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Enhancement the Strength of Pervious Concrete with Different Water Cement Ratio and Admixture

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Abstract: **The Strength of pervious concrete is as important as its permeability characteristics. Studies indicate that pervious concrete has lower compressive strength capabilities than conventional concrete and will only support light traffic loadings. This thesis investigated prior studies on the compressive strength of pervious concrete as it relates to water-cement ratio, aggregate-cement ratio, aggregate size, quantity of admixture and compaction and compares those results with results obtained in laboratory experiments conducted on samples of pervious concrete cube casted for this purpose. Since voids are supposed to reduce the strength of concrete 1% for every 5% voids the goal is to find a balance between water, aggregate, and cement in order to increase strength and permeability, two characteristics which tend to counteract one another. The end result of this research will be a recommendation as to the water-cement ratio, the aggregate-cement ratio, aggregate size, quantity of admixture and compaction necessary to maximize compressive strength without having detrimental effects on the permeability of the pervious concrete system. This research confirms that pervious concrete does in fact provide a lower compressive strength than that of conventional concrete. Researches indicate that the minimum compressive strengths of acceptable mixtures reached in to 2.8 Mpa- and maximum compressive strength reached to 28 Mpa. Extremely high permeability rates were achieved in most all mixtures regardless of the compressive strength.**

Keywords: Admixture, Super plasticizer, Permeability, Water/Cement Ratio, Density

1. INTRODUCTION

Pervious concrete is a composite material consisting of binding material, coarse aggregate, admixture and water. It is different from conventional concrete in that it contains no fine aggregate in the mixture. The aggregate usually consists of a single size and is bonded together at its points of contact by a paste formed by the cement, admixture and water. This mix when hardens results in a concrete with a high percentage of interconnected voids that, allows the rapid percolation of water. Unlike conventional concrete, which has a void ratio approximately 3-5%, pervious concrete can have void ratio from 15-35%.The characteristics of Pervious concrete different from conventional concrete in several other ways. If we compare Pervious concrete with conventional concrete, it has a lower compressive strength, higher permeability, and a lower unit weight, approximately 70% of conventional concrete.

2. USES OF PERVIOUS CONCRETE

These are the various uses of pervious concrete

1. The use of Pervious concrete is limited in areas subjected to low traffic volumes and loads.
2. Pervious concrete is useful in the construction of parking lots, driveways, sidewalks, residential streets, tennis courts, and swimming pool decks.
3. We can construct the pavement for Zoo areas & Sub-base for conventional concrete pavements with the help of pervious concrete.
4. We can also construct the low-volume pavements residential roads with the help of pervious concrete.
5. Sewage treatment plant sludge beds, beach structures and seawalls can be constructed by pervious concrete.
6. Bridge embankments & solar energy storage systems can be constructed by using pervious concrete.

3. LITERATURE REVIEW

Pervious concrete is a combination of Portland cement, controlled amounts of water, coarse aggregate and little or no sand. The thick cement paste bonds the coarse aggregate together but allows adequate void formation of approximately 15% to 35%. The rate at which the water flows through pervious concrete is “typically around 480 in./hr (0.34 cm/s which is 5 gal/ft²/min or 200 L/m²/min)” (Tennis et al, 2004). According to another researcher (V.M. Malhotra) presented in his thesis that to create a pervious concrete structure with optimum permeability and compressive strength, the amount of water, amount of cement, size and type of aggregate, and compaction must all be considered. A number of experiments have been previously conducted throughout the past few decades by a variety of researchers comparing some or all of these elements. The results are presented in a series of tables and graphs. V.M. Malhotra discussed pervious concrete as

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it relates to applications and properties. He provided details on such properties as proportions of materials, unit weight, compactibility, and curing in an attempt to achieve maximum permeability in the pervious concrete. Malhotra also conducted multiple experiments on various test cylinders (specimen) in an attempt to find a correlation between compressive strength and any of the material's properties. We found that the compressive strength of pervious concrete was decreased with the increase of aggregates proportion in mix and if we increase the amount of water in mix, it also results in reduction of the compressive strength of pervious concrete. He also concluded that even the optimum ratios still would not provide compressive strengths comparable to conventional concrete. Malhotra went on to investigate the effects of compaction on compressive strengths. Malhotra presents a correlation between compressive strength and unit weight he shows that compressive strength increases with increase in density, when different aggregate cement ratios along with various aggregate gradings are employed. Malhotra also experimented on different types of aggregates and their effect on compressive strength the relationship between aggregate type and compressive strengths; he shows that Rounded Quartzite Gravel provides higher compressive strength as compare to Crushed Granite and Crushed Limestone (Malhotra, V.M., 1976).

Table-1 Presented by V.M. Malhotra after his experimentation

Source: V.M. Malhotra (1976), ACI Journal, Vol. 73, Issue 11, p633.

*A/C = Ratios are by volume.
**W/C = Ratios are by weight.

4. MATERIALS AND THEIR TESTS

This Chapter provides detailed information about the materials and test procedures used to achieve the objectives of this research. The mixtures of pervious concrete require careful analysis of aggregate size and properties for a road pavement to be capable of bearing expected loads and allowing water to drain through its interconnected voids at a suitable rate. Another function of pervious concrete pavements relates to its filtering capabilities and the time period for which it effectively performs before it clogs with silt or debris. This approach examined with multiple mixes prepared by different aggregate sizes, water/cement ratios and varying quantity of admixtures.

The mix design for each pervious concrete batch had a target unit weight of 1800 – 2000 kg/m3 and a cement-to-aggregate ratio of 0.15 – 0.20 as recommended from the literature review (Tennis et al, 2004). A water-to-cement ratio of 0.34 – 0.38 was determined by performing an experimentation on desired mix.

MATERIALS

I Coarse Aggregate

We used crushed sandstone as coarse aggregate in this thesis. One of the basic reasons for choosing this stone was its wide availability in area nearby. The aggregate of 10 mm single-sized crushed sandstone were used in this thesis. All of the coarse aggregate used in the study were sieved to obtain only single-sized aggregate. The aggregate was as follows:
10 mm i.e. 100% passing through 12.5 mm and 100% retained on 10 mm sieve.
Water absorption capacity and Specific gravity of the aggregates were measured.

Test for Aggregate-

1 - Water Absorption

Water absorption value generally ranges 0.1 to about 2 percent for coarse aggregates normally used in road surface course. Indian Road Congress (IRC) and Ministry of Road Transport and Highways (MORTH) have specified the maximum water absorption values as 1.0 percent for aggregates used in bituminous surface dressing. As per MORTH specifications, the maximum permissible water absorption value is 2.0 percent for the coarse aggregates to be used in bituminous macadam base course, dense bituminous macadam binder course, semi-dense bituminous concrete surface course and bituminous concrete surface course. (Highway Materials and Pavement Testing- S.K. Khanna, C.E.G. Justo, A. Veeraragavan).

Calculations-
Size of Aggregate = 10 mm
W1 = Weight of Oven-dried aggregate
W2 = Weight of saturated surface dry aggregates in air
Water absorption in percentage = [(W2-W1)/W1]*100
Example- Water absorption (%) = [(2026-2000)/2000]*100 = 1.3 %

Table-2 Water absorption of test samples

S.No.	W_1	W_2	% Water absorption
1	2000	2026	1.3
2	2000	2024	1.2
3	2000	2026	1.3
4	2000	2028	1.4
5	2000	2024	1.2
6	2000	2030	1.5

Average water absorption of these sample is = 1.32 %.

2- Aggregate Impact Test

Aggregate Impact Test has been designed to evaluate the toughness or the resistance of the stones aggregates to breaking down under repeated application of impact. Aggregate impact value indicates a relative measure of the resistance of aggregate to impact. The aggregate impact test apparatus and the procedure have been standardized by the Bureau of Indian Standards (BIS).

Calculation –

The aggregate impact value (AIV) is expressed as the percentage of the fines passing 2.36 mm sieve expressed in terms of the total weight of the sample. (Highway Materials and Pavement Testing- S.K. Khanna, C.E.G. Justo, A. Veeraragavan).

the original weight of the oven dry aggregate sample be W1 (gm) and the weight of the broken aggregates passing 2.36 mm IS sieve after the application of 15 blows of the hammer be W2 (gm).So,

Aggregate Impact Value (AIV) = [W2*100 / W1]

Table-3 for Aggregate Impact Value

S. No.	W1 (gm)	W2 (gm)	AIV
1.	400	54	13.5
2.	400	52	13.0
3.	400	54	13.5
4.	400	56	14
5.	400	56	14
6.	400	54	13.5

The Average AIV of the sample is = 13.58.

Aggregate impact values are used to classify the stone aggregates with respect to toughness property,

According to criteria mention in Highway Materials and Pavement Testing- S.K. Khanna, C.E.G. Justo, A. Veeraragavan our aggregate sample is very tough and strong, so we can use this aggregate in our construction.

II Admixture

In this study we use a high range superplasticizer (Conplast sp430) with variable proportions to reduce water cement ratio in the mix and also to found out its effect on properties of pervious concrete.

Applications

High range superplasticising admixtures Complies with IS: 9103:1999 and BS: 5075 part 3. It also conforms to ASTM C-494 Type 'F' and type 'G', depending on the dosages used.

Benefits

In ACI 212-3R [11], the reasons for the use of admixtures are outlined by the following functions that they perform:

1-Increase workability without increasing water content or decrease the water content at the same workability.

2- Retard or accelerate time of initial setting.

3- Reduce or prevent shrinkage or create slight expansion.

4- Modify the rate or capacity for bleeding.

5- Reduce segregation.

Effect of admixture on our mix

Table-4 for effect of quantity of admixture on water cement ratio

S. No.	Quantity of admixture in the mix (ml/kg of cements)	Water/Cement Ratio
1	5	0.38
2	10	0.36
3	15	0.34

These changes we observed when we form a ball which was recommended by P.D., M.L. Leming, and D.J. Akers.s

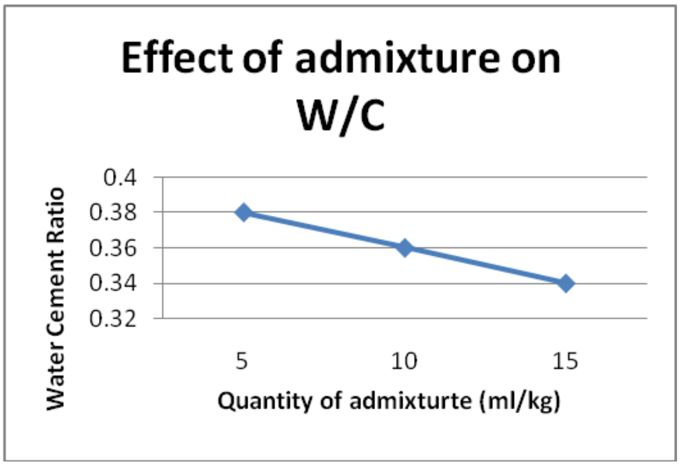

Figure Water cement ratio v/s quantity of admixture

Range of Dosage

250 ml – 1000 ml / bag of cement.

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Proportioning of Material

The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work. Where the proportions of the ingredients of the concrete as used on the site are to be specified by volume, they shall be calculated from the proportions by weight used in the test cubes and the unit weights of the materials.

3-Compressive Strength Test of Cement Concrete Cube

The bearing surfaces of the testing machine shall be wiped clean and any loose sand or other material removed from the surface of the specimen which are to be in contact with the compression platens. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom. The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine. As the spherically seated block is brought to bear on the specimen, the movable portion shall be rotated gently by hand so that uniform seating may be obtained. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

4-Fresh Concrete Unit weight Determined by Proctor Test

Proctor test for unit weight of fresh pervious concrete

There are different methods of compacting concrete for the standard unit weight test.

1- Light compaction.
2- Heavy compaction.

1- Light compaction - Compact the concrete in three equal layers by the rammer of 2.6 kg and free fall 31 cm with 25 evenly distributed blows in each layer of 10 cm diameter mould and 56 blows for 15 cm diameter mould.

2- Heavy compaction - In this we compact the pervious concrete using the rammer of mass 4.89 kg and free fall 45 cm in five layers, each layer being given 25 blows for 10 cm diameter mould and 56 blows for 15 cm diameter mould.

5. EXPERIMENTAL RESULTS AND DISCUSSION

In this Chapter, the experimental results are presented with discussions that provide an interpretation of the results. Statistical analyses of the results were tabularized to aid in understanding the extent of variance revealed in the pervious concrete mixtures when various properties were tested. These properties involved the density, compressive strength, percent air voids, porosity, and permeability.

5.1 Pervious Concrete Unit Weight

One of the important factors of a pervious concrete mix is its unit weight. Since there has been limited research conducted on pervious concrete, there is no standardized test procedure available to measure unit weight, except those published by individual researchers.

The fresh unit weight test was performed on the pervious concrete immediately after mixing and the actual density of the mixture was determined which normally has a tolerance of plus or minus 5 lb/ft3 (80 kg/m3)of the designed unit weight based on the literature (NRMCA, 2004) [20]. As a result of the emphasis placed on the unit weight, the common compaction process, along with another possible method were analyzed when performing the unit weight test for fresh pervious concrete mixes in this study.

5.2 Fresh Pervious Concrete Unit weight Determined by Proctor Test

For determination of the unit weight of fresh pervious concrete, we use modified proctor test in the laboratory. In this we compact the pervious concrete using the rammer of mass 4.89 kg and free fall 45 cm in five layers, each layer being given 56 blows for 15 cm diameter mould.

Table-8 Density of fresh pervious concrete (at last page)

By these observations we found that the density of fresh pervious concrete is in the range between 1844-1905 kg/m3 and it was observed that if we increase the percentage of aggregate in mix it increases the density of pervious concrete. A deduction that can be made from the unit weight correlation relates to the percent of air voids lost to the addition of the other ingredients to the pervious concrete mix, such as cement and water.

5.3 Compressive Strength of pervious concrete

The compressive strength tests were conducted on three specimens from each pervious concrete mix. The results of the compressive tests are shown in Table-7 These results were found after testing the specimens after 7-day curing and 28-day curing.

By these observations we found that the compressive strength of pervious concrete after 7 days and 28 days curing increases with reduction in water cement ratio and we get the values of compressive strength in the range between 57.78 kg/cm2 - 102.22 kg/cm2. It was also found that the increase in percentage of aggregate in the mix increases the compressive strength.

6. CONCLUSION

Pervious concrete has high water permeability due the presence of interconnected air voids in its matrix. The presence of high porosity with respect to conventional concrete makes the pervious concrete to become light weight concrete with limited compressive strength. However, now a days pervious concrete has been becoming more popular for a few decades due to its potential to reduce the incidence of flooding, and to assist in recharging the groundwater table.

In this thesis we use an admixture (Conplast sp430) i.e. a superplasticizer to reduce the water cement ratio in the mix, by this we achieved higher compressive strength with same mix. In this research work we observed that we can achieve the compressive strength of pervious concrete with 10 mm single size aggregate around 100 kg/cm2.

On the basis of our observations on pervious concrete the following conclusion were made:

1- We can improve the compressive strength of pervious concrete around 9%-15 % with use of superplasticizer.
2- The porosity of pervious concrete was between 20%-34% as compare with conventional concrete's 3%-5%.
3- The compressive strength of pervious concrete was around 100 kg/cm2.
4- The permeability of pervious concrete was 22.11 mm/sec- 25.45 mm/sec.
5- The density of pervious concrete was 1844 kg/m3 - 1905 kg/m3 which was 20%-25% lower than that of conventional concrete.
6- The hydraulic conductivity decreased as the decrement takes place in the percentage of aggregate in mix.

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TABLES

Table-1 Presented by V.M. Malhotra after his experimentation

Aggregate Cement Ratio (A/C)*	Water Cement Ratio (W/C)**	Age of Test (days)	Density (lb/ft3)	Cement (lb/yd3)	Compressiv/s Strength (psi)
6	0.38	3	125.8	436	1295
6	0.38	7	125.4	436	1660
6	0.38	28	125.8	436	2080
8	0.41	3	120	326	850
8	0.41	7	119.5	326	1055
8	0.41	28	119.4	326	1365
10	0.45	3	116.7	261	625
10	0.45	7	116.4	261	780
10	0.45	28	116.2	261	1015

Table-5 Compressive strength of pervious concrete

S. No.	Sample No.	Water Cement Ratio	A/C Ratio	Load taken by sample after 7 days (Kg)	Load taken by sample after 28 days (Kg)	Compressive Strength after 7 days (Kg/cm2)	Compressive Strength after 28 days (Kg/cm2)
1	I II III	0.38	5	8000 8000 9000	14000 13000 14000	35.56 35.56 40.00	62.22 57.78 62.22
2	I II III	0.36	5	10000 9000 9000	15000 14000 15000	44.44 40.00 40.00	66.67 62.22 66.67
3	I II III	0.34	5	11000 10000 11000	17000 16000 16000	48.89 44.44 48.89	75.56 71.11 71.11
4	I II III	0.38	4.5	11000 12000 12000	18000 17000 17000	48.89 53.33 53.33	80.00 75.56 75.56
5	I II III	0.36	4.5	12000 12000 13000	18000 19000 18000	53.33 53.33 57.78	80.00 84.44 80.00
6	I II III	0.34	4.5	12000 13000 13000	18000 20000 19000	53.33 57.78 57.78	80.00 88.88 84.44
7	I II III	0.38	4	14000 13000 13000	20000 21000 21000	62.22 53.33 53.33	88.88 93.33 93.33
8	I II III	0.36	4	14000 14000 13000	23000 21000 22000	62.22 62.22 53.33	102.22 93.33 97.78
9	I II III	0.34	4	14000 15000 14000	23000 22000 23000	62.22 66.67 62.22	102.22 97.78 102.22

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Table-6 Density of fresh pervious concrete

S. No.	Water Cement Ratio	Aggregate Cement Ratio	Quantity of admixture (ml/kg of cement)	Weight of concrete (kg)	Density (kg/m3)
1	0.38	5	5	4.288	1905
2	0.36	5	10	4.280	1902
3	0.34	5	15	4.254	1890
4	0.38	4.5	5	4.236	1882
5	0.36	4.5	10	4.231	1880
6	0.34	4.5	15	4.220	1875
7	0.38	4	5	4.168	1852
8	0.36	4	10	4.159	1848
9	0.34	4	15	4.150	1844