EVALUATION OF VENTILATION CONDITIONS IN THE SEWER SANITARY SYSTEM OF AN OFFICE BUILDING USING AIR ADMITTANCE VALVES

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ABSTRACT

This article presents an analysis of ventilation conditions within the sewer sanitary system in an office building. In this case, the vent pipe, performed by branches and ventilation pipe, is replaced by air admittance valves.

In this analysis, experiments in real-sized prototypes of office toilets were carried out, which were assembled in the vertical part of the Building Systems Laboratory of Politecnical School of USP-Brazil.

A system of flow automation of sanitary appliances was installed in these prototypes. Besides this, an instrumentation system was installed to store data related to pressure behavior inside pipes and seal water trap variations.

The experiments were performed with flow rates simulations corresponding to a range from a five-storey building to an approximately twenty-two-storey building.

1 INTRODUCTION

In order to provide a proper flow of the waste originating from the several water uses inside the buildings Collect Systems of Used Water were created, which were conceived and carried out without any care concerning odour coming inside the environment, what compromises the sanitary conditions inside the buildings.

Observing these problems, the systems evolved into the current Building Sewer Sanitary Systems, whose basic requirement is “to collect and conduct the waste originated from the use of sanitary appliances, without the danger of drinking water contamination and, at the same time, blocking the entrance of odour into the buildings environment”.

The roles of collecting and conducting are served by the appropriate choice of sanitary appliances, by the appropriate planning and dimension of pipes.

In regard to the odour entrance, this can be avoided by placing the traps, which are devices presenting a water barrier, called water seals. Even though, because of the flow from the
appliances, pressure is created inside the pipes which, depending on the reached levels, may reduce or even break the water seals causing damage to the function of preventing odours to come inside the buildings.

Hence, in order to balance the pressures inside the pipes, a Ventilation System was introduced, what is formed by a set of pipes interlinked to the sewer sanitary system, which allows the air entrance needed to balance the pressure variation and prevent the trap water seals from breaking.

In Brazil, several researches were done, and others have been developed in order to adequate the Brazilian Sewer Sanitary Systems to the world reality, considering new products, dimension methods and execution techniques.

This research was developed within that context, as it presents a study on the application of air admittance valves in office toilets settings, where the main characteristic is the use of sanitary appliances batteries.

Taking into consideration that air admittance valves in replacement to a conventional vent system, that is, performed by branches and ventilation pipe, reduce considerably the sewer system cost, as well as the labour expenses for its execution, and also the possibility of execution errors.

### 2 BRAZILIAN BUILDING SEWER COLLECTING SANITARY SYSTEMS

The Building Sewer Collecting Sanitary System used in Brazil is formed by a group of vertical and horizontal pipes, differing in diameters. The pipes are composed by:

- **discharge branch**: part of the pipe that receives the effluents from discharge branches.
- **sewer branch**: part of the pipe that receives the effluents from discharge branches.
- **vertical stack**: part of the pipe that receives the effluents from sewer branch or discharge branch.
- **building drain**: part of the pipe that receives the effluents from vertical stacks.

In Brazilian installations, the traps may vary in types and sizes, some of them are integrated to the appliance, such as the water closet traps, and also the ones to be connected to the exit of the appliances, for instance, kitchen sinks, tanks to wash clothes, urinals, water basins, etc. These are “S”, “P”, and “Glass-like” types.

Besides the ones cited above, there are floor drain traps, which have a specially designed shape to conceive the used water from various appliances, such as water basins, showers, etc, and also the water from the washing of floors, leading them directly to the vertical stack. It may be said that they serve as a link between the primary and the secondary sewer in sanitary installations.

In figure 01, we present the shape and component parts of a floor drain trap.

![Floor Drain Trap Diagram](image)

**Figure 01 – Parts components of floor drain trap.**
The Ventilation System is composed by a set of pipes interlinked to the Sewer System, presenting as the main component parts, the following:

- **Branch of ventilation**: this part of the pipe interlinks the trap or discharge branch or sewer branch of one or more sanitary appliances to a vertical vent or to a main vent pipe;
- **Vertical vent**: the vertical part of the pipe that interlinks the pipe branches directly to atmosphere, or to a main vent pipe.

  - **Main vent**: this vent pipe is a prolongation of the vertical stack above the higher branch connected to it, having its extremity open to atmosphere, situated on the top of the buildings.

  This system can be conceived and dimensioned in the following ways, which are:

  - **Main ventilation**: is the ventilation performed only by the main vent pipe;
  - **Secondary ventilation**: is the ventilation performed by column branches and ventilation interlinked to sewer sanitary systems;
  - **Vertical vent**: is the ventilation performed by the vertical vent interlinked directly to the vertical stack, without the ventilation branch.

In the current norms, the NBR 8160 (1999) in the cases where there is need for secondary ventilation, there is the possibility to have it done through air admittance valves.

### 3 METHODOLOGY OF TESTS

The main objective of using tests in prototypes is to reproduce, in laboratory, the most non-favourable conditions in terms of occurrence of self-siphonage, induced siphonage and back pressure phenomena, making the analysis of the usage of air admittance valves possible. It occurs through the magnitude relation of pressure inside the pipes, by the discharge of water closets, and trap seals behaviour present in that installation.

Thus, this experimental research was developed by assembling real-sized prototypes in a sewer sanitary system in an office building.

#### 3.1 Description of Building Systems Laboratory

The tests with prototypes were assembled in the vertical part of the Building Systems Laboratory of Politechnical School of University of São Paulo, which is formed by an eight-storey tower, considering that each of them consists of an area of twelve square meters (12 m²).

In that area there is an electrical building system and a cold water building system, composed by an inferior reservoir located on the first floor, next to a pumping system, formed by a set of three pumps connected in parallel, and a superior reservoir.

All system is located on the eighth floor, whose distribution barrel is on the seventh floor, making the distribution to all others floors through columns located in shafts.

#### 3.2 Prototypes configuration:

In the prototypes which were tried out, real assembly of the installations forming the configuration of an Office toilet was reproduced in laboratory. It was made up of three water closets tank, three urinals and three water basins. Figure 02 presents a ground plan as well the detail of the sewer configuration.
The sanitary appliances used in the prototypes installation were chosen in order to represent what is usual in the Brazilian Sanitary Sewer Systems. Thus, water closets tanks, with two different volumes of discharge were used, that is, the so called conventional volume (11.5 litres) for being the most commonly used in Brazil and the reduced volume (6 litres) of discharge.

The urinals used in this test were the ones without an attached trap, where a glass-like trap with 1 ½’ entrance and 1 ¼’ exit and with a 25mm high water seal was connected.

The water basins were not installed, only their respective flows were discharged directly in floor drain traps, with 150x150x50 dimension, with a water seal 40 mm high, as shown in figure 03.

The appliances and components feeding was carried out by the derivation of two columns coming from the barrel. In the derivation of the first stack a hydrometer was placed in the branch in order to measure the several flows which were tested, and from this a single feeding sub-branch was derived to the three attached tanks of the water closets where a solenoid valve was installed in order to guarantee that after each discharge the tanks would always be filled in with the same volume.
From this column it was also derived the feeding sub-branch of the floor drain trap, with the placing of a solenoid valve and the installation of a register aiming to control the flow which is going to be discharged in the floor drain trap, that is, the flow of the three water basins altogether.

Regarding the second column derivation, which was used for feeding the urinals, it was also placed a hydrometer in its branch. Concerning the sub-branches, solenoid valves and registers were placed according to the combination of determined discharge to each of the floors, also aiming to guarantee the discharge of a same flow throughout all the tests. In figure 05 there is a photo of the assembly performed in the test tower.

![Derivation of first column and second column](image)

**Figure 05 – Detail of cold water system.**

### 3.3 Description of the prototypes measure points:

In order to focus the pressure behavior which occurs along the vertical stack we situated the measure point in the sewer branch in the installations, near the connection with the vertical stack, based on studies already carried out by MONTENEGRO (1987), AOKI (1991), CHENG (1996) and more recently by COSTA (1998).

Besides the pressure measures near the vertical stack, there were also pressure measures in each of the horizontal installations which are part of the five floors, in order to allow the knowledge of the pressures inside these installations due to the flow that goes through the vertical stack and the flow coming from the discharges of the sanitary appliances installed in each floor, as shown in tables 01 and 02.
Table 01 – Pressure measure points.

<table>
<thead>
<tr>
<th>Pressure measure</th>
<th>8°</th>
<th>7°</th>
<th>6°</th>
<th>5°</th>
<th>4°</th>
<th>3°</th>
<th>2°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main vent pipe</td>
<td>PH8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water closet discharge branch</td>
<td>PA37</td>
<td>PA26</td>
<td>PA15</td>
<td>PA14</td>
<td>PA33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urinal waste branch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor rain trap waste branch</td>
<td>PB7</td>
<td>PB6</td>
<td>PB5</td>
<td>PC6</td>
<td></td>
<td></td>
<td>PF2</td>
</tr>
<tr>
<td>N”ar Vert cal Sta’k waste’ branch</td>
<td>PC7</td>
<td>PC5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building rain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 02 – Trap seal measure points

<table>
<thead>
<tr>
<th>Trap seal measure</th>
<th>Floors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7°</td>
</tr>
<tr>
<td>Water closet trap seal</td>
<td>FE37</td>
</tr>
<tr>
<td>Urinal trap seal</td>
<td>FD27</td>
</tr>
<tr>
<td>Floor drain trap seal</td>
<td>F7</td>
</tr>
</tbody>
</table>

Figures 06 & 07 show the locations of measurement points of pressure and trap seal points.

Figure 06 □ Pressure and trap seal measure points.
The pressure measures inside the pipes and the variations in the trap seal were carried out by means of an instrument system together with data acquisition.

The instrumentation system was composed by pressure transducers attached to an amplifier circuit of tension, in order to have the registered pressure turned into electric impulse and conducted to the data acquisition system.

Concerning the acquisition system, it was formed by an interface board that was used to link it to a data acquisition board, where a management software turned the electric impulses into pressure values by means of transducer caliber equations. All data relating to pressure and height of the trap seals was stored in archives for further analyses.

### 3.4 Description of instrumentation system and data acquisition:

Using the basic configuration, different kinds of vent were analyzed in order to make a comparison between the use of ventilation performed with branches and columns and the one performed using air admittance valves. In tables 03 and 04 we present the different kinds of ventilation tested
<table>
<thead>
<tr>
<th>Vent Type</th>
<th>Description</th>
<th>Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TYPE 1B</strong></td>
<td>When the vent subsystem is formed by main and secondary vent, and the secondary vent is placed in the sewer branch of floor drain trap</td>
<td><img src="image" alt="Scheme Diagram" /></td>
</tr>
<tr>
<td><strong>TYPE 1C</strong></td>
<td>When the vent subsystem is formed by main and secondary vent, and the secondary vent is placed in the sewer branch of floor drain trap and in the urinal sewer branch.</td>
<td><img src="image" alt="Scheme Diagram" /></td>
</tr>
</tbody>
</table>
When the vent subsystem is formed by the vertical stack directly connected to the vertical vent, in all floors.

<table>
<thead>
<tr>
<th>Vent Type</th>
<th>Description</th>
<th>Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 4</td>
<td>When the vent subsystem is formed by the placement of the air admittance valve directly into the vertical stack, in all floors.</td>
<td>![Scheme](Esquema Vertical)</td>
</tr>
<tr>
<td>Type 5</td>
<td>When the vent subsystem is formed by the placement of two air admittance valves. One of them is placed in the floor drain trap sewer branch and the other one is fixed in the urinals sewer branch.</td>
<td>![Scheme](Esquema Vertical)</td>
</tr>
</tbody>
</table>
When the vent subsystem is formed by the placement of one air admittance valve, in the floor drain trap sewer branch.

3.6. Description of discharge arrangements used in prototypes

To determine the number of sanitary appliances to be discharged simultaneously is necessary to find out the sewer flows which drain by the pipe installations in study. This flow, called project flow is function of the use of simultaneity and the typology of sanitary appliances.

Brazilian Norms of Sanitary Sewer, the NBR – 8160 (1999), presents a method which uses the binomial distribution, where it is possible to determine the project flow for each part of the installation, based on the knowledge of the number of appliances in simultaneous use, considering a failure factor, that is, the reliability level to be stipulated by the project designer.

Based on these principles, the number of appliances to be discharged simultaneously were determined to simulate, in the five usable floors of the tower, flows that occur in buildings higher than five floors.

3.1.1 Single flow of used appliances:
- Water closet - tank 11.5 liters – Flow = 0.73 L/s
- Wash basin - Flow = 0.15 L/s
- Shower - Flow = 0.20 L/s
- Urinal - Flow = -0.15 L/s

3.1.2 Discharge arrangements for the configurations

The discharge arrangements used in the tests are shown in table 05. The floor drain traps were all tested under a flow discharge equivalent to three water basins in simultaneous use.

<table>
<thead>
<tr>
<th>Sanitary Appliances</th>
<th>Discharge combination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Da</td>
</tr>
<tr>
<td>Water closed of seven floor</td>
<td></td>
</tr>
<tr>
<td>Water closed of six floor</td>
<td></td>
</tr>
<tr>
<td>Water closed of five floor</td>
<td></td>
</tr>
<tr>
<td>Urinal 1 of seven floor</td>
<td></td>
</tr>
<tr>
<td>Urinal 2 of six floor</td>
<td></td>
</tr>
<tr>
<td>Urinal 3 of five floor</td>
<td></td>
</tr>
<tr>
<td>Floor drain trap of seven floor</td>
<td></td>
</tr>
</tbody>
</table>
Based on table 05, and on single flows of appliances, tested flows were the following:

1 – Water closet experiments - 11.5 litre:

- **Da** – Flow rate of 8.37 l/s;
- **Dc** – Flow rate of 5.58 l/s;
- **Df** – Flow rate of 2.79 l/s.
4 Results analysis:

For the analysis of the results found in the several tests, it is verified that, for the cases studied, the substitution of ventilation with branches and columns for the air admittance valves, didn't cause significant increase in the negative pressures along the vertical stack and in branches. As it can be observed in the figures 08, 09 and 10, where we presented the pressure behavior in two points different from the installation. With the flow rate of type Da.

Figure 08 – Pressure behavior with ventilation T1b and T6.

Figure 09 – Pressure behavior with ventilation T1c and T5.

Figure 10 – Pressure behavior with ventilation T1b and T6.
5 References


