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Alternative ECO Friendly and Low Cost Material for Solving Water Pollution Problems- Case Study on Pervious Concrete

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ABSTRACT: Pervious concrete is a two-phase material containing coarse aggregates surrounded by a coating of thin layer of cement paste, without any fine aggregate which saves environment and cement. The combination of these ingredients will produce a hardened material of lower density, lower cost due to lower cement content, lower thermal conductivity, relatively low drying shrinkage (one half of that of dense concrete), no segregation and capillary movement of water, better insulating characteristics than conventional concrete with connected porous ranging size from 2mm – 8mm and void content ranges from 15% to 35% that allows water to pass through easily and the range of water/cement ration lies between 0.23 to 0.43.

The main objective of this research is to investigate the performance characteristics of concrete mixes made without fine aggregates and to suggest possible applications of this pervious concrete for various structural and non-structural uses. Test samples are prepared for various aggregate/cement ratios such as 5:1, 6:1, 7:1 and 8:1 with water cement ratios 0.35, 0.40 and 0.45 for all the above batches. The aggregate selected for the batches are 60:40 of 20mm and 12.5mm respectively. The test results are compared and the best aggregate/cement and water-cement ratio are suggested for various civil engineering applications.

Keywords: Pervious concrete, mechanical properties, durability properties.

I. INTRODUCTION

Pervious concrete pavements offer an eco friendly solution to run off and associated water pollution problems. Pervious concrete also helps to achieve LEED points of the Green Building Council. Pervious concrete has been recognized by the EPA as a best management practice (BPM) to address this most vital environmental concern. The open-cell structure of pervious concrete provides a medium for aerobic bacteria that break down many of the pollutants that seep from parked cars. Pervious concrete also contributes to enhanced air quality by lowering atmospheric heating through lighter colour and lower density, decreasing the impact of heat is land effects. Unfiltered storm water discharged into streams and estuaries also carries fertilizers, pesticides, soils and other pollutants which can kill marine life either directly or indirectly. Indirectly, suspended particles can absorb more sunlight thus further raising water temperatures.

II. ENVIROMENTAL ADVANTAGES

A. Pervious concrete is that it returns rain water to the ground, recharging ground water and aquifers, and eliminating storm water run-off.
B. Reduce or eliminate water pollution by reducing impervious cover, increasing onsite infiltration, eliminating sources of contaminants, and removing pollutants from storm water runoff.
C. Divert 50% of total construction waste from disposal. Use onsite, recycled concrete for pervious base layer.
D. Retains storm water so that retention ponds are not needed for parking lots.
E. Aerobic bacteria that develop within the pavement and base can break down oil and remove other pollutants from the water that washes off the surface.
F. Light reflectivity is higher than with asphalt surfaces, reducing any heat island effect.
G. Allows a project to claim LEED® points. (Leadership in Energy and Environmental Design is a rating system developed by the U.S. Green Building Council to evaluate the environmental performance of a building).

III. ECONOMICAL ADVANTAGES

A. Lower installation costs due to the elimination of costly curbs, gutters, storm drain outlets and retention basins that cost two to three times more to construct than pervious. Less money will be needed for labour, construction and maintenance of ponds, pumps, drainage pipes and other storm water management systems.

B. Lower life-cycle costs equal to that of conventional concrete that if properly constructed will last for 20 to 40 years. Pervious requires fewer repairs than asphalt, and can be recycled once it has reached its lifecycle.

IV. APPLICATIONS

A. Drive-thru, gas stations, parking lots and driveways catch the most oil and grease.

B. Driveways, including residential driveways, low-traffic roads, fire lanes and emergency access roads.

C. Parking areas; especially over-flow parking and those associated with office buildings, shopping centres and recreational facilities.

D. Sidewalks.

E. Road shoulders and vehicle cross-over on divided highways.

V. REVIEW OF LITERATURE

A. Paul D. Tennis, Michael L. Leming, and David J. Akers, (2004)

Pervious concrete as a paving material has seen renewed interest due to its ability to allow water to flow through itself to recharge groundwater and minimize storm water runoff. This introduction to pervious concrete pavements reviews its applications and engineering properties, including environmental benefits, structural properties, and durability.

B. Dan Huffman, (December 2005)

While pervious concrete pavement has been around for more than 20 years, it has only recently garnered much attention due to increasingly stringent storm water management guidelines that now position the product as a sustainable building material. Pervious concrete provides the potential for environmentally responsible site use and lowered construction costs in projects ranging from a simple sidewalks, driveways and patios, to major pedestrian plazas and full-blown multi-acre parking lots for national commercial big box builders.

C. Portland Cement Association, (2004)

Pervious concrete is ideally suited as a solution to storm water management issues with added environmental benefits. The large void content designed into this specialty concrete allows water to pass through rapidly, minimizing runoff and recharging groundwater supplies. Also known as permeable concrete, porous concrete, gap-graded concrete, pervious concrete, and enhanced porosity concrete, pervious concrete can be used in a wide range of applications, although its primary use is in pavements.

D. Dale P. Bentz (2008)

Pervious concrete micro structural models and compares their percolation characteristics and computed transport properties to those of real world pervious concretes. Finally he concluded that potential extension of the virtual pervious concrete to exploring durability issues such as freezing-and-thawing resistance and clogging have been studied.

E. Mahboub, K C,Canler, Jonathan,Rathbone, Robert,Robl, Thomas, Davis, (November 1 2009),

The researchers at Tennessee Technological University conducted studies on pervious concrete, aiming to improve workability through mixture modifications. 2, 3 These modifications included changing the aggregate shape and texture, adding chemical admixtures, adding fly ash, adjusting the w/c, and using uniformly graded aggregates. These studies demonstrated that low-compaction mixtures did not produce superior pervious concrete mixtures. Accurately measuring the air content of pervious concrete is a challenge due to its highly porous nature. Current literature suggests that air porosity of pervious concrete should be within 18 to 35% to ensure a desirable permeability; however, there are no suitable AASHTO or ASTM International test methods for determination of air porosity for such a concrete.

F. Journal of Environmental Management (October 2006).

The experimental results correlated well with the theoretical calculated permeability of the pervious concrete system for pervious concrete systems fully covered on the surface with sand. Two different slopes (2% and 10%) were used. Rainfall rates were simulated for the combination of direct rainfall (passive runoff) and for additional storm water runoff from adjacent areas (active runoff). A typical pervious concrete block will allow water to pass through at flow rates greater than 0.2 cm/s and a typical extra fine sand will have a permeability of approximately 0.02 cm/s. The limit of the system with complete sand coverage resulted in an effective system permeability of approximately 0.004 cm/s which is similar to the rainfall intensity of 30 min duration, 100-year frequency event in the south-eastern United States. The results obtained are important in designing and evaluating pervious concrete as a paving surface within watershed management systems for controlling the quantity of runoff.

VI. TESTING OF MATERIALS

Following tests are conducted for the ingredients i.e. cement and sand

A. Materials Used

Size of aggregates used: 20mm and 12.5mm .
Cement: Portland Pozzolana Cement.(PPC)
Water: Potable/tap water.

1) Test results of Cement

Sr. No.	DESCRIPTION	Values
1.	Specific gravity	3.15
2.	Fineness (by sieve analysis)	2%
3.	Consistency	31%
4.	Initial setting time	120 min
5.	Final setting time of cement	330 min

2) Test results of Coarse Aggregate

Sr.N0.	DESCRIPTION	Values
1.	Specific gravity	2.01
2.	Bulk density	1642.45 Kg/m^3
3.	Surface moisture	0.08%
4.	Water absorption	1%
5.	Fineness modulus	6.98
6.	Aggregate impact value	24.40%
7.	Aggregate crushing value	21.40%

3) Slump test:

The pervious concrete had an extremely high slump caused by the low amount of Cohesion between the aggregate particles. This particular workability test appears to be of little use when considering pervious concrete.

VII. EXPERIMENTAL RESULTS

Totally 78 cubes, 12 cylinders and 12 beam specimens are casted to find out the compressive strength at 7 days and 28 days, split tensile strength and flexural strength respectively. The test results are compared and the best aggregate/cement and water-cement ratio are suggested for various civil engineering applications.

The standard tests such as compressive, flexural and split tensile tests are carried out after 7 days and 28 days. The detailed results and the graphical representation of compressive strength for various mix ratios are given in Table 1, and Figure 1,2,3,and 4 respectively.

Sr. No	Agg/cement ratio	Water cement ratio	7 days		28 days		Split tensile strength N/mm^2	Flexural strength N/mm^2
			Compressive strength N/mm^2	Density Kg/m^3	Compressive strength N/mm^2	Density Kg/m^3		
1	5:1	0.35	5.08	2030.21	12.44	1945.67	0.93	0.794
		0.40	5.77	2073.18	11.11	2044.44	1.34	0.981
		0.45	5.67	2124.34	10.81	2086.02	1.03	2.06
2	6:1	0.35	3.05	2024.98	9.18	1916.04	0.83	1.648
		0.40	1.24	1799.30	4.66	1886.41	0.65	1.962
		0.45	3.61	1972.53	5.48	1965.42	0.65	0.473
3	7:1	0.35	1.37	1827.35	3.40	1906.16	0.49	0.671
		0.40	2.45	1888.88	4.29	1886.41	0.42	0.776
		0.45	4.72	1960.29	6.29	1911.10	0.58	0.902
4	8:1	0.35	1.43	1864.19	4.88	1817.28	0.29	0.687
		0.40	1.88	1833.67	3.99	1817.28	0.35	0.7848
		0.45	1.67	1937.77	5.99	1955.53	0.31	1.294

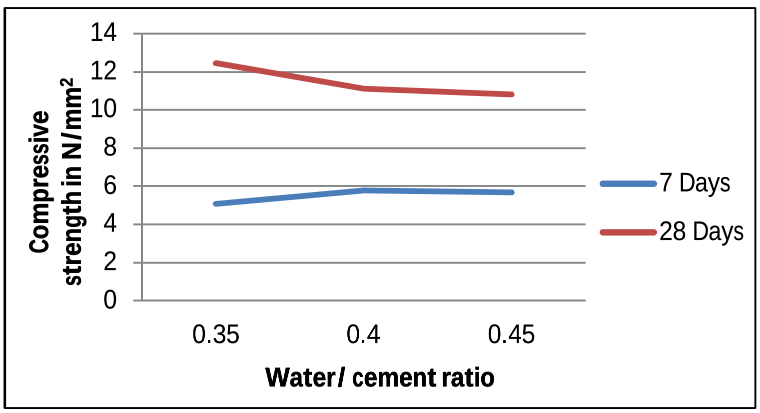

Figure: 1

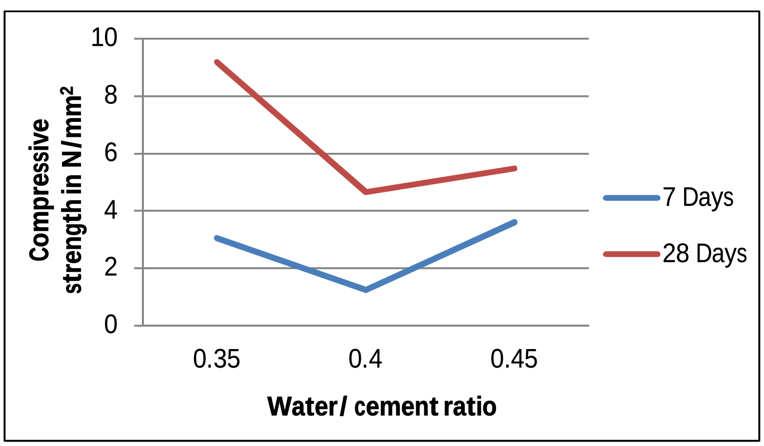

Figure: 2

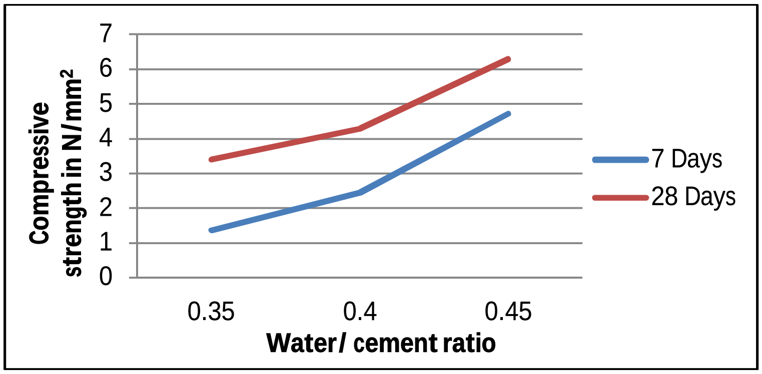

Figure: 3

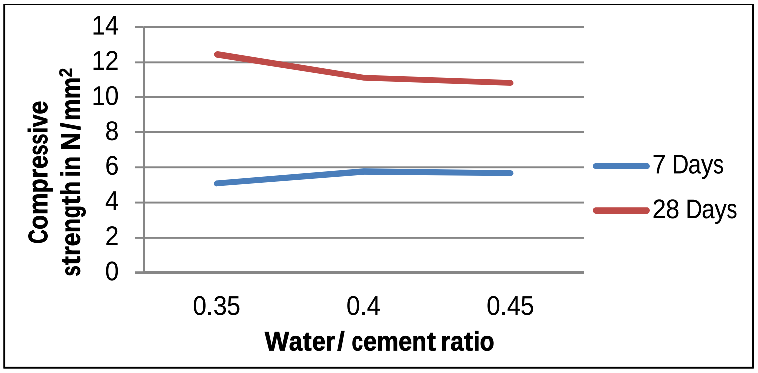

Figure: 4

VIII. CONCLUSION

From this study, it is observed that, though no fines concrete has lower strength values, it has desirable strength values to be used for both structural and non-structural purposes.It can be concluded that pervious concrete is a viable material that has the potential to replace the use of traditional concrete pavements, car parks, residential streets and driveways, cast in-situ walls in low-rise buildings and low cost housing. It has many positive attributes that make its use beneficial to society. It provides an energy conserving building and it does not require too much cement.

Abolishment of fine aggregate from normal concrete mixes lead to higher porosity desirable strength values, and lower cement requirement. It also saves the energy required in extraction, transportation of sand. Also no fines concrete has a lower density and lower normal weight than the traditional concrete mixes. Since it compacts well due to its self weight, it needs no mechanical compaction. As it is a light weight concrete, the necessity for stronger shuttering requirement is not needed.

For structural purpose like low rise building, low cost housing it is recommended to use the aggregate /cement ratio of 5:1 with water cement ratio either 0.35 or 0.4. For non structural purposes like pavement of low traffic density, drainer pipes it is recommended to use the aggregate /cement ratio of 5:1 with water cement ratio of 0.35 or aggregate /cement ratio of 6:1 with water cement ratio 0.35. Finally it can be concluded that the pervious concrete is viable material for civil engineering application and also saves cement and energy.

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