Hybrid ventilation tests in houses following the Spanish CTE

D. Jesús Feijó Muñoz, Dª. María Soledad Camino Olea & D. Alberto Meiss.

E.T.S. de Arquitectura - University of Valladolid, Spain

Corresponding email: feijo@arq.uva.es

SUMMARY

The aim is to present the results obtained for ventilation efficiency in systems of hybrid ventilation for houses, which is about to be implemented in Spanish legislation. We will provide a summary of studies conducted on air extraction rooms, such as bathrooms or kitchens, and transit or air circulation areas such as corridors, halls, or distributors.

INTRODUCTION

The ultimate goal of the study is to increase ventilation efficiency in order to seek a reduction in volumetric flow rates with the desired energy savings. The immediate objective for toilets and bathrooms would be to specify design criteria to obtain ideal ventilation for these areas.

MATERIALS / METHODS

Representative typologies have been chosen, and a twin study has been performed using an experimental model in a laboratory with photoacoustic techniques of tracer gases, and a numerical model with CFD (Computational Fluid Dynamics) software techniques.

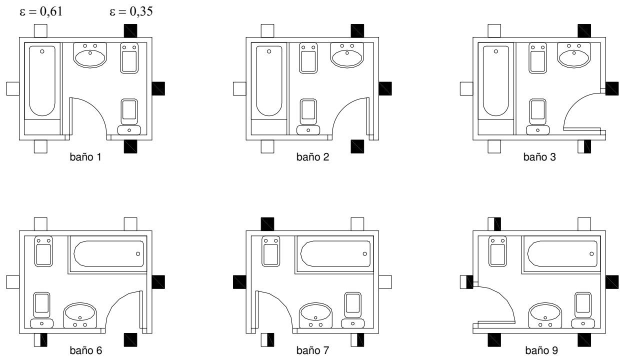
Numerical procedure validation has enabled us to emulate a variety of common situations different to the tested model and obtain conclusions on the architectural design of houses, thus allowing us to improve indoor air quality (IAQ).

RESULTS

By way of a summary we now transfer the numerical results to practical concepts that can be applied directly to architectural design. The following symbols represent three valuations of extraction in terms of their efficiency so their location in the perimeter of the bathroom indicating their position near the vertical and corresponding wall:

good ☐ average ◧ poor ■

In the figure it is attached the most representative distributions together with the numerical and experimental results obtained corresponding to the first bathroom prototype 2.40 x 1.80 x 2.50m.



CONCLUSIONS

Like conclusions of the realized work and the obtained results, it might extract consequences that concern to the architectural design.

For future investigations, also other consequences can be extracted, like the obtained efficiencies in general yielded low values (between 0.35 and 0.61). The induced flow was supposedly nearer to that of displacement, as a result of which theoretically these should have reached efficiency values above 0.7. This encourages further work aimed at improving them.

Hybrid ventilation tests in houses following the Spanish Technical Building Code (CTE)

D. Jesús Feijó Muñoz, Dª. María Soledad Camino Olea & D. Alberto Meiss.

E.T.S. de Arquitectura - University of Valladolid, Spain

Corresponding email: feijo@arq.uva.es

SUMMARY

The present communication forms part of the conclusions to emerge from the research project "Development of a methodology for the estimation of ventilation efficiency in residential houses" financed jointly by the Spanish Ministry of Education and Science and by ERDF, and carried out from 2003 to early 2006.
The aim is to present the results obtained for ventilation efficiency in systems of hybrid ventilation for houses, which is about to be implemented in Spanish legislation. We will provide a summary of studies conducted on air extraction rooms, such as bathrooms or kitchens, and transit or air circulation areas such as corridors, halls, or distributors.
For this purpose, representative typologies have been chosen, and a twin study has been performed using an experimental model in a laboratory with photoacoustic techniques of tracer gases, and a numerical model with CFD (Computational Fluid Dynamics) software techniques.
Numerical procedure validation has enabled us to emulate a variety of common situations different to the tested model and obtain conclusions on the architectural design of houses, thus allowing us to improve indoor air quality (IAQ).

INTRODUCTION

At the Higher Technical School of Architecture in the University of Valladolid we have been researching into the study of ventilation in houses for several years. This study has emerged to a large extent due to the new legislation on Indoor Air Quality (IAQ) introduced by Spain's "Technical Building Code" in which we have been involved.

The last research project has served as the basis to study efficiency in areas where air extraction in houses is common, such as bathrooms and toilets. This work has also served to define the performance protocols for the remaining rooms in houses.

The ultimate goal of the study is to increase ventilation efficiency in order to seek a reduction in volumetric flow rates with the desired energy savings. The immediate objective for toilets and bathrooms would be to specify design criteria to obtain ideal ventilation for these areas.

METHODS

The experimental model was performed inside a 4.80 x 6.00 x 3.60 m (width, length, height), test chamber designed expressly for this project and fitted with the following equipment and instrumentation:

• to obtain the appropriate volumetric flow rate of the air, centrifugal fans UPE 145/200 cm of 37 W and CAB-125 were used. To provide a homogeneous mixing of the gas tracer inside the enclosure, another independent fan BSH-PAE C_VT01 of 30 W was used.
• to regulate the volumetric flow rate of the air, a frequency inverter was used, and to control it two digital anemometers RS 180-7111 and a nozzle TG-40 of calibration were used.
• to control the airtightness of the room the fans were in use with the same frequency inverter and a manometer for measuring the pressure of the interior of the chamber.
• to monitor air movement, we used a smoke machine, model Fz-1200 of 1.2 kW and 500W halogen cycle projectors, together with a video camera for recording.
• to measure air age, we used equipment with a gas analyzer model 1302, a sampler-doser model 1303 and sulphur hexafluoride as tracer gas, managed by 7620 software on a PC computer.

Figures 1, 2 and 3 respectively show a general outside view of the test chamber, the subchamber that represents the bath, and the most important instrumentation, comprising the multi-gas monitor with the multipoint sampler and doser.

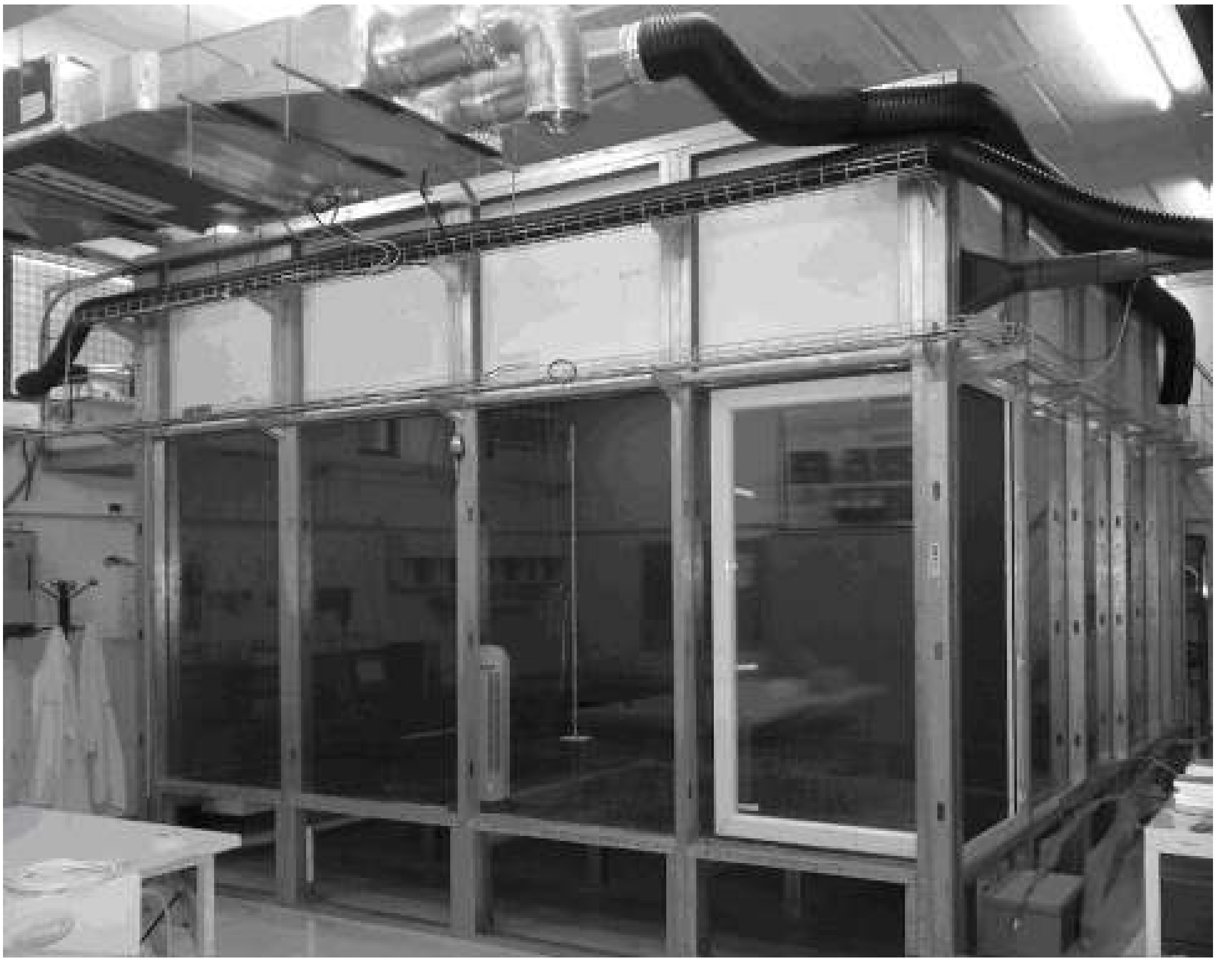


Figure 1. Test Chamber. Exterior view from the air conditioning laboratory.

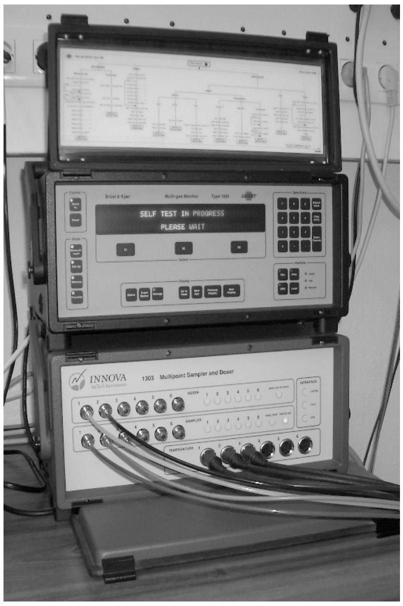


Figure 2. Subchamber reproducing a bathroom. View from the interior of the chamber.
Figure 3. Equipment with multipoint sampler and doser and multi-gas monitor.

The numerical model was carried out using Fluent CFD software with help of the Gambit program for the introduction of the geometry and the meshing of the bath. The process for each test after CFD software adjustment was the following:

• introduction of the geometry, meshing and contour constraints, and the turbulence model.
• validation of the numerical model for comparison with the results of the experimental model, through non-dimensional values.
• numerical study of variants on the same volume and the obtained results.
• graphical results.

PROCESS

We study a prototype model bathroom with a maximum number of alternatives for the distribution of the supply and exhaust openings for the air. The inlet was located in the lower part of the access door and the outlet at the top of the walls. The different distributions were accompanied by the corresponding variations in the locations of the sanitary systems.

Two procedures were employed: the numerical procedure with CFD software (Computational Fluid Dynamics) and the experimental procedure with the mentioned chamber where the size of the bathroom with a specific distribution was reproduced on a real scale. The former allows greater versatility when performing a virtual study of multiple cases, while the second, which is more complex, provides the essential validation of the study in CFD. In both cases the procedure used to calculate ventilation efficiency is based on the expression relating room air age, represented in Equation (1):

$$\varepsilon = \frac{\tau_{exhaust}}{2.\bar{\tau}}, \qquad (1)$$

where ε is the efficiency of the ventilation in the studied room, $\bar{\tau}$ is the room-average age and $\tau_{exhaust}$ is the local mean air age of the outlet.

Since air was entering from other rooms in the house, we were dealing with a common isothermal process, both for the experimental and numerical models. The experimental model applied the concentration decay method using a gas tracer (SF_6) and the averaged data of concentrations obtained were treated in detail by the appropriate spreadsheets.

Figure 4 represents a typical graph showing the evolution of the concentration decay of a gas tracer obtained in one of the numerous tests performed. Conversion from concentrations of gas tracer to mean air ages was carried out by equations (2) and (3).

The experimental results allowed us to validate the results obtained with the numerical model, built with a turbulence model k - ε. The left side of Figure 5 shows a perspective of the model bathroom. The right shows two sections with the mean air ages represented by different colour plots to indicate different ages in seconds.

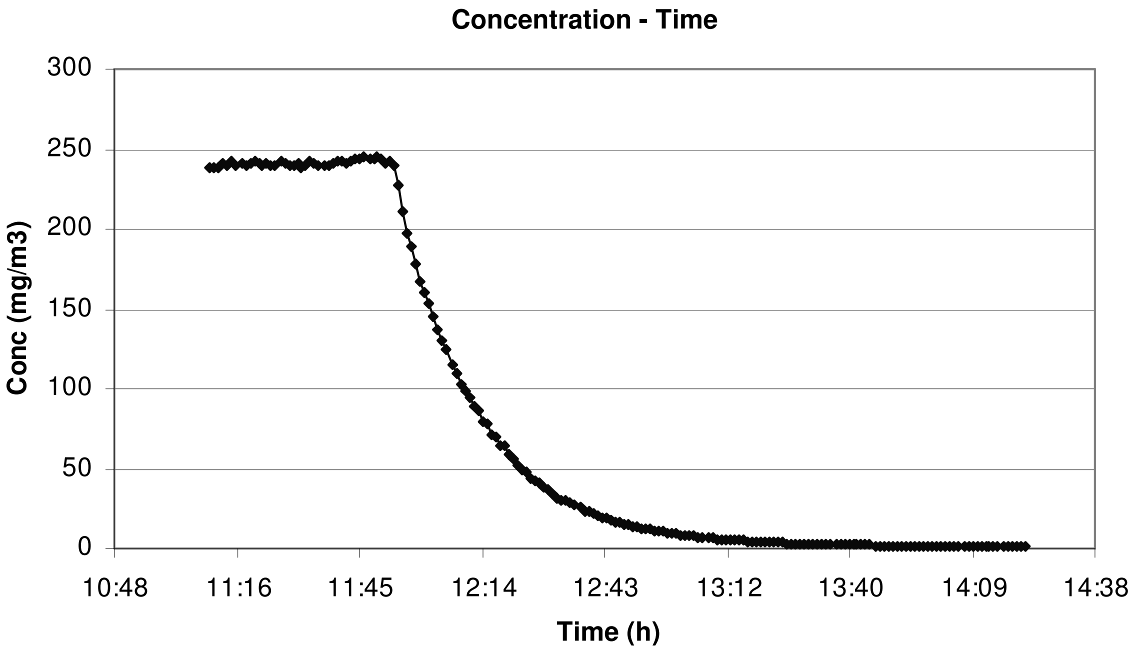


Figure 4. Example of obtained concentration history with SF_6 as tracer gas

Local mean age of air $$\bar{\tau}_p = \int_0^{\infty} \frac{C_p(r_o,t)}{C(0)} d\tau , \qquad (2)$$

Room average age of air $$\tau = \frac{\int_0^{\infty} t \cdot C_e(t)dt}{\int_0^{\infty} C_e(t)dt} , \qquad (3)$$

where:

$C_p(r_o,t)$ tracer gas concentration at point r_o and time = *t*.

$C(0)$ tracer gas concentration at time = 0, where we begin to measure concentration decay

$C_e(t)$ tracer gas concentration at outlet

τ_p local mean age of air (at a random measurement point)

$\bar{\tau}$ room average age of air

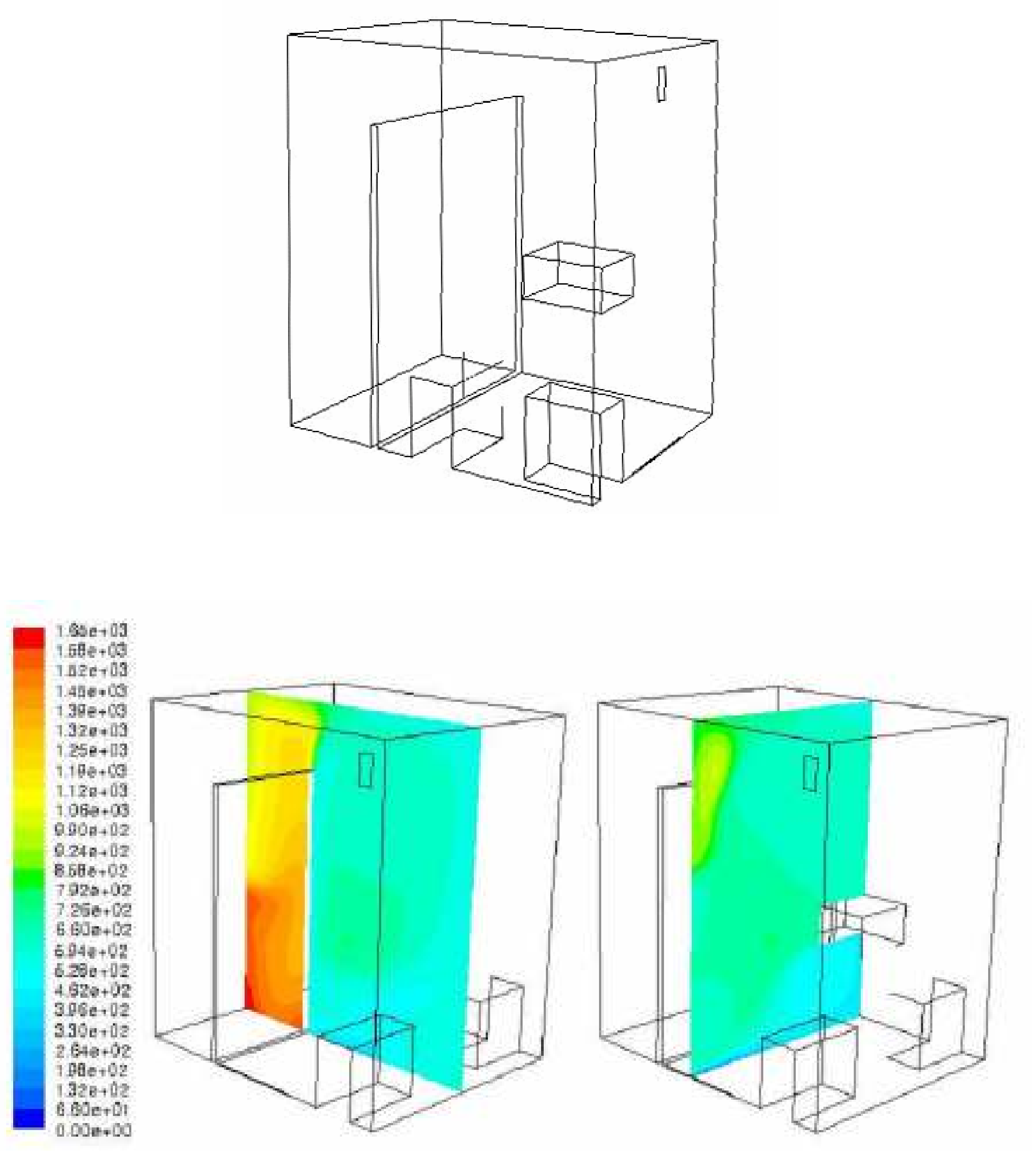


Figure 5. Graphics of the bathroom with graphic results of air ages in certain sections of the room (air age in seconds)

With the obtained results and thinking fundamentally about the possible practical repercussions, efficiencies were sorted into three groups. The first contained values equal to or below 0.45, indicating lower efficiency (near to the theoretical short circuit model), the second group for values above 0.45 and below 0.50, indicating intermediate efficiency (close to the model of perfect mixing) and the third group equal to or higher than values of 0.50, the most efficient (tending to the theoretical model of displacement).

(good) $\varepsilon \geq 0.50$ (average) $0.45 < \varepsilon < 0.50$ (bad) $\varepsilon \leq 0.45$

RESULTS

By way of a summary we now transfer the numerical results to practical concepts that can be applied directly to architectural design. The following symbols represent three valuations of extraction in terms of the above mentioned efficiencies, their location in the perimeter of the bathroom indicating their position near the vertical and corresponding wall.

good location ☐ average location ◨ poor location ■

Figure 6, below, shows the most representative distributions together with the numerical and experimental results obtained corresponding to the first bathroom prototype 2.40 x 1.80 x 2.50m.

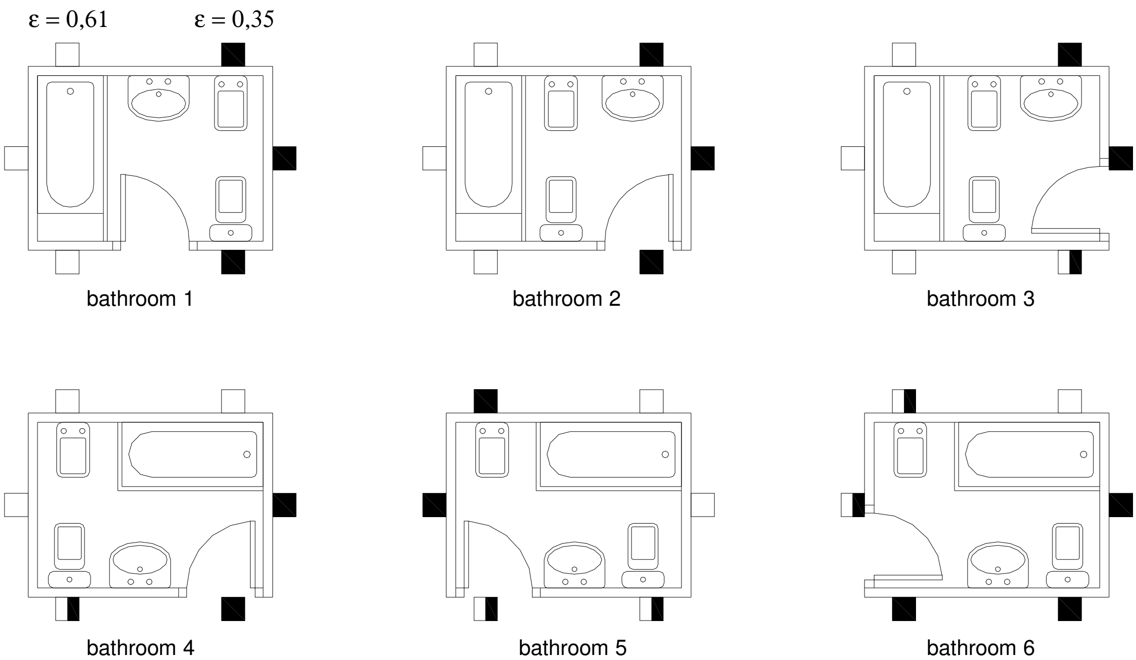


Figure 6. Bathrooms with the same surface and different locations for access doors, sanitary devices and ducts, and the corresponding efficiency for each solution

In two of the variants for the ducts in "*bathroom 1*" (Figure 6), values for efficiencies of 0.61 and 0.35 respectively are shown, coinciding with the maximum and minimum values of all the studied cases.

We also worked numerically with an alternative size of 2.00 x 2.00 x 2.50 m., obtaining a series of results, the most significant of which are shown in Figure 7.

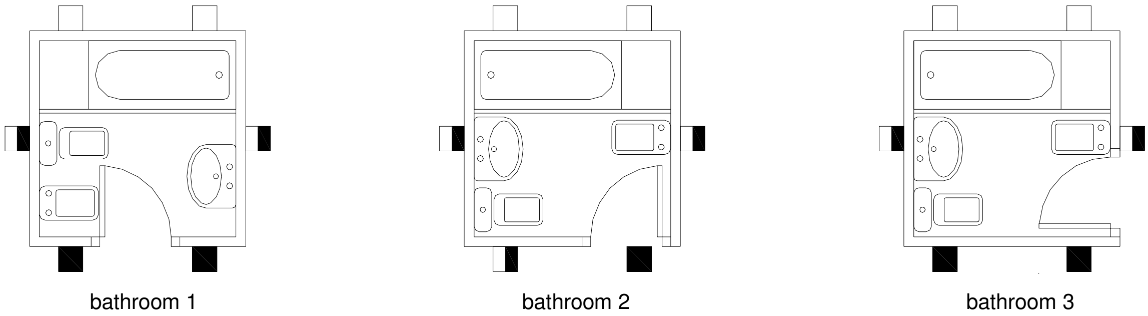


Figure 7. Results of another model of bathroom with other proportions

We even managed to study a conventional 2.00 x 1.50 x 2.50m model of toilet with multiple inlet and outlet variants. One significant example of this study is Figure 8, which offers a perspective of the room with the sanitary devices and a plan with the effects of the distribution.

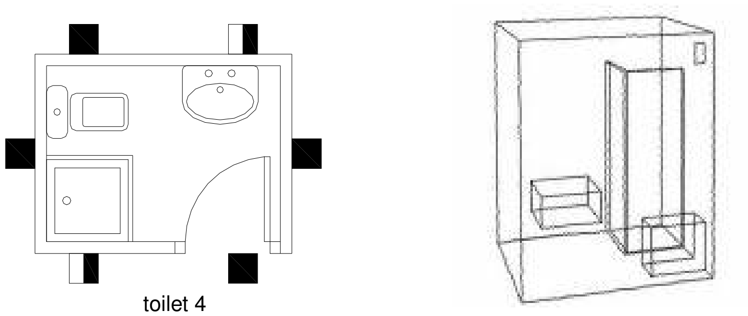


Figure 8. Sample of the results of the toilet

DISCUSSION

The following conclusions concerning architectural design may be drawn from the studies carried out and the results obtained:
• Closing shower spaces and bathtubs with screens, even if they do not reach the ceiling, seriously obstructs ventilation and significantly impacts ventilation efficiency in the toilet or bathroom.
• In general, locating the air outlet close to an entrance door which holds the inlet significantly reduces ventilation efficiency.
• In general, distancing both ducts (inlet and outlet) enhances efficiency, although the key factor is that the outlet should be located on the walls that delimit the shower or bathtub space if these have closed screens.

As pointers for further future research, other conclusions which may also be drawn are:

• The obtained efficiencies in general yielded low values (between 0.35 and 0.61). The induced flow was supposedly nearer to that of displacement, as a result of which theoretically these should have reached efficiency values above 0.7. This encourages further work aimed at improving them.

• In smaller rooms, we seem to have obtained consistently lower efficiencies, between 0.42 and 0.4. It appears that in these cases the location of the inlet and outlet had less impact.

ACKNOWLEDGEMENTS

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