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DETENTION SHAFT FOR FLOOD CONTROL IN BANDEIRA SQUARE, RIO DE JANEIRO - BRAZIL

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ABSTRACT: Bandeira Square is undoubtedly the most emblematic inundation region in Rio de Janeiro, Brazil. Every year losses achieve the amount of millions considering damage to vehicles, commerce, residences and the disruption of traffic and public services. The 2 – 10-years flood result water levels higher than 1.5 meters in Bandeira Square. The structural solution adopted for flood control in Canal do Mangue watershed were planned in the context of Rio de Janeiro Urban Drainage Masterplan – PDMAP (2013), and encompasses detention basins, channel enlargement and a diversion tunnel of Joana River. The Bandeira Square detention shaft, with its 35 meter diameter and 22 meters deep, was built during the last year and it's ready for operating in the next rainfall season that, in Rio de Janeiro, takes place from October to March. Its concept and design criteria are presented in this paper.

Key Words: Detention basin, sustainable urban drainage system.

1. INTRODUCTION

Canal do Mangue watershed, with its 45 km² of drainage area, encompasses Rio de Janeiro downtown and many important urban elements of the city, such as Maracanã stadium, the Carnival center Marquês de Sapucaí, the City Hall and Bandeira Square, an important transportation axis that connects south and north regions of the city.

Among all the frequent inundation areas in Canal do Mangue watershed, Bandeira Square is the most affected and responsible for the greatest damage. Three main reasons could be mentioned as responsible for the vulnerability of this area: (1) a significant reduction of the croos section of Trapicheiros River, a tributary of Maracanã River that drain 5 km² of urbanized area upstream Bandeira Square; (2) tide effects of Guanabara Bay, that promote the sea flow through Mangue Channel and Maracanã River, achieving Trapicheiros River and Bandeira Square during high tide events and (3) The topographical conditions of the catchment area, that naturally conduces the runoff to this lower part of the region. The flood control system planned for Trapicheiros watershed includes a detention pond in the upper part of the watershed, with 70.000 m³, and a 18.000 m³ detention shaft, with local drainage treatment in Bandeira Square.

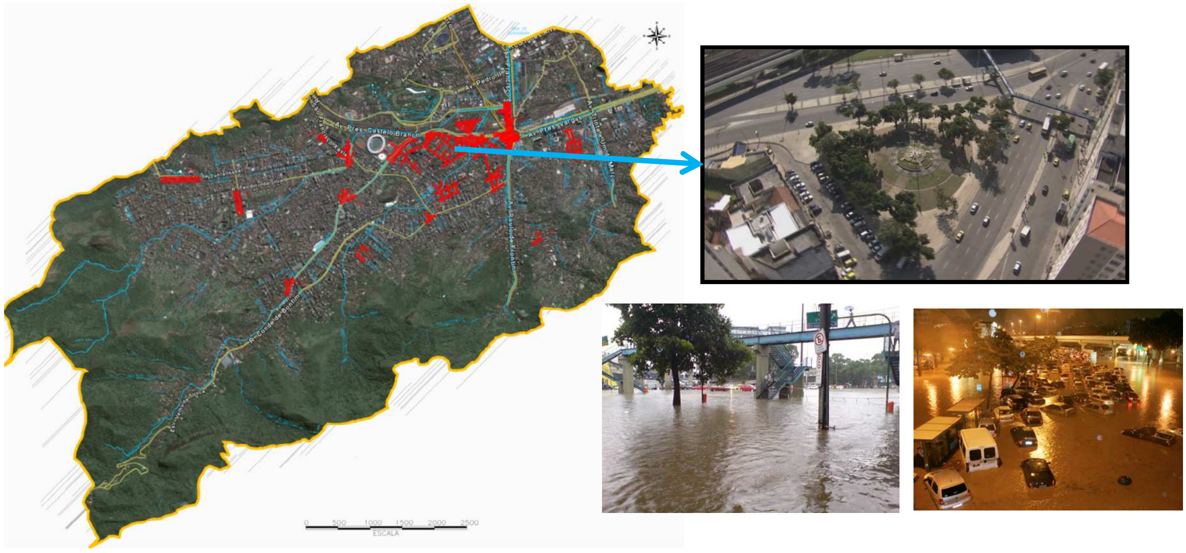

Figure 1 – Inundation map of Canal do Mangue watershed; Photos of Bandeira Square during a flood ocurred in March/2010.

2. HYDROLOGICAL STUDIES

3. DESIGN CRITERIA OF BANDEIRA SQUARE DETENTION SHAFT

The Bandeira Square detention pond were planned to be built as a shaft, due to the lack of area for constructing flood control facilities in this region of the city. It was planned to receive both the local runoff and the overflow from Trapicheiros river, resultant from the reduction of its cross sections in many reaches upstream Bandeira Square. The local drainage was rebuilt in order to protect the shaft and the square against tide effects from Maracanã River during high tide events in Guanabara Bay. “Flap” valves were put at the end of all drainage pipes connected to Trapicheiros River, in order to backwater effects from the river to the shaft.

Figure 2 – Bandeira Square Detention Shaft – RT-2 - Overview of the project and photos of the building.

3.1 Geotechnical and Structural Design

The detention shaft RT-2, in Bandeira Square, with its 35m diameter and 22m deep, is a specially complex intervention, due to its large dimensions and urban localization, with highly dense occupation of the surroundings and many interferences in the excavation area. The shaft was built with diaphragm wall, with 0.80 meter thickness, with 30 meter of total deep, from the level of the square to the bed rock. The vertical soil support wall was built with reinforced concrete rings, in order to control lateral displacement.

The geological structure of the area where Bandeira Square is settled presents sedimentary package founded on a fractured rock basement field with sand and clay. The groundwater level is high, about 1 – 2 meters depth. .

Local geology consists of sand and clay layers with alternating depositional processes of fluvial and marine origin. Also mixed with these sediments there are talus deposits from ancient landslides. The sedimentary process occurred in successive stages of marine progress and regressions, that explains its heterogeneity.

Resistance of sandy sediments measured from SPT ranged from soft to very compact and resistance of clay soils ranged from medium to hard.

In early stages of design the average permeability of marine and fluvial sediments were adopted based on permeability tests in boreholes in 10^{-2} cm/s for sands and 10^{-4} cm/s for clayey soils.

Seepage studies carried out with Plaxis axisymmetric model results seepage flows into the reservoir equal to 320 m^3/h, too high for reservoir operation.PLAXIS Model was applied also to perform plan, axis-symmetrical and decremental analysis for excavation simulation, also considering the reinforced concrete rings, in successives phases.

Diaphragm-wall was adopted as a definitive support structure, without secondary revestment. It has also a cut-off function, protecting the excavation area from groundwater flow. .

The bottom slab was 2.00m thick with tie backs anchored in the rock and soil treatment under the slab with jet grouting.It rquiresd use of temporary drains during construction period to avoid piping during excavation, later injected.

This solution led to an acceptable flow equal to 22 m^3/h and assures structure stability against fluctuation.

Figure below shows initial design.

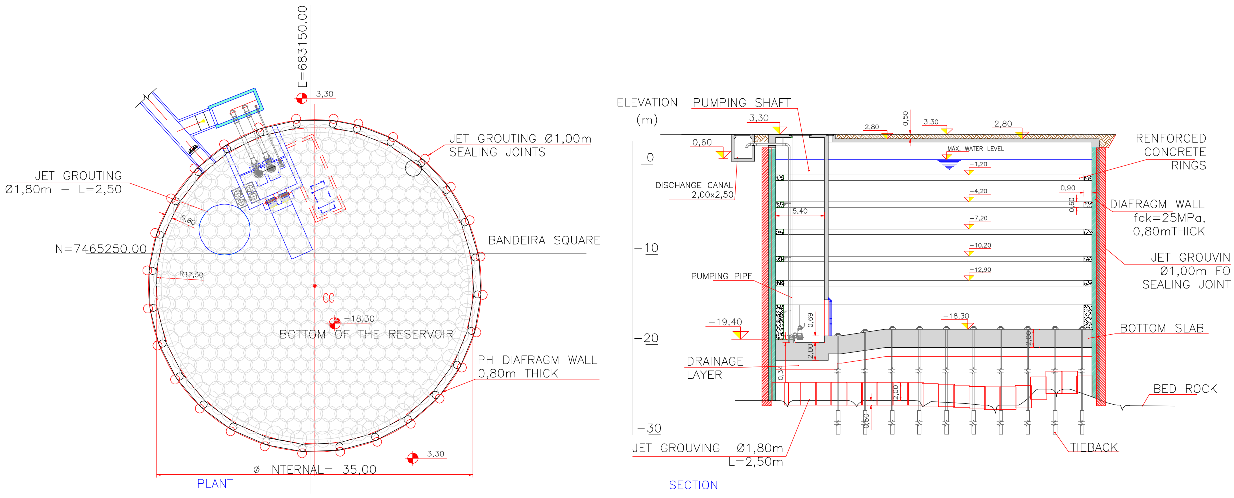

Figure 3 – Initial Design of the Shaft

To improve the determination of sediments permeability a pumping test was performed. Well pumping was installed in the center of the reservoir and additional boreholes were executed with SPT determination in soil and rotary in rock. Permeability tests were carried out in soil and rock and piezometers were installed inside the boreholes to monitor the water level.

Back analysis were carried out from the pumping well flow and piezometric water level data using Plaxis program to obtain the medium permeability of soil and rock.

Table below illustrates the materials permeabilities (cm/s) that best fitted to results obtained from pumping tests.

	SOIL MEDIUM PERMEABILITY	ROCK MEDIUM PERMEABILITY	CONTACT ZONE PERMEABILITY
MODEL A	$Kv=3,6x10^{-6}$ $Kh=7,5x10^{-5}$	$3 a 5x10^{-3}$	
MODEL B	$Kv=3,6x10^{-6}$ $Kh=7,5x10^{-5}$	10^{-4}	$7x10^{-3}$

Kv – vertical permeability (cm/s)

Kh – horizontal permeability .(cm/s)

Permeability values obtained from back analysis of pumping tests were substantially lower than those admitted in the initial design that led the need to seal the reservoir due to high seepage flow.

These new data allowed to eliminate jet grouting columns to ensure the reservoir tightness as well as the tie backs to ensure stability against fluctuation .

Design was optimized making the bottom slab 0,50m thick, over draining layers of granular materials respecting the Terzaghi filter criteria.

To avoid sand boil in soil from seepage in the very permeable rock fractures, nine relief wells penetrating 2.00m in rock with radial arrangement were executed with discharge above the bottom slab.

Jet grouting were performed along of the diaphragm wall joints as well as on the bedrock to minimize seepage flows into the reservoir.

Figure below shows optimized design.

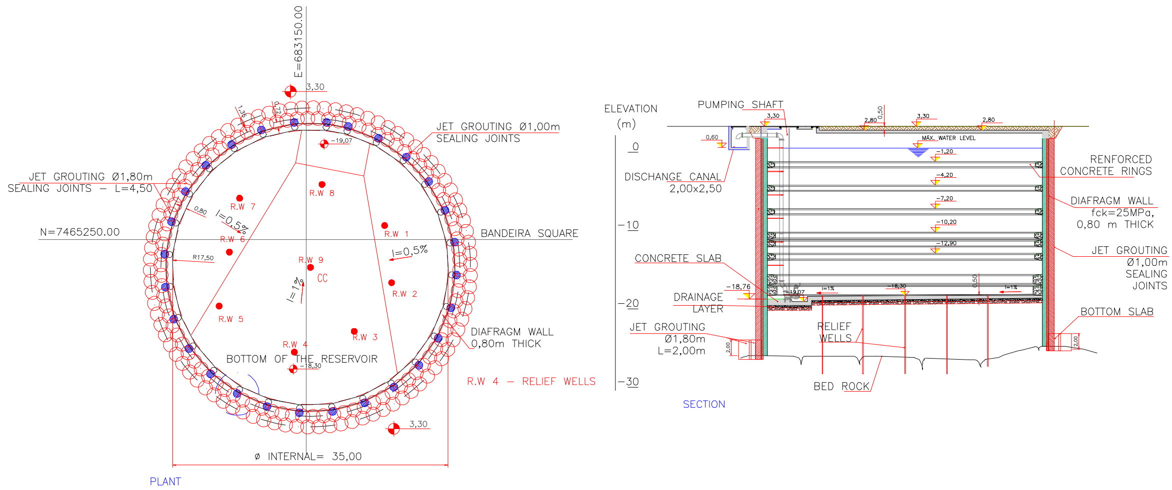

Figure 3 – Optimized Design of the Shaft

The first determinations of seepage flow into reservoir showed values of 14 m^3/h and 6 m^3/h, for different hydraulic heads, lower than the value of 22 m^3/h, stablished in design criteria.

Bandeira Square will be completely rebuilt over the roof slab, as well the operation facilities of the pumping system.

4. CONCLUSIONS

The Detention Shaft of Bandeira Square is a high complex structure for flood control, due to its dimensions, its location – in the middle of a highly dense urbanized area, with several interferences, and also its hydraulics operation. The shaft was designed to receive both local drainage and the overflow from Trapicheiros River and drainage pipes upstream Bandeira Square. Also, the system had to be protected from backwaters from Maracana River, resultant of Guanabara Bay tide effects.

5. REFERENCES

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