that under effect of vibration cement slurry settles down and makes the concrete impervious. Each mould was filled in three layers and hand compacted after each layer with help of tamping road.

(a) Beam moulds prior to filling of concrete

(b) Concrete filled in layers in cube moulds

Fig. 6. Placing and compaction of concrete in moulds

After the mould was completely filled and compacted, the top surface of concrete was leveled and any excessive concrete was removed to provide specimen a well finished surface with help of trowel.

(a)

(b)

(c)

Fig. 7. (a) Levelling, (b) Finishing of top surface of concrete, (c) Levelling and finishing of surface of beams

After the moulds were filled with concrete and levelled, the specimens were left for 24 hours before demoulding so that concrete achieves its hardening. After 24 hours of casting, the cubes were demoulded on very next day without any delay.

Fig. 8. Specimen kept for 24 hours prior to demoulding

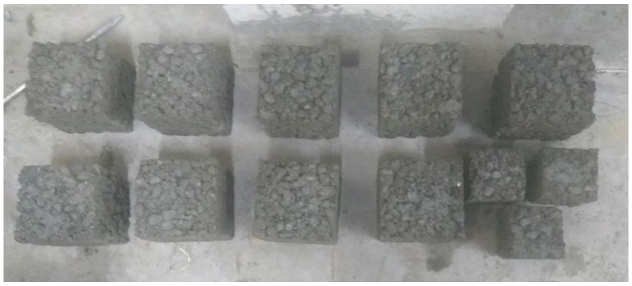

Fig. 9. Demoulded cubes

Once all the specimens were demoulded, they were left for curing in water curing tank, for 3 days, 7 days, 28 days as required for testing.

The temperature of water was at room temperature that is in ambient conditions. Clean tap water was used for curing of specimens. All the specimens were numbered and marked with help of wax crayon (fig. 10) to remember the type of mix.

Fig. 10. Curing of cube specimen in ambient conditions

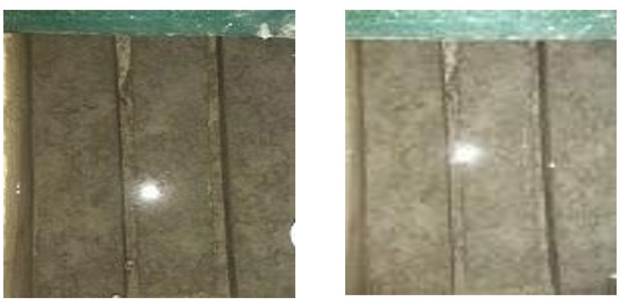

Fig. 11. Curing of beam specimen in ambient conditions

C. Testing of Specimens

All the specimen were tested as per directions given in IS 516 (1959). To check compressive strength of concrete using Pervious Concrete cubes, Compression Testing Machine was used where as to perform check on Flexural Strength of beams, Flexural Testing Machine was used. The load for compression testing machine was set as specified in IS 516 i.e. 140 kg/sqcm/ minute. The load shall be applied slowly without shock and increased continuously until the resistance of specimen (Concrete Cube) to increasing load breaks.

Calculation of Load:

Load as per IS Code =140kg/sqcm/min 1 Kg = 9.81 N

1000N =1KN

∴ (140 x9.81/1000) = 1.373 KN

1min =60 seconds

But load specified in IS516 is in kg/sqcm/minute

∴1.373 x surface area of cube

= (1.373x15 x15)/60

= 5.148kn/sec

Similarly, for flexural Strength test, load specified in IS516=180kg/min for 10cm beams that comes out to be 29.42N/sec.

Fig. 12. Compression testing machine

3. Result Analysis and Discussion

A. Specific Gravity and Water Absorption Result of Coarse Aggregate

Results:

Specific gravity of given aggregate is 2.65 & Water Absorption of given aggregate is 1.66%

B. Specific Gravity of Fine Aggregate Result

Apparent specific gravity = (weight of dry sample/weight of equal volume of water)

$=W_2/(W_2-(W-W_2))$

Table 4
Compressive strength of cubes using no fine aggregates (CA: FA=5:0)

S. No.	Age of Cube (Days)	Weight of Cube (kg)	Density of Cube (kg/m^3)	Compressive Strength of Cube (MPa)
1.	3 days	7.310	2166	6.90
2.	3 days	7.330	2172	7.60
3.	3 days	7.310	2166	7.40
4.	7 days	7.310	2166	8.20
5.	7 days	7.300	2163	8.80
6.	7 days	7.330	2172	9.40
7.	28 days	7.320	2169	10.55
8.	28 days	7.320	2169	11.30
9.	28 days	7.330	2172	11.90

=307.5/(307.5-(500-307.5))
=2.67

Result:
Specific gravity of fine aggregate=2.67

C. Comparison for Compressive Strength

This graph shows the sample 1, sample 2, and sample 3, therefore compressive strength increases from sample 1 to sample 3. Sample 3 shows higher compressive strength as compare to other two samples. And sample 1 shows lower compressive strength as compare to other two sample, but sample 2 having higher compressive strength than sample1 and lower compressive strength than sample 3.

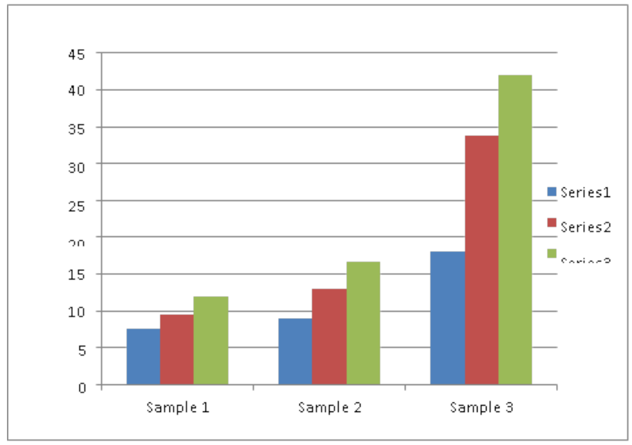

Fig. 13. Compressive strength comparison graph

Table 5
Compressive strength of cube using fine aggregates (CA: FA=4:1)

S. No.	Age of Cube (Days)	Weight of Cube (kg)	Density of Cube (kg/m^3)	Compressive Strength of Cube (MPa)
1.	3 days	7.610	2256	8.53
2.	3 days	7.630	2260	8.88
3.	3 days	7.610	2256	8.10
4.	7 days	7.610	2256	11.87
5.	7 days	7.600	2254	11.82
6.	7 days	7.630	2260	12.88
7.	28 days	7.620	2258	13.55
8.	28 days	7.620	2258	15.70
9.	28 days	7.630	2260	16.66

Table 6
Compressive strength of cube using fine aggregates (CA: FA=3:2)

S. No.	Age of Cube (Days)	Weight of Cube (kg)	Density of Cube (kg/m^3)	Compressive Strength of Cube (MPa)
1.	3 days	7.980	2364	18.00
2.	3 days	7.940	2352	17.82
3.	3 days	7.980	2364	18.10
4.	7 days	7.980	2364	33.64
5.	7 days	7.970	2361	32.26
6.	7 days	7.990	2367	33.82
7.	28 days	7.990	2367	42.04
8.	28 days	7.970	2361	41.91
9.	28 days	7.980	2364	41.56

Table 7
Flexural strength of beams using no fine aggregates (CA: FA=5:0)

S. No.	Age of Beam (Days)	Weight of Beam (kg)	Density of Beam (kg/m^3)	Flexural Strength of Beam (MPa)
1.	7 days	10.100	2020	2.76
2.	7 days	10.230	2046	2.73
3.	7 days	10.410	2082	3
4.	28 days	10.220	2044	2.99
5.	28 days	10.300	2060	3.26
6.	28 days	10.420	2084	3.5

Table 8
Flexural strength of beams using fine aggregates (CA: FA=4:1)

S. No.	Age of Beam (Days)	Weight of Beam (kg)	Density of Beam (kg/m^3)	Flexural Strength of Beam (MPa)
1.	7 days	10.250	2050	4
2.	7 days	10.210	2042	3.25
3.	7 days	10.090	2018	3
4.	28 days	10.240	2048	4.20
5.	28 days	10.260	2052	4.30
6.	28 days	10.220	2044	3.90

Table 9
Flexural strength of beams using fine aggregates (CA: FA=3:2)

S. No.	Age of Beam (Days)	Weight of Beam (kg)	Density of Beam (kg/m^3)	Flexural Strength of Beam (MPa)
1.	7 days	10.840	2168	4.6
2.	7 days	10.720	2144	4.5
3.	7 days	10.350	2070	4
4.	28 days	10.440	2088	6
5.	28 days	10.360	2072	5.75
6.	28 days	10.400	2080	5

D. Comparison for Flexural Strength

This graph shows the sample 1, sample 2, and sample 3, therefore flexural strength increases from sample 1 to sample 3. Sample 3 shows higher flexural strength as compare to other two samples. And sample 1 shows lower flexural strength as compare to other two sample, but sample 2 having higher flexural strength than sample1 and lower flexural strength than sample 3.

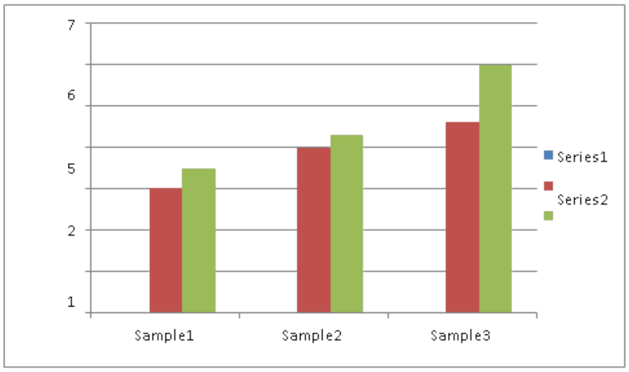

Fig. 14. Flexural strength comparison graph

E. Discussion

1) Compressive Strength

3 Days: Experimental observations establish a increase in the compressive strength of M20 grade (from ratio 5:0 to 3:2 of CA: FA) of pervious concrete by 13.8%.

7 Days: Experimental observations establish a increase in the compressive strength of M20 grade (from ratio 5:0 to 3:2 of CA: FA) of pervious concrete by 25.9%.

28 Days: Experimental observations establish a increase in the compressive strength of M20 grade (from ratio 5:0 to 3:2 of CA: FA) of pervious concrete by 54.8%.

From the compressive strength results we found that compressive strength increases from ratio 5:0 to 3:2 of coarse aggregate and fine aggregate. Compressive strength of pervious concrete is lower than of conventional concrete. At ratio 4:1 sample shows the porosity and good compressive strength. Strength also increases from 3 days to 28 days. It means strength is directly proportional to time.

2) Flexural Strength

7 Days: Experimental observations establish a increase in the flexural strength of M20 grade (from ratio 5:0 to 3:2 of CA: FA) of pervious concrete by 10.7%.

28 Days: Experimental observations establish a increase in the flexural strength of M20 grade (from ratio 5:0 to 3:2 of CA: FA) of pervious concrete by 21.4%.

From the flexural strength results we found that flexural strength increases from ratio 5:0 to 3:2 of coarse aggregate and fine aggregate. Flexural strength of pervious concrete is lower than of conventional concrete. At ratio 4:1 sample shows the porosity and good flexural strength. Strength also increases from 3 days to 28 days. It means strength is directly proportional to time.

4. Conclusion

From this study several conclusions were made to successfully develop pervious Concrete of desired physical and Mechanical properties. All of those conclusions are as listed as under:

a) It was found that content of cement is very important aspect to be considered while designing Pervious Concrete. Excessive amount of cement will form cement slurry when mixed with water and will settle down after the concrete has been placed into the moulds thereby making the base of concrete impervious.

b) It was also found that as the mixture is unable to retain/ hold water while mixing therefore concrete mixer is recommended for heavy concreting. However, for small scale work for eg. lab work, Steel or Iron Mixing Tray can be used in order to avoid loss of water.

c) Thirdly, Table Vibrator or any other vibratory compaction method shall not be used while compacting Pervious Concrete as vibration leads to gravitational settlement of cement slurry again making the base of specimen impervious. Only Hand Compaction is recommended as per this study.

d) While oiling the cubes excessive oil should be prevented on the surface of moulds as it leads to formation of bug holes on the surface of concrete cubes. Type of oil used should be checked for its lubricating properties. Oil should not be sticky rather it should be oily. Motor Vehicle Black Oil is recommended in this study.

e) Out of three different mixes on different proportion of cement i.e. 479kg/m^3, 446kg/m^3 and 384kg/m^3 it was found that specimens having cement quantity as 384kg/m^3 had greater permeability.

f) Three different mixes were prepared having cement content as 384kg/m^{3}of cement –Mix1 having 0% sand, Mix 2 having 15.02% sand and Mix 3 having 30.22% sand. It was found that first two mixes had good permeability while the third mix was impermeable. Out of first two mixes second mix is recommended as it had considerable permeability and good compressive strength as compared to Mix 1 specimens.

Lastly, it was concluded that proportion of fine aggregate can be used in development of Pervious Concrete not exceeding 15% in proportion of mix by weight**.**

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