Rising Damp in Historic Buildings: The Wall Base Ventilation System

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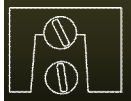
Summary



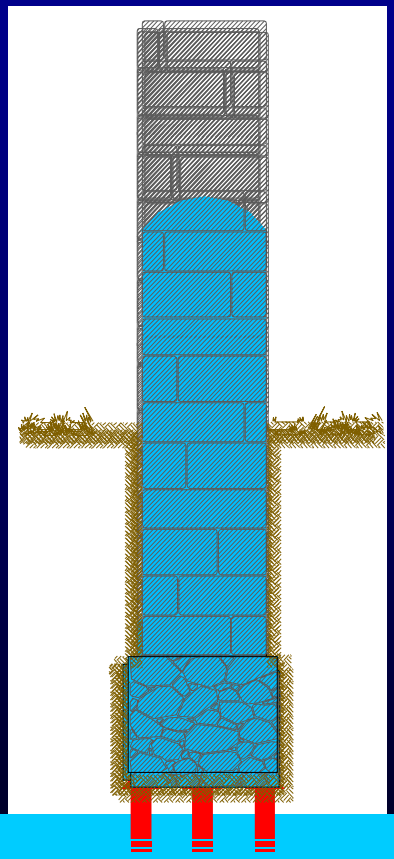
1. Introduction

Rising damp

One of the main causes of old buildings degradation

Limitations of traditionally used technologies in thick walls with heterogeneous composition

New solutions



1. Introduction

Rising Damp: Major cause of decay to masonry material: stone, brick, mortar

The conservation of historical buildings assumes a considerable importance

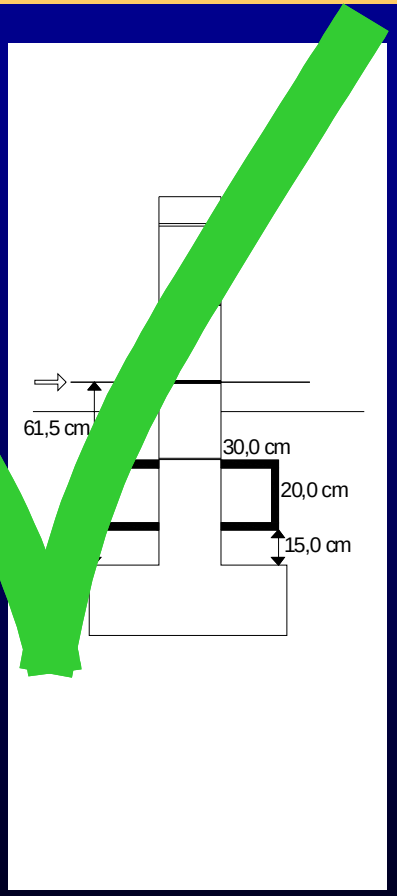
1. Introduction

Building Physics Laboratory (LFC)

Faculty of Engineering of University of Porto (FEUP)

Wall Base Ventilation System

HUMIVENT



1. Introduction

HUMIVENT

Understand the behaviour of air within the conduct

Calculate the water flow removed from the wall

Estimate the front level archived with the system

Aims:

- Develop a model:

  describe and characterize the water vapour transport over the conduct, between the wall and the conduct the relation with the front level on the wall

- Validate the model

2. Analytical Analyse - Wall

2.1 Theory

Hall and Hoff (2002)

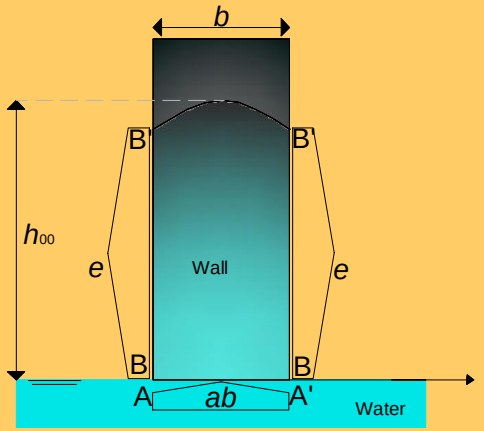
Absorption inflow and evaporation loss in balanced
(Disregarding gravitational forces)

$$b\frac{di}{dt} = b\frac{S}{2}t^{-1/2} - eh$$

$$i = \theta_w h$$

$$h = S\sqrt{\frac{b}{2e\theta_w}\left[1-\exp\left(-\frac{2e}{b\theta_w}t\right)\right]}$$

$$h_\infty = S\sqrt{\frac{b}{2e\theta_w}}$$



b	wall thickness (m)
i	volume of liquid absorbed (m3/m2)
θw	liquid bulk volume (-)
t	time (s)
S	sorptivity coefficient (m/s1/2)
e	evaporation potential (m/s)
h	rising damp height (m)

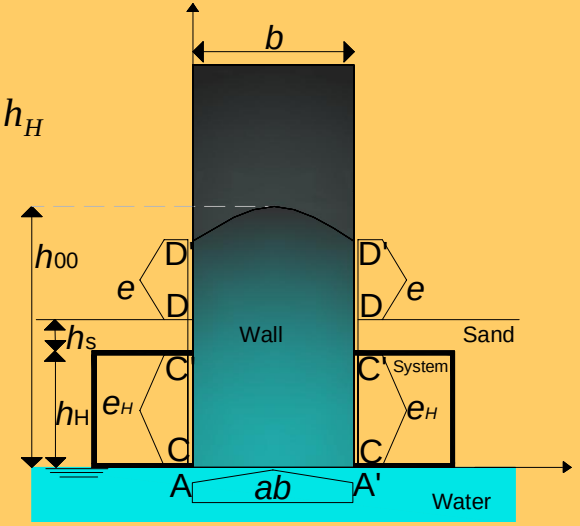
2. Analytical Analyse - Wall

2.2 Our contribution

Absorption inflow and evaporation loss in balanced
(Disregarding gravitational forces)

$$\frac{bS^2}{2\theta_w h_\infty} = e(h_\infty - h_s - h_H) + e_H h_H$$

b	wall thickness (m)
θw	liquid bulk volume (-)
S	sorptivity coefficient (m/s1/2)
e	evaporation potential (m/s)
eH	evaporation potential (HUMIVENT system) (m/s)
hs	height of the sand (m)
hH	height of the HUMIVENT system (m)

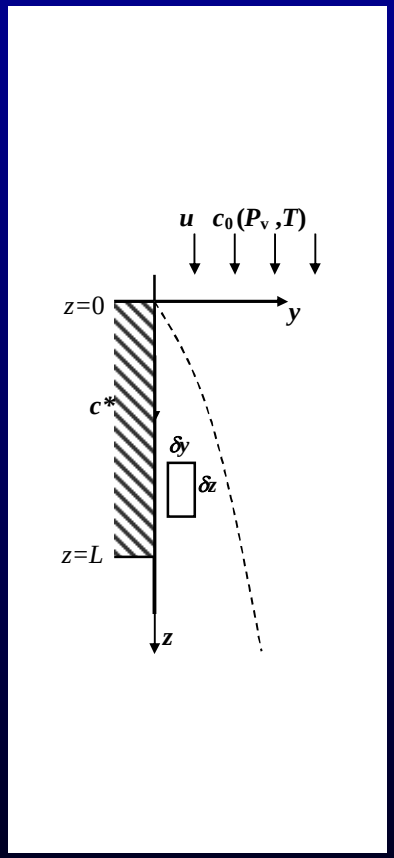


$$h_\infty = \frac{h_s}{2} + \left(1 - \frac{e_H}{e}\right)\frac{h_H}{2} + \sqrt{\frac{bS^2}{2\theta_w e} + \frac{h_s^2}{4} + \left(\frac{e_H}{e} - 1\right)^2 \frac{h_H^2}{4} + \left(1 - \frac{e_H}{e}\right)\frac{h_s h_H}{2}}$$

3. Analytical and Numerical Analyse - System

It is consider:

- A system along which air is flowing, close to the saturated wall ($0<z<L$)
- Air flow will be taken to be steady, with uniform average velocity u
- Concentration of water vapour in the air fed to the channel is $c0$
- Concentration of water vapour in the solid wall is c^*
- Situations for which the moisture transfer boundary layers is thin



Steady state material balance leads to:

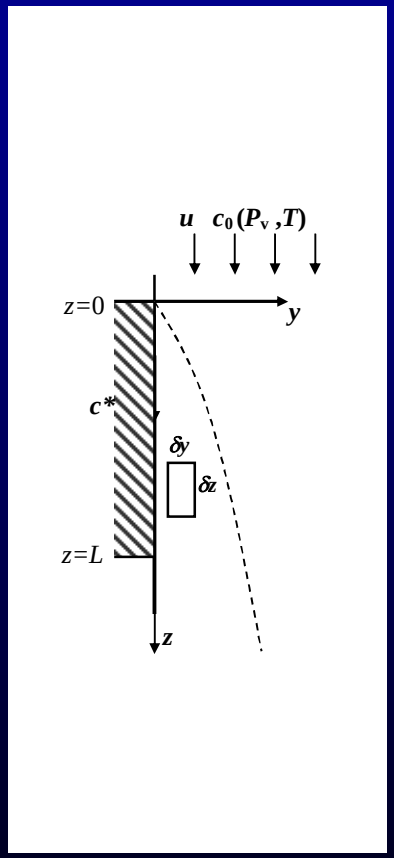
$$u\frac{\partial c}{\partial z} = D_{\mathrm{m}}\frac{\partial^2 c}{\partial y^2} + D_{\mathrm{m}}\frac{\partial^2 c}{\partial z^2}$$

3. Analytical and Numerical Analyse - System

If is consider:

Wall surface, is a surface of constant concentration

Equation of diffusion in one dimension



Analytical solution

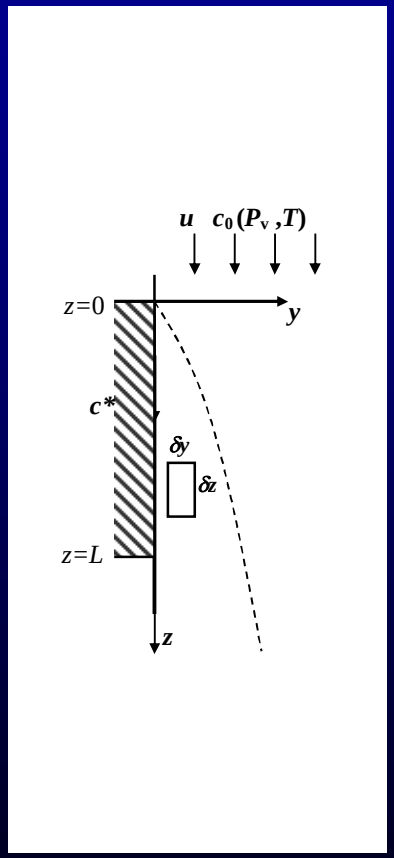
$$e_H = \frac{(c^* - c_0)}{\rho_w}\left(\frac{4D_m}{\pi L/u}\right)^{1/2}$$

Steady state material balance leads to:

$$u\frac{\partial c}{\partial z} = D_m\frac{\partial^2 c}{\partial y^2} + \cancel{D_m\frac{\partial^2 c}{\partial z^2}}$$

3. Analytical and Numerical Analyse - System

Finite-difference method



Numerical solution

$$e_H = \frac{(c^* - c_0)}{\rho_w}\left(\left(\frac{2D_m}{\pi L/u}\right)^{1/4} + \frac{4D_m}{\pi L/u}\right)^{1/2}$$

Steady state material balance leads to:

$$u\frac{\partial c}{\partial z} = D_m\frac{\partial^2 c}{\partial y^2} + D_m\frac{\partial^2 c}{\partial z^2}$$

4. Experimental Study

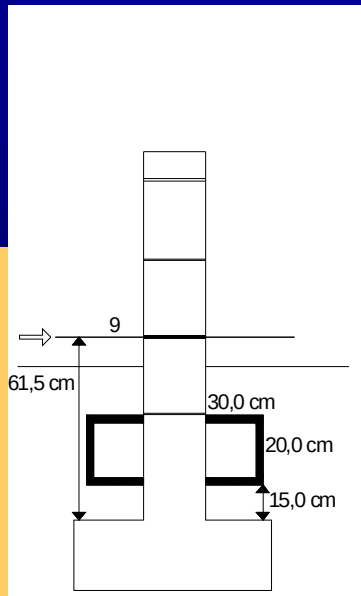
Assess the effect of the HUMIVENT system

Flow entrance:

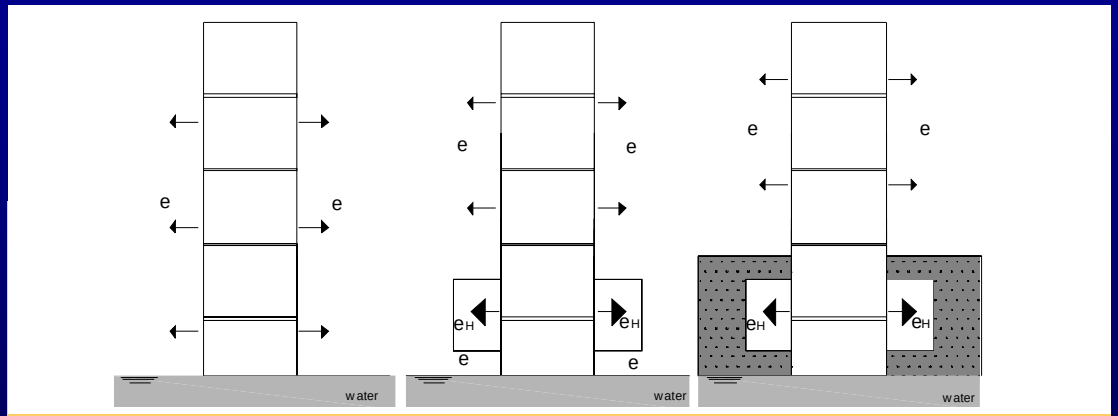
- **Temperature**
- **Relative Humidity**

Flow exit:

- **Temperature**
- **Relative Humidity**



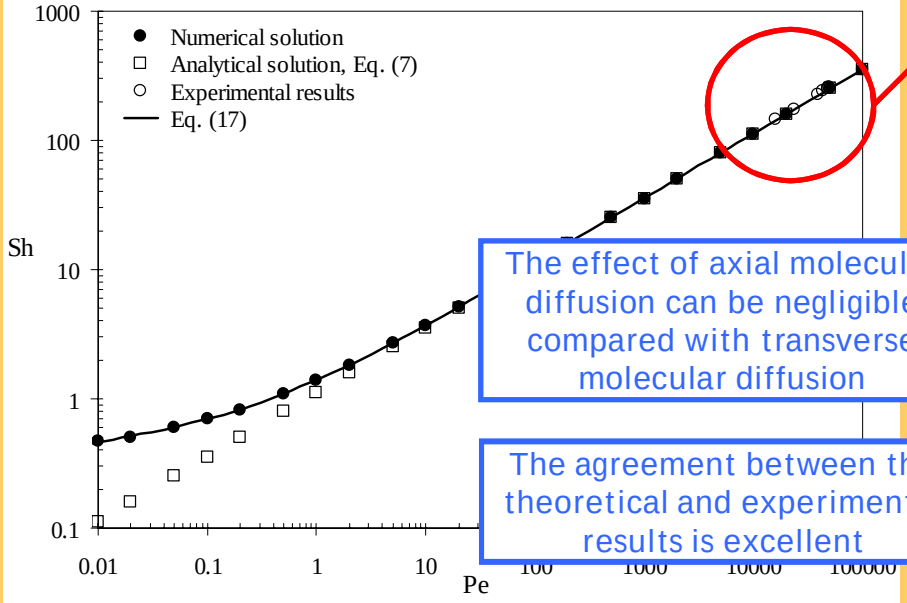
4. Experimental Study



Configuration 1	Configuration 2		Configuration 3	
RH_0 (%)	RH_0 (%)	RH_s (%)	RH_0 (%)	RH_s (%)
60.0	57.8	60.1	58.2	60.3
T_0 (º C)	T_0 (º C)	T_s (º C)	T_0 (º C)	T_s (º C)
20.0	22.6	22.4	23.0	22.8

5. Results and Discussion

1st - Analytical and Numerical Analyse - System



The effect of axial molecular diffusion can be negligible compared with transverse molecular diffusion

The agreement between the theoretical and experimental results is excellent

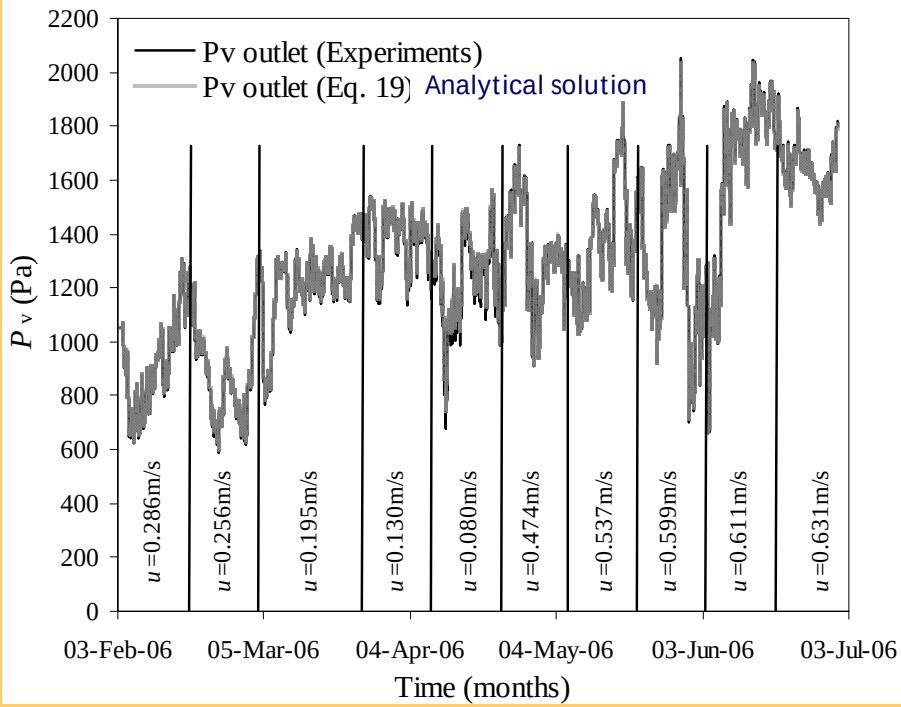
Experimental results

Numerical ≅ Analytical ≅ Experimental

do not deviate by more than 1%

5. Results and Discussion

2nd - Analytical and Numerical Analyse – System and Experimental Results



The agreement between the theoretical and experimental results is excellent:

Over the entire range

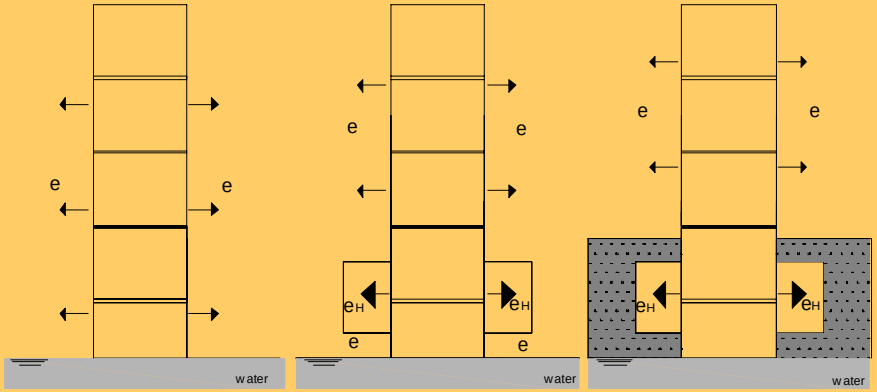
For all tested velocities

For all tested inlet condition

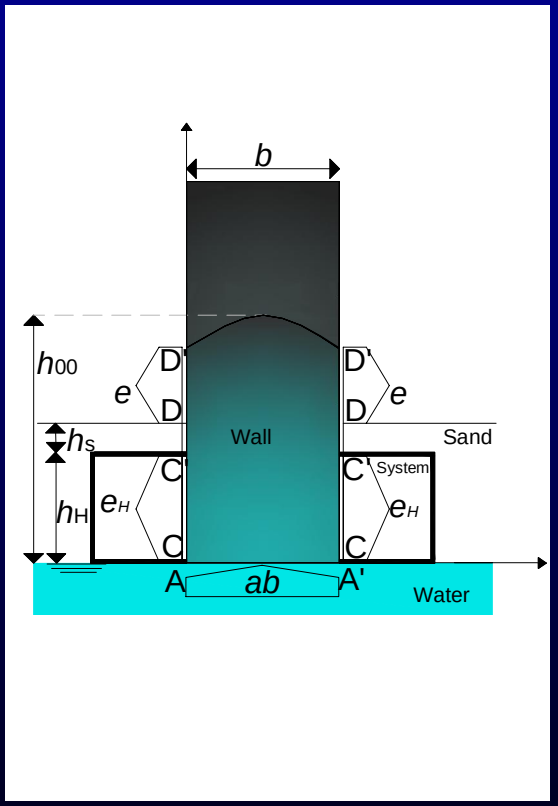
During this research HUMIVENT removed water from the wall

5. Results and Discussion

3rd – Analytical Analyse – Wall and System

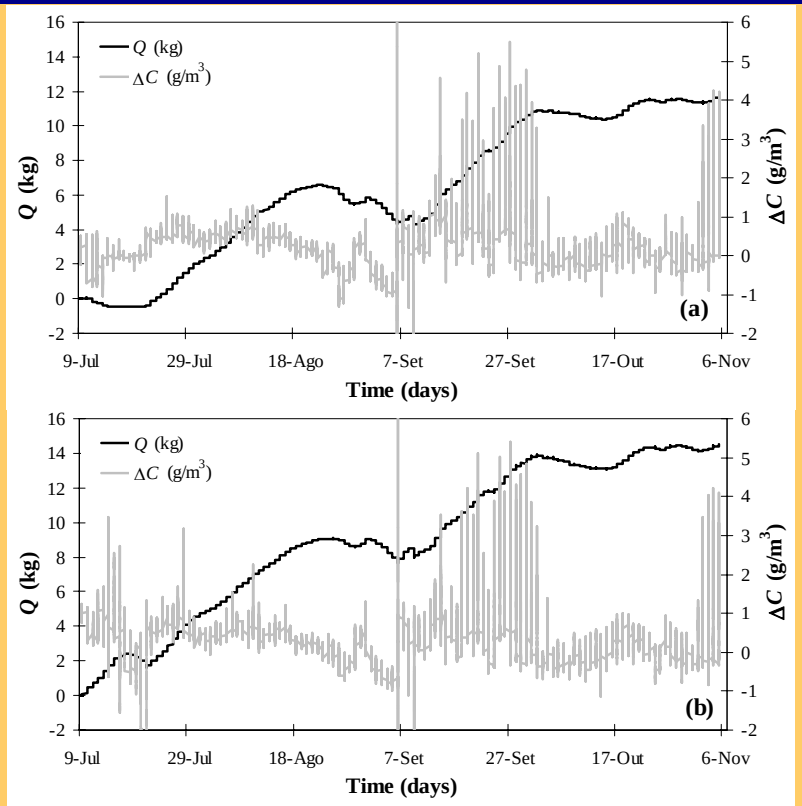


	Configuration 1		Configuration 2		Configuration 3	
	Exp.	Eq.	Exp.	Eq.	Exp.	Eq.
h_∞ (mm)	455 to 540	510	380 to 455	380	455 to 540	451



5. Results and Discussion

3rd – Analytical Analyse – Wall and System



Quantity of water vapour extracted and concentration differential in:
(a) - Configuration 2,
(b) - Configuration 3.

During these months of experimental research, in laboratory tests on Configurations 2 and 3 the new treatment technique extracted approximately 11.8 kg and 14.5 kg of water respectively

In field …

Buildings where, for the first time, HUMIVENT was applied – PORTUGAL

6. Conclusions

Wall base ventilation is a simple technique that has a great practical potential

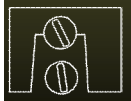
Before treatment

After treatment

HUMIVENT

6. Conclusions

- Moisture transfer between a wall surface and the air flowing along it, lends to a theoretical analysis
- The equations resulting from differential moisture balance has been numerically and analytically solved
- The numerical and analytical similar results let conclude that the axial molecular diffusion effect can be negligible compared with transverse molecular diffusion

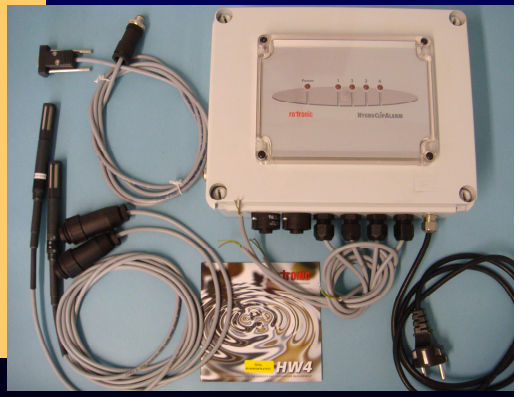


6. Conclusions

- The excellent agreement between the theoretical and experimental results allocate the use of the develop equations to estimate the evaporative process
- The model of rising damp that predicts steady height of rise are consistent with laboratory observations, which provide a good validation of the analysis
- Using this model it is possible to scale the HUMIVENT system, optimise it and predict its behaviour.

HUMIVENT

Prototype



Thank you for your attention

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