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A Method to Contrast the Impact of Extreme Precipitation: A Case Study from Central Italy

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Abstract. Climate change, which is affecting all over the world, leads to different impacts on the environment and therefore on human life. One of the most important impact is the increasing of extreme precipitation. Increases in heavy precipitation may not always lead to an increase in total precipitation, over a season or over the year. Heavy precipitations increasing has also been documented even when mean total precipitation decreases. This may occur when the probability of precipitation (the number of events) decreases, or if the shape of the precipitation distribution changes, but this latter situation is less. Some climate models forecast a decrease in moderate rainfall, and an increase in the length of dry periods, which offsets the increased precipitation falling during heavy events. Climate impacts are compounded by urban development, which removes the vegetation and soil that slow and filter water, coming from rainfall. Urban sprawl also increases impervious surfaces, which move water over the land and put them, directly, into receiving lakes, rivers and estuaries. To contrast these negative impacts, a solution may be to limit the use of non-permeable surfaces, like concrete, in the urban areas. In this regard, the authors, as researchers of “Sapienza University of Rome”, are studying the possibility of using, in the parking areas of a central Italian city (Rieti), pavement with “green infrastructure”, that can reduce runoff and flood risks during storms. The construction of the pavement with “green infrastructure”, can first mitigate the effect of exceptional rains, secondly reduce the soil consumption. Permeable, or pervious, pavements reduce runoff by allowing rain and melting snow to infiltrate. A first study of the materials, that can be used as parking paving, has led to estimate a permeability coefficient of $2,70 \cdot 10^{-5} \text{ m.s}^{-1}$. In the case study, object of this paper, the authors have first calculated the area, in square meters, of the municipal parking areas of Rieti city. Secondly, they have valued the possibility of change the concrete pavement, today present in this areas, with a “green infrastructure” pavement, and they have estimated volumes of water that will be infiltrate, in case of extreme precipitations. This estimation was made through the real precipitations data of the last 7 years, measured by the National Hydrographic Service of Italy.

1. Introduction

Climate change, which is affecting all over the world, leads to different impacts on the environment and, as a consequence of it, on human life [1]. Therefore, humanity must be able to respond to these different negative impacts. For decades’ cities and communities have been strategically balanced, competing economics, environmental, and social justice goals [2]. Now there is an increase in the number of problems, but also for the resilience, or the ability to cope with disturbances or changes [3]. Resilience in physics is the ability of a material to absorb a shock without breaking. Specifically, a



"resilient city" is an urban system, that adapts to climate change, and to ongoing global warming, but also to social, cultural, and economic ones. Climate change puts a strain on cities, because it subjects them to extreme events such as the increase in heavy rainfall. It is important to plan and modify cities to make them resilient and, therefore, able to adapt to the changes taking place. In this regard, in 2012, the European Environment Agency published the report "Urban adaptation to climate change in Europe", in this paper it is highlighted that European cities need to improve their climate change resilience [4].

2. Extreme Precipitation Impact in the urban area

One of the most important impact of the climate change is the increasing of extreme precipitation. Increases in heavy precipitation may not always lead to an increase in total precipitation, over a season or over the year. Heavy precipitations increasing has also been documented, even when mean total precipitation decreases [5]. Extreme precipitations are an extraordinary event that consist in precipitation with short duration and strong intensity. This event matches with the increasing of the land consumption, and leads to different negative impacts in the urban areas. Urban areas, in fact, have expanded in recent decades and have led to the removal of the vegetation and soil that slow and filter water, coming from rainfall. Urban sprawl also increases impervious surfaces, which move water over the land and put them, directly, into receiving lakes, rivers and estuaries [6]. Excessive amounts of rainfall cannot drain into the ground, where a high share of the city's area is imperviously sealed and thus generates or worsens flood events [4].

The main effects of the problem above mentioned are:

- Flooding
- Increase of meteoric water management costs
- Reduction of groundwater recharge in waterproofed areas
- Overload of the combined sewage networks and treatment plants (the water overload makes them poorly performing)
- Worsening of the water drained quality, due to the pollutants collected on the surfaces from the extreme rains characterized by short duration
- Change of the microclimate

Greater precipitation threatens water quality and public health by increasing agricultural runoff and causing Combined Sewer Overflows (CSO). Combined sewer systems are designed to collect and treat storm water and wastewater, and during high intensity rainfall events, systems can discharge untreated wastewater into receiving waters [5]. This problem is represented in the following figure 1.

A major strategy for enhancing the sustainability and resilience of cities and communities, in the aim to answer to problems associated with extreme precipitation in urban areas, is the expansion of "green infrastructure" [7]. The European Commission, in fact, encourages green solutions as well, considering green infrastructure as an essential tool for climate change mitigation and adaptation [4].

3. Sustainable water management system: permeable pavement

"Green infrastructure" uses vegetation, soils, and natural processes to manage water and improve urban environment quality. Site-integrated designs manage stormwater onsite with structures that enable infiltration, filtration, storage, and uptake by vegetation structures [6].

Sustainable management systems of meteoric water, which are usually used, are:

- Permeable pavement
- Green roofs
- Surface infiltration systems, such as infiltration basins
- Underground infiltration systems, such as draining trenches
- Combined infiltration systems

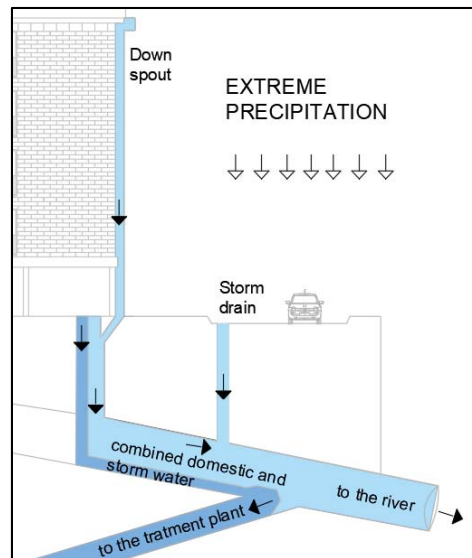


Figure 1. Combined sewer overflows (Modified from C2ES, 2018)

The method, that has been analysed and investigated by the authors, is the permeable pavement system. Permeable, or pervious, pavements reduce runoff by allowing rain water drainage. Pervious asphalt and concrete, interlocking pavers, and plastic grid pavers allow water to seep through the pavement to soil. Permeable pavements can reduce runoff by an estimated 45 to 85 percent [6]. In addition to these functions, draining floors offer numerous design solutions that allow diversifying the urban image, thanks to the variety of materials available on the market and in nature. The size of this system varies depending on the context, the availability of space and of the material used.

Specifically, as part of this research, it has been planned to use draining concrete floors in two municipal parking areas of Rieti city. Permeable paving, pedestrian or driveway, in fact, is not limited to new constructions, but can be also applied for rehabilitations or extraordinary maintenance, thus creating floors that replace waterproof ones [8].

The authors have thought of using the materials "draining concrete block" and "concrete turf grating", described in the Guidelines wrote by the National Association Cementitious Manufacturing Industries of Italy (ASSOBETON). In this Guidelines is reported the experimental plot stratigraphy with the permeable pavement (figure 2), the stratigraphy is the same for both the materials that are hypothesized to use.

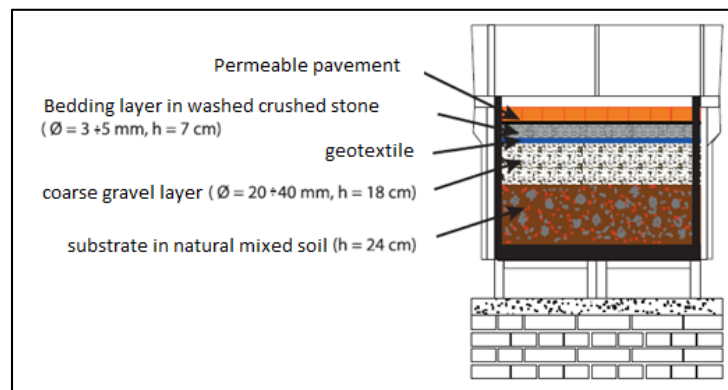


Figure 2 – Experimental plot stratigraphy (ASSOBETON, 2011)

In the guidelines previously cited, it has been determined the permeability of the experimental plot stratigraphy through the test method with infiltrometer. This test has provided, for each pavement, a permeability coefficient of:

$$C_p = 2.70 \cdot 10^{-5} \text{ m/s}$$

4. Results and discussions

As previously explained, the object of this paper is a case study in central Italy, specifically in the city of Rieti. The authors have studied the possibility of using the draining concrete floors, whose characteristics have been exposed in the precedent section, in two municipal parking areas of Rieti city.

At first, the authors have created the drawing of the two municipal parking areas of Rieti in the AutoCAD software, and thus have calculated the available areas, in square meters.

The first parking area, nominated A1, is collocated in a historical area of the city and has an area of 2.685 m² and 53 parking spaces. The second parking area (A2), instead, is of 1.622 m² and it has 95 parking spaces. The two parking areas, drawing with the two permeable pavements hypothesized in this research ("draining concrete block" and "concrete turf grating"), are represented in the following figures 3 and 4.

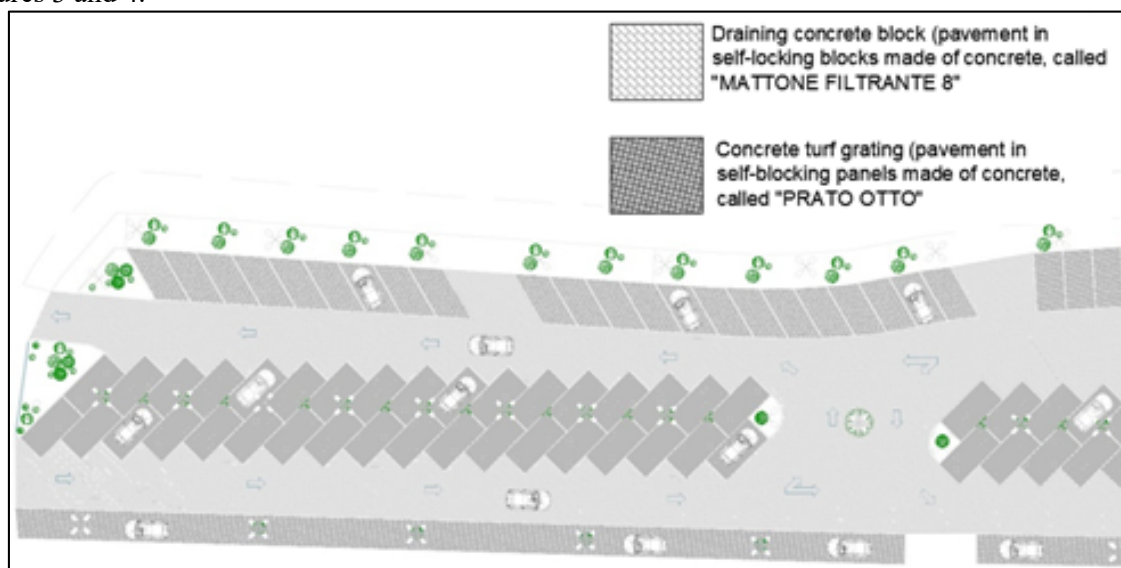


Figure 3 – Drawing of the parking area A1 with the indication of the two types of permeable pavements hypothesized. (Area A1: 2685 m² and n. 53 parking spaces).

Afterwards, we have studied the real precipitations data of the last 7 years, measured by the National Hydrographic Service of Italy at the main Rieti Station Gauge, Velino. Specifically, precipitations of huge intensity and short duration have been taken in account, i.e. the maximum precipitations of 15, 30 and 45 minutes for each year (table 1).

Starting from the value of the permeability coefficient of the materials, which is characteristic for the chosen permeable pavements, given by the producer, the maximum volume of water, that will be infiltrated in the subsoil through the two areas A1 and A2, in case of extreme precipitations (15, 30 and 45 minutes of rain), has been calculated.

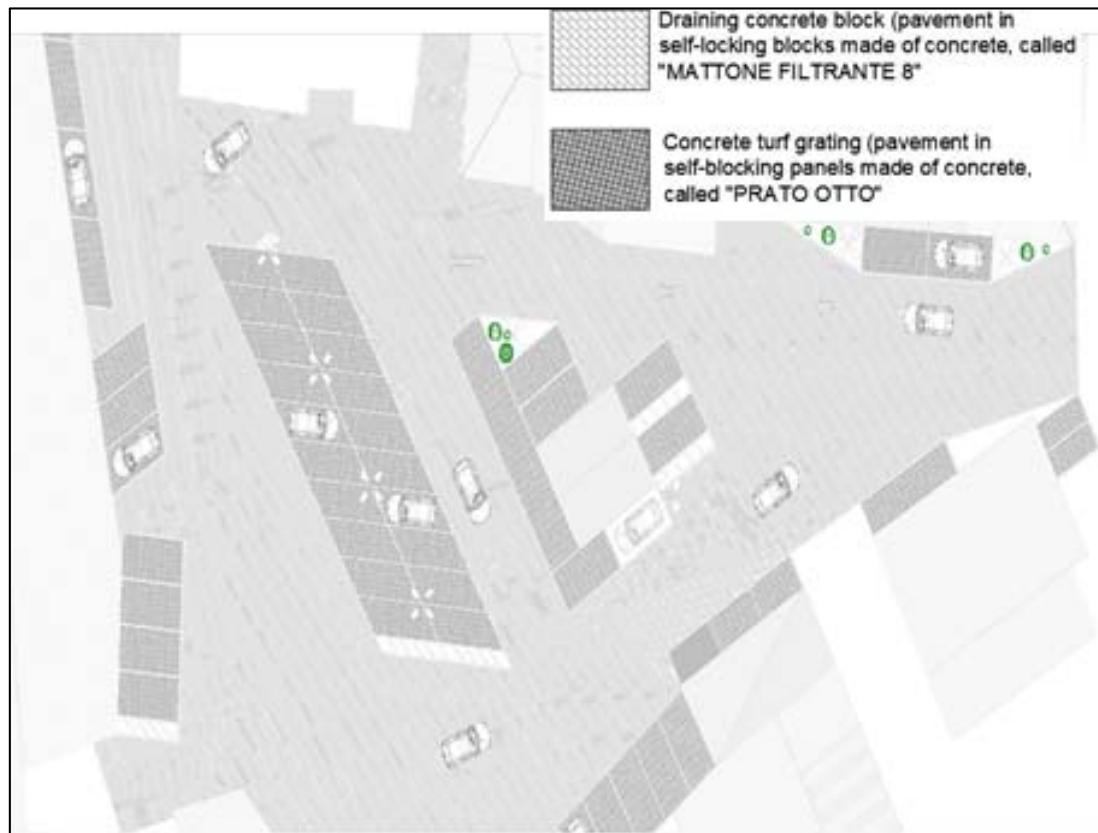


Figure 4 – Drawing of the parking area A2 with the indication of the two types of permeable pavements hypothesized. (Area A2: 1618 m² and 95 parking spaces).

Table 1. Heights of rain precipitations of 15, 30 and 45 minutes, years 2010-2017 (Velino Station, Rieti).

Year	<i>h (mm)</i> <i>15 minutes</i>	<i>h (mm)</i> <i>30 minutes</i>	<i>h (mm)</i> <i>45 minutes</i>
2010	11.8	16.2	17
2011	15.6	24	33.6
2012	27.8	38.6	48.5
2013	24.1	34.8	36.8
2014	19.9	21.7	21.9
2015	12.2	18.7	20.3
2016	12.9	14.2	15.2
2017	14.7	18.8	19.8
Average	17.37	23.37	26.63
Minimum	11.8	14.2	15.2
Maximum	27.8	38.6	48.5

Table 2. Maximum drainable water volume, in the two parking areas A1 and A2.

	<i>15</i> <i>minutes</i>	<i>30</i> <i>minutes</i>	<i>45</i> <i>minutes</i>
V_{A1} (m³)	39.15	78.29	117.44
V_{A2} (m³)	65.25	130.49	195.74

On the second, the volumes relating to the maximum rainfall values in the three time ranges (short duration precipitations), have been calculated. Therefore, these maximum volumes were compared with volumes that the soil system is able to drain, and so the cases in which there would have been runoff have been highlighted, if the permeable pavements have been utilized.

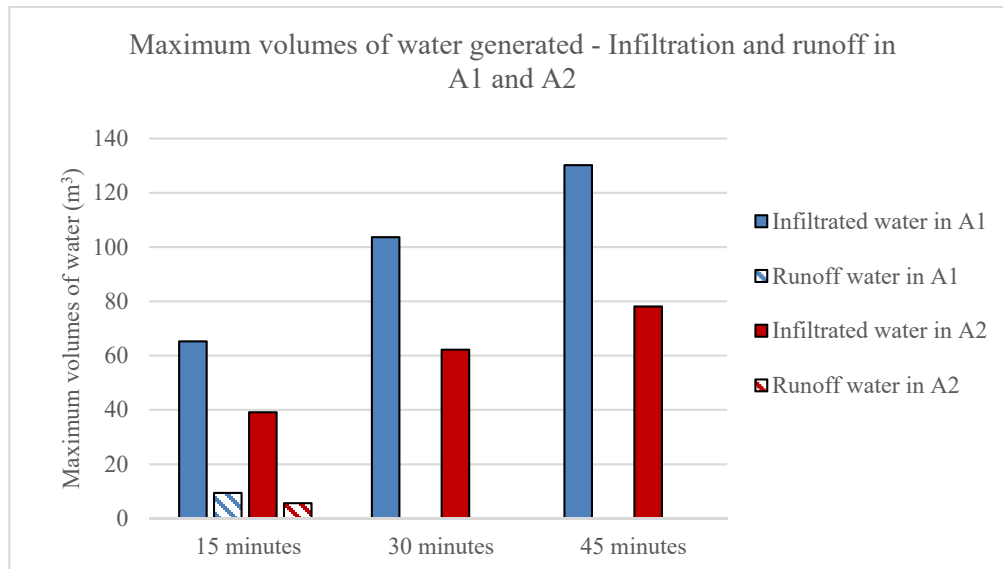


Figure 5 - Volumes of water that can be infiltrated in the parking areas A1 and A2, for maximum water volumes generated by precipitations of short duration and great intensity (2010 - 2017).

In figure 5, we can see that the most critical case for the maximum precipitations previously calculated (short duration and great intensity precipitations), is the one that related to 15 minutes. In this case, in the two parking area of Rieti, there would be runoff of a water part.

The water runoff in the areas A1 and A2, object of this research, there would be only for the maximum value of the 15 minutes' precipitation, in the data of the 7 years that the authors have studied. This is a good result, in fact the permeable pavements can't be infinitely permeable, but these allow to absorb most of the volumes generated by the extreme precipitations.

5. Conclusions

The Climate Change is a growing and contemporary problem. In this paper it has been discussed a method to oppose the extreme precipitations impact in the urban area. Specifically, it has been analysed a case study in central Italy, in the Rieti city, and like the European Commission encourages, the authors have studied the possibility of using green infrastructure in the urban areas.

The authors analysed the rain data provided by National Hydrographic Service of Italy, relating to the Velino Station, and calculated the maximum water volume values for short-term extreme rainfall, i.e. 15, 30 and 45 minutes. These values have been compared with the drainage capacity of the two parking areas, considered in the case study, to define the real efficiency of the permeable pavement (draining concrete floors). The use of the draining concrete floors, in two parking areas of Rieti, leads to a good result. In the two parking areas (A1 and A2), where the authors have designed the permeable pavement, in places where, at now present, there is only water runoff. In the designed solution there would be run off, only when the maximum value of 15 minutes' precipitation happens, referring to data of 7 years of observations. The present research describes that, in an Italian city, the permeable pavements allow to drain most of the volumes generated by the extreme precipitations.

This result comes from use of the permeability data of draining concrete floors, taken from the Guidelines by the National Association of Cementitious Manufacturing Industries of Italy, and through the analysis of real data of extreme precipitations, which affected the area under examination.

Based on the above, permeable paving can be used for rehabilitations or extraordinary maintenance, in urban areas, like parking areas, to build extreme precipitation impact resilience.

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