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ANALYSIS OF INFLUENCE OF PRECIPITAION ON PERVIOUS CONCRETE ROAD SURFACE

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Abstract

Aim of this paper is defining of the pervious concrete road surface in order to completely eliminate the need for atmospheric sewerage system. In this paper a hydrological modeling of pervious concrete road surface system has been carried out in EPA SWMM 5.1 software. Based on the formed dynamic model it has been examined whether it is possible to completely eliminate the need for atmospheric sewerage system for adopted thickness of pervious concrete road surface and soil characteristics. For drainage area the whole parking area together with communications, parking lots and pedestrian pavement have been adopted. For the purpose of analysis in the model a cylindrical atmospheric sewerage system of closed type has been adopted with the alignment in centre line of the road. A conclusion has been derived that it is possible to completely eliminate the need for atmospheric sewerage system considering the negligible amount of water achieved inside of adopted atmospheric sewerage system.

Key words

Atmospheric sewerage system, EP SWMM 5.1, pervious concrete, road surface

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1 INTRODUCTION

Lately the world is facing a growing number of citizens, which is leading to higher energy consumption, higher natural resources utilization and the mass urbanization of the area. In particular, the problem of area urbanization is reflected in transformation of green areas into impermeable surfaces such as roads, parking space and plateaus. These impermeable surfaces have direct influence on increased amount of water in drainage basins. As a result of increase in surface runoff natural disasters of huge proportions, such as floods and soil erosion are happening more frequently.

One of alternatives to deal with threat of floods is to use a pervious road surface as ecological material for the construction of parking space, access roads and plateaus in Republic of Serbia, which enables the storm water to be gradually infiltrated into soil instead of being conducted with sewage tubes to drainage basins and causing water effusion in basins, soil erosion etc. Mass urbanization certainly does not benefit the fight against floods but it is an inevitable part of today. Increase in urbanization creates the need for construction of roads pavements, parking space, plateaus and buildings. All of these surfaces are often largely impermeable, preventing the natural drainage of storm water and disturbing the natural cycle. In rural areas 95% of water is naturally infiltrated into soil and 5% ends up in drainage basins while in big cities only 5% of water manages to be infiltrated into soil and 95% ends up in storm water drainage basins [1].

With the growing need for environmental and sustainable building drainage concrete is emerging as an economically and environmentally friendly alternative for drainage of rainwater and snow. A reason for selection of the drainage concrete for making pervious pavement lies in the fact that we are witnessing large-scale climate changes. Consequences of these climate changes had been experienced in 2014, when Serbia was afflicted by huge floods that have left catastrophic consequences in both economic and social terms [2]. The fear of reliving the same has risen awareness of people about efficient drainage of excess water from impermeable surface and reducing the risk of floods.

Name of drainage concrete comes from the fact that it has a large proportion of the pores which is the result of complete or substantial absence of aggregates of fine particles in its composition. The porosity of the drainage concrete varies between 15% and 35% [3-6]. The biggest drawback of this material is its reduced strength, which is a direct result of high porosity. Common values for the permeability coefficient are in the range of 0.2 cm/s to 0.5 cm/s. This feature of drainage concrete may completely eliminate the need for the construction of the drainage system [7-9].

In this paper a hydrological modelling of pervious concrete road surface system has been carried out in EPA SWMM 5.1 software. Based on the formed dynamic model it has been examined whether it is possible to completely eliminate the need for atmospheric sewerage system for adopted thickness of pervious concrete road surface and soil characteristics.

2 RESULTS AND DISCUSSION

2.1 Hydrological modelling of pervious concrete road surface

When designing pervious pavement, it is necessary to determine whether the location meets the basic requirements for reasonable use of this system. The main condition that must be fulfilled in order to eliminate the storm sewerage system is a good soil permeability. Usually, pervious pavement is reasonable on the ground which is made up of sand, silty sand or sandy silt. Geotechnical study has shown that the soil of the future parking space JP "Sports Business Center Vojvodina" in Novi Sad, which is the subject matter, is composed mainly of sandy silt, sand and silty sand. Results of classifications of soil considering the depth of trial pit are shown in Tab. 1.

Tab. 1: Soil classification considering the depth of trial pit

Trial pit	Depth [m]	soil classification to SRPS EN ISO 14688-2
SJ-1	3.00	saSi-sandy silt
SJ-2	0.90	Sa-sand
	3.00	saSi-sandy silt
SJ-3	3.00	siSa-silty sand
	0.90-1.50	saSi-sandy silt

In Tab. 2 depths of trial pits as well as depths of water occurrence (WO) and saturation line (SL) are shown on each study cite. Given the fact that the level of groundwater in the soil of future parking is 2 or even more meter deep, there is no risk of interference with water infiltration due to high groundwater levels.

Tab. 2: SL data

Trial pit no.	Depth [m]	WO [m]	SL [m]
SJ-1	3.00	not registered	not registered
SJ-2	3.00	not registered	not registered
SJ-3	3.00	-2.50	-2.00

Since all prerequisites for design of pervious road surface system are fulfilled, thickness of drainage concrete layer as well as blanket course made of crushed stone aggregate are adopted. Thickness of drainage concrete layer is determined based on estimated load of road surface and it is 20cm for road surface and 15cm for pedestrian pavements. Adopted thickness of blanket course is 35cm for road surface and 30cm for pedestrian pavements. For calculation of rain amount the data from meteorological stations in Rimski Sancevi has been used. For parking space it is common to adopt amount of precipitation with a return period of 2 years. Fig. 1 shows cumulative diagram of height of precipitation with a return period of 2 years for duration of 20 minutes.

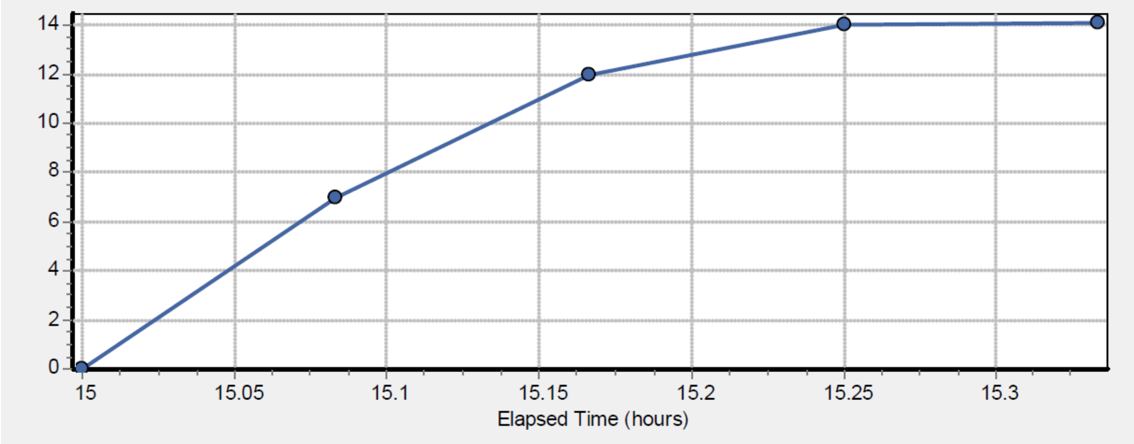

Fig.1: Cumulative diagram of height of precipitation with a return period of 2 years for duration of 20 minutes

Hydrological modelling of pervious concrete road surface system has been carried out in EPA SWMM 5.1 software. This program predicts various hydrological processes which lead to storm water runoff, including water capture and retention of rainfall/runoff using a functional integrated storm drainage. Using dynamic model of simulation of precipitation/runoff amount, it has been examined whether adopted thickness of pervious road surface layers are sufficient to completely eliminate the need for atmospheric sewerage system. The model was created by dividing the map of the studied catchment area into 70 characteristic sub-basins. The catchment area includes the whole parking area together with roads, parking lots and pedestrian pavements. Each sub-basin was formed in order to represent a LID component for itself. LID component was separately defined for pedestrian pavement and roadway since thickness of layers differ in the two cases. A cylindrical atmospheric sewerage system of closed type has been adopted with the alignment in center line of the road. Adopted sewerage system has two branches with total length of 226.6m and a diameter of Ø300. 9 manholes are anticipated and is set that surface runoff (if there is any) drains from pedestrian pavements across parking space and road surface into adopted drains.

2.1 Results analysis

In order to completely eliminate atmospheric sewerage system, the idea is to achieve negligible amount of water when performing simulation of rainfall in the pipes of adopted storm sewerage system. Due to given rain gauges with a two-year rain lasting for 20 minutes, the simulation results showed that the pipes of adopted storm sewerage system were completely empty (Fig. 2) because there was no surface runoff.

Total amount of rain, 14,1mm in height, is functionally stored in predicted tank that is made of layers of pervious pavement. 5.7mm of water will infiltrate into the soil immediately, and the remaining part of the water amount, 8.45mm in height, will be successfully stored in the blanket course and within a period of 48-72 hours will be infiltrated into the soil. The model does not take into account the amount of water that will evaporate. This phenomenon depends on numerous external conditions and it is not easily defined. But in any case, water vapor can only affect the overall reduction of the amount of stored water in the blanket course. Since the protection from floods is a topic to which should be paid a great amount of attention nowadays, behavior of the system for amount of precipitation with return period of 5 years has been examined. Cumulative diagram of the amount of rainfall for rain with a return period of 5 years for a period of 20 minutes is shown in Fig. 3. In this case, adopted pipes of storm sewerage are completely empty.

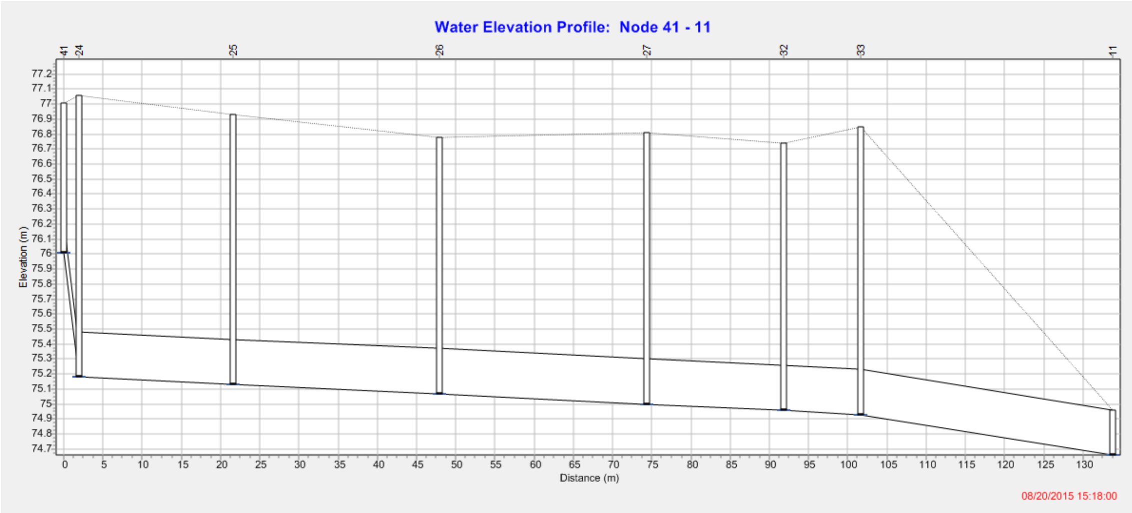

Fig. 2: Front view of atmospheric drainage system pipes for solution with parking area made of drainage concrete

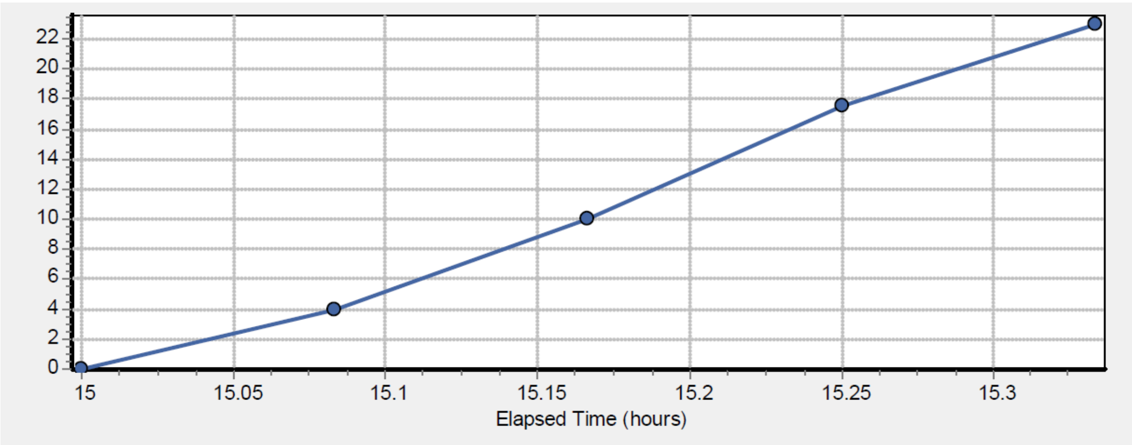

Fig. 3: Cumulative diagram of height of precipitation with a probability of 5 years for duration of 20 minutes

For better insight into influence of pervious road surface use on amount of water in pipes of sewerage system, two more cases have been examined. In the first version, for the same sewerage system and the same catchment area, parameters that correspond to flexible road surface and road surface made of prefabricated concrete elements are adopted. For asphaltic concrete adopted percentage of permeability is 0% and for prefabricated concrete elements adopted percentage of permeability is 40%. Thus defined areas of sub-basins correspond to results in Fig. 4. Water level in adopted pipes is even greater than adopted diameter of pipes Ø300 at one point.

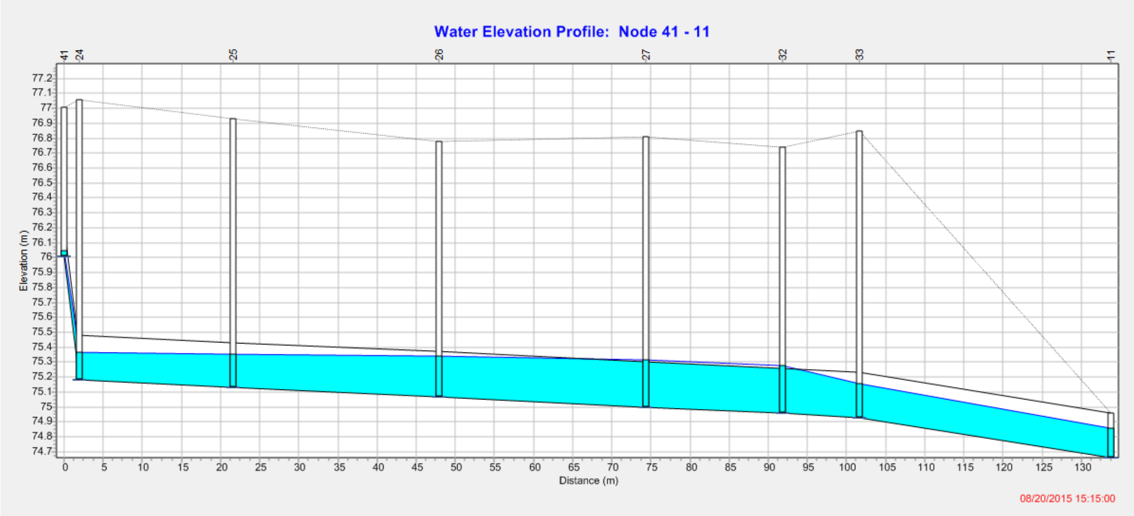

Fig. 4: Water level in pipes for solution with flexible road surface and prefabricated concrete elements

In the second version, flexible road surface has been kept as in the first model but instead of prefabricated concrete elements drainage concrete with LID characteristics has been adopted. Obtained results by rain simulation in Fig. 5 shows much lower water level for the same diameter of pipes and the same route of sewerage system as in the previous case.

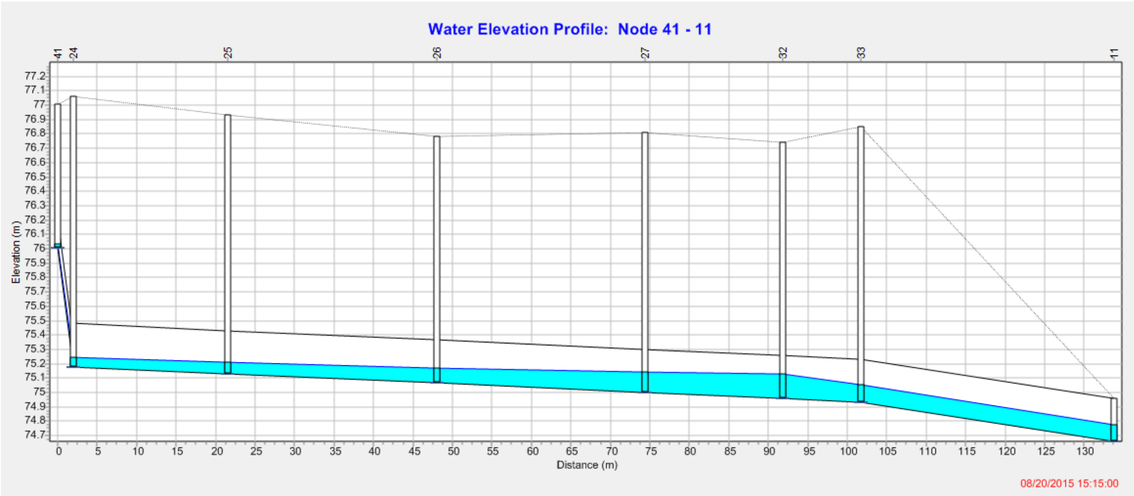

Fig. 5: Water level in pipes for solution with flexible road surface and drainage concrete

3. CONCLUSIONS

We are experiencing great climate changes and extreme weather conditions combined with increasing urbanization of area. As a consequence, green areas as well as permeable surface are reduced meaning that volume of rainwater that needs to be collected by sewerage system is increased.

The solution lies in the use of pervious pavements that have beneficial effects on the environment and a great potential in sustainable construction. With its composition, pervious pavement allows the biodegradation of oil from motor vehicles, water filtration into the soil, it reduces the "heat island" effect, enables undisturbed development of trees in its surroundings, and can greatly influence the reduction of the flood risk. In addition, with pervious pavement there is no need for further development of already complex network of sewerage system.

Based on analyzed models, it has been concluded that with use of pervious concrete road surface it is possible to completely eliminate the need for atmospheric sewerage system. Since the implementation of the drainage concrete does not sufficiently prevail in our region, additional studies are necessary in order to get a better insight into the behaviour of pervious pavement in a long-term period. This region is known for its temperate continental climate with cold winters so further examinations of drainage concrete on frost influence are needed.

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