Study of the dynamics of fire and smoke control in case of evacuation in high buildings, based on continuous model FDS+Evac

Influence of ventilation systems in smoke control

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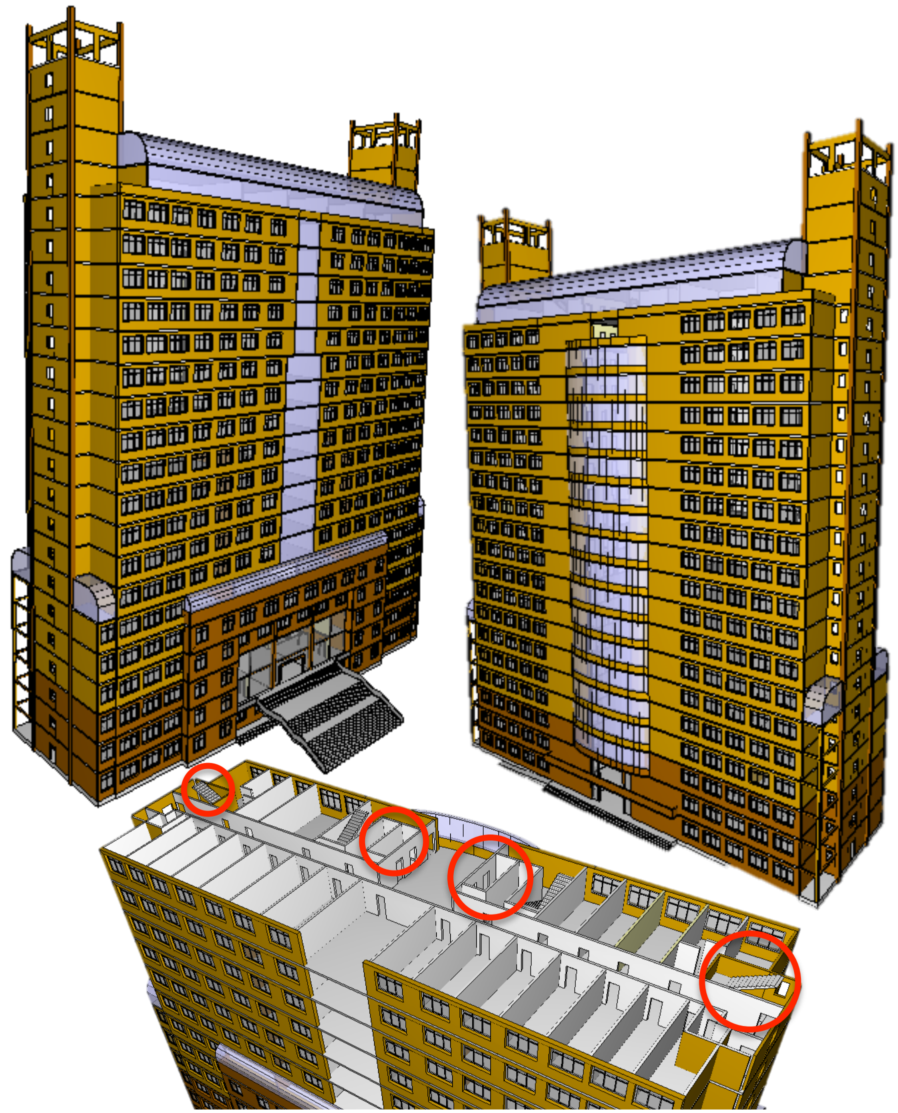
Introduction

To understand the fire behaviour depending on the structure of the building, it is extremely important, not only to analyse and interpret the ventilation systems, but also to understand the forms of support for smoke control and analyse the best strategy evacuation in case of emergency of zones of high flow of occupants. Thus, the **objective** is to improve the visibility of evacuation by controlling the smoke based on ventilation systems to enforce the desired requisites.

Geometric model under study

Our work focused on the study of one of the stairwells of the Technology Department of Wuhan University of Technology, Hubei, China.

- No of floors: **21**
- Area: **2060m²**



Geometric model under study

Based on standard document stipulated by the Chinese code GB50045-95 [3], the minimum output width of the stairs shall not be less than the values:

Building type	Minimum exit width	
Hospitals	1,3m	52''
Apartments	1,1m	44''
Others	1,2m	48''

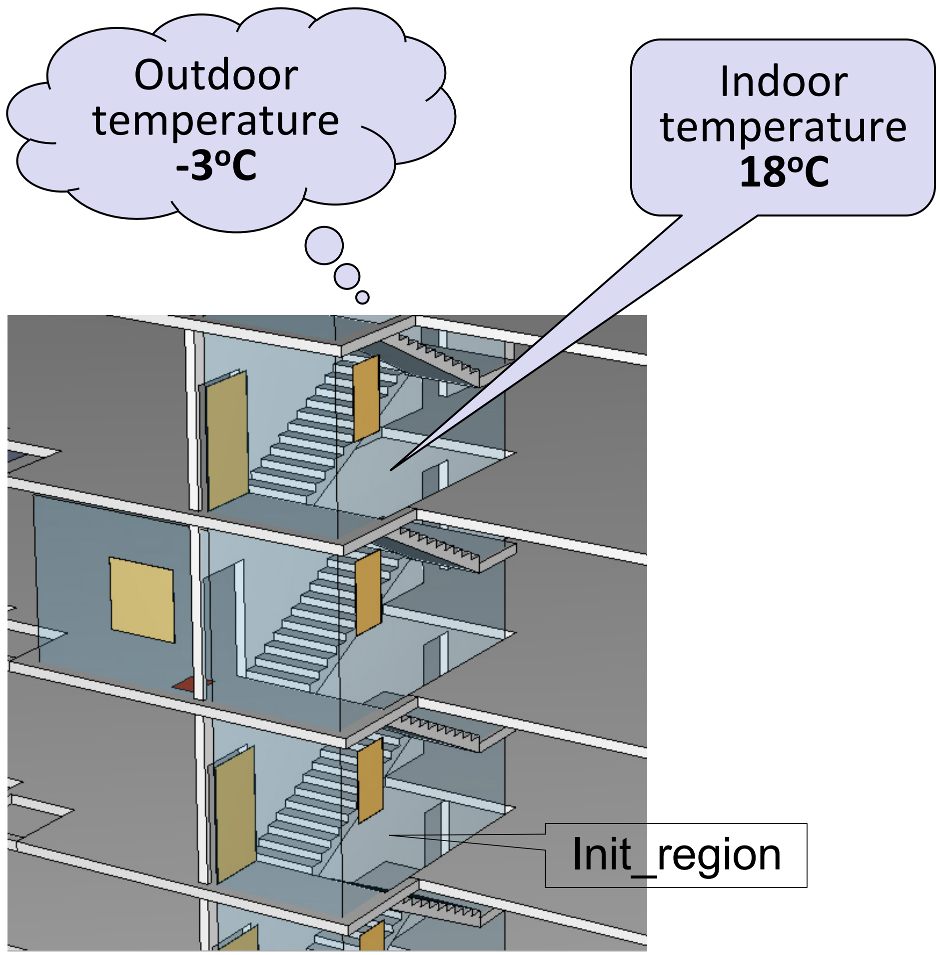
In this work, the main exit stair width and partial measures of stairs per floor are:

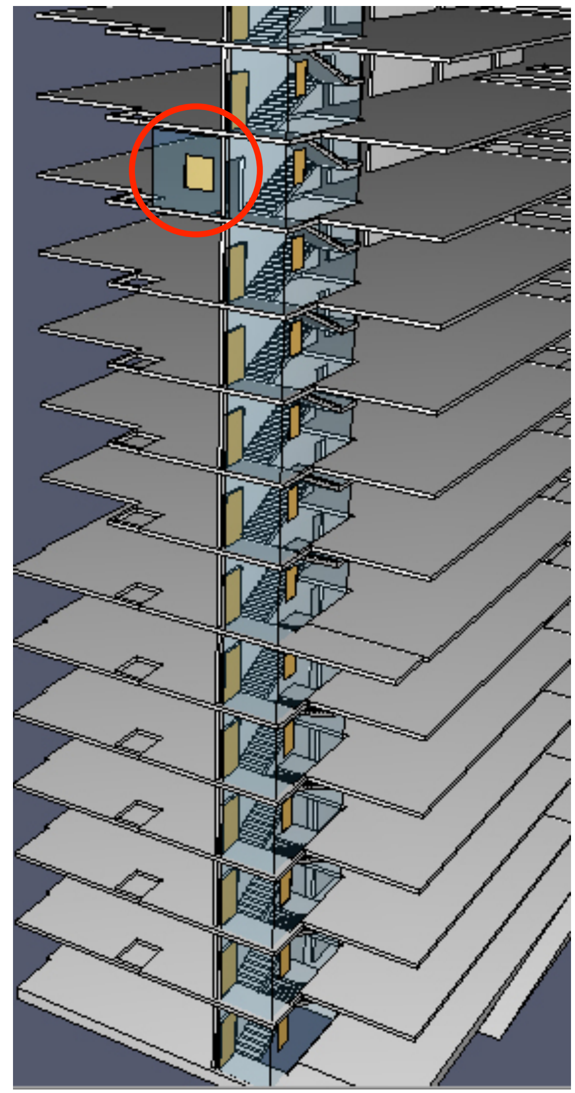
Width of exit stair	Stairs per floor		
1,2 m	Length	5,8m	232''
	Width	2,8m	11''
	Height	3,3m	132''

Simulation parameters

The simulation of fire occurred in the winter, in the lobby of access to one of the side staircases, on the 12th floor.

- Initial power of fire: **5000**$_{KW}$
- Simulation time: **5**$_{mn}$

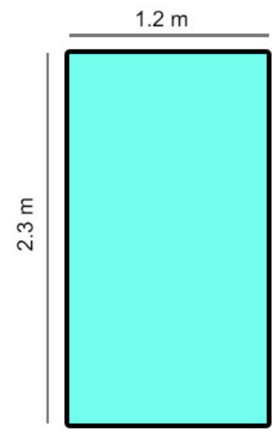


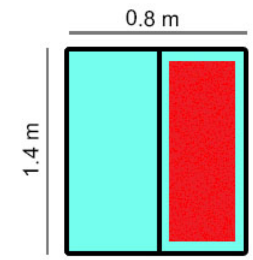


Leakage area of the openings (doors-windows)

Open – *open surfaces* was used

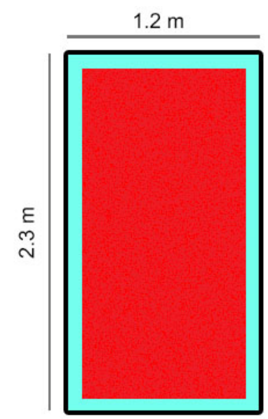
1 door: 2,76m² → total: 52,44m²
1 window: 0,5644m² → total: 10,7236m²
Total door-window: **63,1636m²**

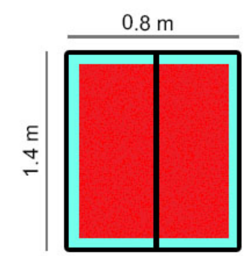




Closed – *obstruction* was used

Thickness leak: 0.002cm
1 door: 0,0140m² → Total: 0,266m²
1 window: 0,0088m² → Total: 0,1672m²
Total door-window: **0,4332m²**





Semi-open – doors and windows structured alternately between floors: (open in pairs floors) - (closed on odd floors).

Total door-window: **32,6796m²**

Characteristics of Ventilation Systems

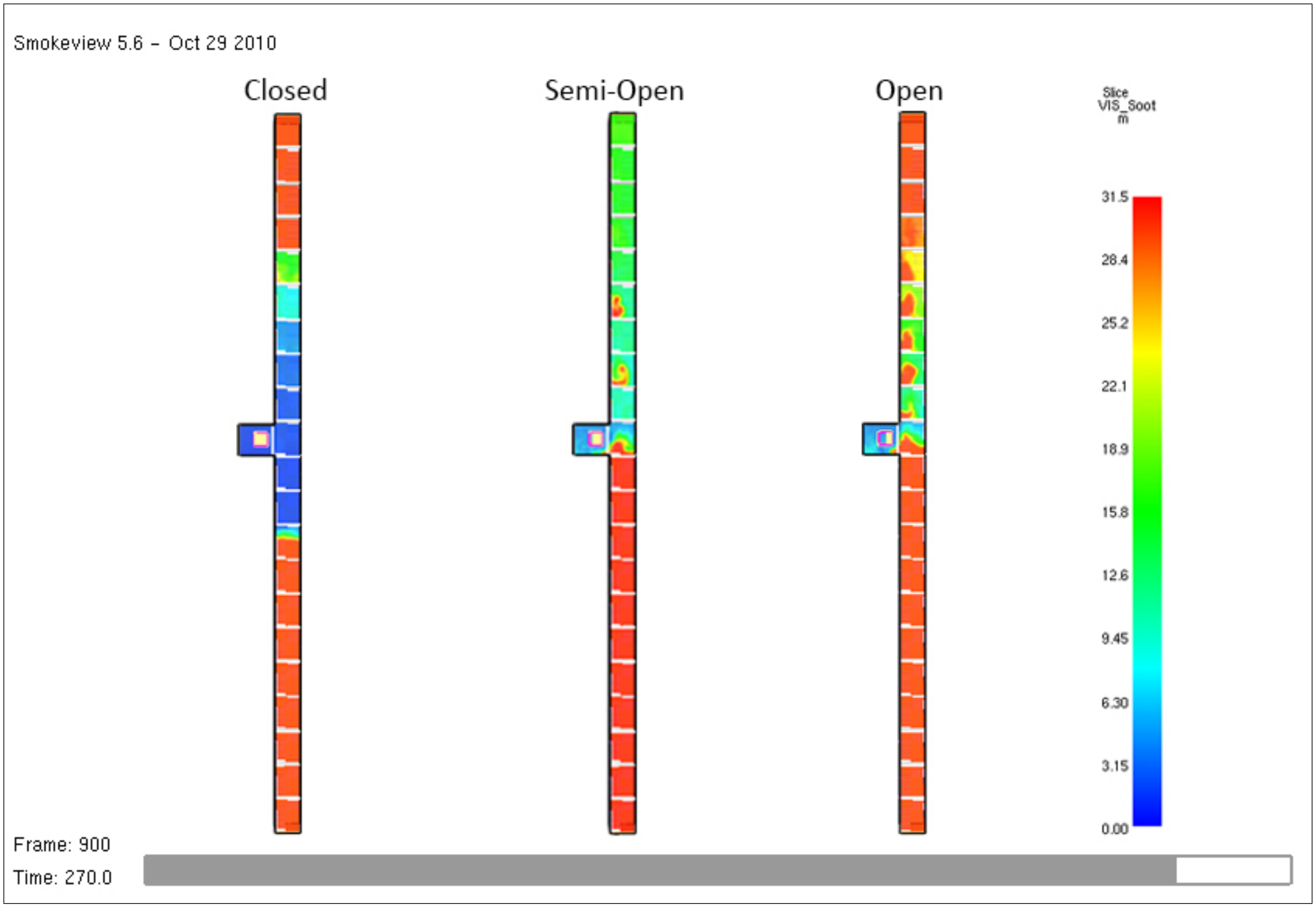
Natural ventilation – here the study is done without any preventive measure be taken. According to the standard document stipulated by the Chinese code GB50045-95, the total area of the open windows of the stairwell for each 5 floors must not be less than **2m^2** [3].

Pressurization – the pressurization system of the staircase, provides a ventilation to inside the stairwell of **18000m^3/h**, through 5 "*fans*" of (20,5$_{cm}$*20,5$_{cm}$) positioned alternately (floor 8, 10, 12, 14 and 16) on floors nearest of fire, where each one provides a air flow of approximately **1m^3/s**.

Dilution – in this system the amount of air drawn is equal to the amount that is provided by the "*fans*". In the case of dilution, extraction of air is taken through five "*exhausts*" of (20,5$_{cm}$*20,5$_{cm}$), wherein each one extracts **1m^3/s** of air.

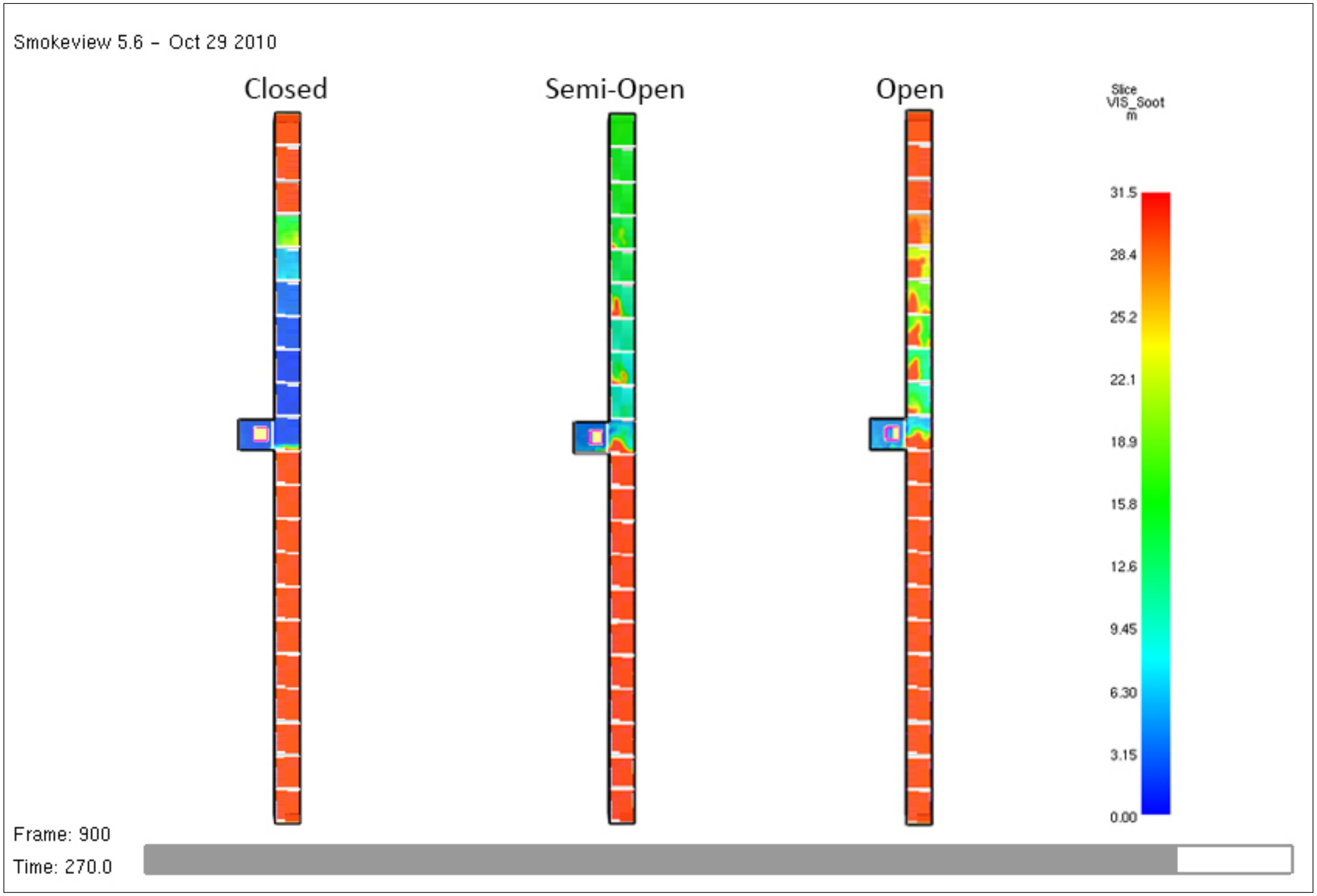
Visibility in the *Natural Ventilation* System

It is noticed that the smoke tends to occupy most of the stairs, due to heat pressure and stack effects.



Visibility in the *Pressurization* System

We perceive, that the smoke was prevented from entering the staircase.



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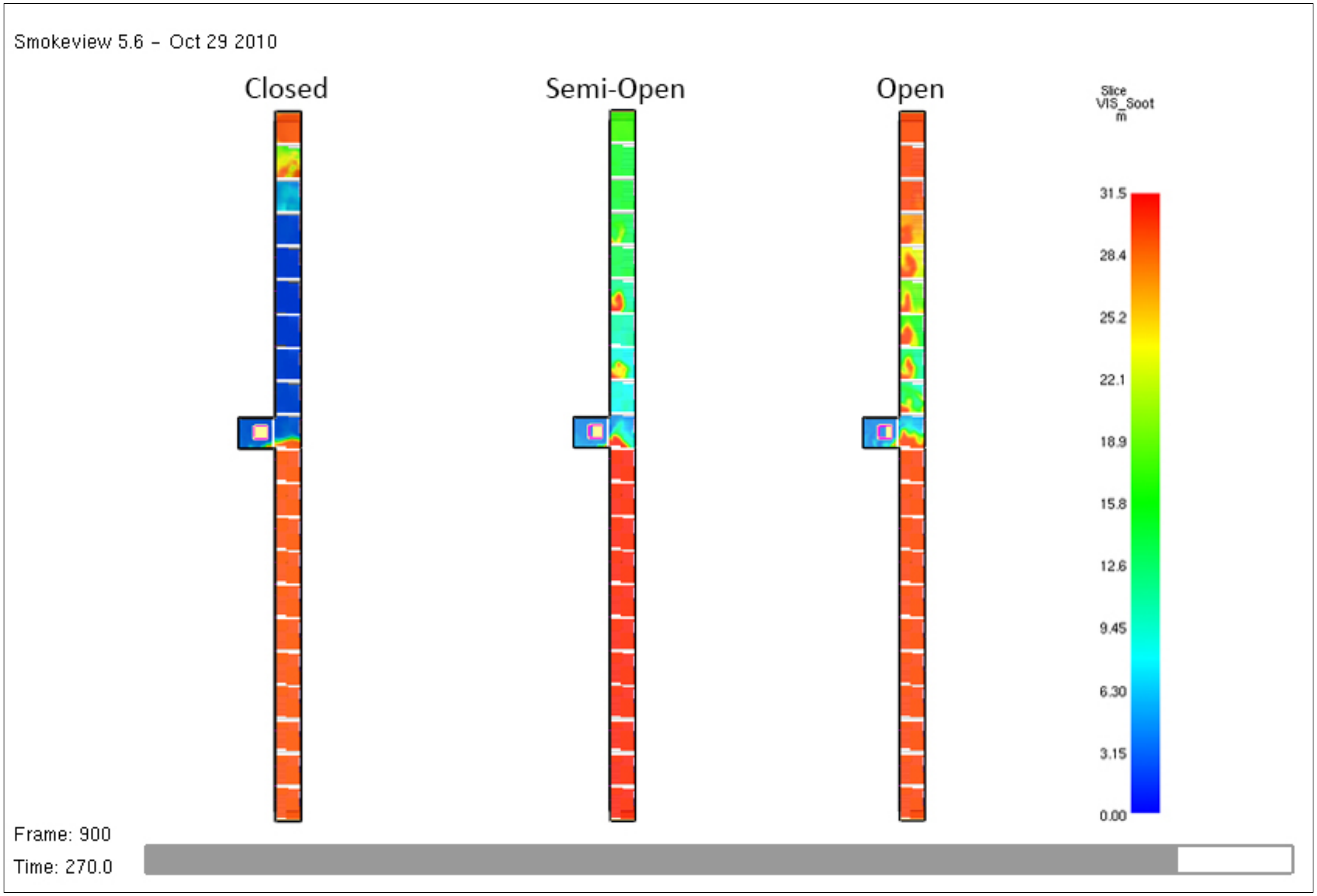
Visibility in the *Dilution* System

Only a little smoke was allowed to enter the staircase.



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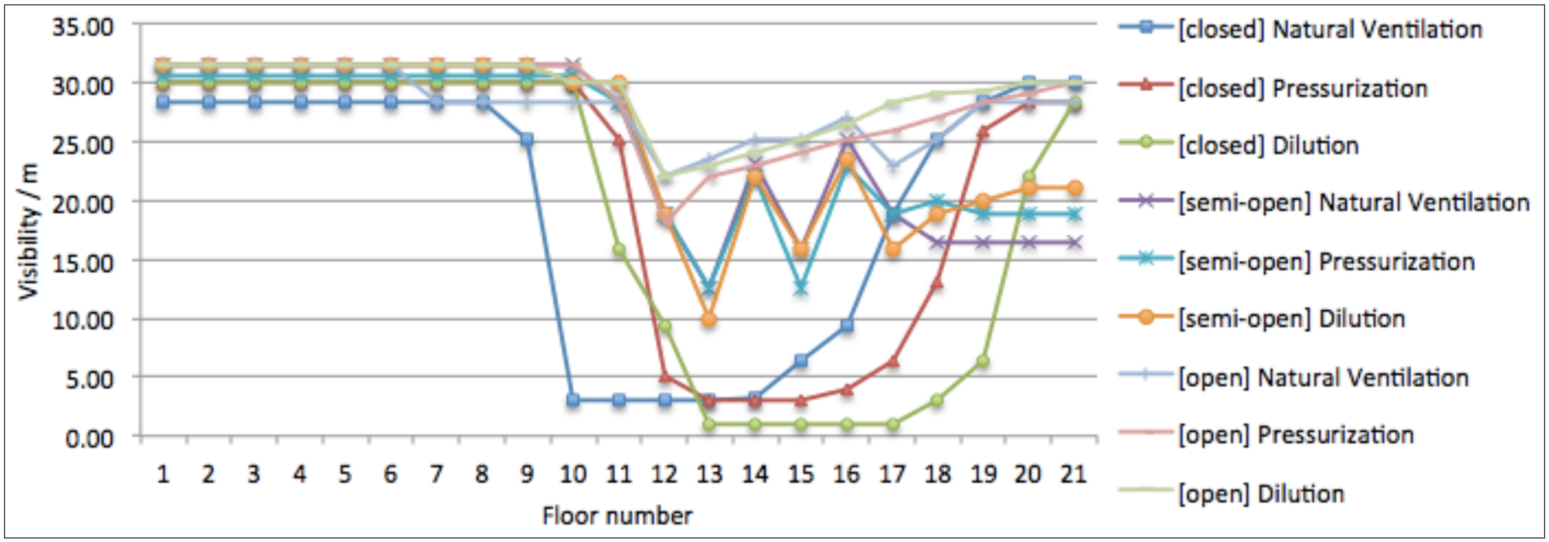
Visibility in the 3 ventilation conditions

In order to frame the interpretations, are considered minimum visibility of **5m** for unfamiliar and **13m** for people that are familiar with the building [10].



Natural ventilation – system the visibility hovers around:

- ***Closed***: from 10th till 14th floor the visibility is less than 5m, in 15th and 16th the visibilities vary around 10m, slightly less than the required code, and from 17th the visibility exceeds 18m;
- ***Semi-open***: with the exception of the 13th floor with 12,6m, the others floors visibility exceeds 15m;
- ***Open***: in this case the visibility is more than 20m.

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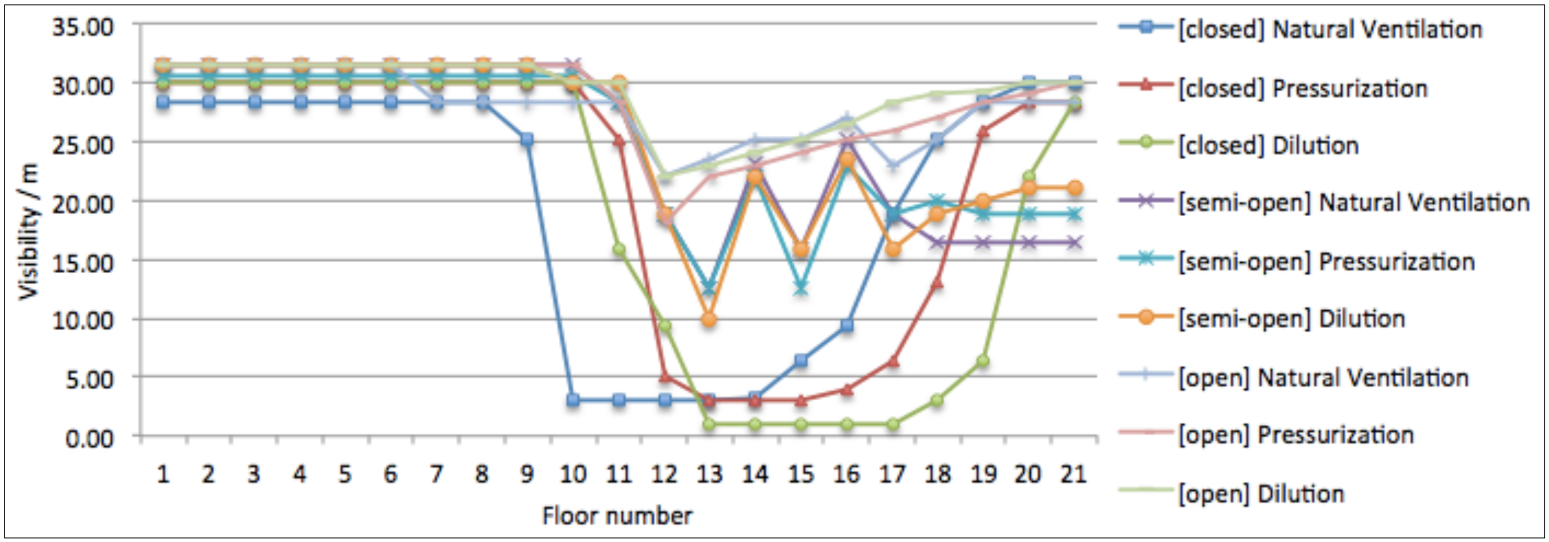

Pressurization system – exerting a pressure that prevents the smoke from entering the stairwell, so the visibility is:

- ***Closed***: between 12th to 16th floor the visibility is less than 5m, in 17th and 18th is between 5m to 13m and the others is greater than 25m;
- ***Semi-open***: with the exception of the 13th and 15th floor with 12,6m, the others floors visibility exceeds 15m.
- ***Open***: with the aid of the circulation of air flows, the visibility is more than 18m.

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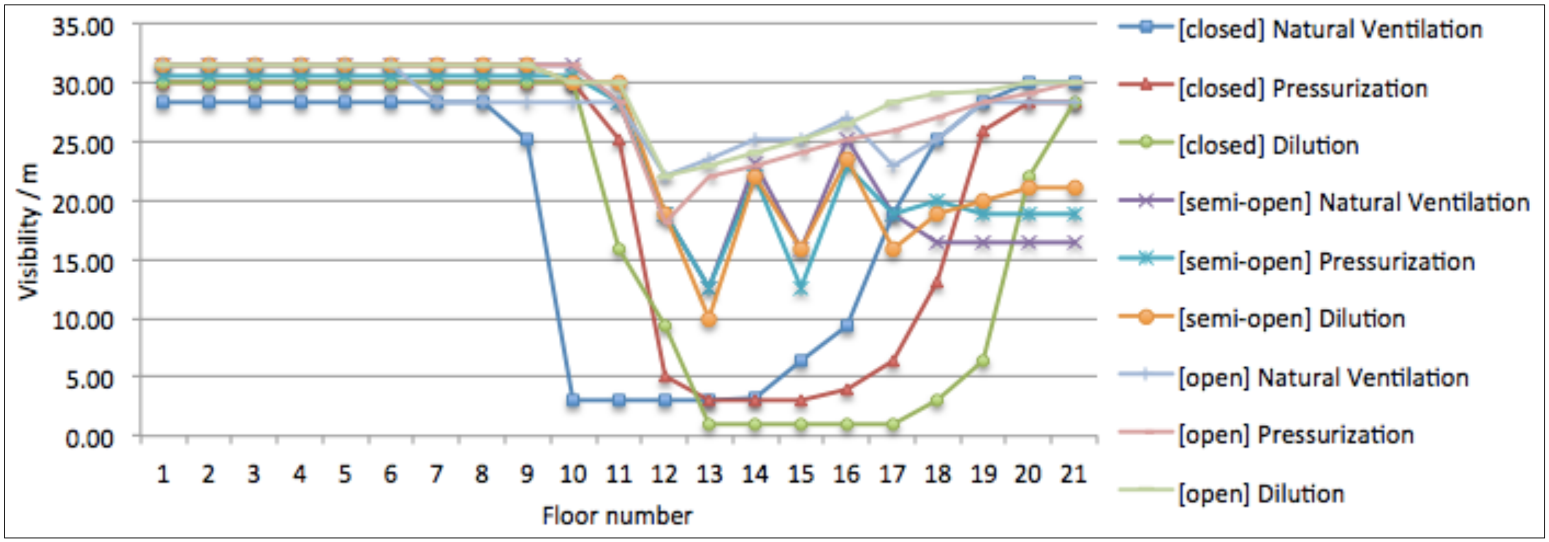
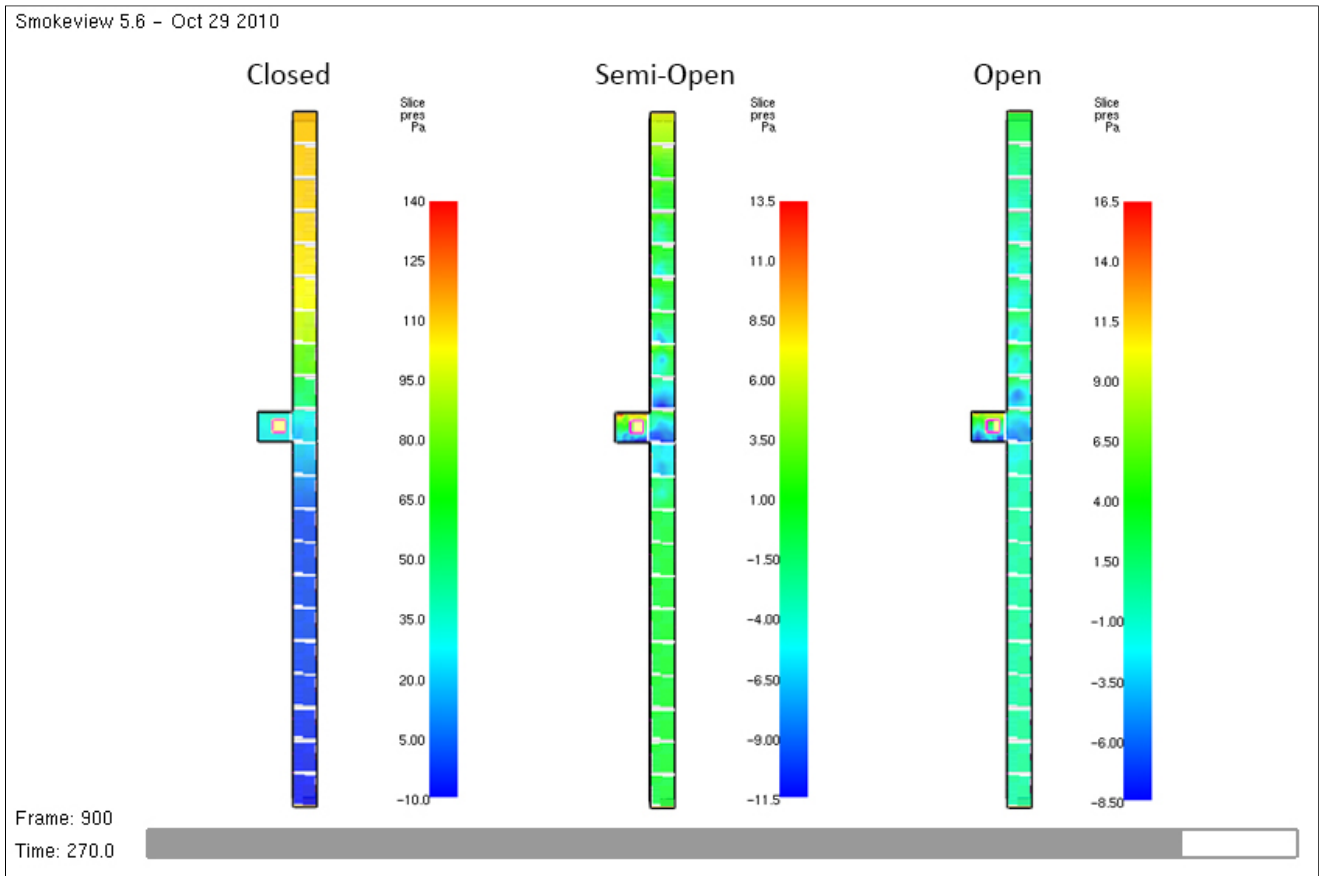


Dilution system – the visibility is:

- ***Closed***: the lowest visibility occurred between 13th to 18th floor with less than 3,5m, the 12th is 9,45m, allowing visibility exceeding 15m in other floors.
- ***Semi-open***: with the exception of the 13th floor with 10m, the other floors visibility exceeds 15m.
- ***Open***: here, the visibility is clearly greater than 21m.

Differential Pressure on the *Natural Ventilation* System

The pressurization when in the closed state reaches the bottom of a pressure **0_{Pa}** at the top reaches **110_{Pa}**. If this pressure increases at the bottom, it tends to be much higher in the upper part, consequently very high pressures, difficult to open the doors, affecting the evacuation. If we consider the open state, we find that the pressure is evenly distributed when the most pressure is less than **6_{Pa}**.



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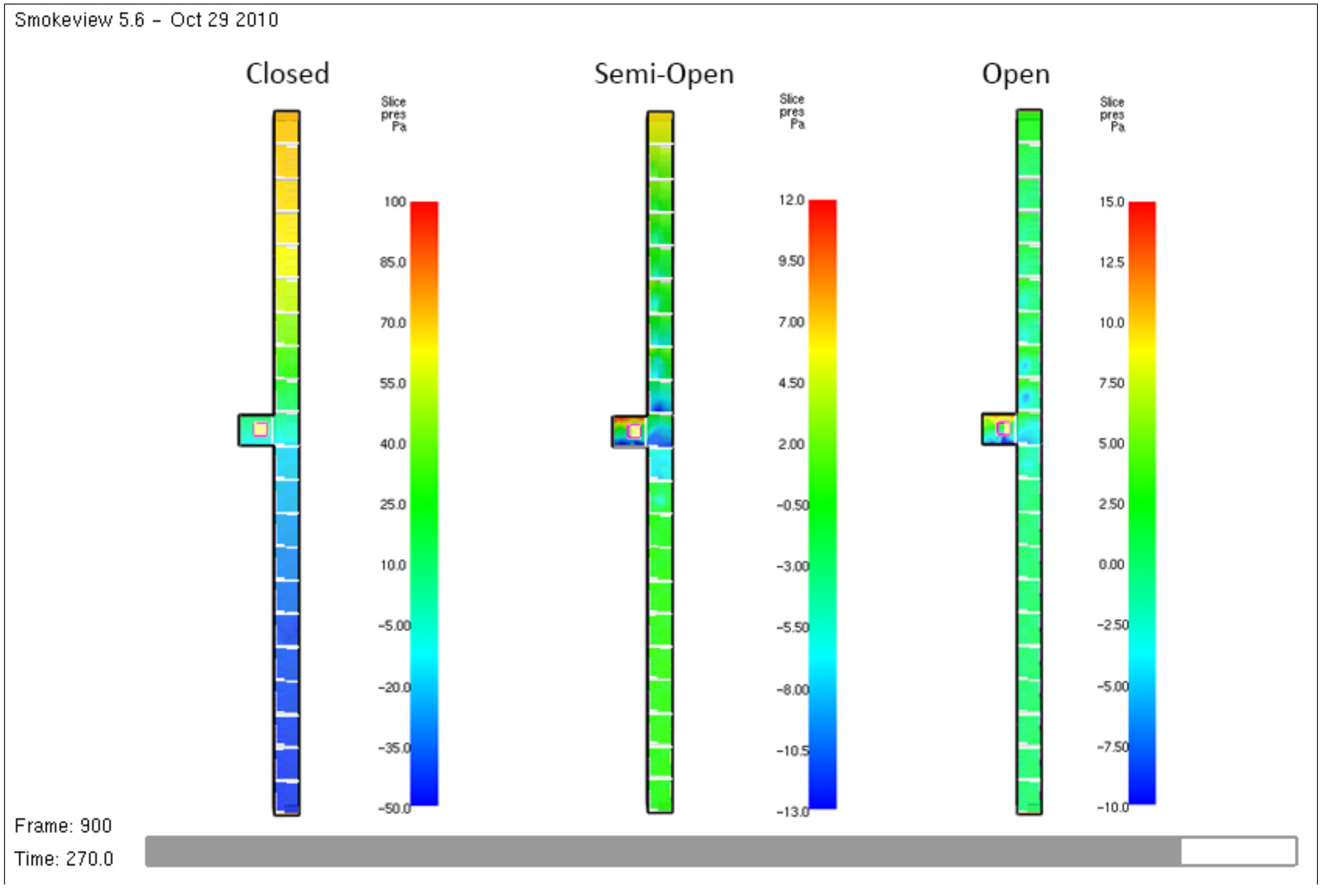
Differential Pressure in the *Pressurization* System

The pressurization in the closed state, exerts a very high pressure on the top of the staircase, thus creating a difficulty to open the exit door. While the measurement of pressure is **-40**$_{Pa}$ on the first floor, however it tends to achieve **70**$_{Pa}$ on top.



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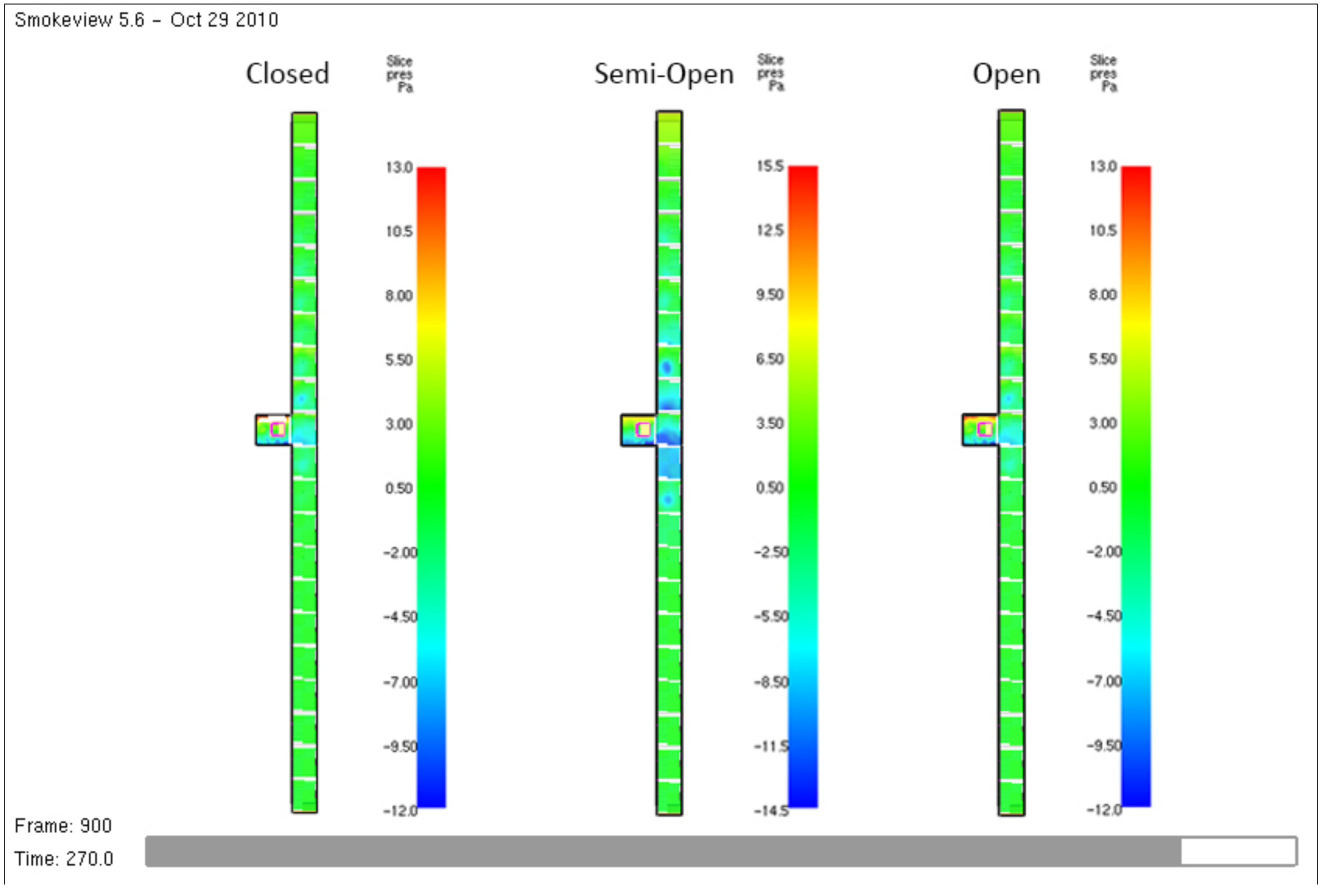
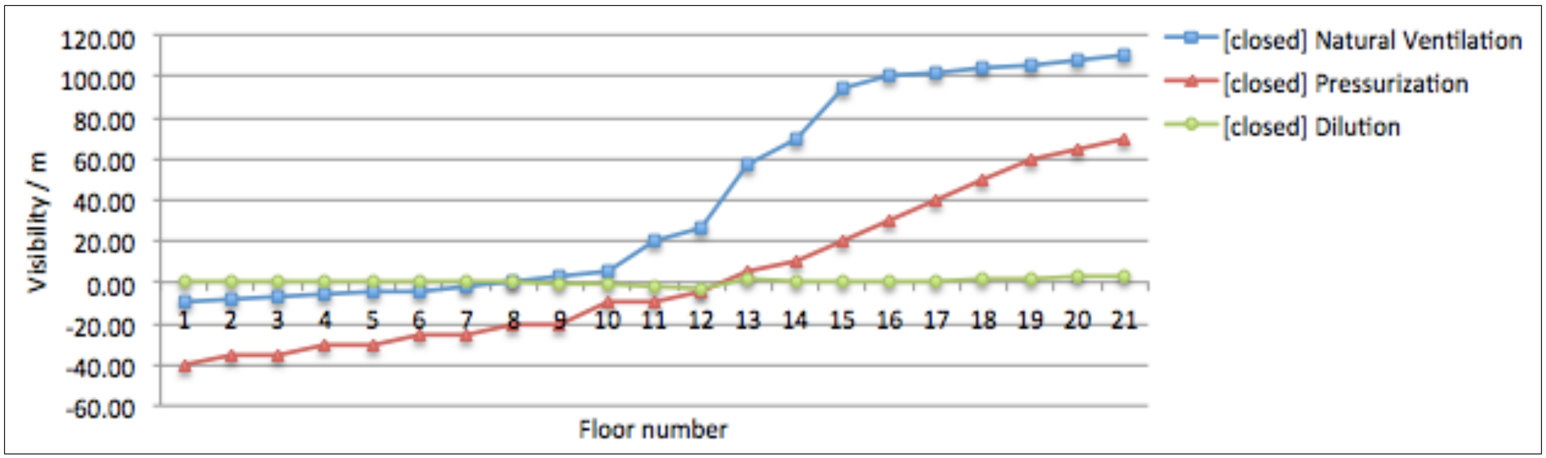
Differential Pressure in *Dilution* System

Although the negative pressures occurring in the closed state, but uniformly distributed on the height change, thus the best result is given that the highest pressure is less than **4_{Pa}**. With some doors open in three conditions, the pressure was slightly lower in each stairwell.



Differential Pressure in the Closed state

With the fire remained burning for **4.5**$_{mn}$, one realizes that a negative pressure caused by stack effect occurred in the first 8 floors below the 12th floor, meaning that if the fire appears in these stories, the smoke quickly spread to the stairs.



Features of the machine simulation

Was run 9 simulation of **5**$_{mn}$ each on, using a machine with OS Windows 8, 64bit, processor intel(R) Core (TM) i7-3537U CPU @ 2.50GHz, 8.00GB RAM, GeForce GT 740M Graphics memory 4095MB.

Summary of results

Ventilation system	Visibility	Pressure differential
Natural ventilation	unacceptable	acceptable
Pressurization	very good	unacceptable
Dilution	acceptable	very good

In this sense, we can increase the amount of ventilation so that it reaches the ideal requirements. In the high buildings and considering the cases of large temperature difference between the indoor and the outdoor, the pressurization system, it is recommended that buildings be built a zone of refuge dividing the staircase in the middle, so as to weaken the pressure difference between the first and last floor, caused by stack effect.

Conclusion

Based on the simulation model, and according to the results clearly show that the dilution system is a possible solution and has better performance than other systems, both to issues of visibility in the stairwell as well as the difference pressure. So we believe that it is worth applying the dilution system in projects based on performance. However, regarding the amount of exchange ideal air into the system, need an even more comprehensive and thorough investigation.

Reference

[3] GB/T 50045-2005, *Code for Fire Protection Design of Tall Buildings* {S}

[10] Yin-Ging, L. (2004). *Fire Protection Engineering for Buildings* {M}. Beijing: Chemical Industry Press.

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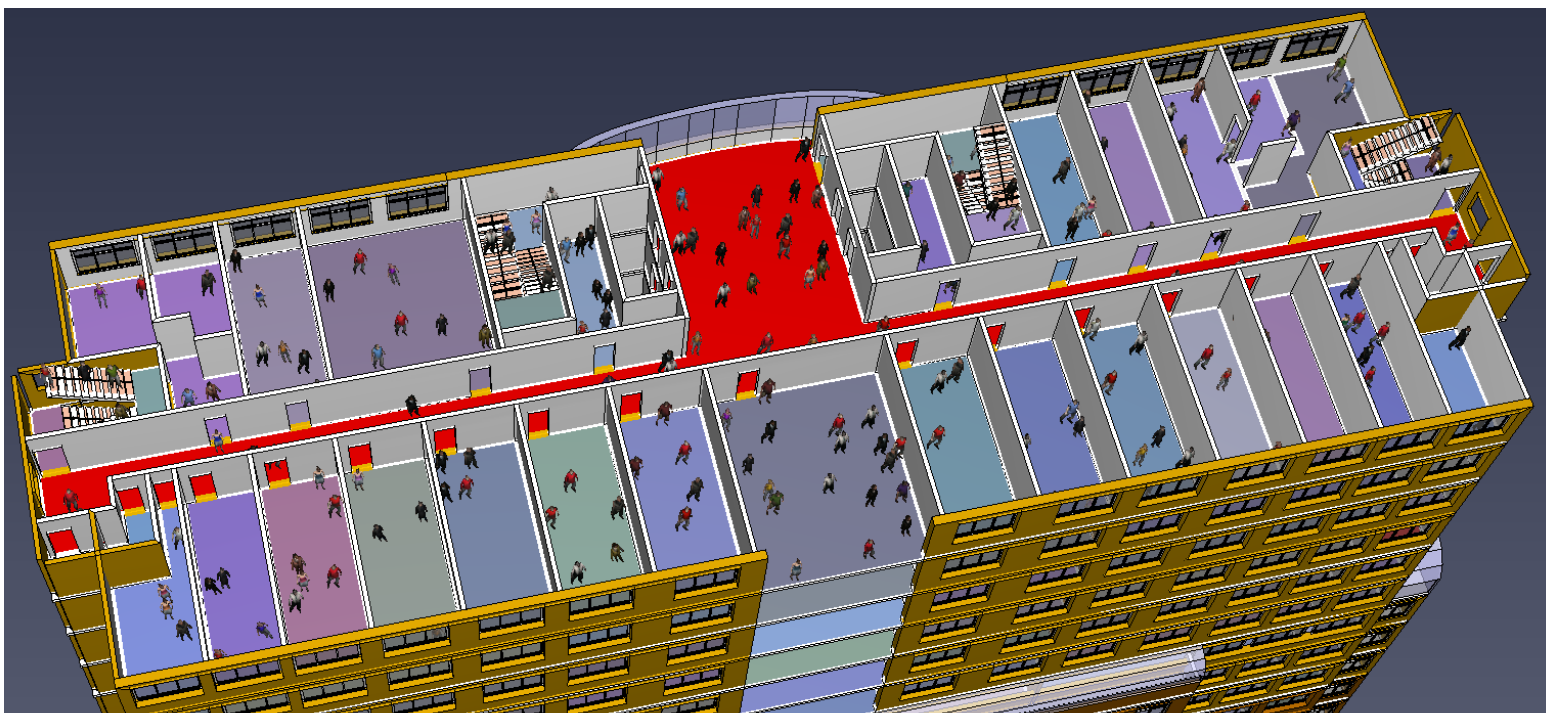
Future work

Centered in the methodology of projects based on performance, the future work will further validate the model by comparing these experimental data and the calculated results with simulation models of the evacuation zones of higher flow of occupants (FDS+Evac *vs* Pathfinder) according to the structure of the building under the fire in the study.



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Thank you

Obrigado

谢谢

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