Pervious Concrete: Step towards Green Concreting

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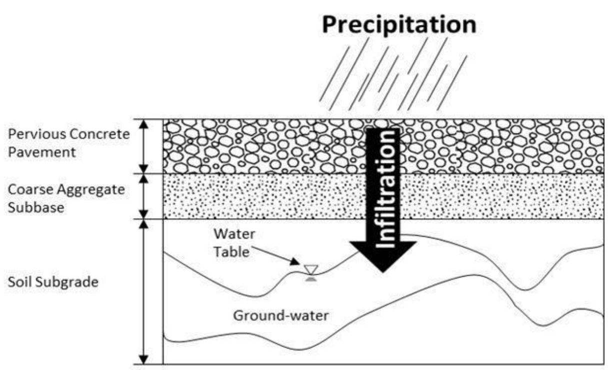
Abstract - Pervious Concrete is a specialty concrete used to allow water to intentionally pass through the surface of a pavement and allow stormwater to eventually absorb back into the surrounding soils. Pervious concrete pavement is unique and effective means to meet growing environmental demands. The effect of aggregate size and its gradation on the various strength parameters of pervious concrete are presented in this paper. This paper also shows the effect of supplementary cementitious material such as fly ash and blast furnace slag (GGBS) and variation on the strength performance of pervious concrete

Keywords: Pervious Concrete, Fly Ash, GGBS, Permeability

INTRODUCTION

Pervious concrete is a mixture of gravel or stone, cement, water and little or no sand which creates an open cell structure that allows water and air to pass through it. According to EPA (Environmental Protection Agency's) storm water runoff can send as much as 90% of pollutant such as oil and other hydrocarbon. The ability of pervious concrete to allow water to flow through itself recharges ground water and minimizes the extent of pollution and storm water runoff. Pervious concrete is considered a sustainable building alternative for concrete and/or asphalt pavement parking lots because it provides pollution mitigation and storm water management. Pervious concrete acts as a filtration device for storm water and turns the entire parking area, pathway, or other paved surface into a retention treatment basin



This research focuses on the influence of paste density and aggregate size on pervious concrete. Moreover, graphs between the properties examined are developed. These relationships will aid in the ability in correlating mix properties (permeability, compressive strength, flexural strength etc.) to mix

LITERATURE SURVEY

Silvija Mrakovčić, Nina Čeh, Vedrana Jugovac have experimentally determined Fresh and hardened pervious concrete properties. The correlation between the compressive strength, flexural tensile strength, flow coefficient, and aggregate grading is analyzed

Omkar Deo, Milani Sumanasooriya, and Narayanan Neithalath through experimentation have described a study on permeability reduction in pervious concretes due to physical clogging using both experimental and modeling approaches. Significant permeability reductions were observed with incremental finer sand addition for pervious concrete mixtures.

A.K. Jain, Dr. J.S. Chouhan, S.S. Goliya [2] presented the laboratory results of the study undertaken to determine the effect of shapes and size of aggregates on permeability of pervious concrete. The result indicates that permeability of pervious concrete vary as a function of angularity number of aggregates used

Lian & Y. Zhuge has concluded through their laboratory to explore the optimum type of aggregate for porous concrete using Australian local quarries. It can be concluded that the grading of aggregate also need to be controlled in order to achieve the best strength of porous concrete.

ADVANTAGES OF PERVIOUS CONCRETE

- The benefits of pervious concrete are not limited to its infiltration capacities.
- A number of studies have shown its potential to remove pollutants from water,
- Decreasing flooding possibilities, especially in urban areas and reducing puddles on the road
- Reduce noise, improve skid resistance, and
- Help mitigate the heat island effect
- It returns rain water to the ground, recharging ground water and aquifers
- The runoff from paved areas is reduced, which reduces the need for separate storm water retention
- Supporting vegetation growth

APPLICATION OF PERVIOUS CONCRETE

- Application in green buildings
- Pathways
- Street storm water drainage
- Ground water Recharge
- Low traffic pavement
- Parking lots

- Use as subgrade level/ drainage level in pavement

Pervious Concrete Materials

Cement & Cementitious Materials

Portland cement is readily available in the Navi Mumbai market and used for pervious concrete production. Slag Cement (Ground Granulated Blast-Furnace Slag, aka. GGBFS) is a cementitious material available in the market and used in pervious concrete production. Fly Ash Type C and Type F are both available in the market and used in pervious concrete production. Slag and fly ash are supplementary cementitious materials often used to replace the amount of cement. Both products are industrial byproducts. Using them in concrete keeps them out of landfills helping to green our environment. They both offer good benefits to concrete and they offer strength gain. This means they add durability in the long run. Both require longer curing times for the concrete to initially set and gain strength. Before using, their chemical and physical analysis should be done to get good results.

Aggregates

Aggregates can have a direct influence in the permeability, surface texture and the appearance of the pervious slab. A uniform large aggregate size is preferable for maximum permeability. This is opposite of the optimized gradation usually wanted in a regular concrete mix. The size of the large aggregate will have an effect on aesthetics and the top size of the “holes” in the surface. The hardness and durability of the aggregate can also have an effect on the durability of the pervious pavement. The aggregates should be good quality clean aggregates. Dust and debris can add to clogging the wet pervious matrix.

Water

Water is an important ingredient of concrete, which not only actively participates in the hydration of cement but also contributes to the workability of fresh concrete. Cement is a mixture of complex compounds, the reaction of cement with water leads to its setting and hardening. All the compounds present in the cement are anhydrous but when brought into contact with water they get hydrolyzed, forming hydrated compounds. Since water helps to form the strength giving cement gel, the quality of water is to be critically monitored and controlled during the process of concrete making. Water used for the pervious concrete mix shall be potable, drinkable water and conform to IS 456-2000.

3.5.4 Admixture

Air entraining admixtures shall conform to ASTM C260. Dose as per the manufacturer recommendation for conventional concrete, Water reducing admixtures shall conform. Dosages for pervious concrete can exceed theranges typically used for conventional concrete.

3.6 PROPERTIES OF PERVIOUS CONCRETE

Density and porosity

The density of pervious concrete depends on the properties and proportions of the materials used, and on the compaction procedures used in placement. In place densities on the order of 1600 kg/m3 to 2000 kg/m3 are common, which is in the upper range of lightweight concretes. The porosity of pervious concrete largely depends on aggregate size.

Permeability

The flow rate through pervious concrete depends on the materials and placing operations Typical flow rates for water through pervious concrete are 288 in. /hr, 120 L /m2/min, or 0.2 cm/s to 770 in. /hr, 320 L /m2/min, or 0.54 cm/s, with rates up to 1650 in. /hr, 700 /m2/min,1.2 cm/s and higher having been measured in the laboratory.

Compressive strength

Pervious concrete mixtures can develop compressive strengths in the range 3.5 MPa to 28 MPa, which is suitable for a wide range of applications. Typical values are about 17 MPa. As with any concrete, the properties and combinations of specific materials, as well as placement techniques and environmental conditions, will dictate the actual in-place strength.

Flexural strength

Flexural strength in pervious concretes generally ranges between about 1 MPa and 3.8 MPa Many factors influence the flexural strength, particularly degree of compaction, porosity, and the aggregate: cement (A/C) ratio. However, the typical application constructed with pervious concrete does not require the measurement of flexural strength for design.

Experimental Procedures

Cement

Ordinary Portland cement of 53-grade will be used in this study conforming to IS: 8112-1989 having Specific gravity 3.15.

Aggregates

The coarse aggregate passing through 20 mm and retained on 10 mm sieve was used in research. Aggregates of size 10 mm and 20 mm used in the project will be local angular aggregates available with distributer.

Ground Granulated Blast Furnace Slag (GGBS)

The GGBS used in research was obtained from JSW Steel Plant. The specific gravity of about GGBS is 2.88.

Fly ash (FA)

Fly ash required for the project was obtained from local fly ash brick manufacturer having its source from Nasik Thermal Power Plant having a specific gravity of 2.15.

Admixtures

Water Reducing Admixtures is being used for preparing the pervious concrete mix. BASF admixtures Master Polyheed 8650 was used for the purpose.

Water

Water quality used in pervious concrete should be the same as that used in conventional concrete: potable water, recycled water from the concrete industry, or tap water. Due to the sensitivity of pervious concrete, water quality control is very important.

Mix Proportion

Trial concrete mixes shall be prepared keeping water to cementitious material ratio (W/C_m) constant for all the six concrete mixes. The design mix proportions are as follows:

Table 3.4.1 Mix Proportions for Pervious Concrete Mixes

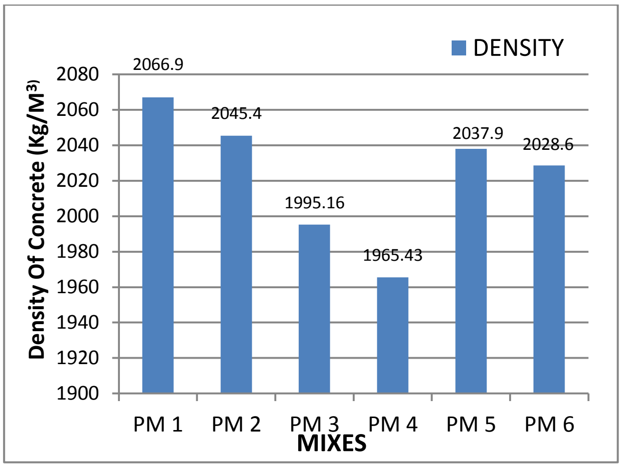
Mix Composition	Mix Abbv	Quantity (Kg/m^3)						
		Cement	Fly Ash	GGBS	Water	CA 10	CA20	Admix
C:FA/GGBS = 100:0	PM 1	300	0	0	100	1780	0	1
C:FA/GGBS = 100:0	PM 2	300	0	0	100	712	1068	1
C:FA = 85:15	PM 3	255	45	0	100	1780	0	1
C:FA = 65:35	PM 4	195	105	0	100	1780	0	1
C:GGBS = 75:25	PM 5	225	0	75	100	640	960	1
C:GGBS = 50:50	PM 6	150	0	150	100	640	960	1

C: Cement; FA: Fly Ash; GGBS: Ground Granulated Blast Furnace Slag

Testing Methods and Procedures

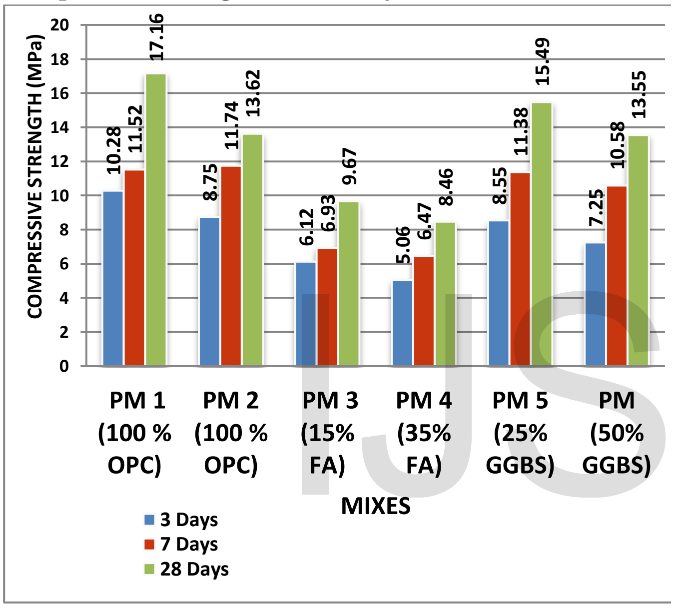
All the six concrete mixes were tested for

A. Compressive strength at 3, 7 & 28 days following the guidelines of IS 516,
B. Flexure test for beams at 28 days,
C. Permeability test



RESULTS

Compressive Strength and Density



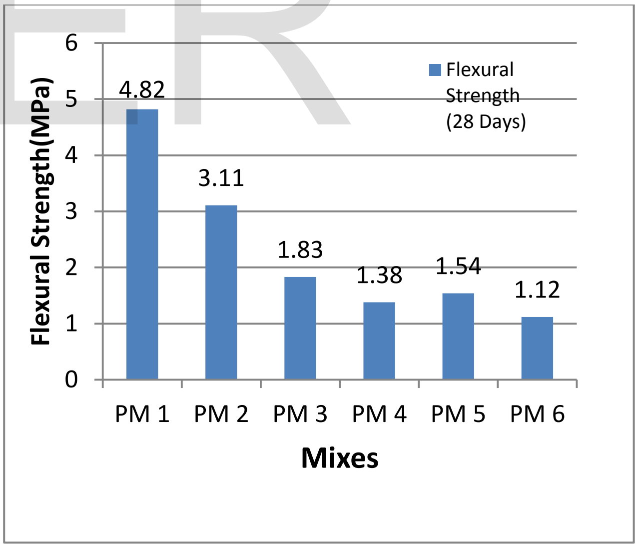
The pervious concrete showed significantly lower strength. The mean value of the 28 days compressive strength of pervious concrete with 100% cement had 17.16 MPa for 10mm aggregate and 13.62 MPa for mix of 10 and 20mm aggregate. As expected, pervious concrete resulted in 26% low compressive strength due to its higher porosity. Further, the samples were prepared using 10 mm aggregates.

At the same age, pervious concrete with 15% fly ash had the strength of 9.67 MPa, while the strength of pervious concrete with 35 % fly ash had strength of 8.46 MPa, which is only 55.4% and 48% respectively of the 100% OPC.

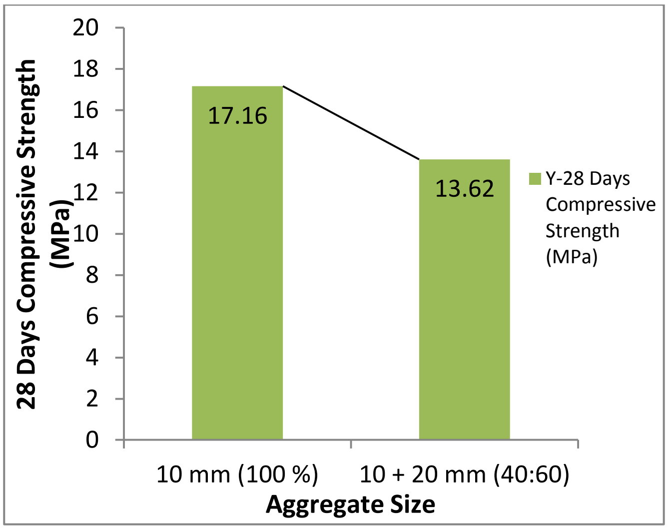
When cement replaced with GGBS with 25% and 50% variation gave 28 days strength of 15.49 MPa and 13.55MPa respectively which is 10.78% and 26.64% less than 100% OPC respectively.

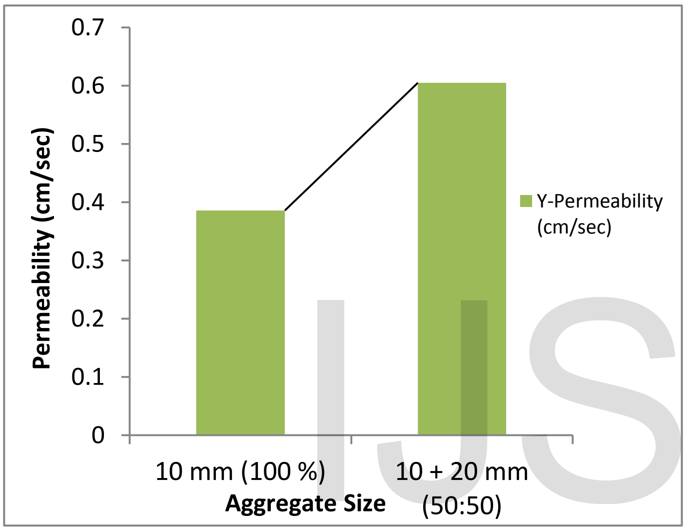
The mean density for conventional concrete varies between 2400 and 2500 kg/m^3, while pervious concrete has a density between **1965 and 2067 kg/m^3**. Therefore, the pervious concrete showed nearly **21-27%** lower density than conventional concrete. The age of concrete does not influenced to the density of pervious concrete. The cement replacement with fly ash and GGBS had marginally affected decreasing the density for both pervious concretes.

Flexural Strength



The flexural strength graph shows a depreciation of strength throughout. For PM 1 mix it showed the highest of 4.82 MPa. For PM 2, 55% reduction in strength was observed. For PM3 and PM 4 mixes containing FA compared to PM 1 showed gain in strength only about 38% and 28.6%. For mixes PM 5 and PM 6 containing GGBS also showed lower strength. Gain in strength was only 32% and 23.2% respectively with respect to PM 1.





It can be seen that the aggregate size and permeability are related to each other. The lesser the aggregate size lesser is the permeability and vice-versa. The results are reversal for what it is seen for aggregate size and compressive strength.

CONCLUSIONS

- Grading of aggregate is equally important to get desired strength and on the other hand permeability. Greater the aggregate size the greater is the permeability but lower is the strength and vice-versa.
- Flyash reduced the strength properties of the concrete, the major reason may be the grade and quality of Flyash.
- GGBS as supplementary material gave a good results regarding the strength properties although lower than 100% OPC.
- Permeability is largely related to method of compaction and size of aggregates used.

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