

Environment friendly pervious concrete for sustainable construction

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ABSTRACT

Now-a-days our modernized cities are covered with air-water proof building material. It obstructs the lack of air permeability and water permeability common concrete pavement so that the rain water is not filtered underground. A large amount of rain water ends up falling on impervious surface such as parking lots, drive ways, sidewalks and streets rather than soaking into soil. This creates a natural imbalance in the ecosystem and leads to various problems like soil erosion, floods, ground water depletion. A simple solution is to be avoiding these problems to stop construction impervious surface and switch to pervious concrete. Working on rain-drain concept, porous concrete allows large amount of water in the body system resulted ground water rechargement and control storm water management. Pervious concrete pavement is the best solution for protecting trees in a impervious surface. Many plants have faced difficulty growing in impervious because air and water can't touch to the roots. Porous concrete helps the adjacent trees to receive more water and air from the soil. Pervious concrete creates opportunity for lands caper and architects who wish to use greenery in parking lots and paved urban areas. Inspired by the pervious concrete technology and the fact that fly ash is a waste material abundantly available, the research Group at KIIT University, India commenced a comprehensive research programme on fabrication of Fly ash based pervious Material [FPC] from fly ash. The compressive strength of the material falls on the range of 3-28 MPa , porosity 15 - 35 % with permeability 8 - 20 mm/s. This material has potential application such as ground water rechargement, storm water management, noise reduction, control surface run-off, temperature behaviour and pollution retention sinks. The research mainly focuses on the manufacture of fly ash-based pervious material for ground water rechargement and large amount of utilization fly ash.

Keywords:-Pervious, Concrete, Fly Ash, Strength, Permeability, Porosity

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1. INTRODUCTION

Now-a-days our modernized cities are covered with air-water proof and building material. It obstructs the lack of water and air permeability inside the body system, so rain water is not able to filter underground. A large amount of rain water are not to be utilized in proper manner it ends up on falling drive way, parking lots, pedestrain road rather than soaking in the soil which on further creates some natural imbalance leads to flood, soil erosion, water depletion. A prominent solution of the problem is to controlled impervious surface and switch off to pervious concrete which offers multidirectional benefits [1-3]. Working on rain-drain concept, porous concrete allows large amount of water in the body system resulted ground water rechargement and control storm water management[4-6]. Implementation of porous concrete is one of the ideal solutions for save the trees in a impervious surface. It seems that in impervious surface many plants have not able to grow properly as water and air can't able to touch the root of the tree.[7-9].According to National Ready Mixed Concrete Association (NRMCA, 2004), porous concrete (PC) is a mixture of aggregate, cement, water and admixture combined to form a no-fine structural material. Pervious concrete has many different names including zero-fines concrete, pervious concrete and porous concrete. It is a special highly porous concrete, basically used for concrete flatwork applications. It allowed water pass through the body system and percolate to the ground[10-11]. In the past 30 years, the demand of this concrete is gradually increasing in the United States and Environmental Protection Agency(EPA) recommended it is the Best Management Practices (BMPs).The use of pervious concrete in building site design can also aid in the process of qualifying the building for Leadership in Energy and Environmental Design (LEED) Green Building Rating System credits[12-14].This material has high volume of voids inside the body system which causes lower strength. In pervious concrete, the large sized pores ranging from 2 - 8 mm, porosity ranges from 10- 35% permeability rate from 5-20 mm/s, compressive strength range from 3-30 MPa and density 1600-2000 kg/m³ [15].

2. BACKGROUND OF PERVIOUS CONCRETE

Pervious concrete was first introduced in the 1800s in Europe as pavement surface and bearing walls. Previously, in the 19th century this concrete was used in a variety of purposes such as load bearing walls, panels and paving. The use of this material is very limited because

of its lower strength. Pervious concrete has been extensively used as a structural building material in Europe, Australia and the Middle East for over 70 years. It became popular again in the 1920 for two storey homes in Scotland and England. It became more popular in Europe after the Second World War due to the shortage of cement. It did not become as popular in the US until the 1970s. In India it became popular in 2000. In the United Kingdom in 1852, two houses were constructed using gravel and concrete. It wasn't until 1923 when pervious concrete resurfaced as a usable construction material. In that time it was applied in a limited way to the construction of two story homes in areas such as Scotland, Liverpool, London and Manchester [ACPA, 2006]. After the World War II era the use of no-fine concrete in Europe increased steadily. Since pervious concrete contains less amount of cement content than conventional concrete and cement was scarce at the time, so pervious concrete was gain the popularity for best material in that period. Once again housing construction was its primary use. Later, pervious concrete spread to areas such as Venezuela, West Africa, Australia and Russia.

3. MATERIALS AND MIX PROPORTION

The specimens are obtained by the mixture of cement, aggregates, little amount of sand or no sand, water and admixture. During the mixing process, extreme care was taken in order to maintain water content so that the pervious concrete can get better workability. Generally, the mix design were produced with cement to aggregate ratio (C/A) of 1:3, 1:4, 1:6 and water cement (w/c) ratio of 0.30, 0.35, 0.40 respectively are summarized in Table . Additionally admixture 7-15 % of silicafume and 5-7 % of super plasticizer (weight of cement) were added to the mixture in order to get maximum strength. All the mix designs are prepared to achieve good permeability and porosity. The mix proportion of pervious concrete is shown in table 1.

Table 1. Mix proportion of Pervious concrete

Mix Proportion of Pervious Concrete	
Materials	Proportion
Cementious material	270 to 415 Kg/m ³
Aggregates	1190 to 1480 Kg/m ³

Water: Cement ratio(by mass)	0.27 to 0.40
Aggregate: Cement ratio(by mass)	4 to 6:1
Admixture	5 -7 %
Fine: Coarse aggregate ratio (by mass)	0 to 1:1

4. CHARACTERSTICS OF PERVIOUS CONCRETE

The properties of Pervious concrete (PC) such as compressive strength, split tensile strength, permeability, porosity, density, were found vary satisfactory performance and the test results are discussed below in table.2.

Table 2.Properties of Pervious concrete

Properties of Pervious Concrete	
Density	1600 to 2000 Kg/m ³
Compressive Strength	3.5 to 28 MPa
Flexural Strength	1 to 3.8 MPa
Tensile Strength	1 to 3 MPa
Permeability	8-20 mm/s
Porosity	15 to 35%
Slump	Zero

5. APPLICATION OF PERVIOUS CONCRETE

Natalia I. Vázquez-Rivera et al.(2015)have studied Optimization of pervious concrete containing fly ash and iron oxide nano particles and its application for phosphorus removal. The laboratory prepared pervious concrete can remove phosphorus with the first-order removal constant at 0.031 h^{-1} and the Freundlich isotherm constant at $2.48 \text{ mg}^{1-1/n} \text{ kg}^{-1} \text{ L}^{1/n}$ [16].Darshan S. Shah et al.(2013) have studied the application of Pervious concrete : New Era for Rural Road Pavement. This paper gives the idea about uses of pervious concrete in rural road pavement as well as solves ground water depletion and agriculture related problem.Porous concrete is more favourable because it allows water pass in its body system and control storm water runoff. The research concluded that it is possible to prepare $1\text{m} \times 1\text{m} \times 0.15\text{m}$ size pavement with durability properties with a minimum case of Rs 29 per m^3 or Rs 193 per m^2 or Rs. 18 per feet^2 [17]. Shihui Shen et al.(2012) have studied the Pervious concrete with titanium dioxide as a photo catalyst compound for a greener urban road environment In this study titanium dioxide (TiO_2) applied into pervious concrete pavement to remove some of these organic pollutant from the air, so that pervious concrete pavement for sustainable application such as air pollutant removal and storm water management [18].M.Carsana et al. (2013) have studied the use of porous concrete as a building material subjected to its strength durability properties and corrosion control through embedded steel. In the present research mechanical as well as durability properties were studied. Apart from this carbonation induced corrosion properties of the concrete were studied. It is observed that w/c ratio 0.34-0.41 and cement to aggregate ratio 1:4 subjected to fast carbonation and it can't provide long term passivation to embedded steel [19]. Morgenroth et al.(2013) ,have studied the belowground effects of porous pavements—Soil moisture and chemical properties. In the present study, how porous pavement related to soil moisture and their chemistry subjected to relate urban vegetarian were studied in Christchurch, New Zealand. The test result indicates that soil PH 5.6 which is acidic becomes going to neutral 6.3 after passing through pavement altered soil. Similarly concentration of soil Fe, Al, and mg decreased[20]. Ravindra Rajah et al.(2010) have studied the environmentally friendly pervious concrete for sustainable construction. This paper reports an experimental investigation into the, physical and engineering properties of pervious concrete having varying amount of low calcium fly ash as the cement replacement material. Replacement of 50% cement by fly ash had no significant effect on water permeability but it was noted that there is a marginal strength effect of pervious concrete. Three pervious concrete mixtures were prepared by replacing 0, 20 and 50% of fly ash, and its properties were studied. Based on the data, it is obtained that there is a co-relation between strength and porosity and

between permeability and porosity. It also found that pervious concrete maintain a porosity range of 15% to 30%. Also it is assuming that replacement of 50% of cement has no significant effect on water permeability. So it is possible to prepare environment friendly pervious concrete with significantly reduced amount of Portland cement with fly ash [21]. Brian Shackel et al.(2006) have studied the Design of permeable paving subject to traffic. This paper describes the multidirectional benefits of porous concrete on conventional concrete in terms of sustainability and environmental impact [22]. Norbert Belatte et al.(2010) have studied the Sustainability benefits of pervious concrete pavement. Portland cement pervious concrete is a material of increasing interest for parking lots and other application because of its important sustainability benefits. Pavement concrete greatly reduces the quantity of runoff and first flush pollution from parking areas and can enhance ground water recharge. Also it's found that light colour pavement material can help mitigate urban heat Island effect [23]. Sonia Rahman et.al (2014) has studied the long term drainage performance of no-fines concrete pavements in Canada. It includes the permeability evaluation, performance analysis, and strength assessment [24].

6. LIFE CYCLE COST OF PERVIOUS CONCRETE

No-fine concrete is the ideal solution for light weight roadway such as pedestrian road, parking lots and residential street. As porous concrete is porous in nature, so its various mechanical properties are weaker than conventional concrete but it can solve many environmental issues such as storm water management and urban heat island effect. The best way to compare this material with other is of its cost parameter and application. In the present there is no long studied has been conducted for its cost analysis. If available it is only suitable for local condition. Only few studies have been done on comparative analysis of cost construction between porous concrete and conventional concrete. The result reveals that the initial cost of porous concrete is high due to controlled design and to maintain proper void. If life cycle cost is determined then its overall benefits can be calculated. It is sometimes very difficult to determine the life cycle cost because of lack of large scale testing, performance analysis and maintenance cost. By determining the actual life cycle cost its cost would be reduced up to 30%. In another study it reveals that by installation of pervious concrete it can save up to \$64,649 for water treatment benefits and \$3,788,856 for installation cost for more than 25 years as compared to conventional concrete. The reduction cost of pervious concrete can be increased because it doesn't require a drainage system. Since more pores are present inside the body system helps to percolate water. According to Federal Highway

Administration (FHWA) the cost of Pervious concrete is 15-20 % more than traditional concrete. It basically depends upon few factors such as material employed and application method. In the present report the cost analysis of full, partial and no filtration pavement is studied. It is found from the literature only few work has been done on cost analysis of pervious concrete (PC). And the data available which shows that the construction cost of PC more expensive than other concrete. Due to non-availability of long term performance data. Most of the studied are conducted on storm water runoff but none one include the scope of taking UHI mitigation benefits. The author identify this is a potential area of research to study its various properties such as durability, construction cost, life cycle etc [25-26].

7. ONGOING RESEARCH AT KIIT UNIVERSITY, ODISHA, INDIA

Under the aegis of National Aluminium Company (NALCO, India) project ,the Research Group at KIIT University, Bhubaneswar, Odisha, India commenced a comprehensive research programme on fabrication of Fly ash based pervious Material [FPC] from fly ash. This material has potential application such as ground water recharging, storm water management, noise reduction, control surface run-off, temperature behaviour and pollution retention sinks. The research mainly focuses on the, the manufacture of fly ash-based pervious material for ground water recharging and large amount of utilization fly ash. A wide range of pervious concrete mixture samples were prepared at the KIIT University, Bhubaneswar laboratory facilities, which included cube sample of (150*150*150 mm) size were used to measure compressive strength, beam size (500*100*100 mm) were used to measure flexural strength and cylinder size (150*300 mm) were used to measure water permeability as shown in Figure 1.

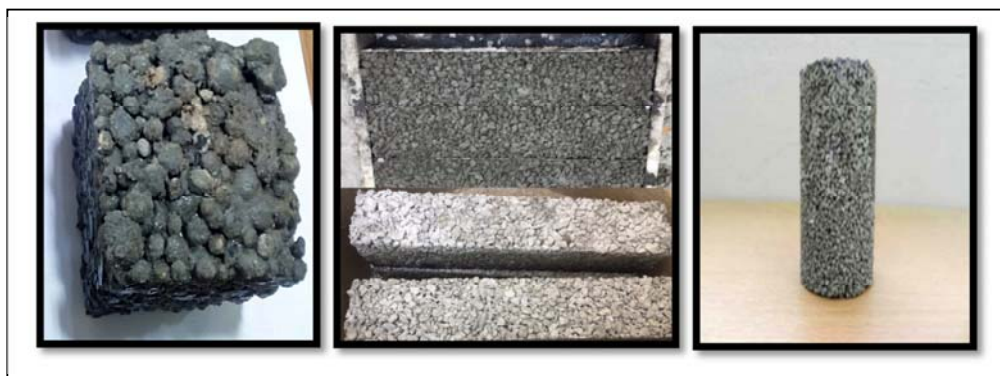


Figure1. Concrete Sample used in the research

As the demand of pervious concrete gradually increasing day by day ,so various design of pavement materials are prepared in laboratory scale and which can be implemented in parking lots and other areas which shown in Figure 2.



Figure 2. Fly ash based Pavement material

8. CONCLUSIONS

This paper looked at various studies conducted on permeable pavement systems and their current application. Also discussed about the detailed design of permeable interlocking concrete pavement in brief. Maintenance and water quality control aspects are also discussed.. The water quality aspects as well as the recent innovations of PC were highlighted and explained their potential application in various field and explain the possibility of further research work .The recent innovations like water treatment and recycling pavement system, development of a combined geothermal heating and cooling is promising and it is detailed in cut short, future research works are outlined in brief. These permeable pavement systems are changing the way human development interacts with the natural environment. Its application towards parking lots, highways and even airport runways are all improvements in terms of water quality, water quantity and safety.

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