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ASSESSMENT OF AN ON SITE STORMWATER DETENTION RESERVOIR OPERATION WITH THE VOLUME REQUIRED BY BELO HORIZONTE'S LEGISLATION

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ABSTRACT: This article analyses the operation of an OSD tested at laboratory scale, with the volume required by land use and occupation law of Belo Horizonte to compensate the total of waterproofing in a lot of 360 m². The hydrograph generated for the lot under those conditions was simulated and damping provided by the OSD was analyzed for seven different outlet pipe diameters: 3/4"(19.2 mm), 1" (25 mm), 1.1/4" (32.6 mm), 1.1/2" (42 mm), 2"(50.6 mm), 2.1/2" (65.6 mm) and 3"(75.4 mm). In accordance with the Book of Specifications of Sudecap (2008), the minimum diameter of the discharge outlet of the OSD should be 3”. The results of the tests showed that the volume defined by the legislation is less than the required to achieve the desired peak flow damping. It was noted also that even if the OSD has a sufficient storage volume, the discharge pipe with a diameter of 3 "does not restrict the input hydrograph peak.

Key Words: OSD – On-site Stormwater Detention, damping of peak flows, urban drainage.

1. INTRODUCTION

Belo Horizonte was the first capital of Brazil to require the construction of drainage device of source control for lands with great waterproofing rate.

The Municipal Law N°. 7.166/96 set guidelines and parameters for the partitioning, occupation and land use in the city, dividing and classifying the territory into occupation zones. The restriction to the occupation of areas still preserved, to set minimum rates of soil permeability and the requirement of building reservoirs hold rainwater for cases with waterproofing above allowed, were the greatest advances in the aspect of urban drainage.

Municipal Laws N°. 8.137/00 and N°. 9.959/10 changed the law of 7.166/96, modifying, in some situations, the minimum rates of the land permeability.

The Article 50 of the current law (n ° 9.959/10) sets minimum rates for each occupation zone of the town permeability, as shown in Table 1, on this article is allowed the buildings, except those located in zones of Environmental Protection . - ZPAM and Protection – ZPs, waterproof up to 100 % (one hundred percent) of the land area since retainers for rainwater are built. These should enable the retention of up to 30 L (thirty liters) of rainwater per square meter of land waterproofed exceeding the limit established by law .

Table 1 – Parameters definite in Belo Horizonte’s Law

Occupation Zone	ZA, ZAP, ZARs, ZHIP, ZCs e ZEs	
Rate Low Permeability	10% ($A_{Lot} \leq 360m^2$)	20% ($A_{Lot} > 360m^2$)
Volume of OSD (m^3)	30 L x Aw	

Obs: * A_{Lot} = Lot Area; A_W = Waterproofed Area above the established by law;
ZA – Densification of Zone; ZAP – Preferred Densification Zone; ZAR – Restricted Desinfication Zone; ZHIP – Hypercenter Zone; ZC – Central Zone; ZE – Equipments Zone.

Drummond *et al.* (2011) performed a comparison between the legislation of Belo Horizonte and other cities (Curitiba, Guarulhos, Porto Alegre, Rio de Janeiro and Sao Paulo). There were determined the volume's of OSD's for areas from 125 m² and 1,000 m², by the formulas defined in each legislation. The study showed that the laws of Belo Horizonte and Guarulhos demanded the lowest retention volume of all evaluated.

Regarding the other important parameter for the design of OSD, that is the output flow to be launched in public drainage, Belo Horizonte's Law didn't set the diameter of the outlet pipe or the area of the discharge opening of the reservoir dimensions that define the maximum output flow of lots.

The Sudecap - Superintendent of the Capital Development has released through its Book of Specifications (2008), models of OSD to meet the specifications of Law partitioning, occupation and land use of the municipality. The document proposes that the retainers can be built with solid brick masonry reburned, filled concrete blocks or precast concrete , shall have dimensions (width and length) of minimum 60 cm and minimum discharge pipe of 3".

Aiming to evaluate the damping peak flow provided by OSD with the same characteristics defined by the Municipal Administration of Belo Horizonte, for a lot of 360 m² , fully waterproofed, a model was constructed in CPH - Hydraulic Research Center and Water Resources of UFMG.

2. MATERIALS AND METHODS

2.1 Experimental apparatus

According to LPOUS of Belo Horizonte, in a batch of 360 sqm fully waterproofed must deploy a OSD with volume of 1.08 m³ (according to the formula shown in Table 1) .

The experimental apparatus constructed in CPH had a total volume of 1.40 m³ and an approximate working volume of 1.07 m³. As has been reported through modeling the diameter of 3", recommended by Sudecap, would not be enough to make the damping of the peak discharge of the hydrograph generated for the batch there were tested other diameters of the discharge pipe.

Discharge tubes with 15 cm length were placed in the bottom of the reservoir following the nominal diameter: 3/4", 1", 1.1/4", 1.1/2", 2", 2.1/2" and 3". In addition to the discharge pipes, one spillway was installed at the height of 1.10 m. Figure 1 shows a picture of the experimental apparatus used to perform the simulations.

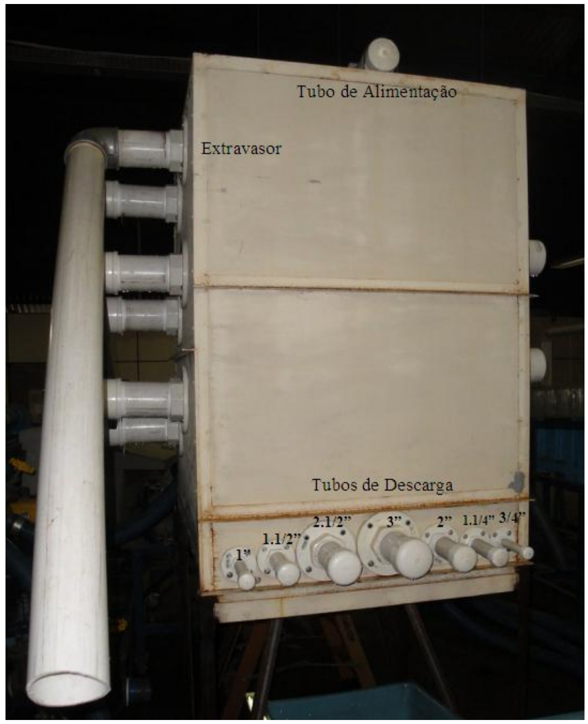


Figure 1 – Photo of reservoir built in CPH / UFMG

2.2 Determination of the hydrograph input reservoir

In order to calculate the hydrograph input reservoir was used the Soil Conservation Service method - SCS, for being one of the most currently used in the drainage projects.

In the calculation of rainfall intensity was used the formula of IDF curve type determined by Pinheiro and Naghettini (1998) for the Metropolitan Region of Belo Horizonte.

In order to calculate the rain project payback time of 10 years and a duration of 10 minutes were adopted, setting a value of the intensity of 194,48 mm / h .

Knowing the existence of a great variety of slopes in lots of the city of Belo Horizonte, it was assumed the average value of the concentration time as five minutes to the fully waterproofed soil.

The temporal distribution of rainfall was performed using the method of Huff (50% Probability of exceedance) by means of the curves of temporal rainfall distributions for different probabilities of exceedance and durations prepared for the Metropolitan Region of Belo Horizonte - MRBH by Pinheiro and Naguettini (1998), with the discretization interval of one minute.

The value of 98 for Curve Number - CN was defined by referring to the Belo Horizonte's Master Plan for Urban Drainage (2000) and the study of Ramos (1998) for sealing areas.

2.3 Procedure of the trials

For tests procedures it was necessary to use a pump to direct water to reservoir and a channel with a triangular weir to record the flow output reservoir.

The pump flows were controlled by a frequency inverter calibrated prior to testing by volumetric method.

In order to determine the rates of output flow reservoir it was used a channel with triangular spout and a level sensor to record the height variation of water in the channel.

In order to improve the flow in the channel and make it less turbulent, was installed at the exit of each pipe tested one PVC hose with a diameter of 4 ", directing the water to the bottom of the canal, in a region filled with boulders as can be seen in Figure 2 (a). The level sensor is installed one meter above the triangular spout, as shown in Figure 2 (b).

(a) (b)

Figure 2 – Rectangular channel used to measure the output hydrograph (a) Layout of the hose and boulders (b) Location of water level sensor

Before each trial, the calibration of the flow of the weir channel was performed. From constant and known flows at the pump outlet, the flow relation with the height of water level in the canal was obtained.

The trials were performed in the laboratory as follows:

1. There was controlled all incoming flows in reservoir through frequency inverter connected to the pump. Flow rates of entry were changed every minute, according to the calculated hydrograph;

2. The registration of water level heights in the reservoir were recorded by means of a level sensor positioned within the reservoir. The excess water was expelled from the spillway ;

3. Through a laptop could verify the measurements of the height of water level sensor in real time. In order to ensure the records of the heights of the water level in the channel of the spillway, was annotated every minute from the beginning of the hydrograph, the value of NA shown on the computer;

4. After the end of the tests, the records of heights of water in the weir channel and reservoir were extracted from the dataloggers, which stored the average of the measured values of the level sensors in each minute;

5. From the height values of the water level in the weir channel, there were determined the outflows of the pipes discharge and consequently the hydrograph output.

The layout of the experimental setup is shown in Figure 3.

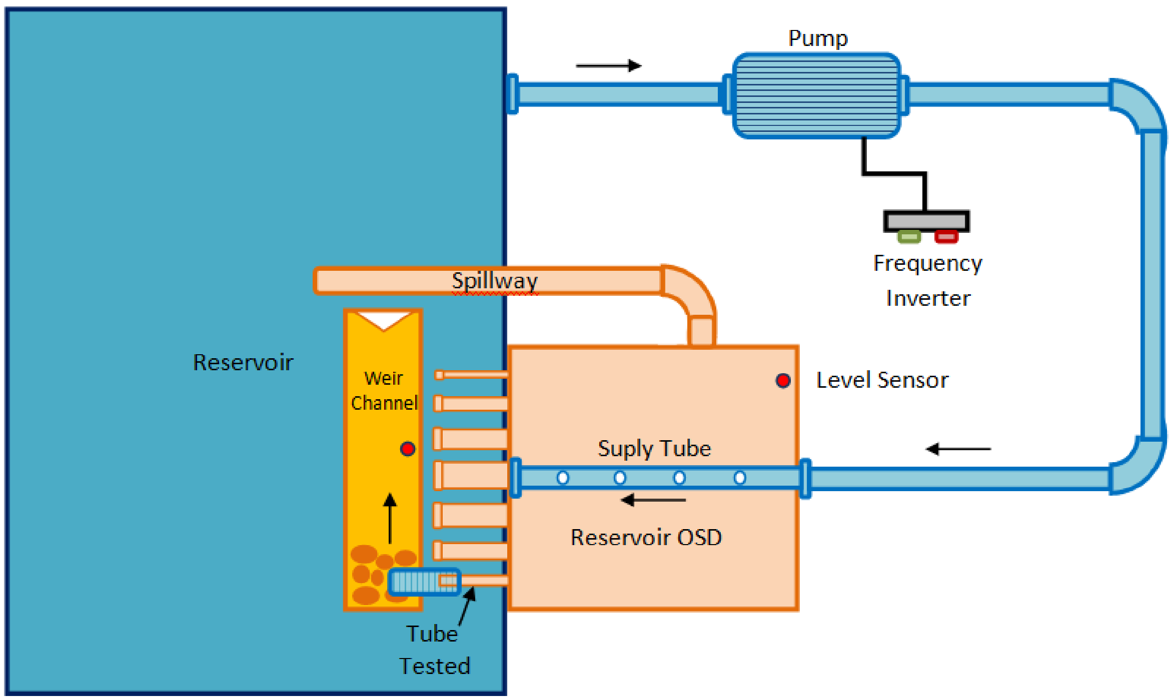


Figure 3: Layout of experimental setup

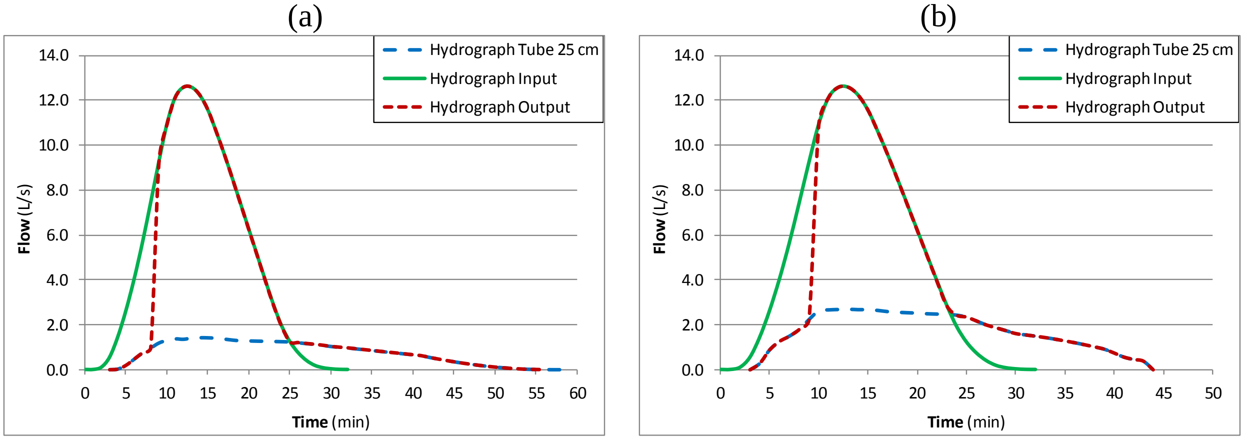
3. RESULTS AND DISCUSSION

As described in Materials and Methods, the water level records were processed into flow, generating hydrograph output tubes tested in reservoir.

In simulations where there was overflow, the output of spillway flows were calculated by subtracting the flows of entry reservoir and the output flow in the discharge pipe.

Figure 4 shows the results of simulations with seven discharge tubes. The "input hydrograph" simulated was calculated for a plot of 360 m² fully waterproofed. The "hydrograph Tube 25 cm" shows the flows of effluent discharge tubes tested and "hydrograph output" shows the flows discharged from reservoir (extravasated flow + flow of the discharge tube).

(a) (b)



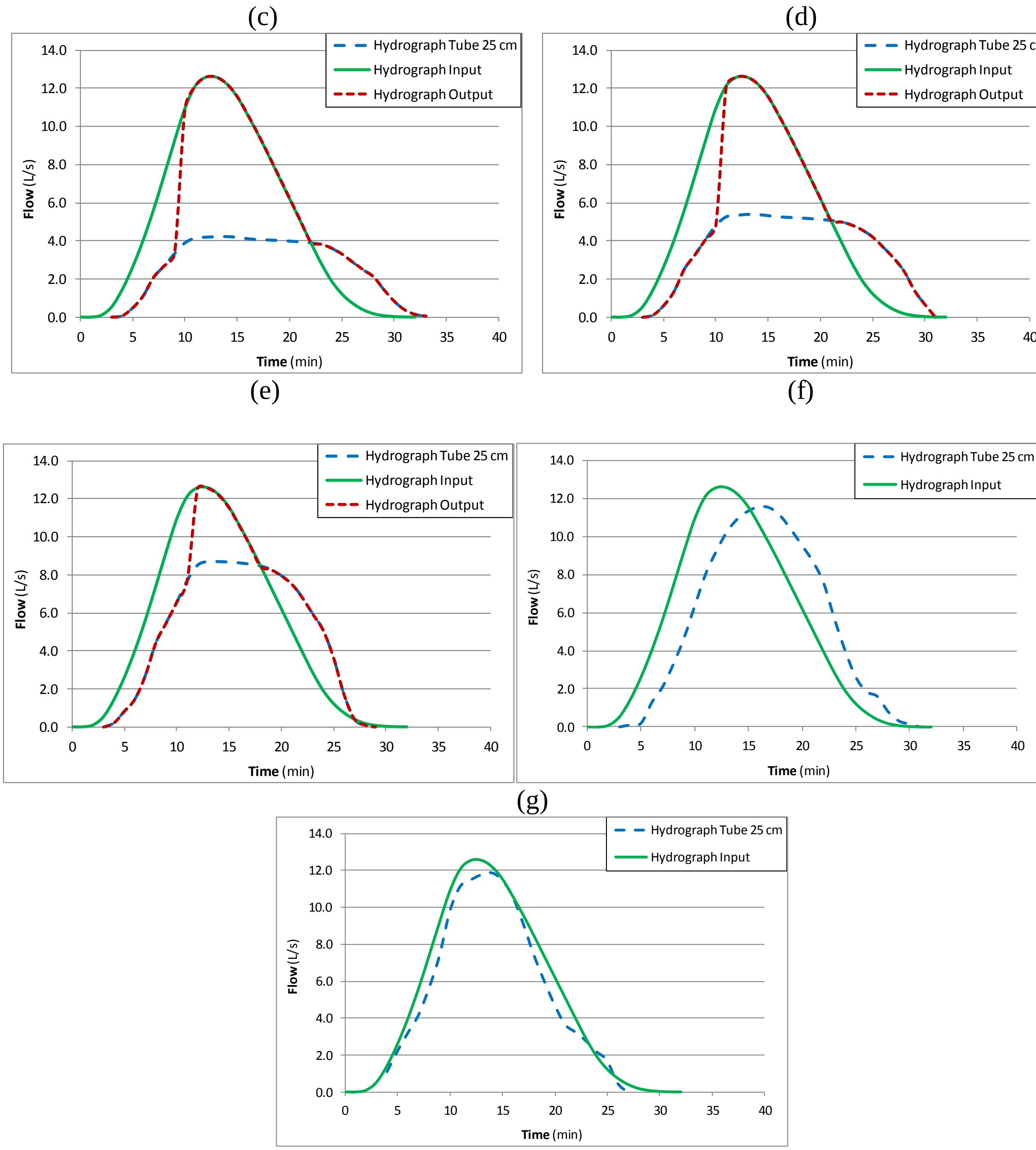


Figure 4: Results of simulations of the hydrograph input and output reservoir with discharge tubes of diameters (a) 3/4” (b) 1” (c) 1.1/4” (d) 1.1/2” (e) 2” (f) 2.1/2” (g) 3”

The results showed no damping peak flow hydrograph input in the trials. In simulations with discharge tubes with diameter up to 2", there was extravasation of reservoir, while the simulations with discharge tubes of 2.1/2" and 3", the peak discharge of the hydrograph input was equal to flow peak output tubes.

The extravasated volumes in trials with discharge tubes with diameters of 3/4", 1", 1.1/4", 1.1/2" and 2" were, respectively, 7 (seven) m^3, 6 (six) m^3, 4 (four) m^3, 3 (three) m^3 and 1.2 m^3. These volumes should be added to the existing volume of reservoir to provide damping.

Despite not having occurred damping for the simulations with discharge tubes of 2.1/2" and 3", the maximum height of the water level in the reservoir with tube 2.1/2", was 75 cm and the tube 3" was 42 cm.

3.1 Damping needed to maintain natural flows

There was performed an analysis of the optimal configuration for reservoir to occurr damping of peak flow input and maintain the maximum output flow near of peak flow of ground under natural conditions.

The calculation of hydrograms was also performed with the SCS method. There were used the studies made by Smith *et al.* (1995) and Ramos (1998), which classified the soils of the city of Belo Horizonte in two Hydrologic Groups B (GH-B) and D (GH-D). According to the Master Plan for Urban Drainage BH (2000), these soils in permeable conditions have the CN of 69, for the GH–B, and CN from 84, to GH-D.

As time of concentration is higher in conditions with permeable soil, it was considered a time of concentration of 10 minutes to calculate the hydrograph output of lots under natural conditions for both soil types. The other parameters were the same as described in calculating hydrogram input reservoir. The Figure 5 shows the calculated hydrograms to 360 m² plots under natural conditions for the two types of soil.

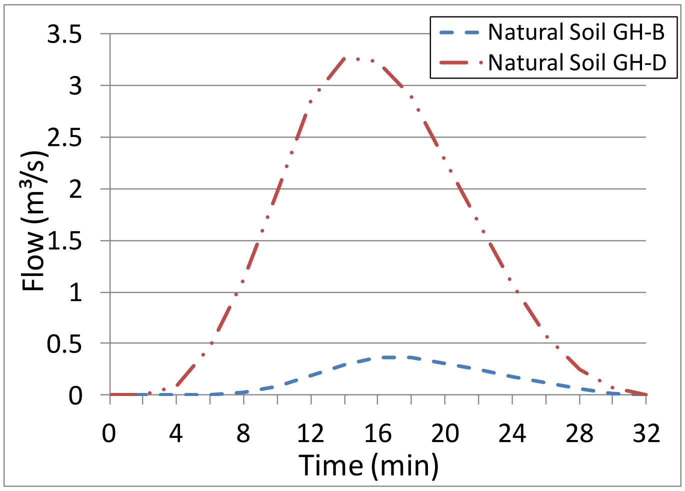


Figure 5: Hydrographs generated in a lot of 360 m² with permeable soil conditions

Based on the simulations, it was verified that none of the tested tubes restricts the flow peak in the reservoir to values near the flow calculated for the natural conditions of soil hydrologic group B, which was 0.37 L/s . The test tube with the smaller diameter (3/4") gave a maximum output flow of 1.66 L/s.

However, for the lot of GH-D, it was noticed that in one reservoir with volume of 7 (seven) m³ and a discharge pipe with a diameter of 1", the maximum output flow (2.61 L/s) is less than the peak flow in the hydrogram of natural conditions, which was 3.27 L/s.

4. CONCLUSION

The simulation results allows to conclude that the retention volume defined by Law of Installment, Occupation and Use of Land of Belo Horizonte for a batch of 360 m² completely waterproofed, it is not enough to compensate peak discharge increase generated with a change of soil permeability.

It was also found that the minimum diameter indicated on the Book of Specifications of Sudecap (2008) for the discharge pipe of reservoir provides no restriction to the flow hydrograph input.

In order to prevent the excess flow caused by waterproofing in a lot located on an land belonging to the Hydrologic Group D, it is necessary that the damped reservoir has a useful volume of approximately seven (7) m³ and a discharge pipe with diameter of 1 "(25 mm). However, for a lot with of Hydrologic Group B soil it was not possible to determine a diameter that allows the reduction of the peak discharge of the hydrograph input levels near maximum flow generated with the soil under natural conditions. The smaller diameter tested allowed the passage of a flow of 1.66 L/s, about 4.5 times greater than the natural soil.

These results highlighted the need to review the legislation of Belo Horizonte, changing parameters and criteria for determining the volume of reservoir and for the implementation of a flow restriction to situations which the lots can have waterproofed soils.

Require the storage of stormwater at the source, using a OSD technique, is a way to force the responsible for changing ground conditions to compensate the addition of flow excess caused with waterproofing soil and maintain the peak flow rates near the peak flows to the natural conditions.

5. ACKNOWLEDGEMENTS

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