Laboratory experiments in a large-scale urban drainage physical model considering roofs, streets and drainage system.

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Highlights

- Rainfall-runoff and sewer flow experiments under laboratory conditions in a large-scale facility.
- Free distribution experimental dataset to validate urban drainage models.

Introduction

The development and performance of urban drainage models must be validated by observed data. Experimental data is expensive to obtain, both in field and laboratory campaigns, and its availability is very limited. Datasets obtained in field campaigns usually introduce more uncertainties than laboratory tests. Thereby, experimental results obtained in urban drainage facilities under laboratory conditions are more suitable to assess the numerical performance of numerical models (Naves et al., 2019).
This research presents a set of experimental tests carried out in a new large-scale urban drainage facility to study rainfall-runoff processes on roofs and street surface and sewer network flow. All the information necessary to replicate the experimental tests is provided with a high spatial resolution.

Methodology

Urban drainage facility

The experimental tests were carried out in a large-scale urban drainage facility located at the Hydraulics Laboratory of the Centre of Technological Innovation in Construction and Civil Engineering (CITEEC) of the University of A Coruña (Spain). A conceptual scheme of the facility is shown in Figure 1. The facility represents a T-intersection street of 100 m^2 linked to a sewer system, and it is equipped with a rainfall simulator able to generate spatially homogeneous rainfall intensities of 30, 50 and 80 mm/h. The street consists of two 2.5-m width roadways with a 30-cm width tile pavement located on both sides. The roadways and the pavements are separated by a 6-cm high curb and have 2% and 1% transversal and longitudinal slopes respectively. In addition, four building blocks with ceramic tile roofs and different slopes are located at both sides of the main street (Figure 2a).
The sewer network (Figure 2b) has a principal pipeline along the longitudinal dimension of the facility which consist of four manholes connected by pipes with inner diameter of 240 mm and a slope of 1%. Additionally, a transversal pipe with an inner diameter of 194 mm and a slope of 0.5% intersect the principal pipeline at manhole 3 (MH3). The surface runoff enters the sewer system through four inlets of 0.5 x 0.2 m and a downstream transversal grid of 2.5 x 0.13 m that covers the roadway width. Each inlet is directly connected to the nearest manhole. The water discharge generated by the roofs are conveyed through a semi-circular gutter and caught by four gully pots, one for each roof. The transversal grid and the roof gullies are connected to the manholes by 90 mm PVC conduits. Furthermore, the facility has a pumping system that allows the generation of surface runoff and inflow on the upstream boundary of the roads and pipes, respectively. At the drainage system outlet there is a channel equipped with a triangular weir and a water level sensor.

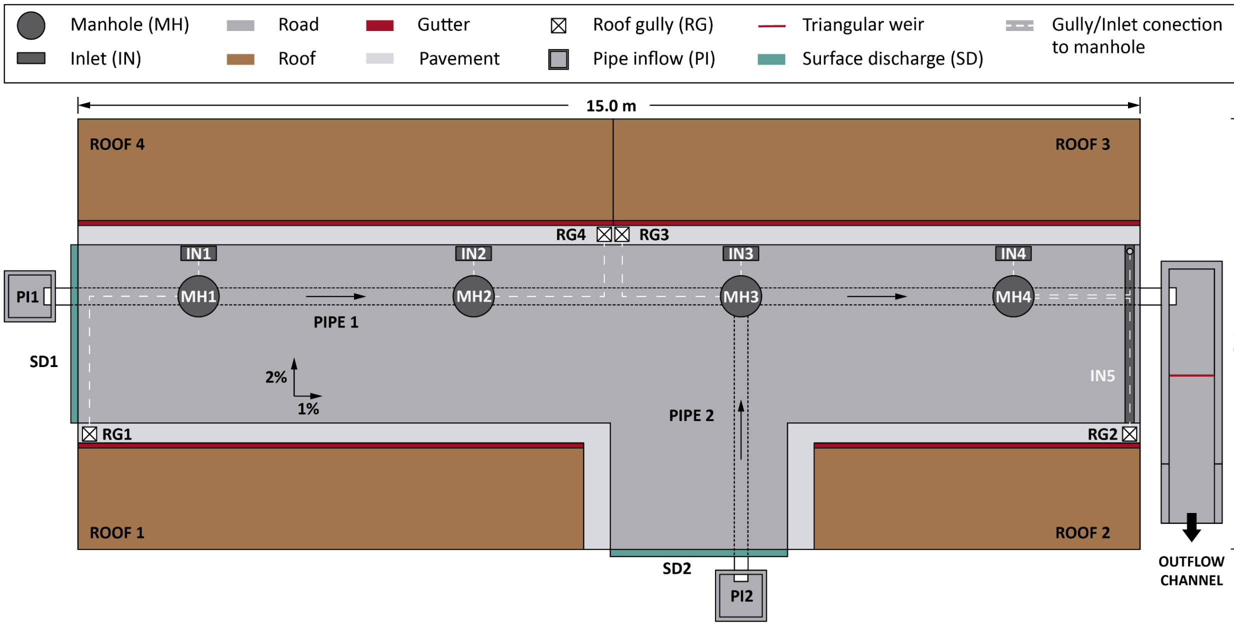

Figure 1. Scheme of the urban drainage facility.

Figure 2. Surface system (a) and sewer network (b) of the urban drainage facility.

Experimental procedure

In order to provide a full experimental data package, the following main tasks were carried out:

(i) Characterization of the rain: A grid of 325 vessels was located over the facility to generate rain intensity maps based on the mass captured by each vessel during a limited period of rainfall. This procedure was replicated for each intensity generated by the rainfall simulation.

(ii) Topographic survey of the surface and sewer networks: A high resolution 3D surface model of the roofs, roads and pavements of the facility was obtained using the Intel® RealSense™ LiDAR Camera L515 sensor and the RecFusion 2.1.0 scanning software. The geometry of the sewer network was obtained using traditional survey methods.

(iii) Experimental tests: First, the discharges generated at the outlet of each roof were measured indirectly by recording the depth increments of a water tank located at the end of each gutter. Then, the flow captured by the inlets was measured using a pre-calibrated triangular weir located at the outlet of the gully pot. The depth at the gully pot was measured with an ultrasonic depth sensor carefully located below the inlet grate. Similarly, the total discharge at the outlet of the sewer system was measured by recording the water level over a triangular weir. In addition, depths at different points of the road surface and pipes were measured. The experiments were carried out for 6 different combinations of rain hyetographs and different combinations of surface runoff inflows.

Results and discussion

High spatially uniform rain maps with mean rain intensities of 30.3, 54.2 and 85.0 mm/h were obtained for each of the three rainfall intensities generated by the simulator. In addition, a high-resolution topography with a spatial resolution of 5 mm was generated (Figure 3a). This resolution is high enough in order to replicate very accurately the overland flow in roofs and in the street surface in a numerical model. Regarding the experimental tests, Figure 3b shows the hydrographs measured at the outlet of roofs, inlets and at the outlet of the whole drainage system for an intermittent rainfall hyetograph of 50 mm/h. It should be noticed that the shape of the individual peaks due to the intermittent rainfall event is not visible at the outlet of the sewer system and thus the impact of roofs and inlets hydrograph shape disappears.

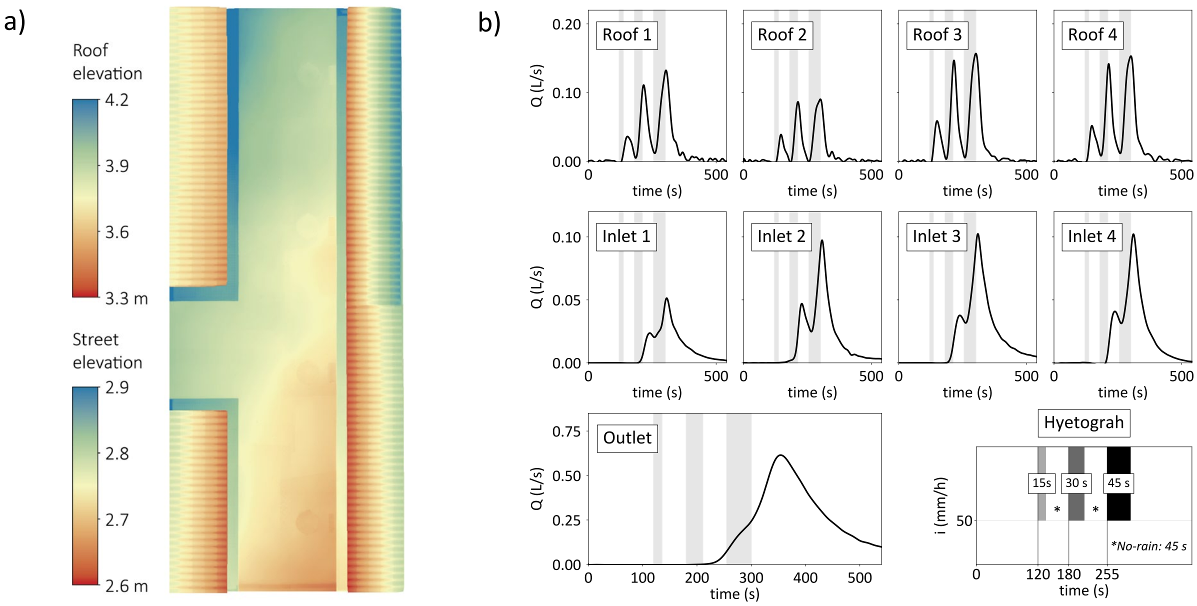

Figure 3. Digital Model Elevation of the facility with 5-mm cell resolution (a) and experimental hydrographs at the outlet of roofs, inlets and at the outlet of the drainage system for an intermittent rainfall hyetograph of 50 mm/h (b).

Conclusions and future work

An experimental campaign in a large-scale urban drainage facility was carried out. The tests considered the surface and sewer network runoff processes that occur during a rainfall event, i.e., the rainfall-runoff transformation, the overland flow and the sewer network flow convey. The research provides to the community an accurate and complete dataset including a high-resolution characterisation of rainfall, geometry and discharge data, suitable to develop, calibrate and validate urban drainage models. Future work includes the performance assessment of the dual urban drainage model Iber-SWMM (Sañudo et al., 2020), using these experimental tests.

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