Acta Polytechnica CTU Proceedings **33**:188–192, 2022
https://doi.org/10.14311/APP.2022.33.0188

BENEFITS OF PERVIOUS CONCRETE FOR URBANIZED HABITATS

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Abstract.

Pervious (draining) concrete is a new generation concrete which, for its structure, allows rainwater to enter the subsoil and at the same time is determining the final surface without the need for any additional layer. Pervious concrete allows to drain off up to 95 % of precipitation, which represents a significant contribution to ecology and sustainability. Therefore, its use is particularly suitable in city parks, bike paths, in the vicinity of apartment buildings, swimming pools and parking lots. Rainwater is not purposelessly be drained by the city sewer system, but it is absorbed directly in place and contributing to the environmental improvement of the urban habitat (replenishment of groundwater supplies, water for roots of plants and trees, reduction of the thermal island of the city, etc.). Unlike prefabricated paving blocks (interlocking and flat paving), pervious concrete makes it possible to realize structured and complex shapes of finished surfaces without the need for laborious cutting, waste, dust and with generally faster laying. This paper summarizes the current achievements within the Buzzi Unicem Group and the use of pervious concrete in the Czech and Slovak Republic.

Keywords: Environment, pervious, ready mix, water.

1. Introduction

Continuous expansion of impervious materials in construction (as asphalt and concrete) and agricultural cultivation prevent rain water infiltration into the soil. The logical outcome is the decline of the level of underground water. From the natural ecosystem prevails evaporation of water (72 %) over the drain and infiltration, while in the case of urban agglomerations is the opposite, thus draining is prevalent (54 %) upon evaporation and infiltration of water. There is a need to intensify efforts for the purpose of creating systems of water management in the civil engineering. And one of the instruments is pervious concrete, which gives a possibility not to transport water into sewage system, but to soak in a given place and environmentally contributes to the improve the urban environment (refill reserves of underground water, water for the roots of plants and trees, reduce the heat of city islands, etc.

2. Pervious concrete

Pervious concrete has been used in different variants since the 1980s, mainly in the USA, Japan and the Nordic countries (Finland). Pervious concrete has so far been successfully applied mainly on less frequented roads, car parks, sidewalks, courtyards, access roads, etc. [1, 2]. In the Czech Republic, the production of pervious concrete is still in its infancy, including valid legislation, standards and technical regulations. Currently, the American test method ASTM C 1701, which solves and describes the rate of water infiltration into permeable concrete, is used to test the drainage ability of concrete. ZAPA DROP is one of the pervious concrete material in Czech Republic that can be used not only on the base layers, but mainly on the final surface layers, also in various color variants using mineral pigments, with natural or crushed aggregates.

In technical terminology, it is necessary to distinguish between pervious concrete and drainage concrete. Drainage concrete is used mainly as a simple base layer part of the structure, pervious concrete instead, must be considered much more important. It is not just one layer, but multilayer structure with high capability to drain water. To reach all these expected performances we need to observe the technological principles of laying or keeping thicknesses of the embankment of the underlying layers. Thus, porosity values are therefore essential for the liquid to pass through this pervious concrete. The effective void content for a sufficient water permeability is between 15 - 30 %. The gaps in the structure of concrete have an average diameter from 1 to 8 mm. The volumetric weight of pervious concrete, which is normally approximately 70 % compared to conventional concrete, is closely connected to its porosity. The water flow through pervious concrete is usually about 0.34 cm/s, which is 200 l/m^2/min (but in some cases much more, depending on the maximus diameter of aggregate used).

3. Raw materials

Production of pervious concrete is obtained with the same raw materials used in ordinary concrete, but with the exclusion of fine aggregates. The grading of aggregates has a significant effect on the hardened pervious concrete strength results [3]. The grading of coarse aggregates is calculated very precisely in order to improve the physical and mechanical parameters. Like in ordinary concrete, Portland cement or blended cements as well, can be used as a binder in a pervious concrete composition. Accurate dosing of water and cement is used to form a cementitious paste which perfectly envelops the coarse aggregates, creating a system of interconnected cavities which are highly water permeable. Normally in pervious concrete, we use retardants and VMA stabilizers chemical admixtures.

4. Application and use of pervious concrete

To design pervious concrete structures for parking lots or roads it is necessary to avoid the use any kind of absorbing and frosty material. Pervious concrete ZAPA DROP (which is the commercial name of ZAPA beton portfolio) can be delivered to construction sites by standard open dumpers or with concrete truck mixers. Pervious concrete is produced in S1 consistency (according to EN 12350-2 Testing of fresh concrete - Part 2: Slump test) and for its laying a finisher machine is used. Excessive compaction of pervious concrete results in higher compressive strength but lower porosity (and thus lower permeability) [4]. The base layer must be capable to drain off the infiltrated rain water (in some cases drainage pipes is desirable).

A pervious concrete is designed with a low water-cement ratio [5], therefore, in order to allow full hydration of the cement, it is necessary to protect its surface covering it with nylon foils or paraffin spray. It is strongly suggested to avoid excessive drying of the structure surface for at least a minimum period of 48 hours after the laying and follow standard procedures of curing.

Pervious concrete naturally helps water to reach ground water reserve, contributes to the growth of surrounding vegetation and contributes to decrease contaminants such as hydrocarbons which, on the contrary, are present on asphalt surfaces [6].

The porous surface of pervious concrete can significantly reduce the effect of the urban thermal island, which shows noticeably higher summer temperatures than its surroundings. The cooling effect is mainly due to the absorption of huge evaporative heat when moisture evaporates under the porous concrete surface. In addition roads casted with pervious concrete demonstrate their ability to increase surface friction and thereby reduce the risk of aquaplaning and tires noise up to 8 decibels [7].

5. Benefits of using pervious concrete

- No limitation of shape, no waste of trimming such as with interlocking pavement;
- Open possibility to choose any color and size of used aggregate;
- Significantly higher infiltration ratio than interlocking pavers;
- Fast drainage of large amounts of water;
- Less susceptibility to icing due to drainage of surface water;
- Usage of natural aggregates - pleasant for barefoot, ideal for swimming pools, terraces and gardens;
- Use of crushed aggregates - better anti-slip properties, ideal for roads;
- Minimal shrinkage which eliminates the use of dilatation joints.

6. Experimental setting of pervious concrete

The aim of the experiment was to verify the properties of pervious concrete, including the its production, transportation and feeding of finisher at the jobsite. As well the time of fresh concrete setting and verifying properties of hardened pervious concrete.

During this experiment we tested pervious concrete with different size of aggregates: $D_{max} = 8$ mm and $D_{max} = 16$ mm.

During the casting of ZAPA DROP concrete samples were taken to determine:

- Density of concrete in fresh and hardened state according to EN 12350-6 Testing fresh concrete - Part 6: Density and according to EN 12390-7 Testing hardened concrete - Part 7: Density of hardened concrete;
- Concrete strength according to EN 12390-3 Testing hardened concrete - Part 3: Strength of test specimens (test specimens of dimensions $150 \times 150 \times 150$ mm;
- Flexural tensile strength according to ČSN EN 12390-5 Testing hardened concrete - Part 5: Tensile bending strength of test specimens (test specimens of dimensions $100 \times 100 \times 400$ mm);
- Frost resistance according to ČSN 73 1322 Determination of frost resistance of concrete (test specimens of dimensions $100 \times 100 \times 400$ mm;
- Resistance to chemical and de-icing substances according to ČSN 731326 -Z1, Determination of resistance of cement concrete surface to water and chemical de-icing substances (test specimens of dimensions $150 \times 150 \times 150$ mm).

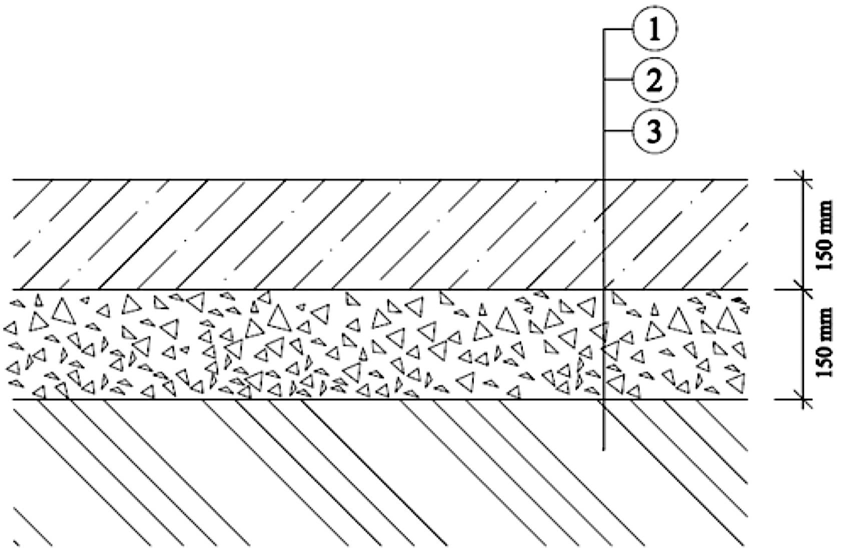

Figure 1. Subsoil composition.

Figure 2. Finisher machine.

After 24 hours all specimens were demolded and stored in laboratory at 20 ± 5 °C and RH 40 to 60 % for 28 days.

Fresh concrete density with D_{max} = 8 mm was 2150 kg/m^3, while with D_{max} = 16 mm was 2080 kg/m3. Hardened concrete density with D_{max} = 8 mm was lower than 0.3 % (compare to the fresh density), while with D_{max} = 16 mm did not differ.

Compressive strength with D_{max} = 8 mm reached 38.4 MPa, while with D_{max} = 16 mm the compressive strength was lower then 30%, due to bigger size of air pores.

Flexural tensile strength of concrete with D_{max} = 8 mm was 3.9 MPa, while with D_{max} = 16 mm was recorded a value lower that 30%, in line what recorded with the compressive strength.

Test of resistance to chemical de-icing agents appears to be highly problematic due to the porous structure of the concrete surface. So it is necessary to continue the research and define new methodologies to perform such test.

The subsoil under pervious concrete was sufficiently compacted by means of a cylinder with subsoil composition, see Figure 1.

1. Pervious concrete D_{max} = 8 mm, thickness 150 mm.
2. Aggregate crushed D_{max} = 16 mm, thickness 150 mm.
3. Compacted soil.

For better stability and water retention it is necessary to have below the pervious concrete a compacted crushed stone layer. In case of greater demand of water retention capacity it is necessary to design a layer thicker than 200 or 300 mm. After compaction, the deformation modulus Edef$_2$ of substrate should be more than 50 MPa but to ensure adequate stability deformation modulus Edef$_2$ of the substrate must be bigger than 30 MPa.

This machine work by pouring material into the so-called basket. At the bottom of the basket are usually

Figure 3. Laying down of pervious concrete.

Figure 4. Detail of pervious concrete surface with $D_{max} = 8$ mm.

Figure 5. Detail of pervious concrete surface with $D_{max} = 16$ mm.

two belts in the shape of a ladder, which convey the material in front of the smoothing bar (iron). With the transverse helix this material reaches the entire span of the screed. Then the material is placed between the substrate and the screed, which ensure the primary compaction of the material an even distribution of the material on the substrate. The working span of the machine is always adjustable thanks to the telescopic smoothing bar [8].

Pervious concrete placement seems to be very suitable with a finisher machine. The finisher machine smoothly places concrete in plane without using vibration. The final surface was then rolled without the use of trowels in order not to close the porous surface of the pervious concrete. Finished concrete surface has been treated with a film-forming CMD set against evaporation to reduce the loss of moisture during the process of maturation. This material forms a thin film against evaporation, which protects the concrete surface from rapid drying due to sun and wind and prevents the formation of micro-cracks due to plastic shrinkage.

7. Conclusion

All the monitored parameters of concrete in fresh and hardened condition, show the most suitable to use the $4-8$ mm aggregate fraction, also due to the fact that the resulting surface had the best walking and "traffic" properties and is therefore suitable for use such as bike paths, sidewalks, park paths, etc. As part of the laying of water-permeable concrete, the use of a paver with subsequent rolling of the concrete surface has proved most successful. This is closely related to the consistency of the concrete mix. The more fluid the mixture is, the better the physical and mechanical parameters, but there is a lower the water permeability of the concrete. Therefore, a moist mixture in the consistency S1 with a water cement ratio of $0.2-0.3$ seems to be the most suitable. Due to the low water content, shrinkage is eliminated and thus the formation of cracks in the cement matrix. Further research will monitor the use of plasticizers to reduce the amount of recipe water, as well as the use of air-entrained agents to improve frost resistance and monitor the effects on compressive strength. Further measurements and research will take place on the laid surface made of water-permeable concrete, followed by tests of the water-permeability of concrete over time and under different climatic conditions.

Next monitored parameter was the mixing time of fresh concrete in the agitator that for the production of this type of concrete it is suitable to set a longer mixing time for homogeneous mixing of the concrete, due to the small amount of water. A longer mixing time is also necessary for sufficient coating of the aggregate with cement paste, which also affects the resulting physical and mechanical parameters of the hardened concrete.

Water-permeable concrete with a correctly designed composition of the formation has a positive effect on ecology and the environment only by supplementing the amount of groundwater thanks to its water permeability. Furthermore, thanks to its properties, it improves safety for vehicles and pedestrians, especially in the winter months, when there will be no water on the surface, thus eliminating skidding of vehicles or slipping of pedestrians. One undisputed advantage of water-permeable concretes over the use of asphalt should be mentioned, and that is a light gray color that reflects more light from the surface, so there is no need for such strong artificial lighting around water-permeable concrete, which has a double effect on energy savings.

The development of water-permeable concrete in the country is still at the beginning. Although research is progressing relatively quickly, many problematic issues related to this material still need to be addressed, so that it can be used in different climatic conditions and can successfully face strong competition from traditional concrete or the use of asphalt.

References

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

[2] Spragues' Ready Mix Concrete, Pervious Ready Mix Concrete, 2015. Srmconcrete.com.

[3] J. T. Kevern, V. R. Schaefer, K. Wang. Mixture Proportion Development and Performance Evaluation of Pervious Concrete for Overlay Applications. *ACI Materials Journal* **108**(4), 2011. https://doi.org/10.14359/51683117.

[4] M. T. Suleiman, J. Kevern, V. R. Schaefer, et al. Effect of Compaction Energy on Pervious Concrete Properties. *Concrete Technology Forum-Focus on Pervious Concrete*, National Ready Mix Concrete Association, 2006.

[5] D. Desai. Pervious Concrete - Effect of Material Proportions on Porosity. Civil Engineering Portal, 2011. https://www.engineeringcivil.com/pervious-concrete-effect-of-material-proportions-on-porosity.html.

[6] E. Ashley. Using Pervious Concrete to Achieve LEED Points (PDF). National Ready Mixed Concrete Association, 2008. https://www.perviouspavement.org/downloads/LEED_PointsAshley.pdf.

[7] EPA. Reducing Urban Heat Islands: Compendium of Strategies, 2005. https://www.epa.gov/sites/production/files/2014-08/documents/coolpavescompendium_ch5.pdf.

[8] Finišer, 2017. https://cs.wikipedia.org/wiki/Finišer.