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Previous Concrete Permeability Rate Modeling

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Abstract**:** *Pervious concrete is a highly permeable concrete with zero slump and the ability to reduce run-offs and decrease pollution of water running through the impervious layers. This type of concrete can be utilized in roads, and parking lots, driveways and walkways. In addition, pervious concrete pavement not only recharge underground water resources but also remove water from pavement surface leading to a higher level of safety for vehicles. In spite of all these advantages, this pavement suffers from clogging of pores. The main aim of this paper is to closely monitor the permeability rate of pervious concrete pavement over time. For this purpose, a pervious concrete slab was adequately designed and placed on a campus. The rate of its permeability has been measured after its installation on different spots for several months. The results show that although after almost a year the pervious concrete pavement is highly permeable but its permeability rate is decreasing with a slight reduction on early ages and a sharp one afterwards.*

Keywords: *concrete, pervious concrete, run off, water treatment, road pavement*

1. Introduction

"Pervious concrete" is a term used to refer to materials with zero slump in which water penetrates through the pores and recharge underground water resources. This type of concrete has discrete grading include Portland cement, coarse aggregates, a slight (or zero) amount of fine aggregates, water and additives. These materials form a hard concrete with interconnected pores (American Concrete Institute, 2010) [1]. Pervious concrete is of significant importance to the management of surface wastewater and water quality. Engineers have found out that run-offs have the potential for affecting groundwater resources and water resources. As the residential land use expands, the impervious area increases. As a result, the volume of run-offs also escalates and leads to flooding and erosions of the downstream edges. Pervious concrete pavement (PCP) not only reduces the effect of land development and thus diminishes the amount of run-offs, but also protects water resources (American Concrete Institute, 2010) [1].Having applied PCP is one of the best management practices (BMP) recommended by the Environmental Protection Agency (EPA) (Tennis et al., 2004) [3]. The most important issue from the viewpoint of a pavement engineer is how to reduce the volume of run-offs and improve the safety of roads (Water Environment Research Foundation, 1999) [4]. Moreover, PCP has other advantages such as reducing the noise, minimizing the heat, protecting native ecosystems, and protecting the growth of trees. An appropriate structural and drainage design of PCP can reduce the need for drainage facilities such as sewage pipeline systems and surface wastewater ponds and subsequent protections (such as preventing drowning, etc.) as well as legal problems for the owners or developers of land. However, PCP has a few disadvantages that should be taken into account including clogging, low strength, high rate of ravelling, susceptibility to freeze-thaw damage specifically in cold climates. Previous concrete has constantly been referred to as one of the best solutions for watercourse management, and so a number of studies have focused on this type of concrete. Several researchers (Tyner, Wright, Dobs, 2009) [5] have studied the permeability of previous concrete, although their efforts focused on variations in concrete permeability rate with respect to subgrade. Coughlin et al. (Coughlin, J., Campbell, C., and Mays, D., 2012) [6] have also conducted a number of research studies about previous concrete permeability. Their main focus has been the clogging effect of sand and clay on permeability. Golroo and Tighe[7] carried out a number of studies on previous concrete permeability rate and its vulnerability regarding freeze-thaw damage. Having reviewed several research studies in the field of pervious concrete pavement, there is still a big gap in modelling the performance of this pavement in terms of its permeability. The main aim of this paper is to monitor and test the permeability rate of pervious concrete pavement after its installation and over its initial life span. The ultimate goal of this ongoing research is to provide a comprehensive permeability rate model depicting the pattern of decreasing this rate during life cycle of pervious concrete pavement. The scope of this model is limited to light duty applications such as walkways to bike path excluding heavy vehicle loading such as streets or highways. In terms of structure design, it is a common medium thick layer (15 cm deep). Finally, the environmental condition is considered as a region with a medium precipitation and a few freeze-thaw cycles.

2. Research Methodology

After literature review, it was concluded that the permeability rate modeling is still lacking. So, as a part of on-going research on pervious concrete pavement performance, its permeability is studied. For this purpose, a slab which was designed and placed at the campus of Amirkabir University of Technology, as a symbol of sustainability with a tree planted in the middle (Fig. 1), was selected as an appropriate location for executing the field study.

Fig. 1: pervious concrete pavement slab

A permeameter was designed and built for this purpose with three different cylinders on top of each other as illustrated in Fig. 2. Each cylinder is tightly stick to the adjacent one and sealed. A measure is stick to each cylinder to be able to read the falling head of water in each cylinder. The whole apparatus was pushed hardly on the slab surface along with putty on the edge of the bottom cylinder to ensure that water is only percolated along the vertical direction not distributed on vertical directions on the surface.

Fig. 2: A Gilson device built for measuring permeability.

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In order to carry out the permeability test on the slab, four spots were marked on corners of the slab as shown in Fig. 3. Each spot was tested using the apparatus illustrated before on weekly basis and each test was replicated three times. The time interval considered between each consecutive replicate was changed on purpose to study the effect of presence of water in the structure of pervious concrete pavement on its permeability.

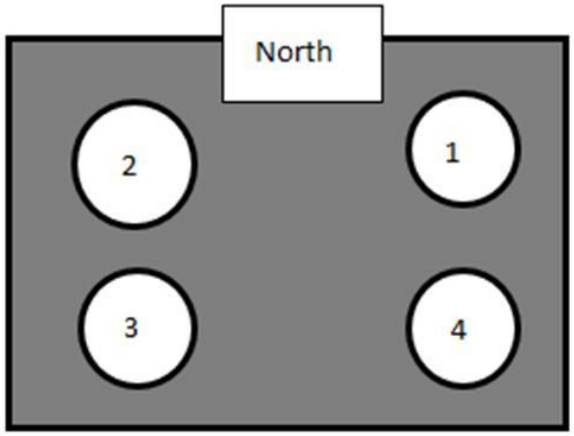

Fig. 3: Testing spots on the slab

The tests were conducted by pouring a high volume of water in the apparatus and waiting till the falling level of water moving slowly and smoothly (not with high fluctuation) to be able to read the falling head of water in a specific time span. Then, the Darcy equation as stated below was used to calculate the permeability rate.

$$K = \frac{a.L}{T.A}\ln\left(\frac{H1}{H2}\right)$$

Where:

K is the coefficient of permeability, cm/sec

a is the inside cross-sectional area of the permeameter A
is a surface of slab through which water is penetrating L
is the thickness of the dahl of previous concrete layer T
is the elapsed time between h1 and h2

H1 is the initial head

H2 is the final head

3. Result

The preliminary results have been obtained from permeability tests following the instruction described above since the slab was placed. The permeability rates presented in Table 1is the average of three replicates measured on the basis of millimetre per second.

TABLE I: permeability tests

Weeks	Permeability(mm/sec)
1	21.1
2	20.6
3	20.1
4	19.8
5	19.6
6	19.5
7	19.4
16	11.7

Fig. 4 clearly depicts the trend of permeability rate decrease over time. As it is expected, during the first few weeks after installation the rate of decrease is slight and afterwards it became more extensive. However, it is still highly permeable during high volume precipitation as it happen a few months ago.

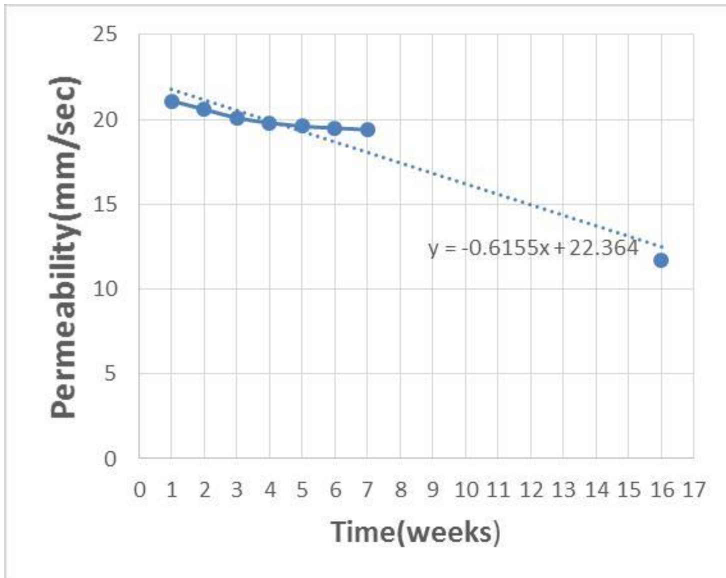

Fig. 4: Permeability rate model

Fig. 4 depicts the slow decrease of permeability rate over the early stages of pervious concrete pavement. It perfectly expresses the model of permeability degradation during initial ages of this kind of pavement. The porous structure of the pervious concrete pavement was fully/partially clogged after several months of its application, so that it caused decreasing in the permeability rate. A routine maintenance plan is of significant importance to be able to maintain the permeability rate at an adequate level. This plan could encompass vacuuming, water pressure, and air blowing.

It is worth mentioning that to study the effect of time interval between tests on permeability rate reduction, the permeability tests were performed on each spot three times with three time intervals: 1, 3 and 5 minutes. This was considered to examine the effect of time and complete penetration of water inside concrete. Results from this experiment indicate that in 1-minute intervals, the permeability rate is influenced by previous steps that is since water has not yet completely penetrated to below layers, pores might have been filled by water. Therefore, water penetration rate is consequently decreased in the subsequent replace, while it is expected that the permeability rates of each spots become almost identical. In 5-minute intervals, the rate of decrease between consecutive replicates is negligible which makes logical sense. It shows that this interval is to some extent adequate for water penetration (Fig. 5, table 2).

TABLE II: sixteenth week data

Averages			**Test Data**								
5 min	**3 min**	**1min**	**5 minute gap**			**3 minute gap**			**1 minute gap**		
			k3	k2	k1	k3	k2	k1	k3	k2	k1
15.30702	15.57611	15.77889	14.26019	14.69199	15.25796	14.72543	15.12714	16.07964	14.71427	15.93442	16.68798
14.12317	14.41452	15.09938	13.4034	13.95264	14.13556	13.46851	13.69663	14.14586	14.52704	14.57066	16.20043
5.412052	6.045939	6.73397	4.394955	4.498869	4.40593	5.161734	5.299869	5.304215	5.632072	7.201529	7.368307
9.759147	10.57938	11.98734	9.708915	9.598477	8.394516	7.911994	8.629667	9.570079	11.07769	11.09035	13.79397

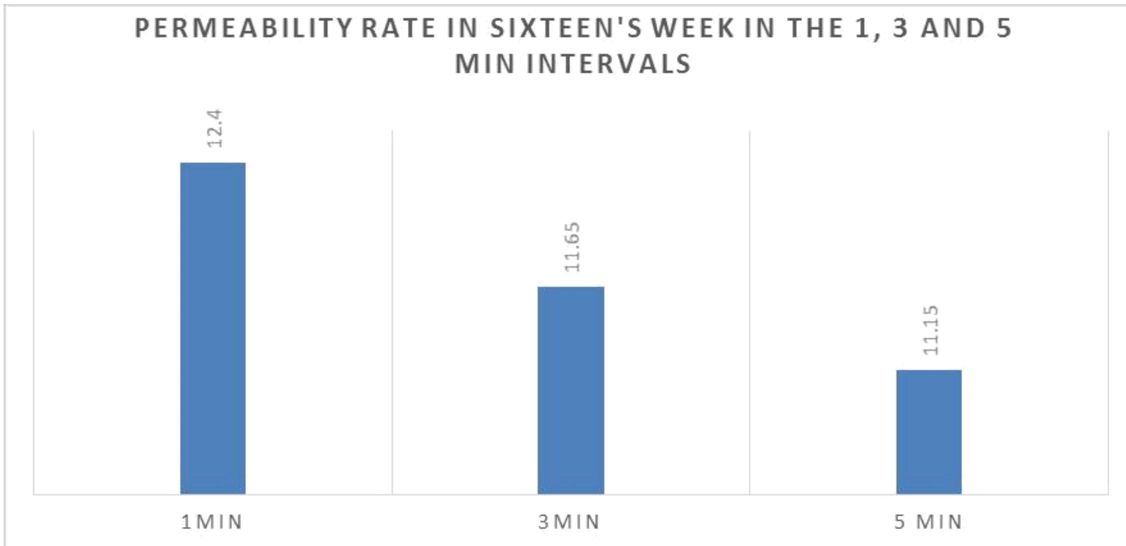

Fig. 5: Variations of permeability rate in the 1, 3 and 5 min intervals

4. Conclusion

Pervious concrete is recently employed over a wide range of application not only in building structure but also in pavement. It has several advantages related to sustainability i.e., recharging underground water, lowering water pollution, increasing traffic safety, etc. However, one the major concern about this pavement is the clogging issue. This paper successfully fulfilled the primarily investigation on pervious concrete pavement permeability rate trend over its initial stages of life. The following achievements have been gained:

1. Permeability rate is slowly decreases during the early ages of pervious concrete pavement, while the trend becomes sharper after a few months.

2. Permeability test replications on a time interval of five minutes or more is on the safe side with regards to providing almost similar results and deducing systematic errors.

3. The main reason for decline in permeability rate is clogging over time. That is due to the dust and dirt brought by wind, passing vehicles and pedestrians enter the pores of pervious concrete pavement and block its pores over time.

5. Acknowledgment

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6. References

[1] "Report on Pervious Concrete". American Concrete Institute. 2010.ISBN 9780870313646. Report No. 522R-10.

[2] "Report on Pervious Concrete". American Concrete Institute. 2010.ISBN 9780870313646. Report No. 522R-10.

[3] Leming, M. L., H. R. Malcom, and P. D. Tennis. 2007. Hydrologic Design of Pervious Concrete. Engineering Bulletin 303. Portland Cement Association, Skokie, IL, and National Ready Mixed Concrete Association, Silver Spring, MD.

[4] "Storm Water Technology Fact Sheet: Porous Pavement." United States Environmental Protection Agency, EPA 832-F-99-023, September 1999.

[5] J.S. Tyner , W.C. Wright , P.A. Dobbs.2009. Increasing exfiltration from pervious concrete and temperature monitoring

[6] Coughlin, J., Campbell, C., and Mays, D. (2012). "Infiltration and Clogging by Sand and Clay in a Pervious Concrete Pavement System." J. Hydrol. Eng http://dx.doi.org/10.1061/(asce)he.1943-5584.0000424

[7] Golroo A.Tigh S.L Alternative modeling framework for pervious concrete pavement condition analysis