Treatment of Rising Damp in Historic Buildings Using a Wall Base Hygro-Regulated Ventilation System

Case Study

Vasco Peixoto de Freitas

Francisca Barbosa; Ana Sofia Guimarães; João Delgado

Faculty of Engineering, University of Porto

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

CONSTRUCT

LFC

Summary

1. Problem statement and research questions
2. Treatment techniques
3. Hygo-regulated wall base ventilation system - principle
4. Numerical and experimental validation
5. Design Procedure – HUMIVENT System
6. Implementation – Case Study
7. Conclusion

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
CONSTRUCT
LFC

1.

PROBLEM STATEMENT AND RESEARCH QUESTIONS

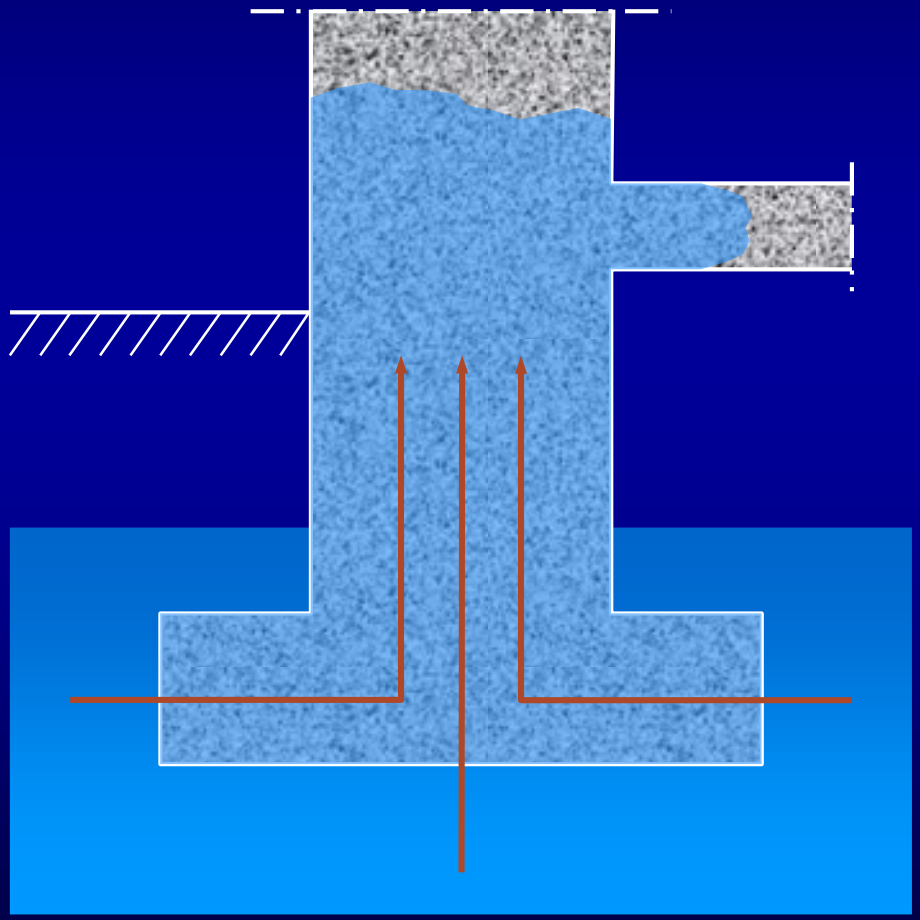
U.PORTO
FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
CONSTRUCT
LFC

In old or historic buildings the walls are in direct contact with the ground…

U.PORTO
FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
CONSTRUCT
LFC

Rising Damp – is a problem in stone or brick…

Groundwater – Precipitation (Rainwater)

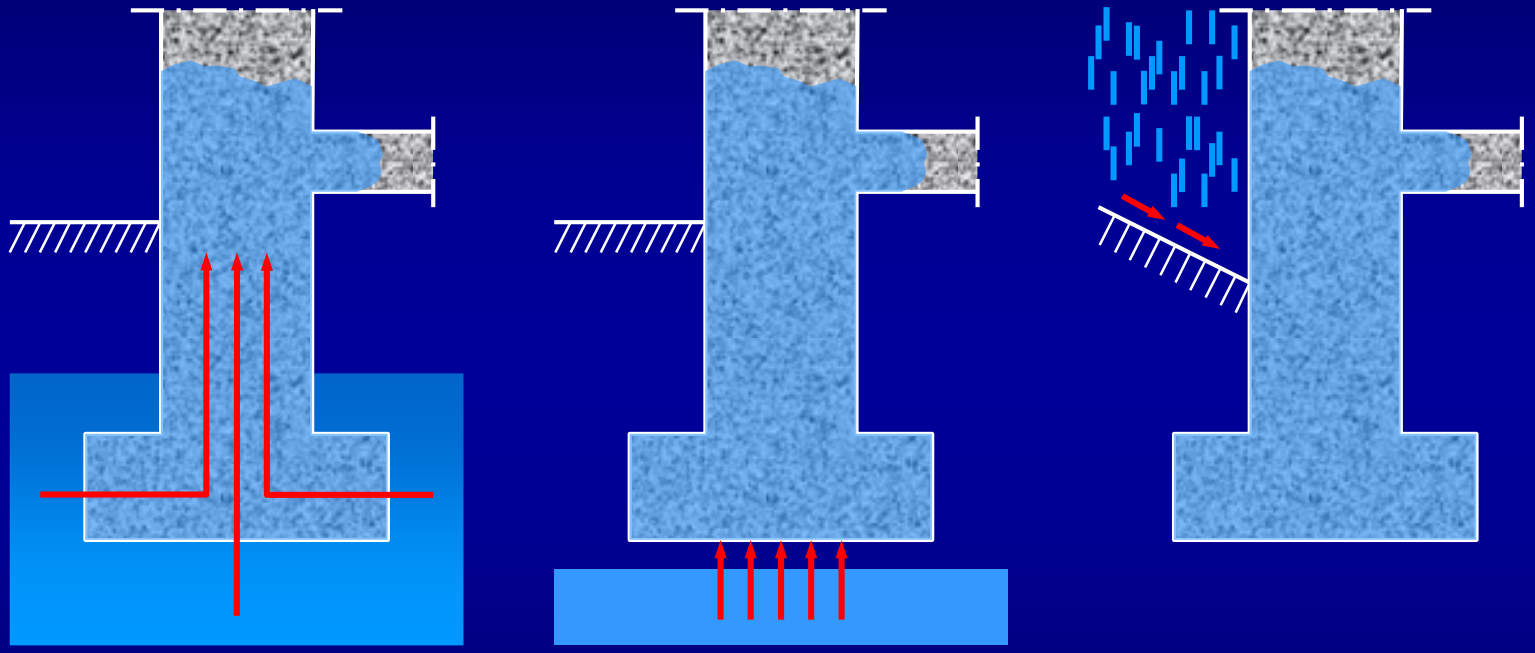


U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

CONSTRUCT

LFC

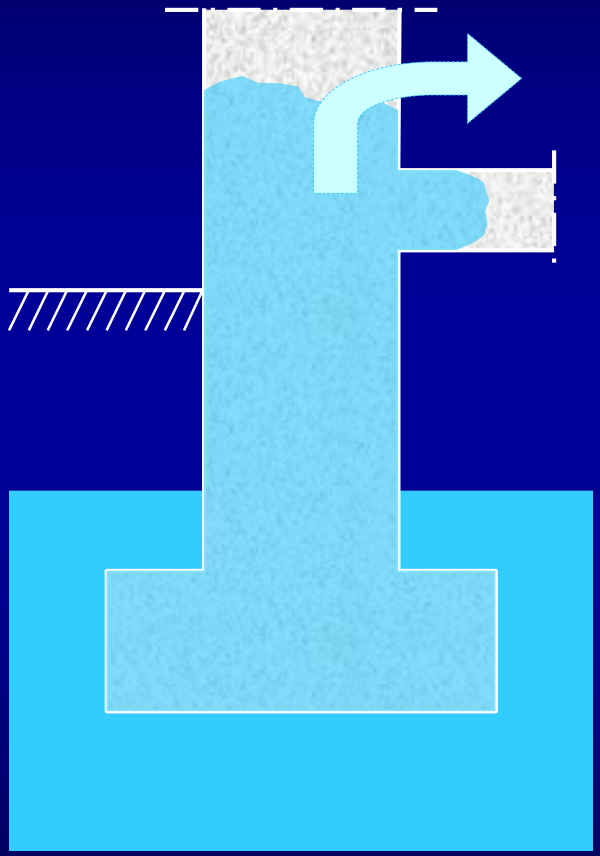
Moisture transfer by capillarity

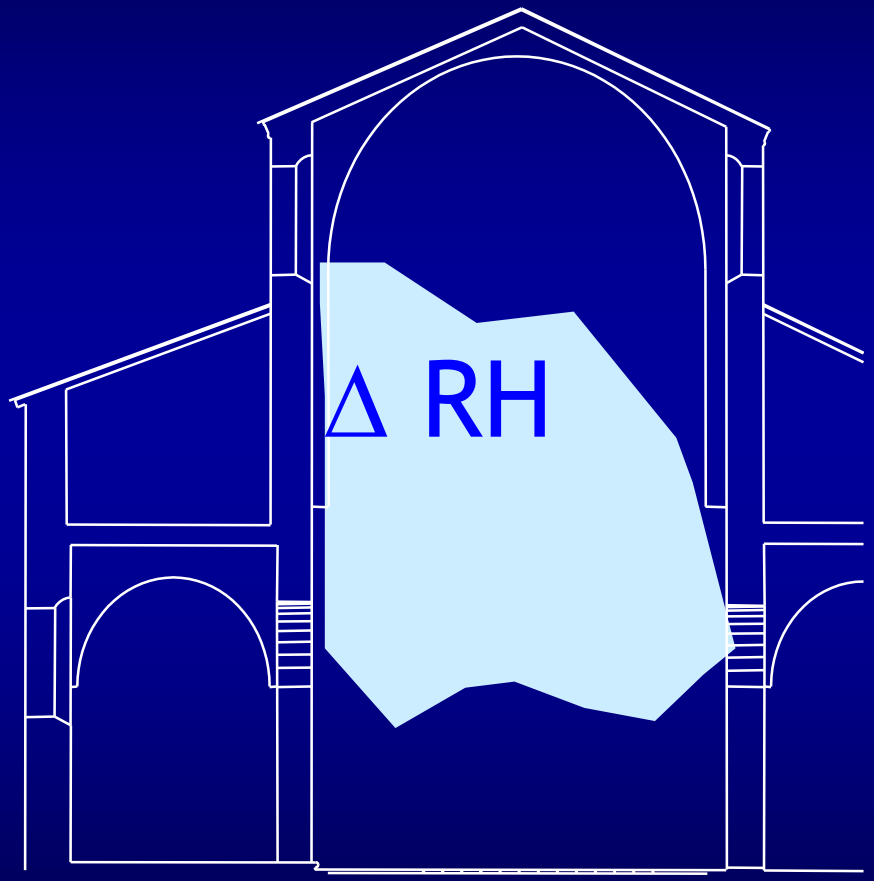


Groundwater

Surface water

The drying process increases the INDOOR RELATIVE HUMIDITY





Consequences: Damages inside the building

As a result: SALT CRYSTALLIZATION

DAMAGES OUTSIDE THE BUILDING

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

CONSTRUCT

LFC

HOW TO SOLVE

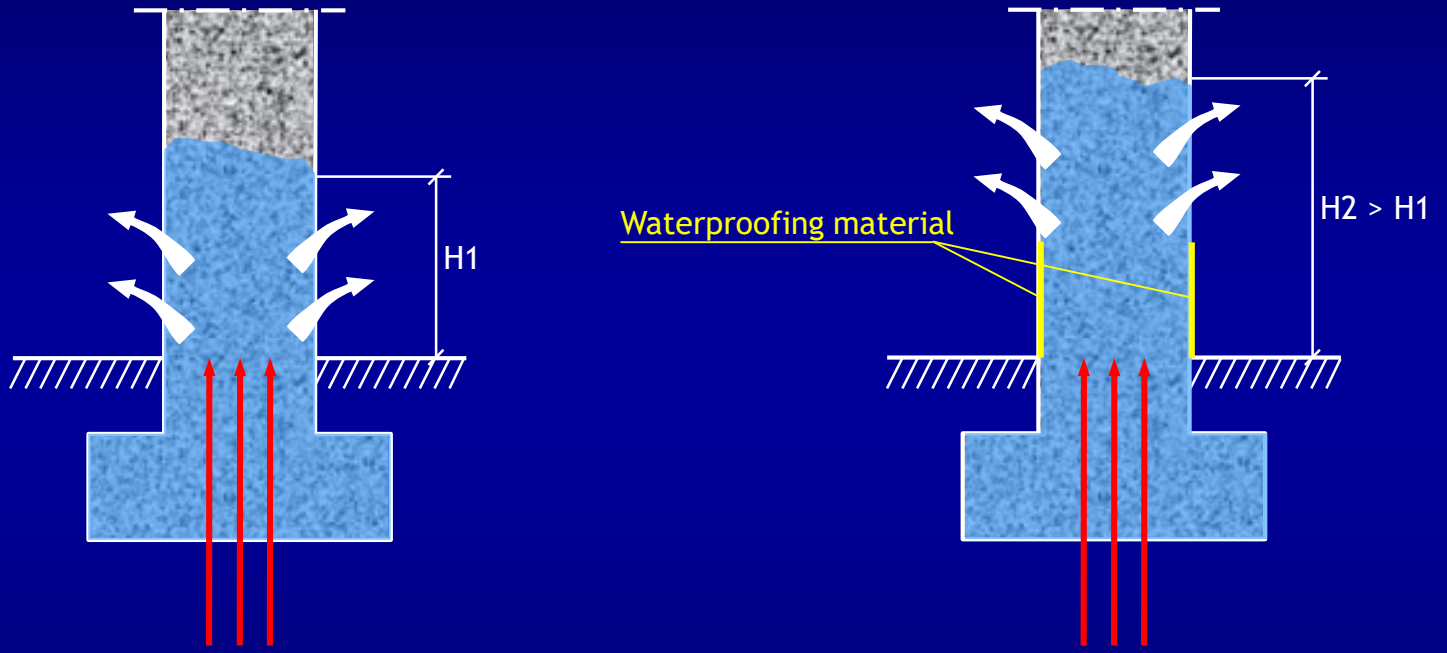
U.PORTO
FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
CONSTRUCT
LFC

2.

TREATMENT TECHNIQUES
Some examples

U.PORTO
FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
CONSTRUCT
LFC

Wall surface waterproofing?

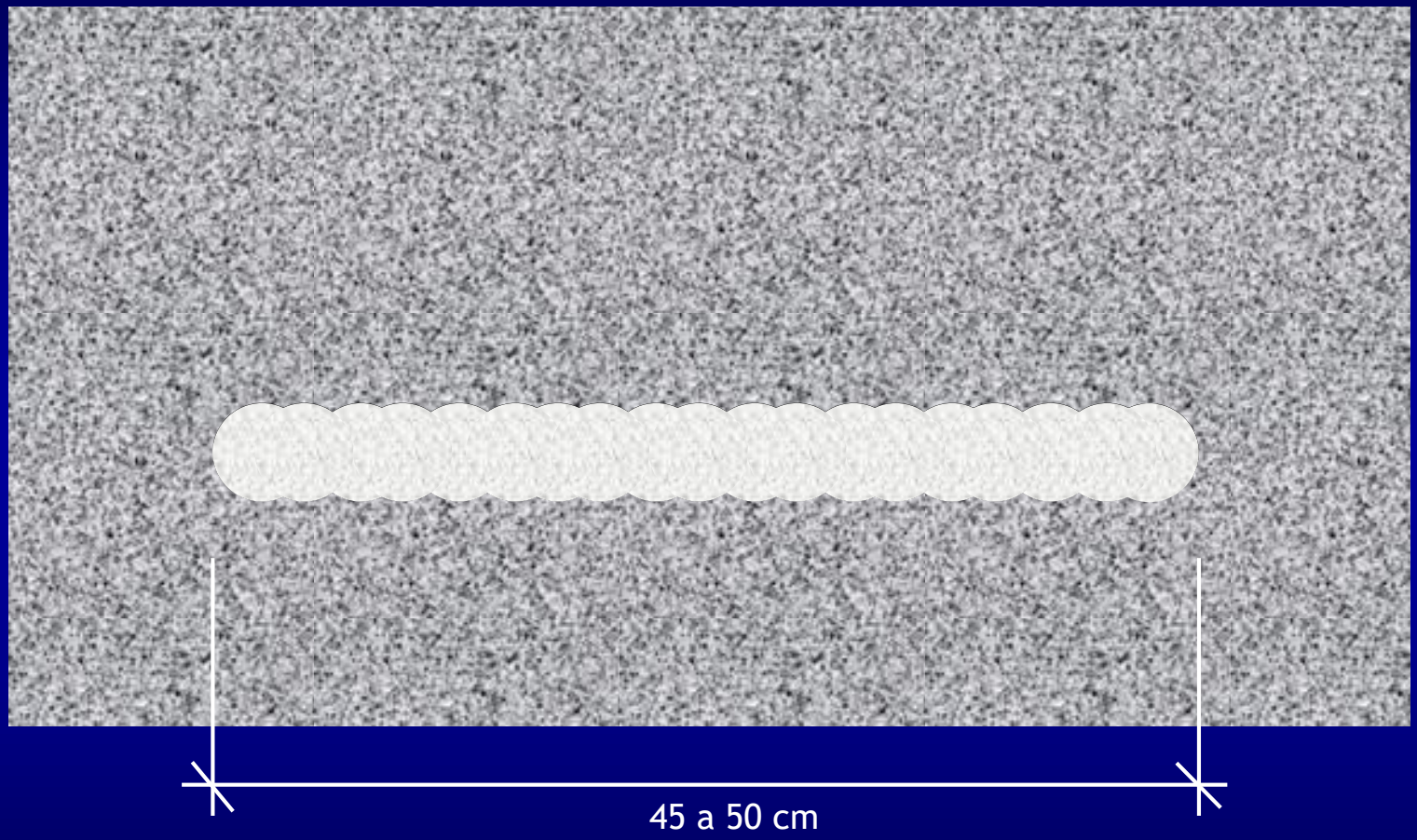


Waterproofing material coating effect → increases the level of the wet front

IN SITU...

U.PORTO
FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
CONSTRUCT
LFC

PHYSICAL BARRIER



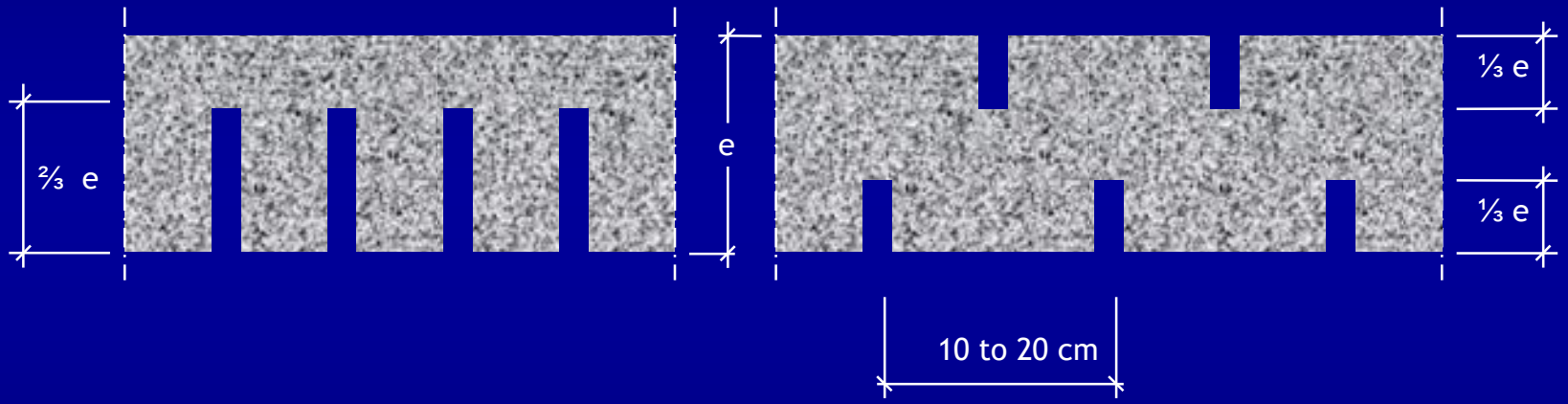
***Massari* Method**

CHEMICAL BARRIER

Catálogos comerciais.

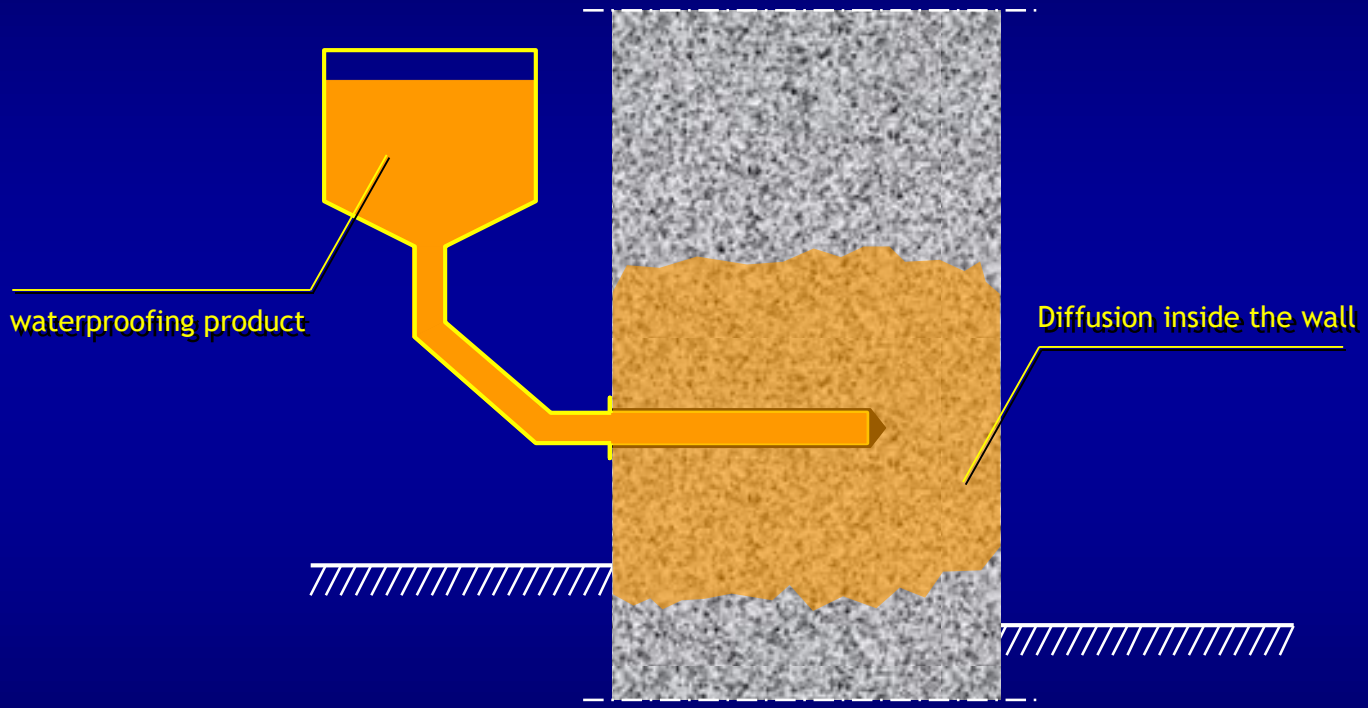
Introduction of waterproofing products by diffusion

CHEMICAL BARRIER



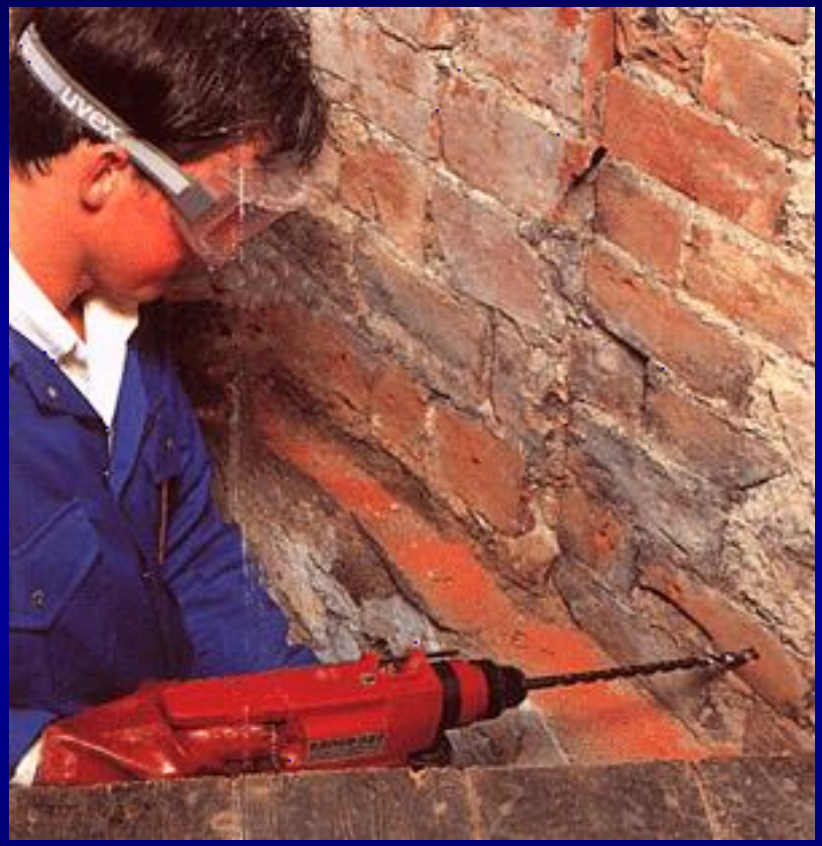
Introduction of waterproofing products: drilling scheme

CHEMICAL BARRIER - DIFFUSION



Introduction of waterproofing products by diffusion

CHEMICAL BARRIER - INJECTION



Catálogos comerciais.

Application in brick masonry

Performance

Are these techniques effective enough for walls with considerable thickness and heterogeneous materials

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

CONSTRUCT

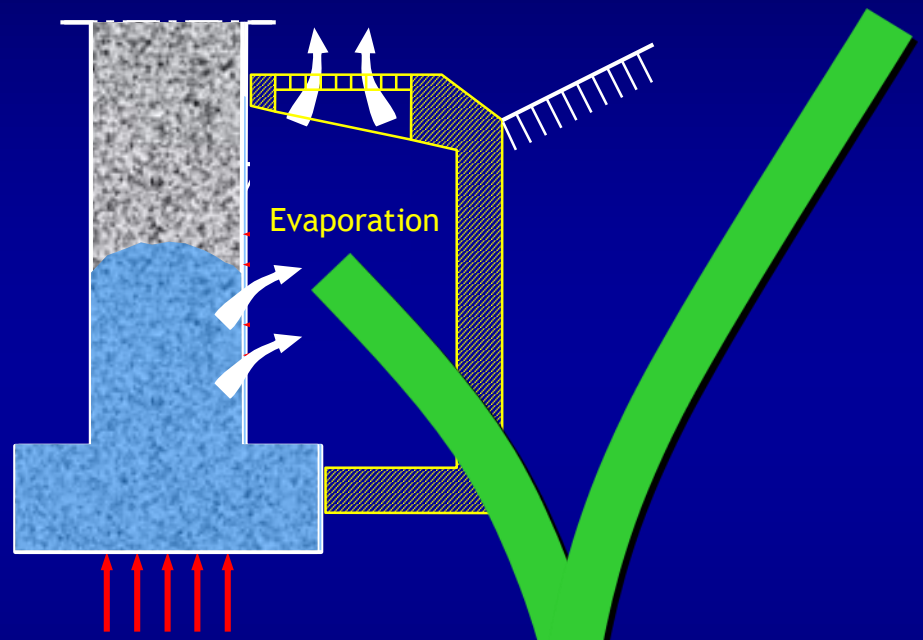
LFC

3

HYGRO-REGULATED WALL BASE VENTILATION SYSTEM (PRINCIPLE)

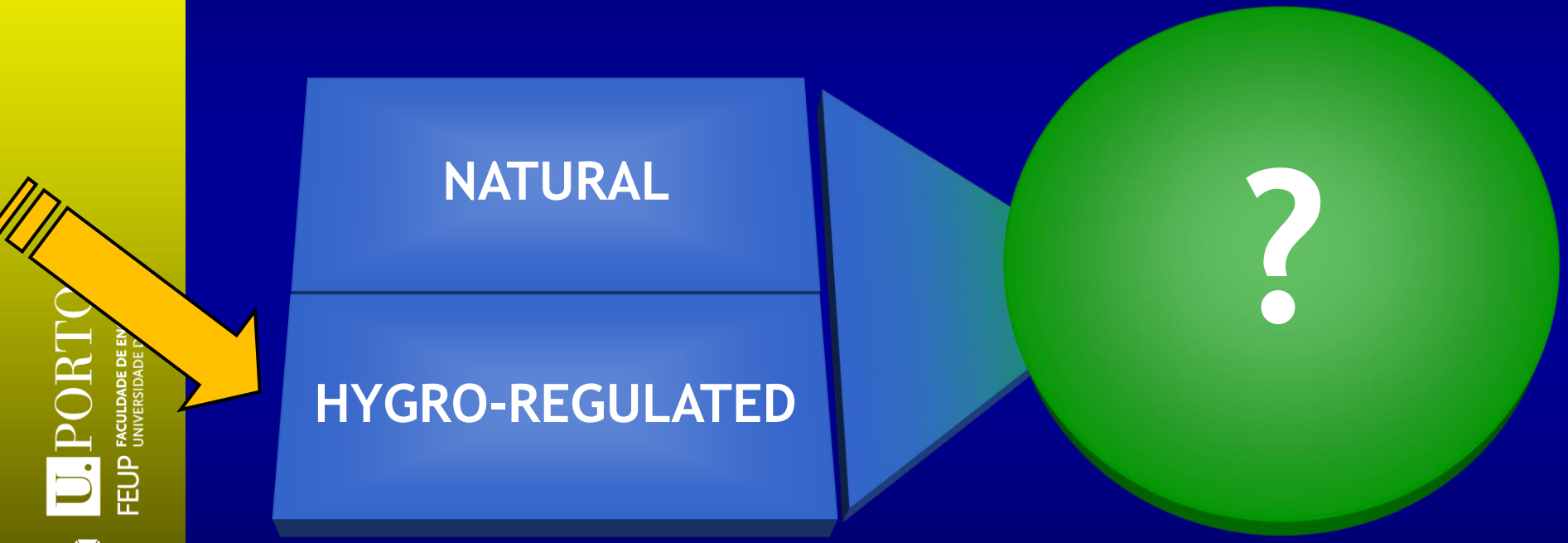
U.PORTO
FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
CONSTRUCT
LFC

The principle is not new - is based in the AIR circulation (VENTILATION)



Capillarity

BEST VENTILATION STRATEGY?



U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

CONSTRUCT

LFC

4.

NUMERICAL AND EXPERIMENTAL VALIDATION

U.PORTO
FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
CONSTRUCT
LFC

4 research steps

1. Physical Model and numerical validation
2. Geometry optimization of the channel
3. Development of the hygro-regulated ventilation device
4. “In situ” validation

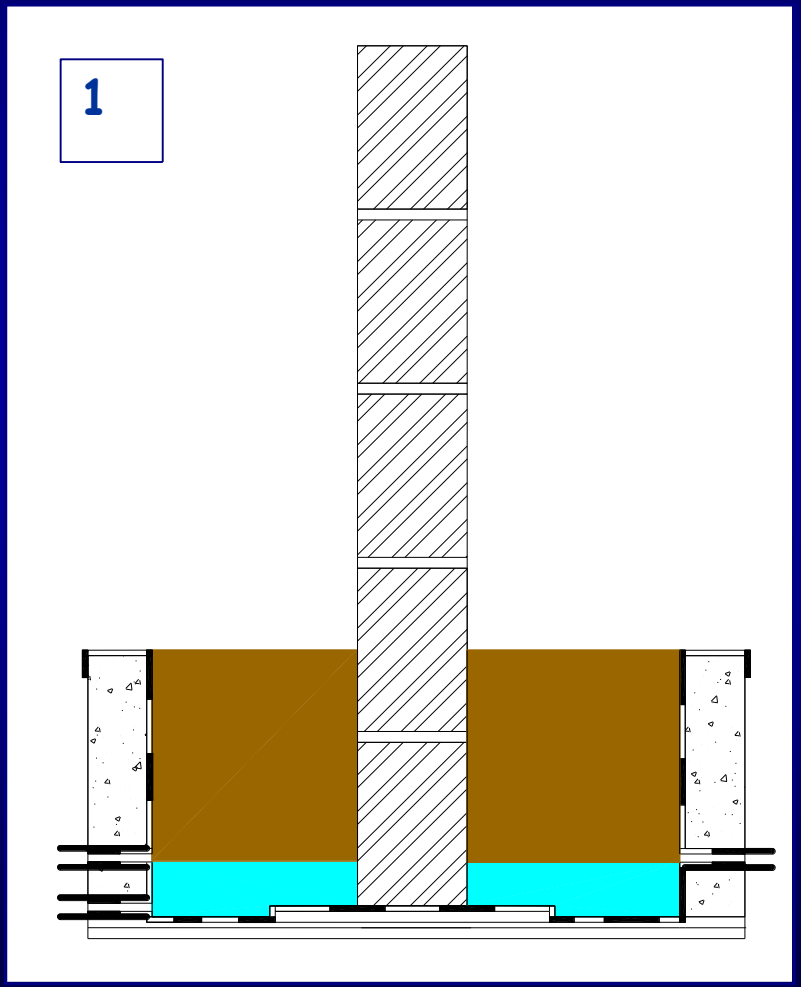
U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

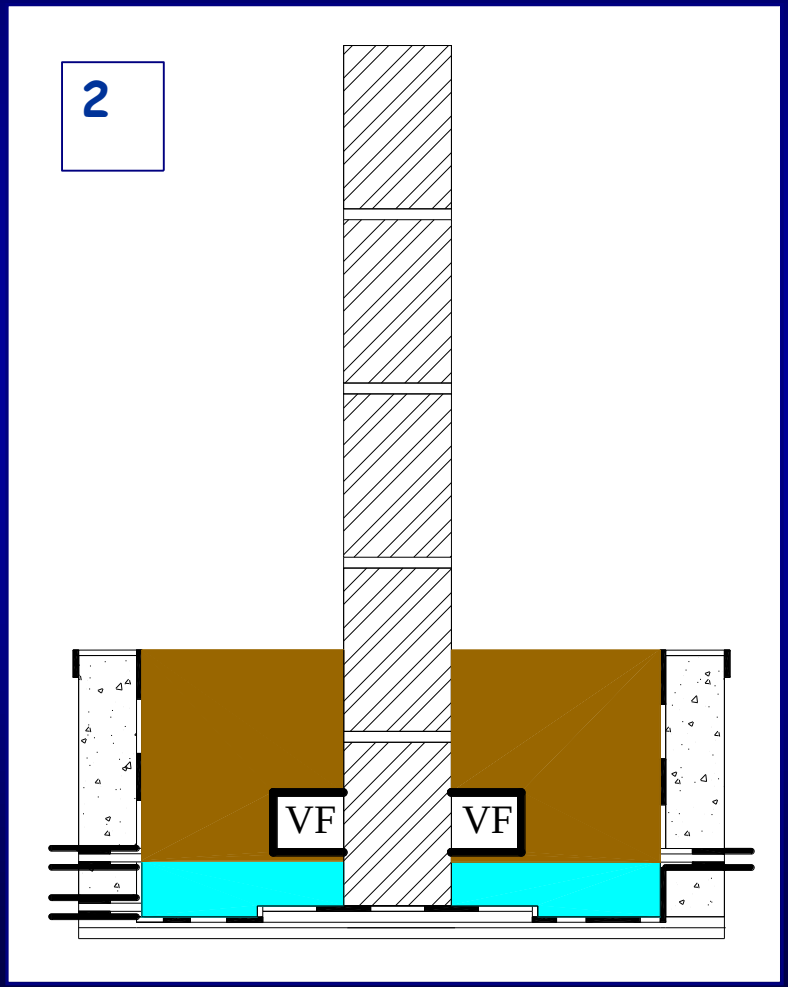
CONSTRUCT

LFC

Step 1 - PHYSICAL MODEL

EXPERIMENTAL WORK - LABORATORY





U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

CONSTRUCT

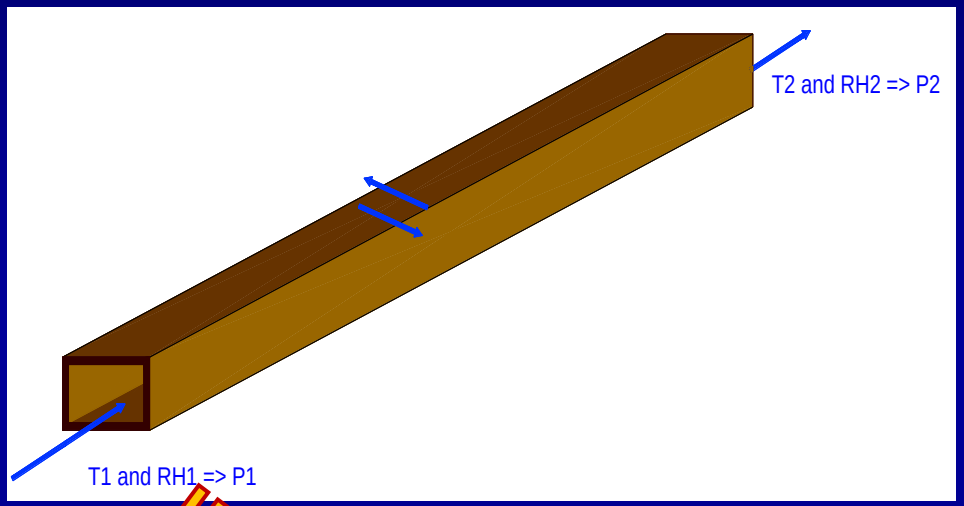
LFC

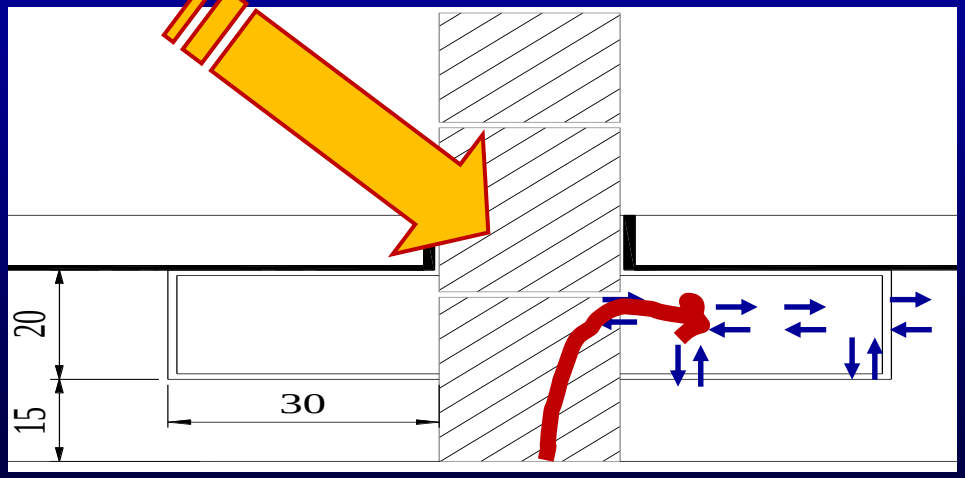
PHYSICAL MODEL

LABORATORY MONITORING

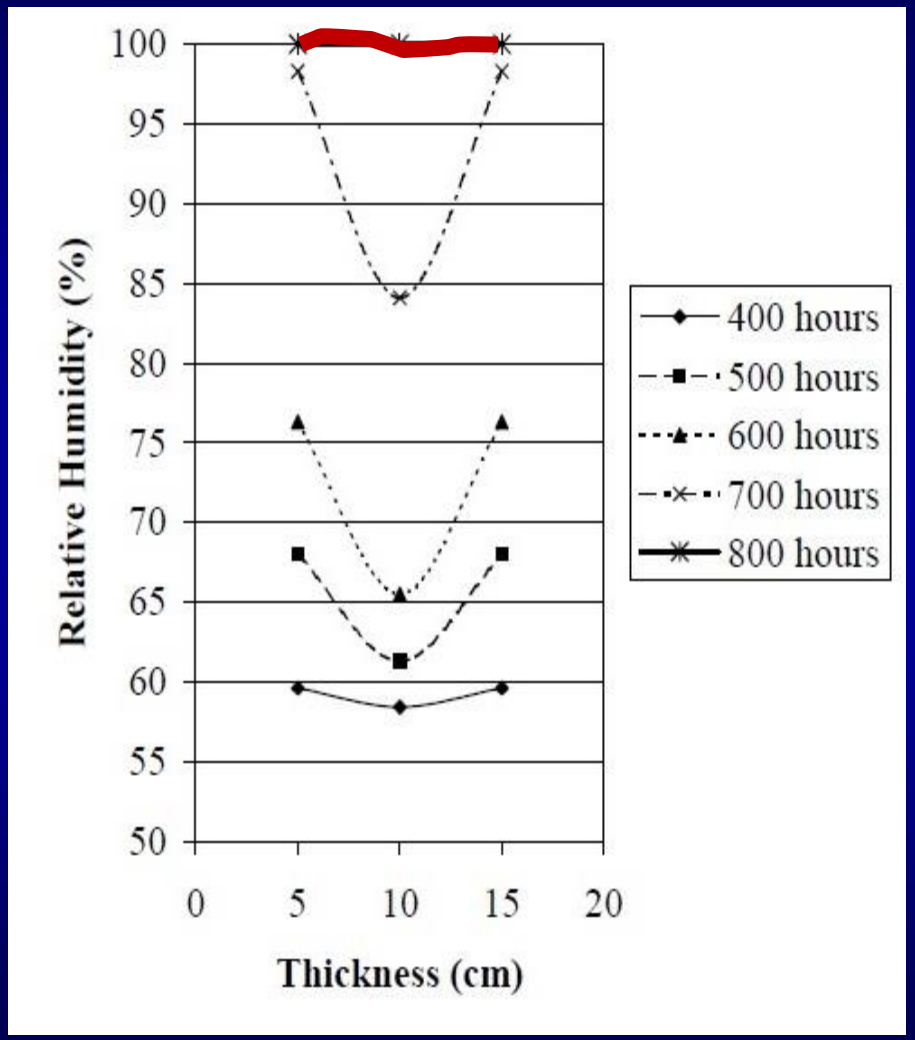
TECHNOLOGY VALIDATION - LABORATORY

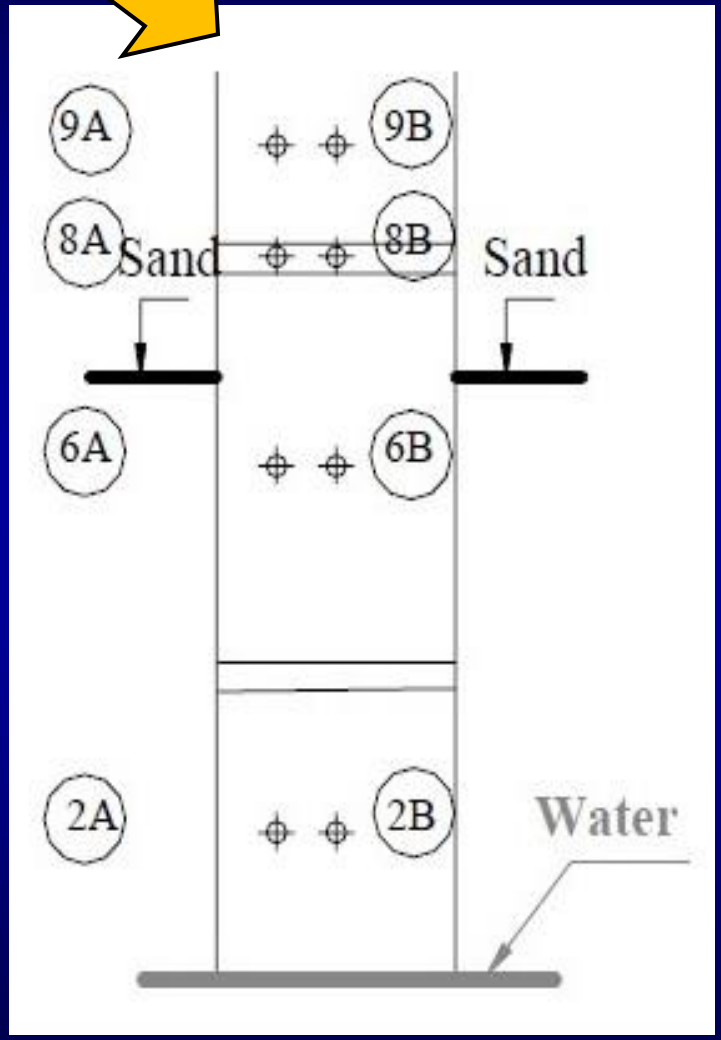
THE VENTILATION SYSTEM





EXPERIMENTAL RESULTS





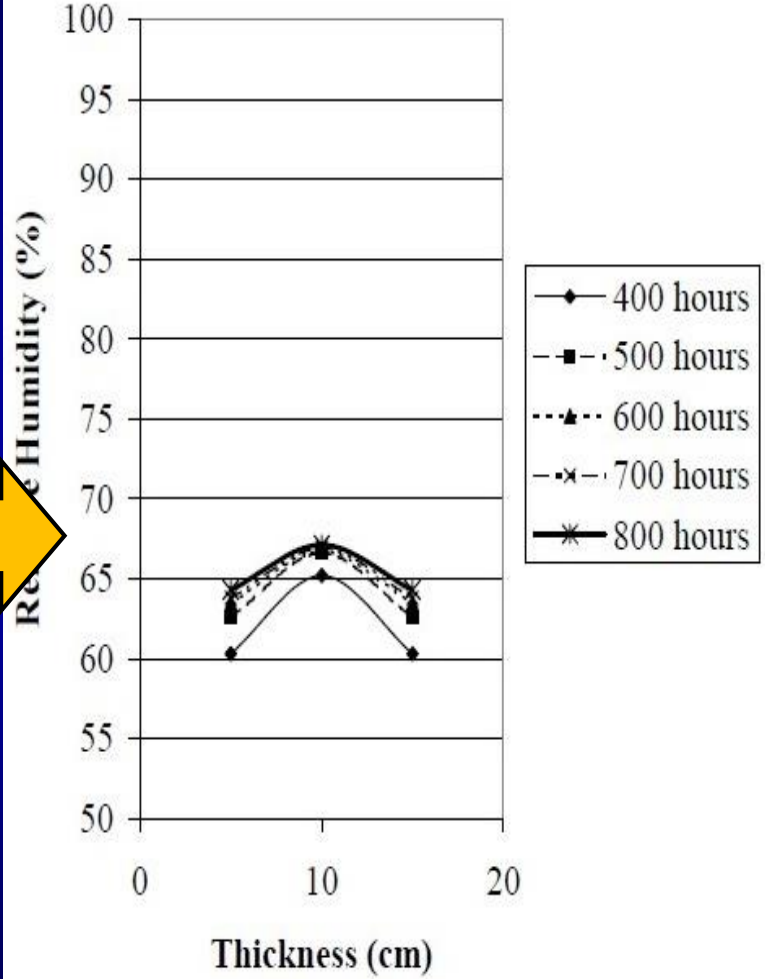
Isabel Torres – Vasco P. de Freitas.

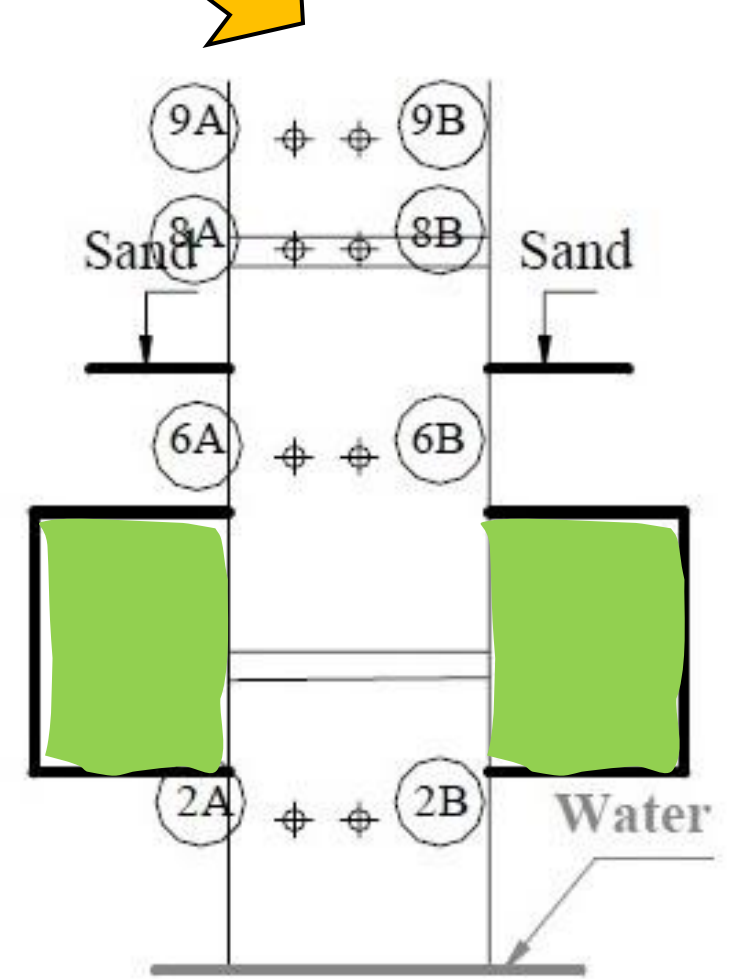
U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

CONSTRUCT

LFC

EXPERIMENTAL RESULTS



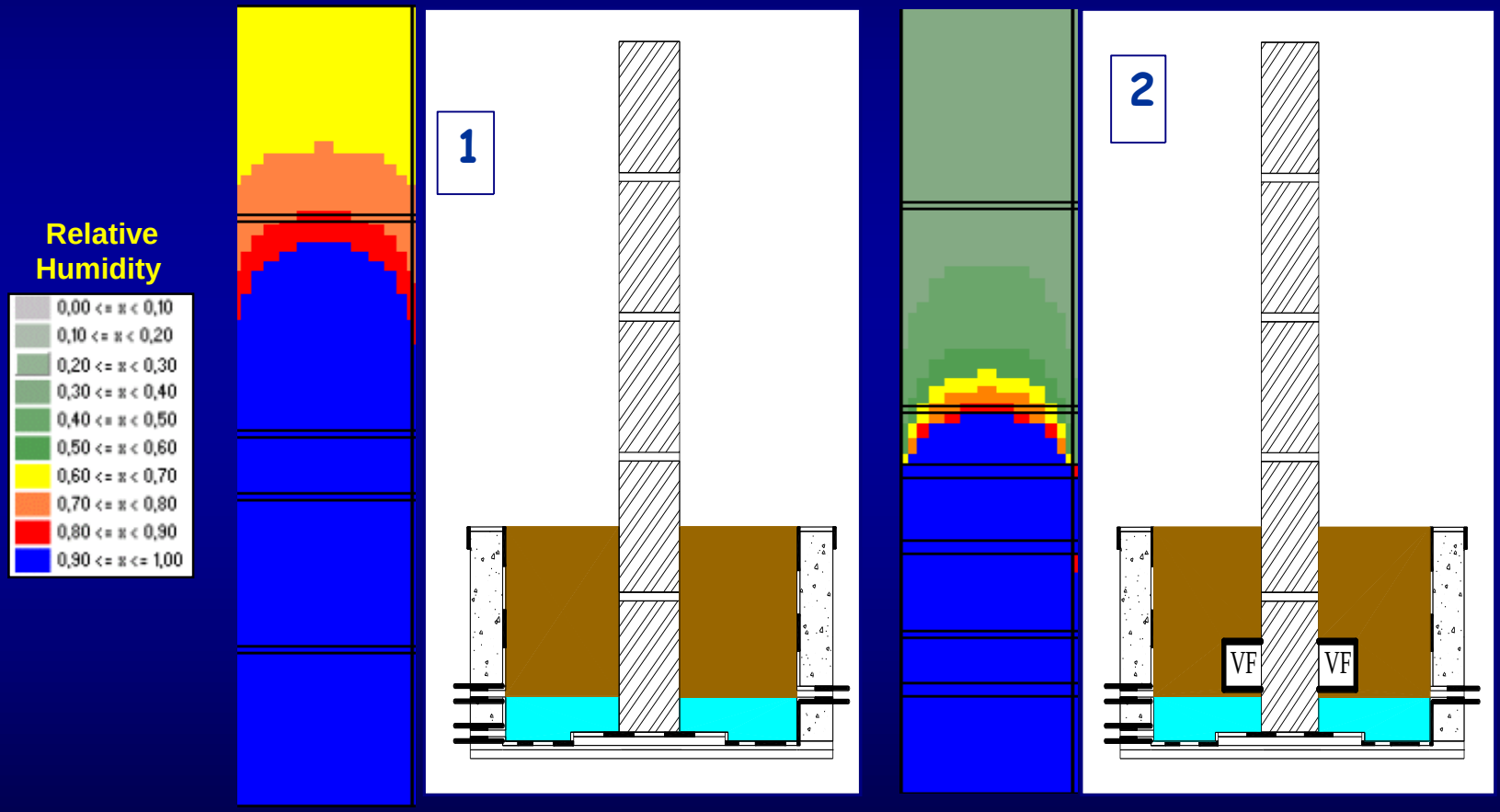


Isabel Torres – Vasco P. de Freitas.

NUMERICAL VALIDATION

WUFI 2D

WUFI 2D



Configuration 1

Configuration 2

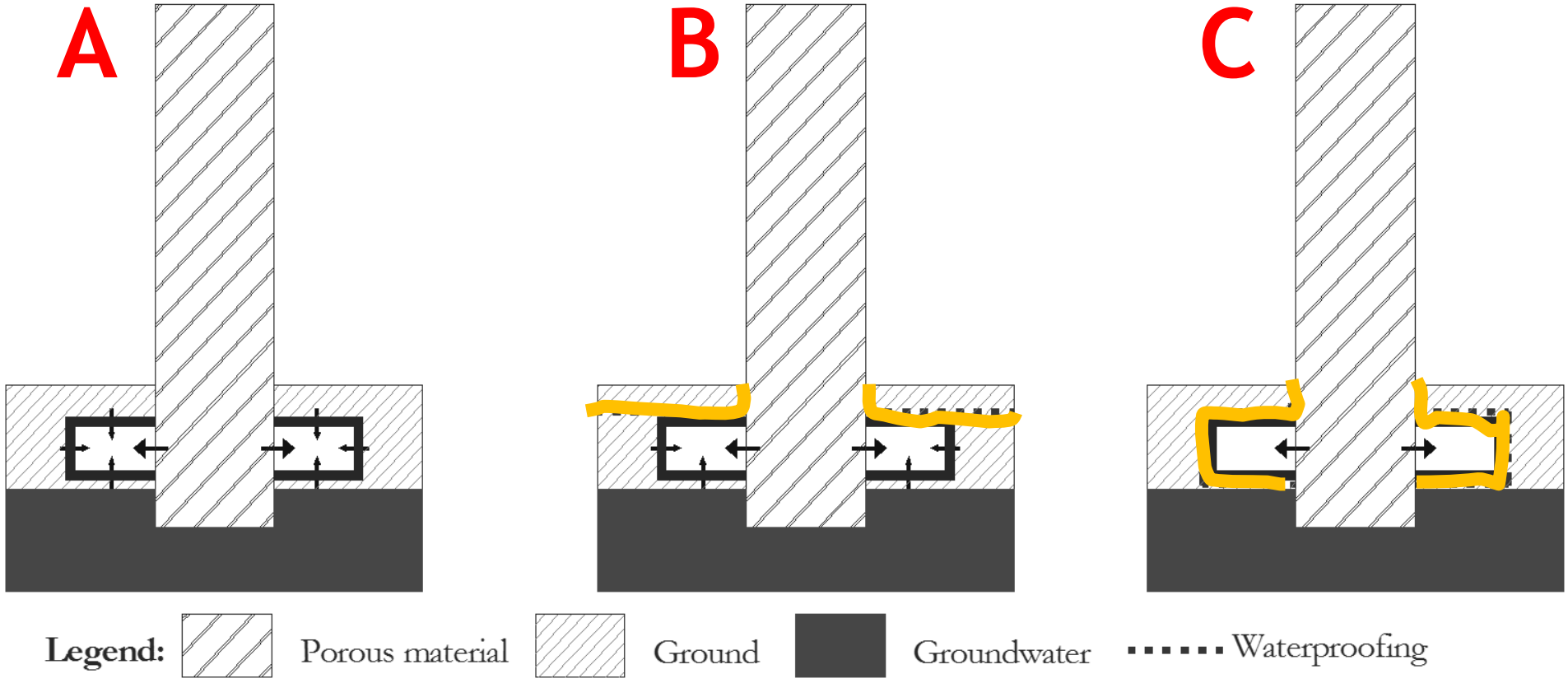
U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

CONSTRUCT

LFC

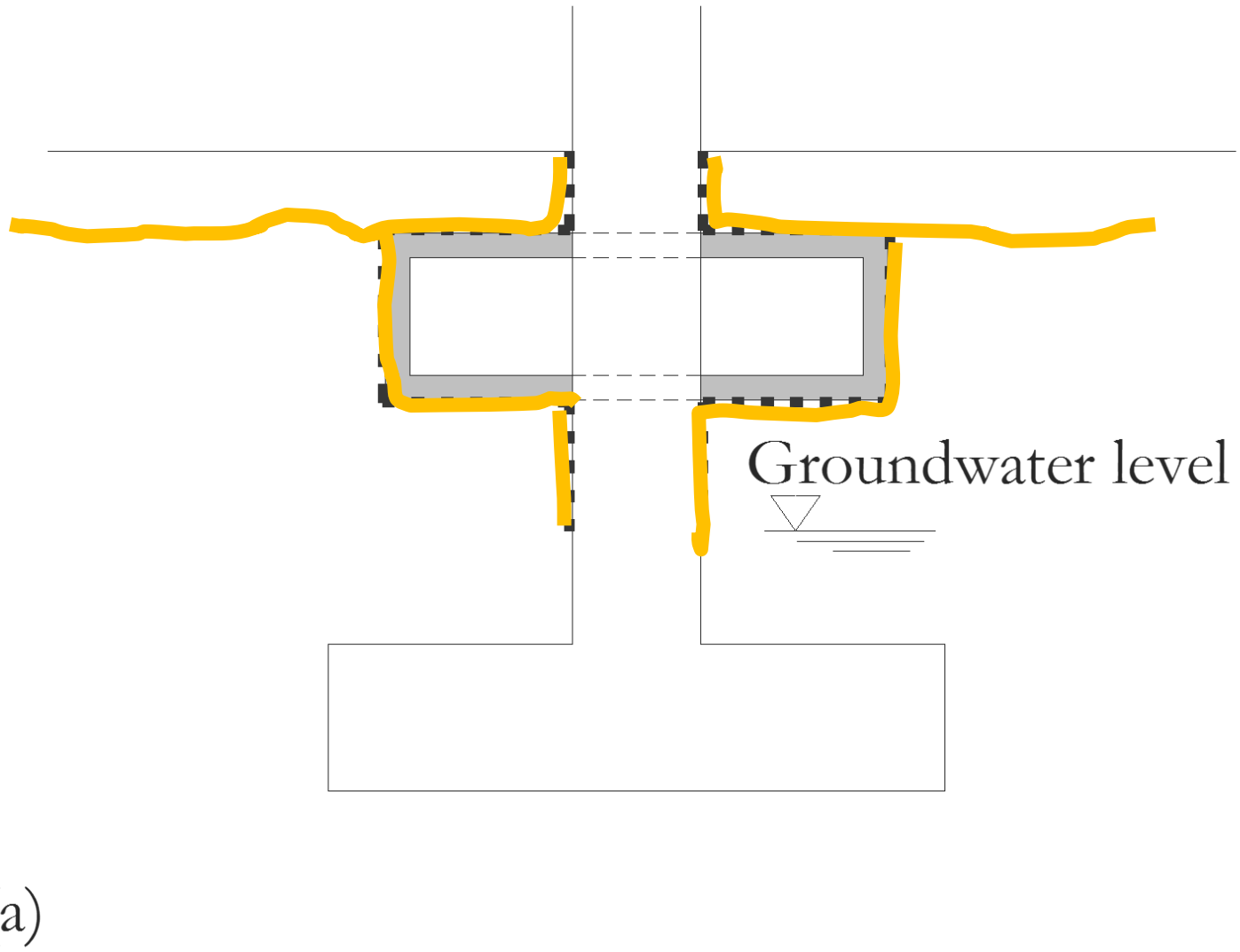
Isabel Torres – Vasco P. de Freitas.

Step 2 - Geometry Optimization

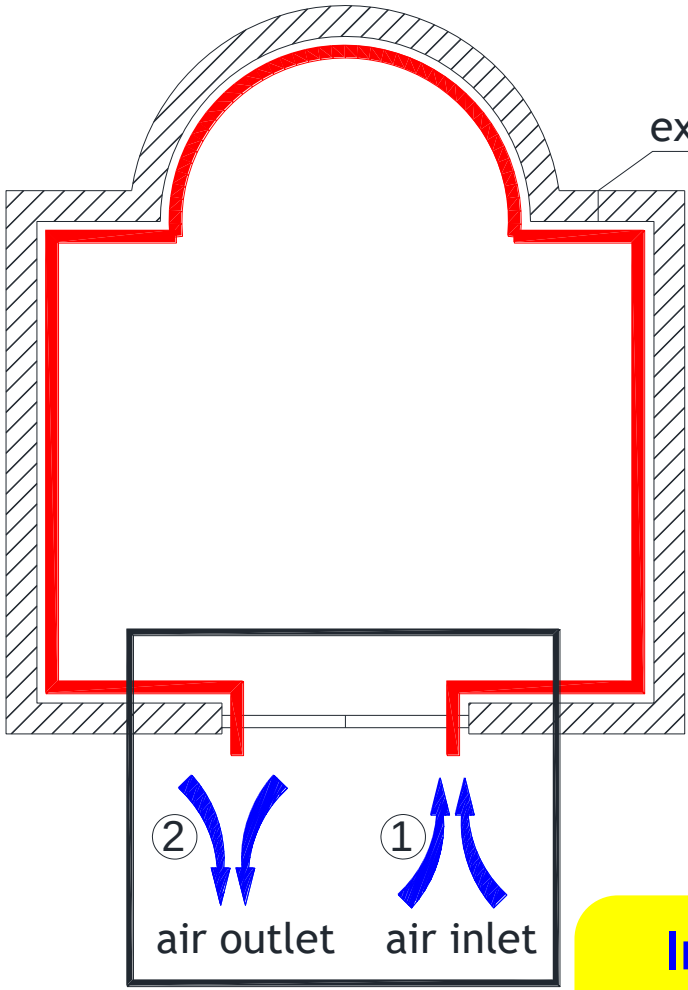


The most efficient → Solution C
In practice → Combining C+B

Configuration used in practice - with good behavior



Step 3 - Hygro-regulated Ventilation System



Inlet: T_1, $RH_1 \rightarrow P_1$

Outlet: T_2, $RH_2 \rightarrow P_2$

Vasco Peixoto de Freitas

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
CONSTRUCT
LFC

Step 3 - Hygro-regulated system (HUMIVENT)

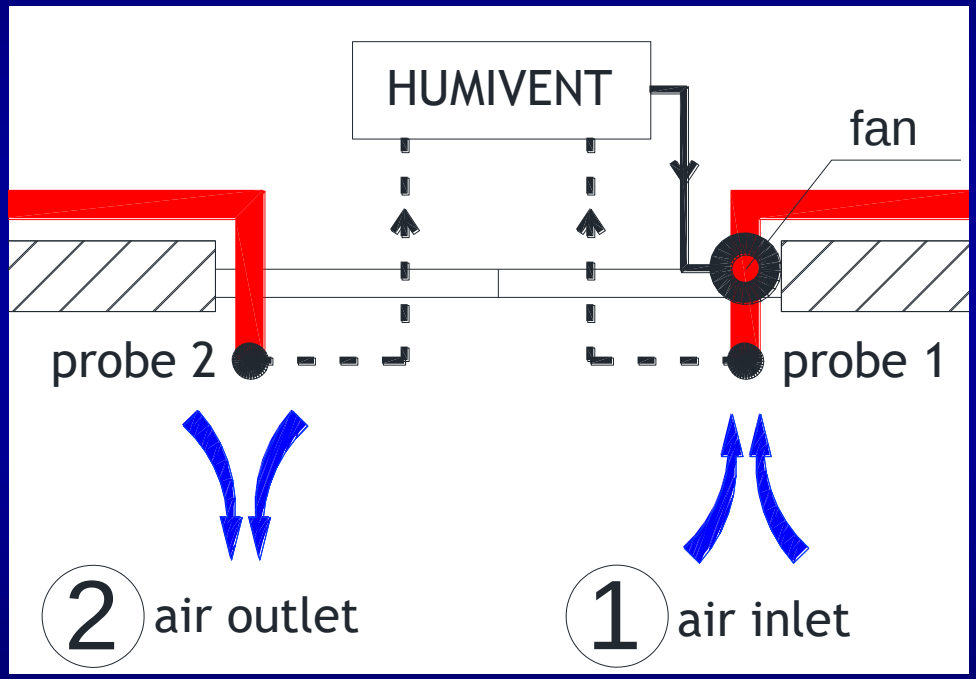
The principle

1 – Air Inlet (T, RH)
2 – Air Outlet (T, RH)

HUMIVENT:

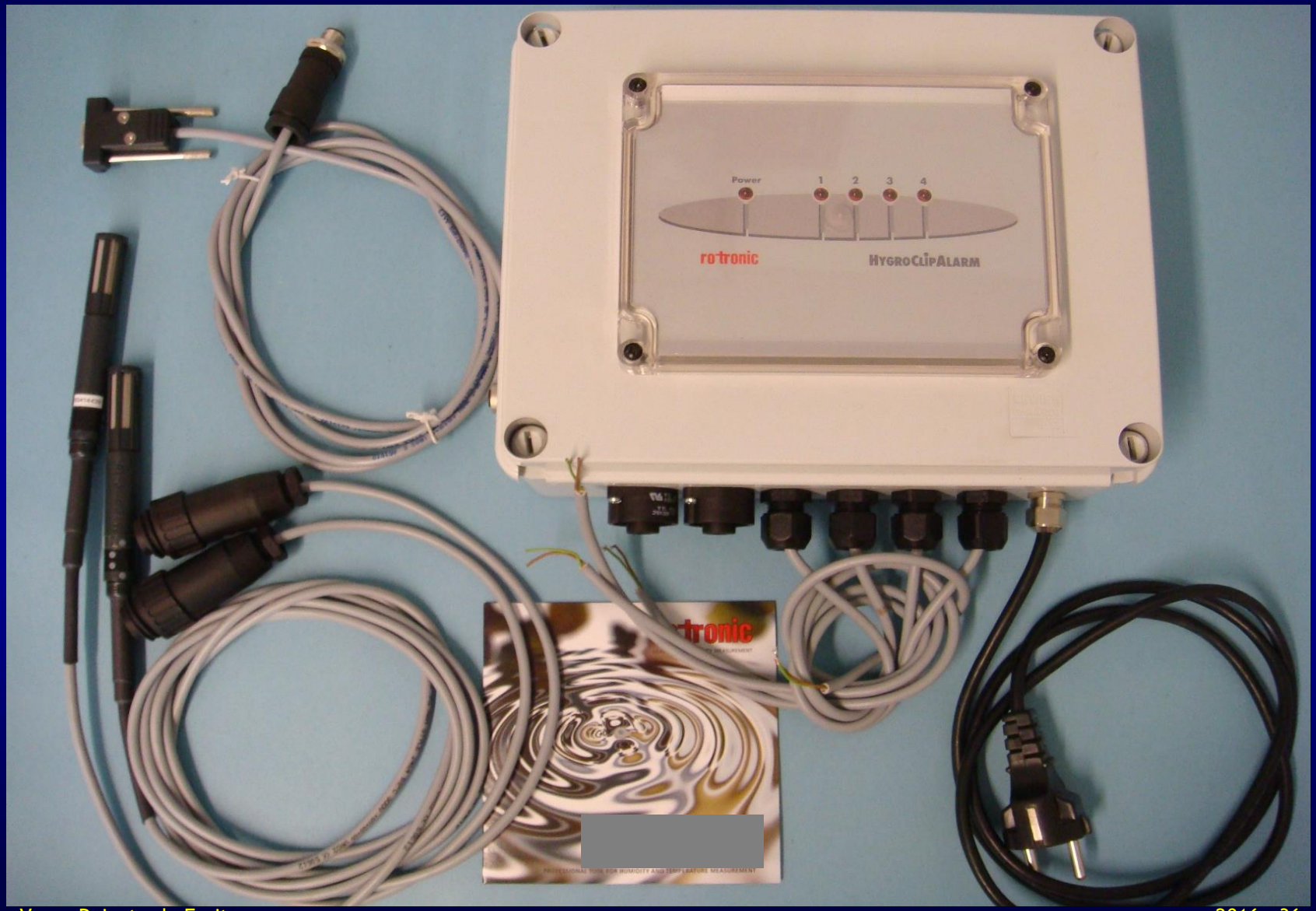
T1 and RH1 => Vapor pressure 1 (P1)
T2 and RH2 => Vapor pressure 2 (P2)

$$\Delta P = P2 - P1$$



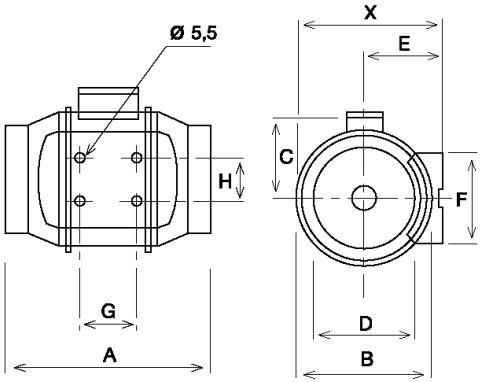
On if $\Delta P \geq 0$
Off if $\Delta P \leq 0$
RH1 < Reference value

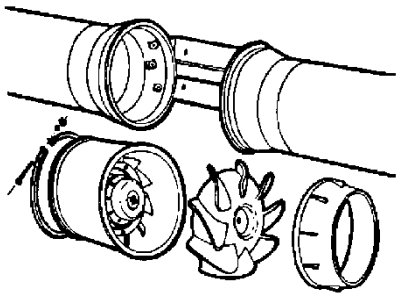
Prototype - Patent



FAN - Ventilator

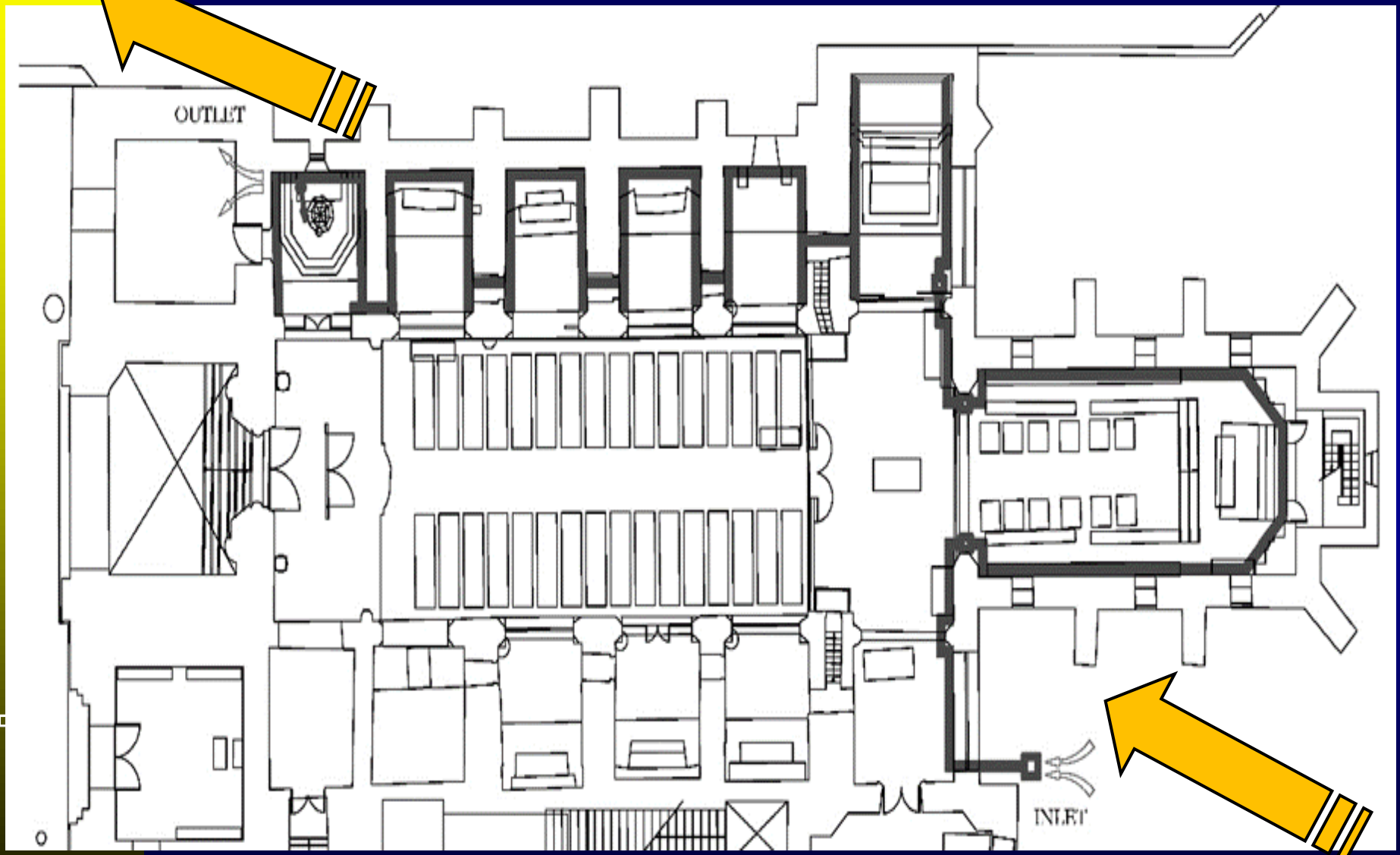
Variable speed





Catálogos comerciais.

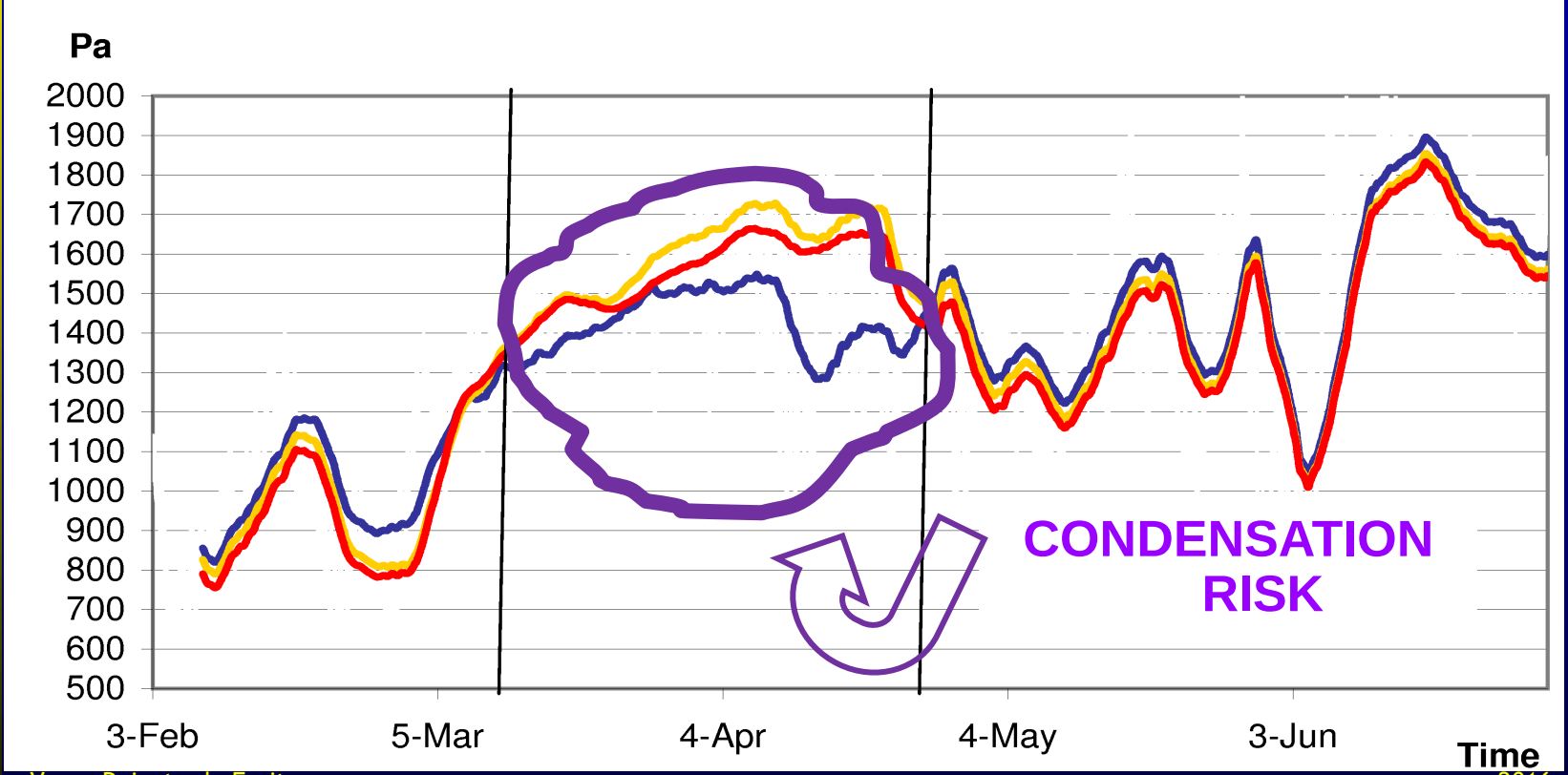
Step 4 – In situ validation



Interpretation of the experimental RESULTS

CONDENSATION RISKS?

Air inlet → Middle → Air outlet

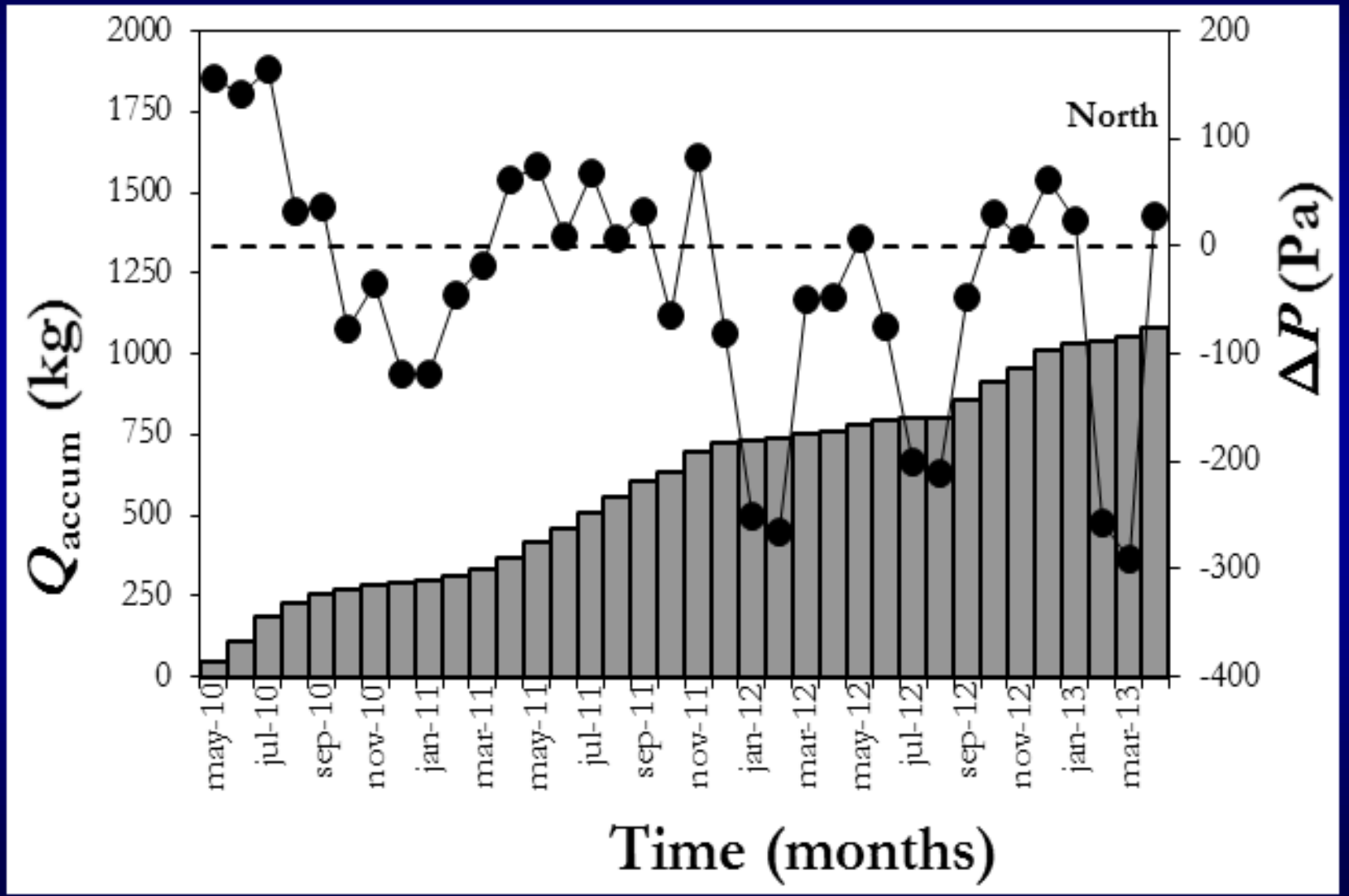


U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

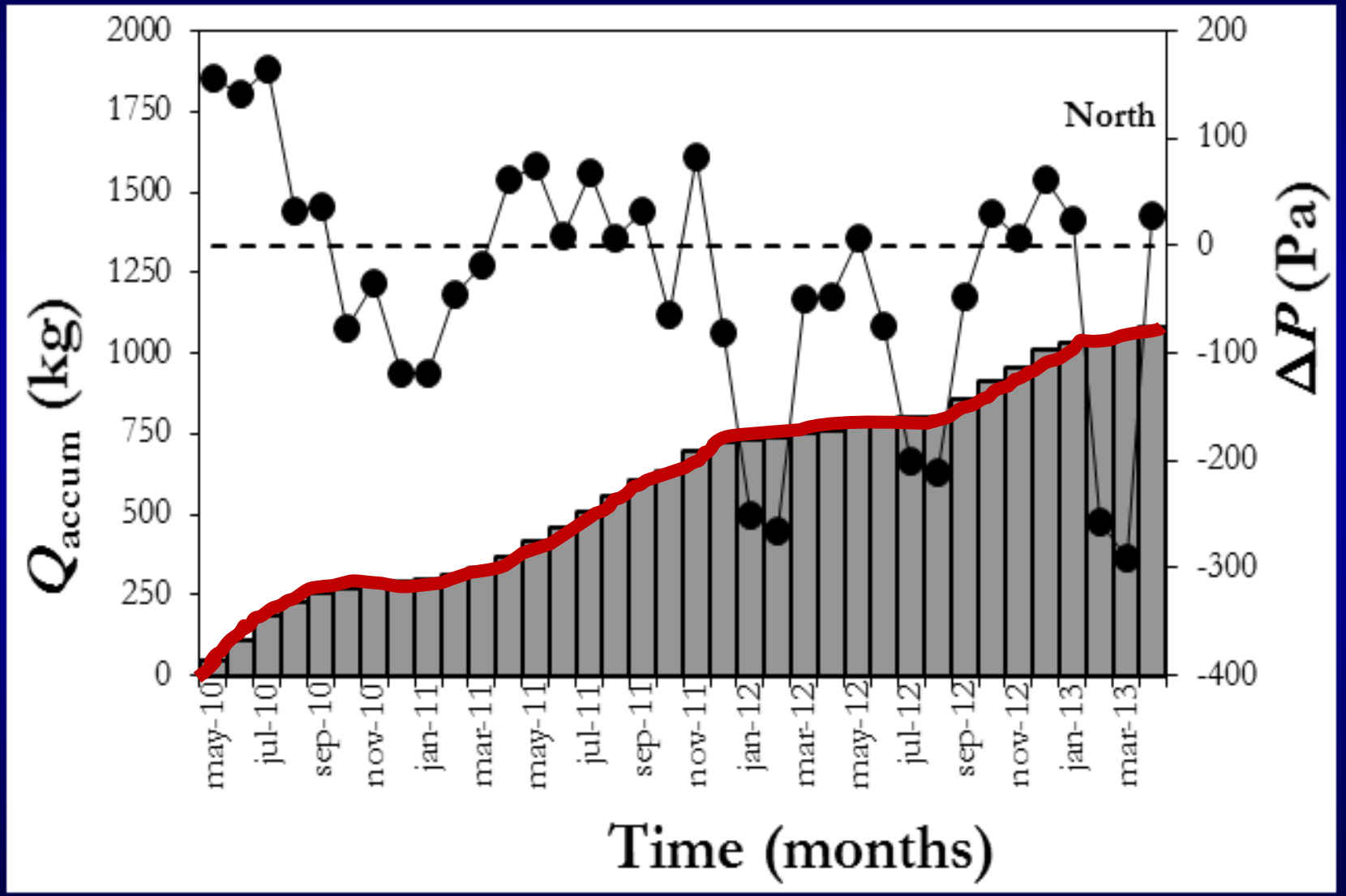
CONSTRUCT

LFC

Accumulated amount of water removed



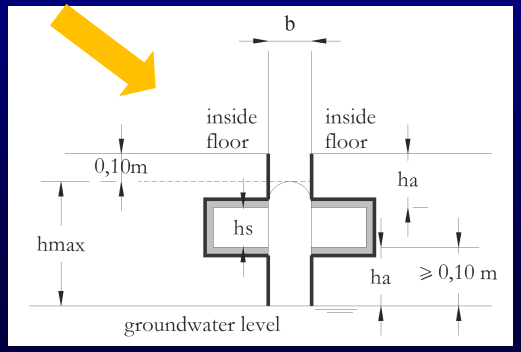
Accumulated amount of water removed



Practice

The main goal of this paper is to present a simplified methodology for designing the wall base ventilation system and a case study.

The maximum acceptable level of the damp front in the wall, h_{max}, must be defined.

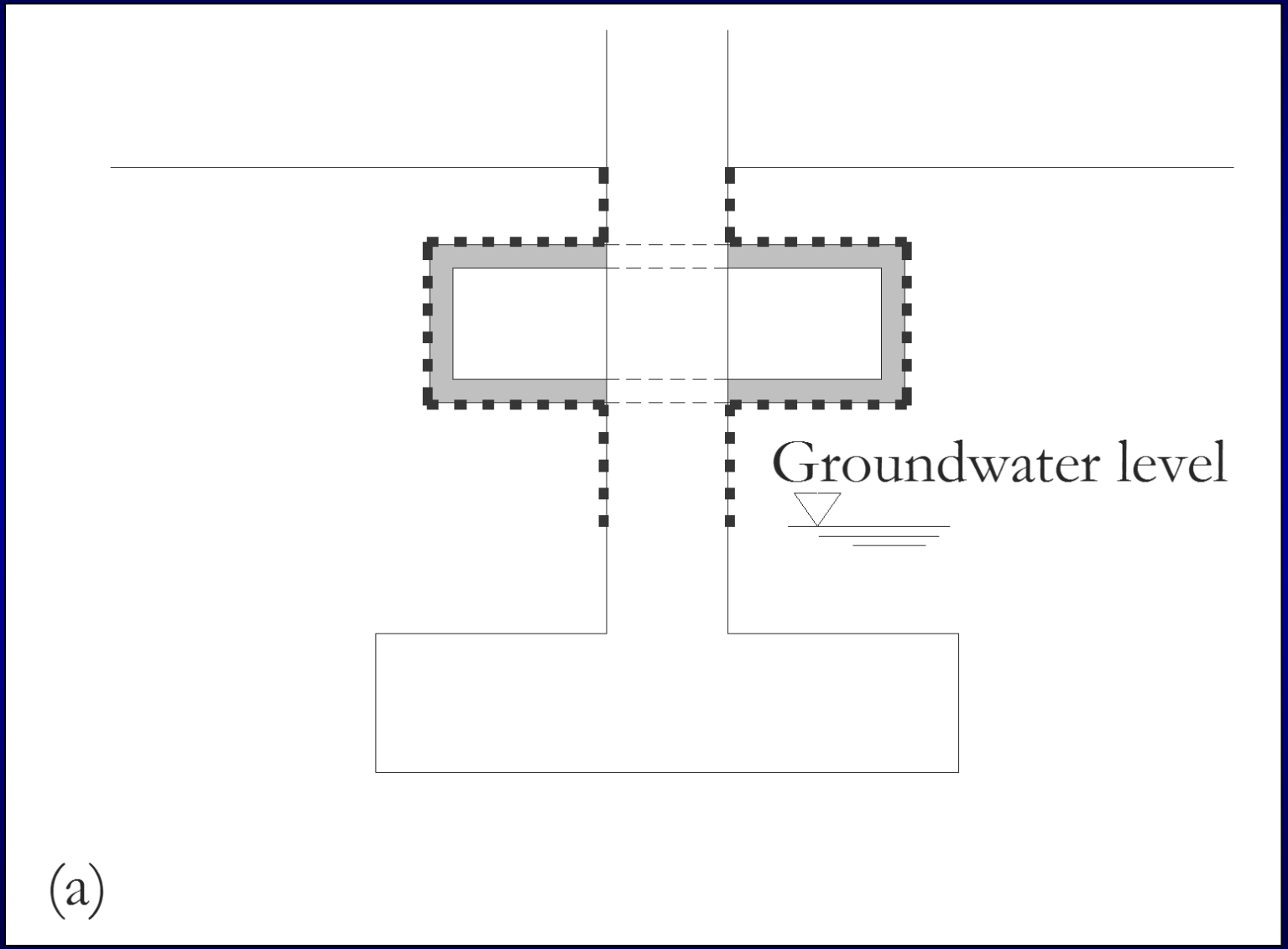


5.

DESIGN PROCEDURE - HUMIVENT SYSTEM

U.PORTO
FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
CONSTRUCT
LFC

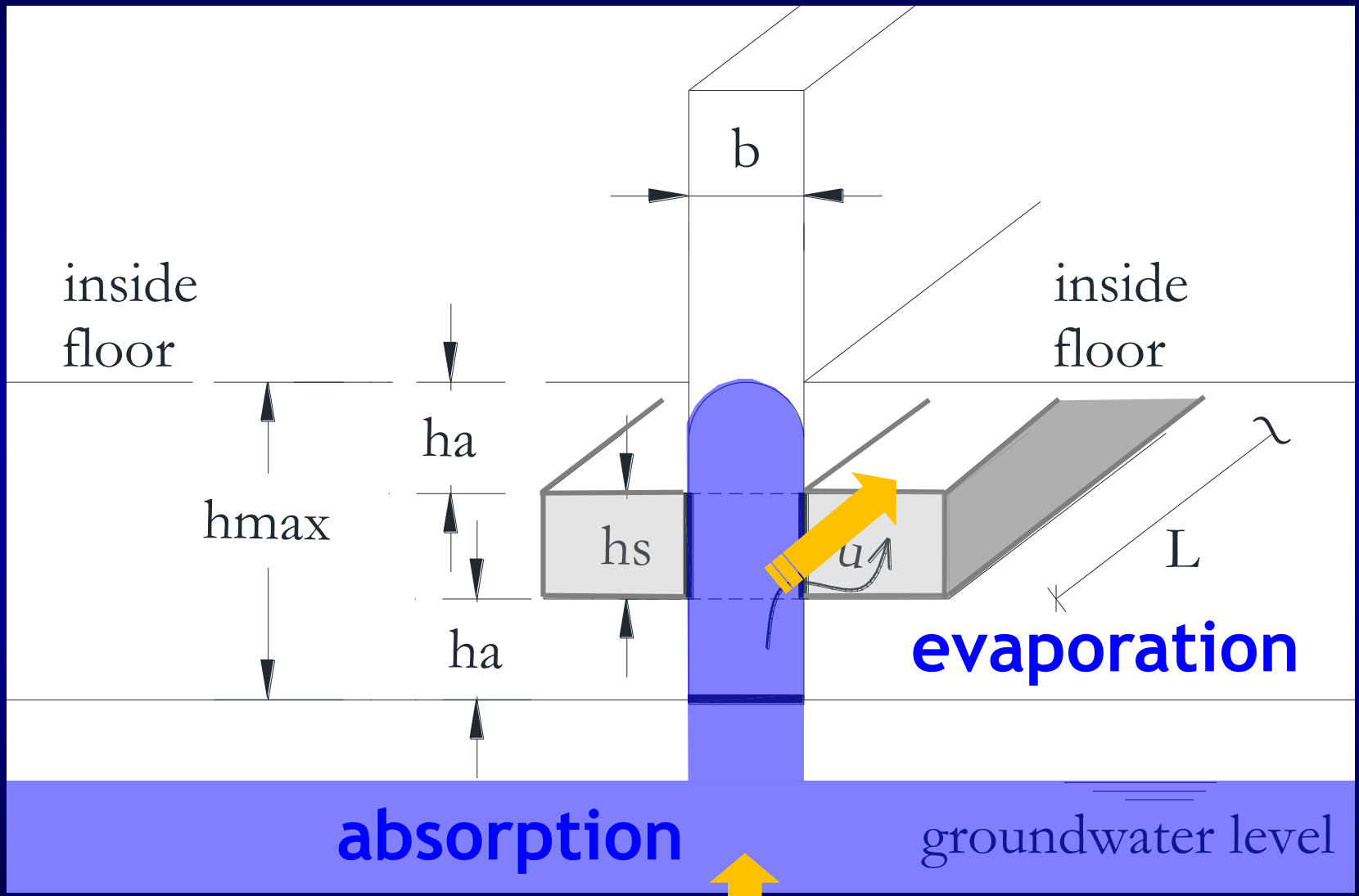
Require the installation of a channel in the base of the wall



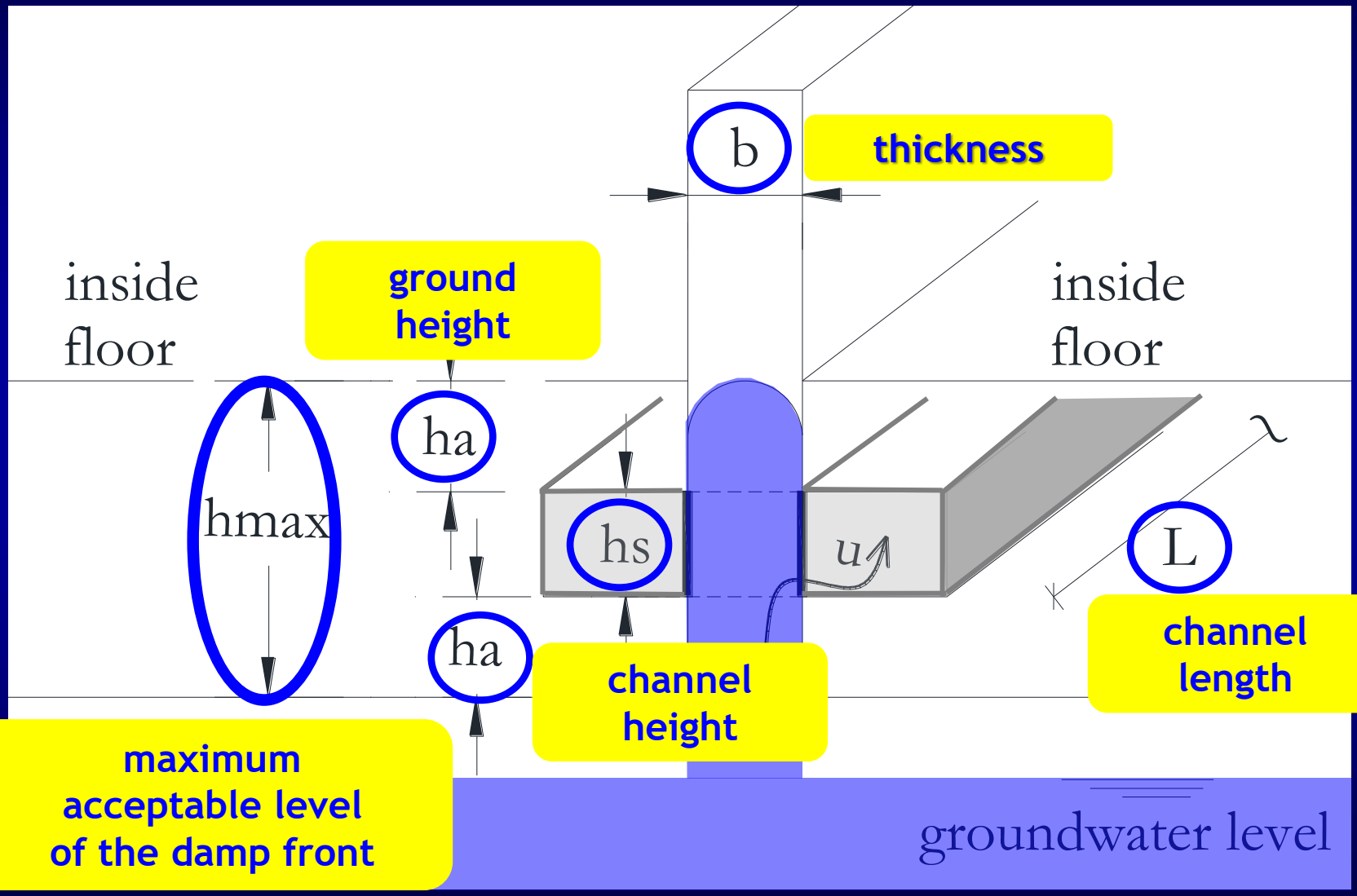
DESIGN – Simplified Model

Maximum acceptable level of the damp front in the wall...

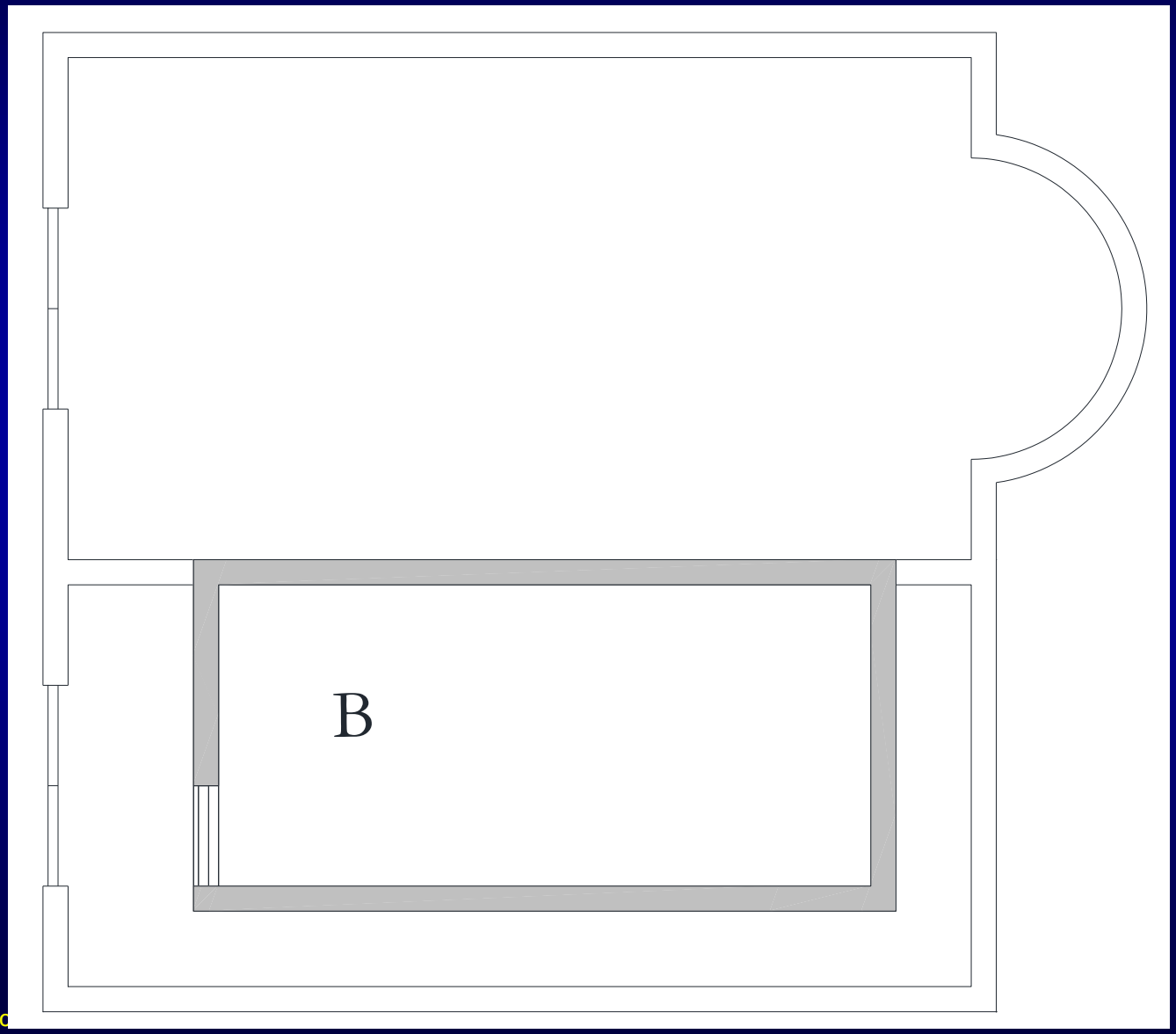
Parameters needed?



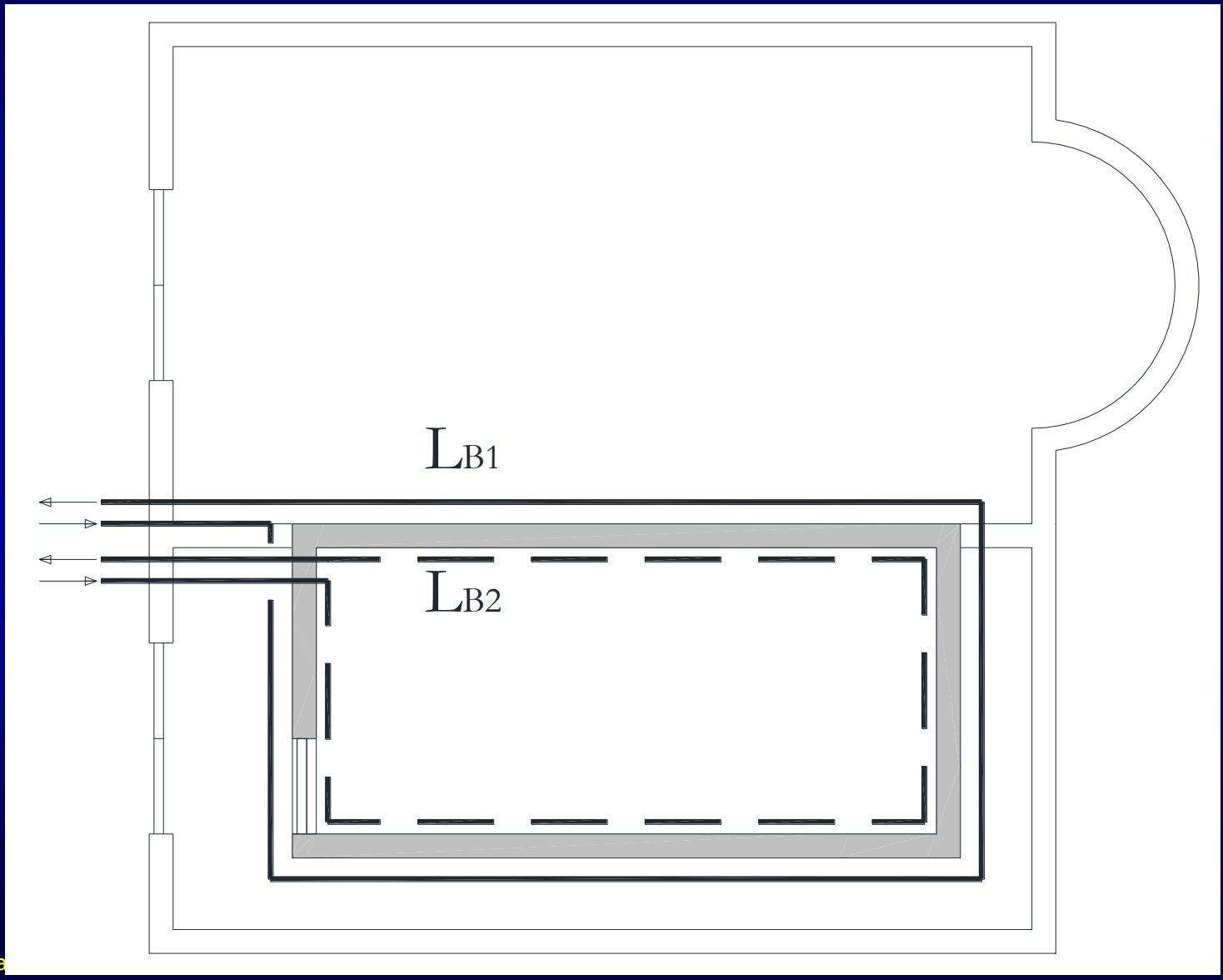
Parameters needed?



Ground building geometry…
Ventilation system geometry…

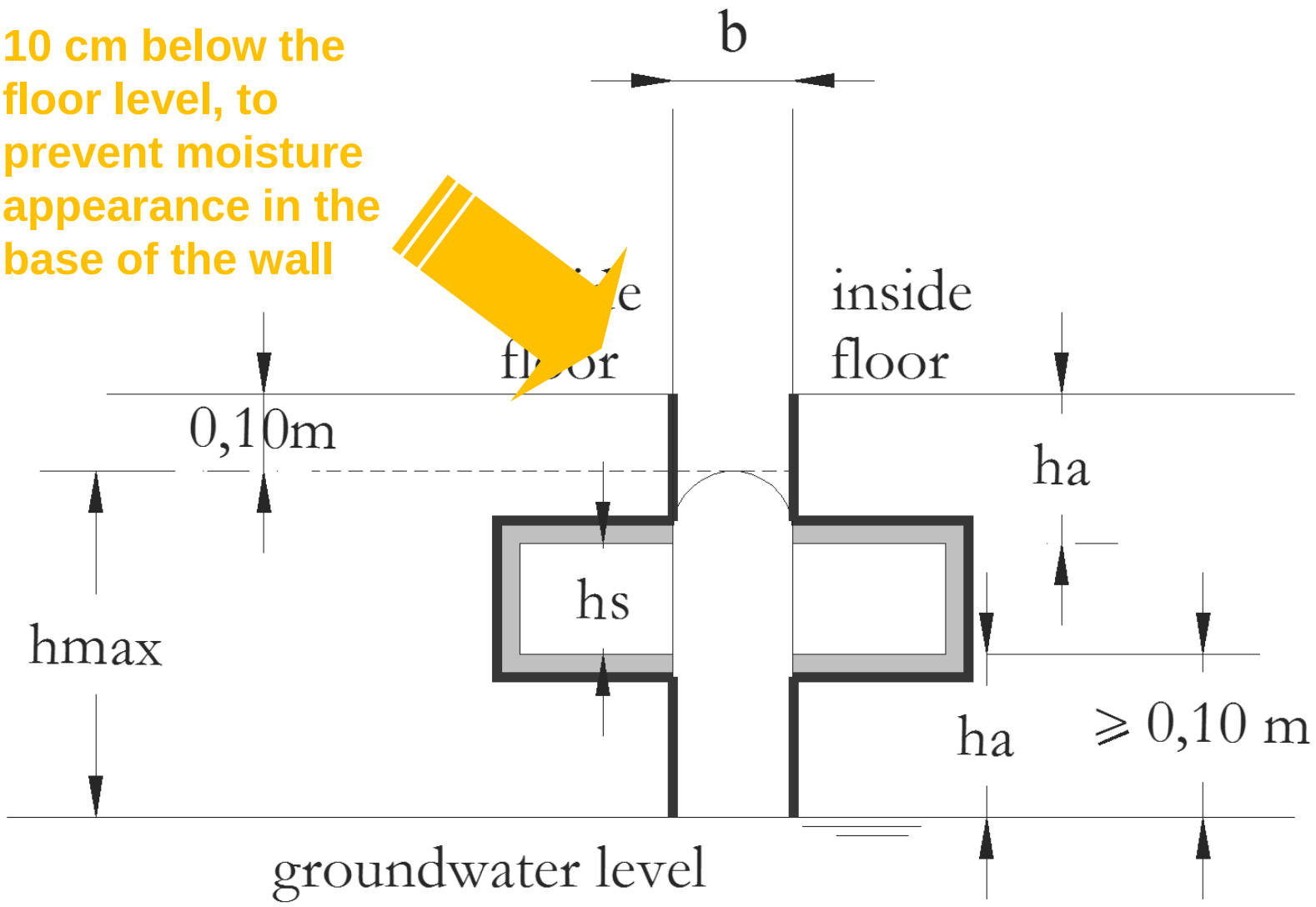


Wall base ventilation system in both sides of the *B* room walls - b, h_a and L



Step 1 - Define h_{max}

10 cm below the floor level, to prevent moisture appearance in the base of the wall



Step 2 – Parameters determination

b – Wall thickness

h_a – Ground height

L – Wall length

S – Sorptivity

w – Moisture ratio by volume

c* - Vapor concentration at the wall surface

ρ_w – Water density

D_m – Water vapor diffusion coefficient in the air

c_0 – Vapor concentration at air inlet

T – Inlet air temperature (average)

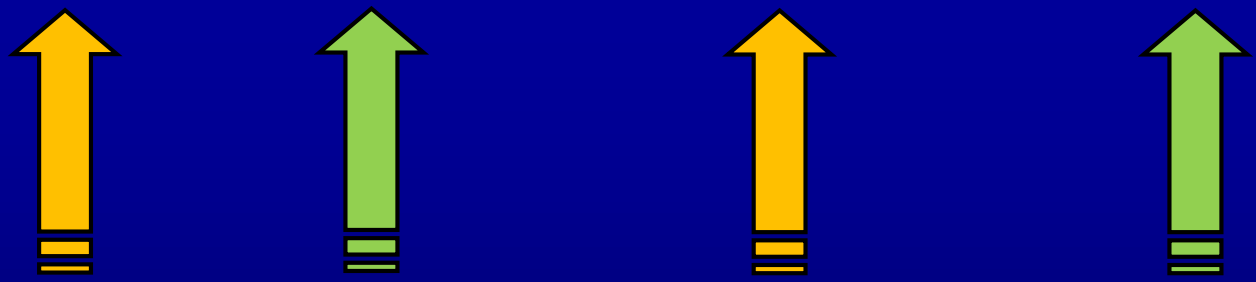
ϕ_0 – Inlet relative humidity (avarage)

Quantification of the parameters

Geometry	b	=	0,50 m
	h_a	=	$h_{max} - h_s + 0,10$
	L	=	40 m
Properties	S	=	0,000025 $m/s^{1/2}$
	w	=	0,17 m^3/m^3
	c^*	=	0,01539 kg/m^3
	ρ_w	=	1000 kg/m^3
Environment (average)	D_m	=	0,000025 m^2/s
	c_0	=	0,009234 kg/m^3
	T	=	18ºC
	Φ_0	=	60%

Step 3 - Calculation
The relation between: L, h_s and u

$$\frac{b.S^2}{2w.h_{max}} = e_s.h_s \quad <=> \quad \frac{b.S^2}{2w.h_{max}} = \frac{(c^* - c_0)}{\rho_w}\sqrt{\frac{4D_m}{\pi\frac{L}{u}}}.h_s$$



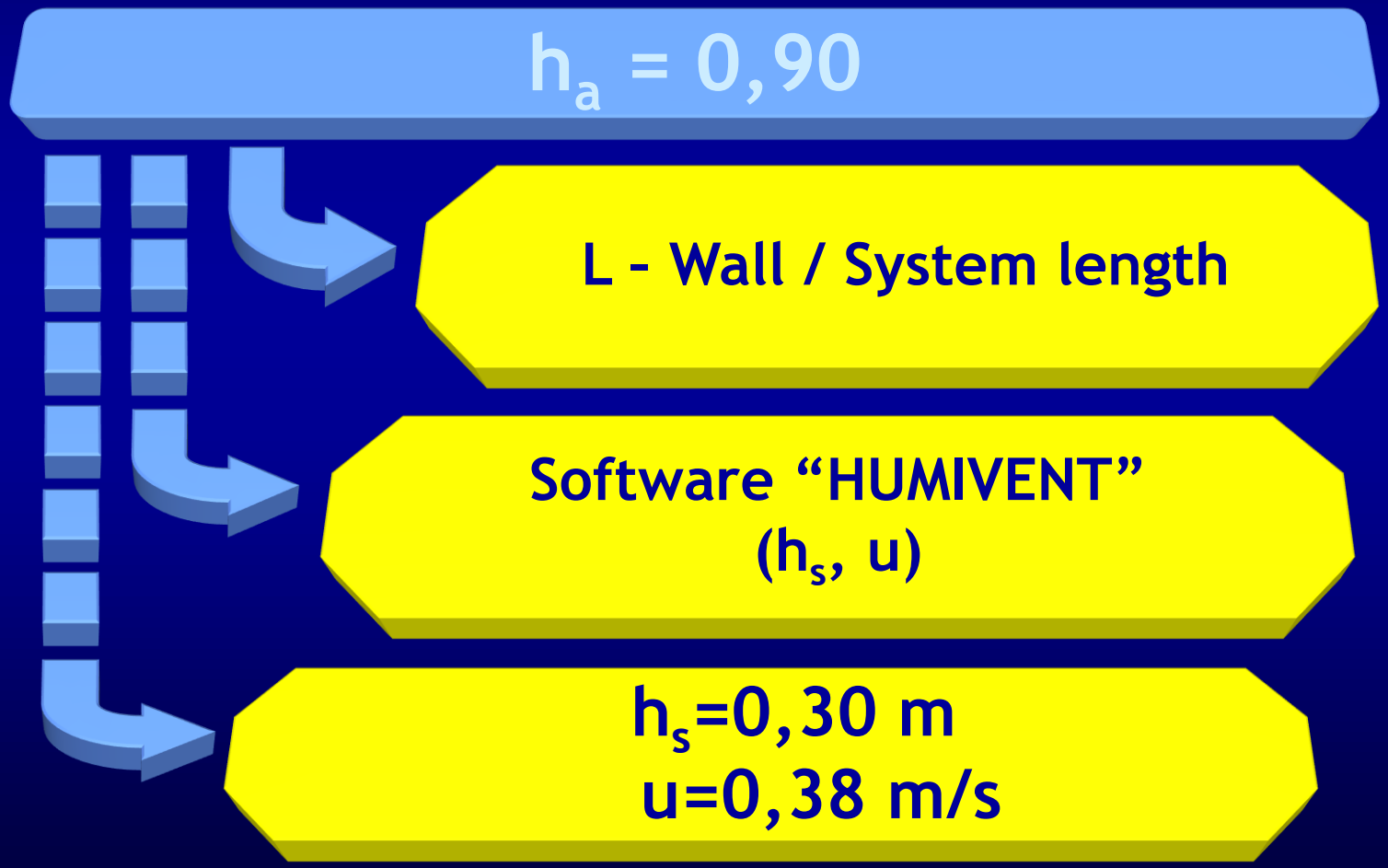
absorption evaporation absorption evaporation

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

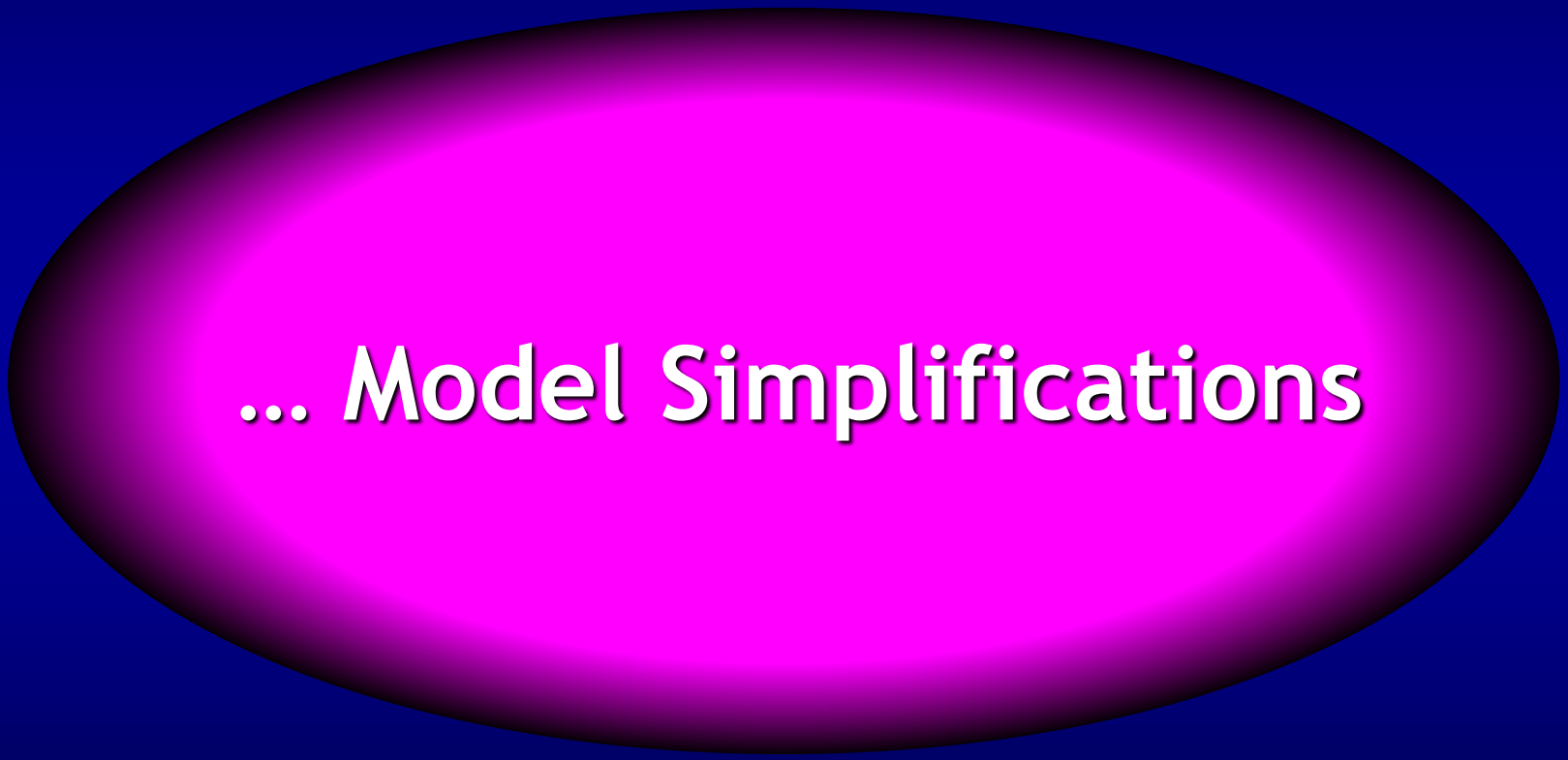
CONSTRUCT

LFC

Step 3 – The link between: *L*, h_s and *u*



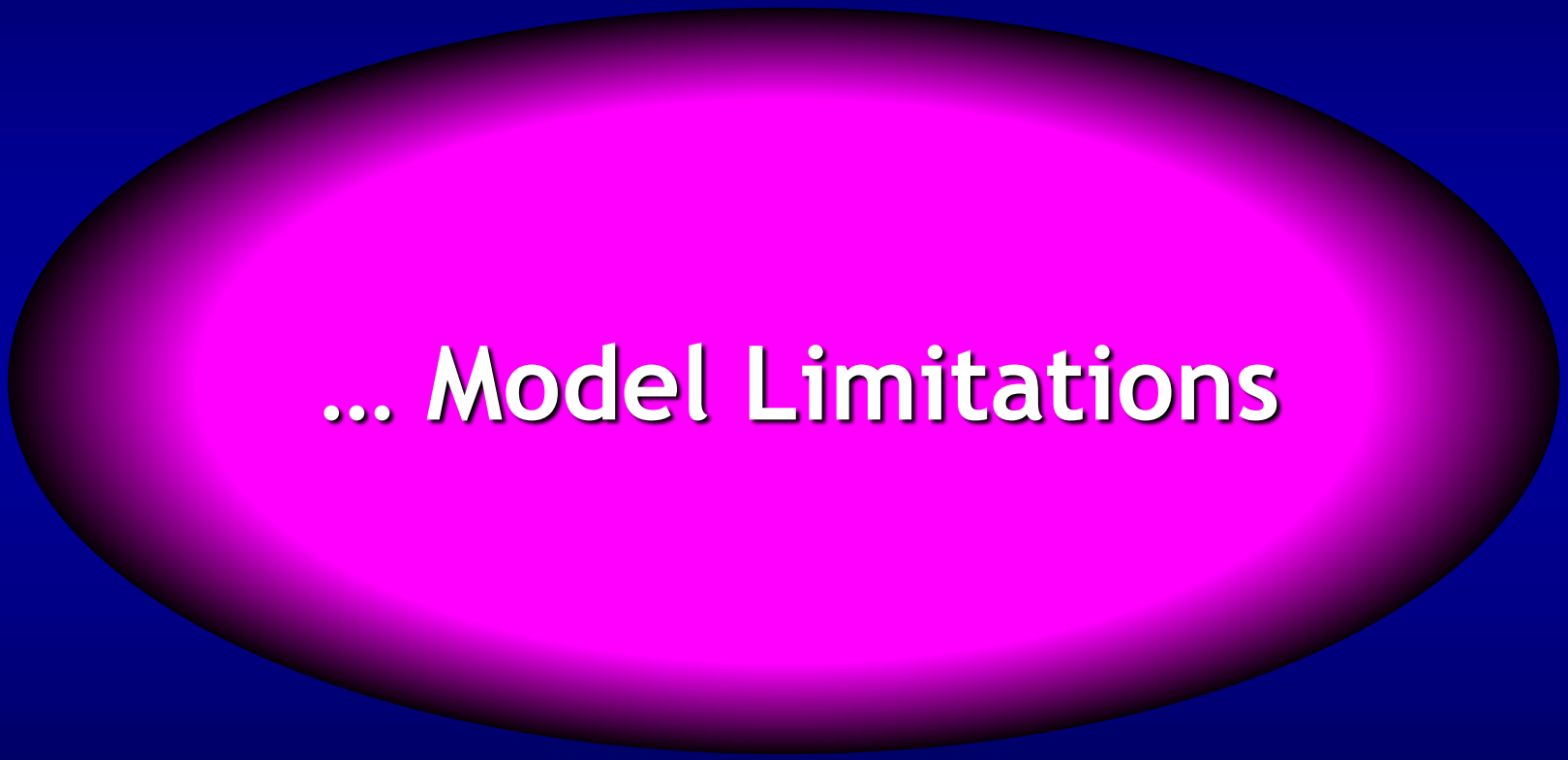
Take into account



Simplifications

1. This is a steady-state model (average conditions).
2. The air velocity inside the system is constant.
3. The thickness of the channel has no relevant influence.
4. The ventilation channel is isothermal.
5. The interface effect between the layers of the material is not considered.
6. The absorption of water occurs exclusively at the base wall level.

Take into account



Take into account

1. The wall and the ventilation system have to be symmetric.

2. The lower level of the system must be above the groundwater level.

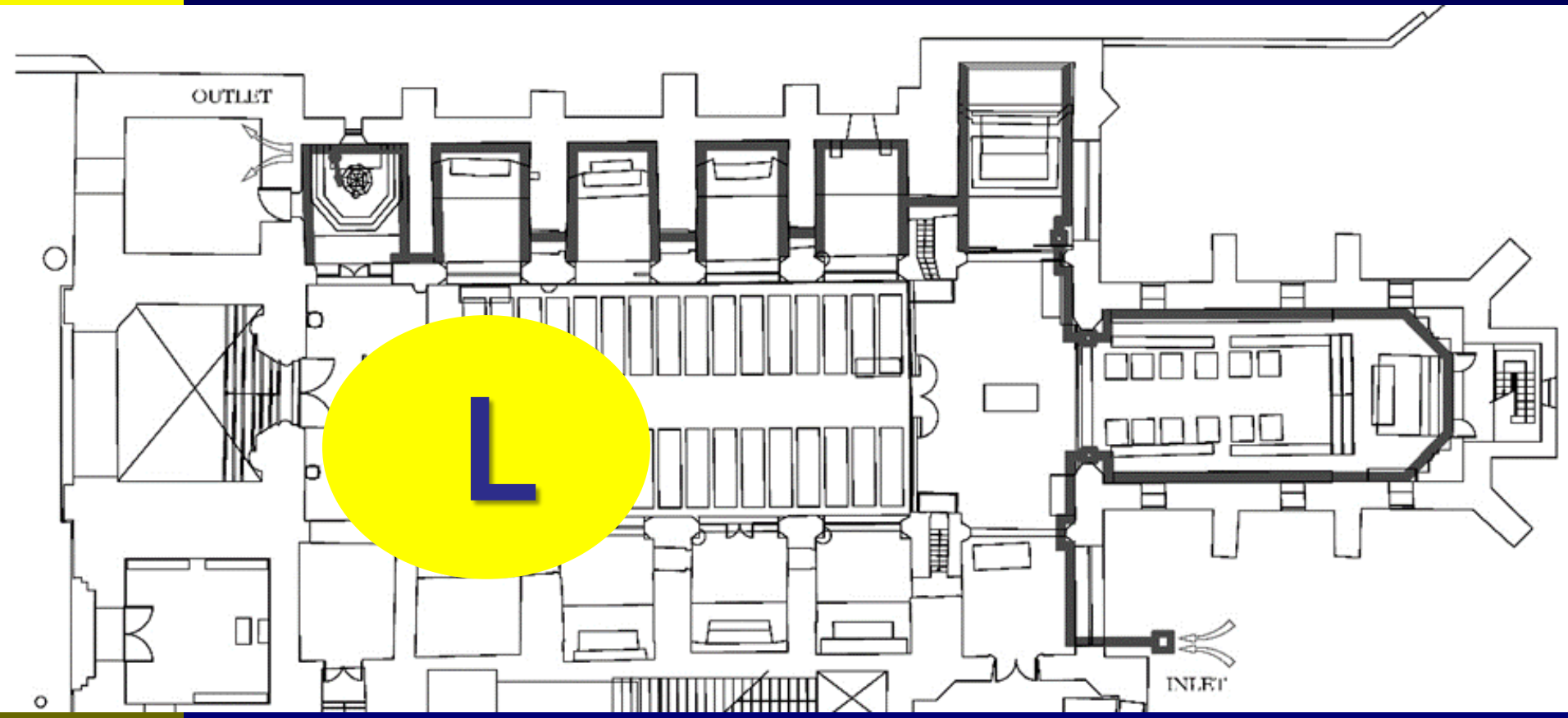
3. This model is applicable to walls with less than 1 m thick.

6.

Implementation - Case Study

U.PORTO
FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
CONSTRUCT
LFC

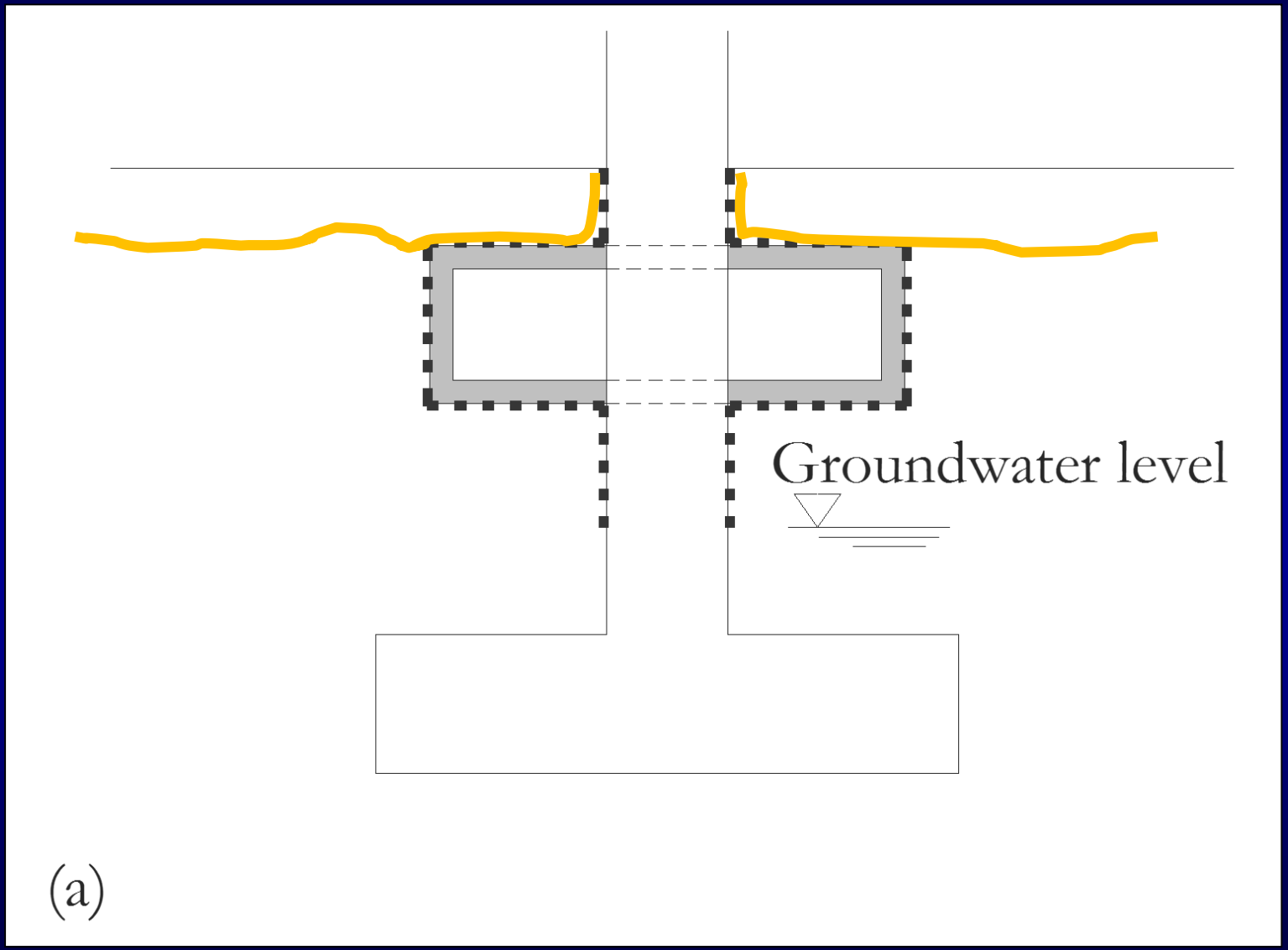
System length - L



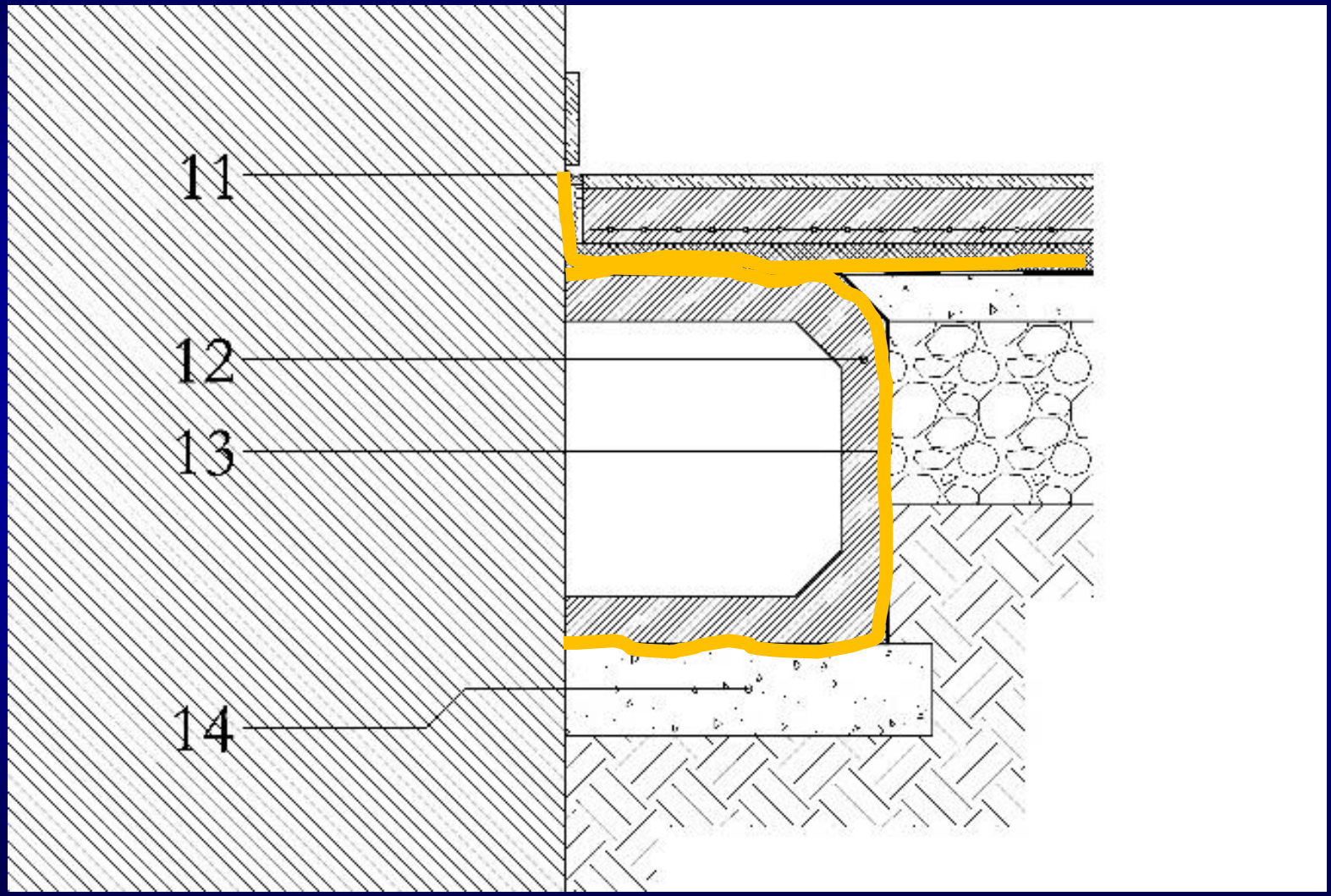
CONSTRUCT

LFC

Waterproofing of the ground - Vapor barrier



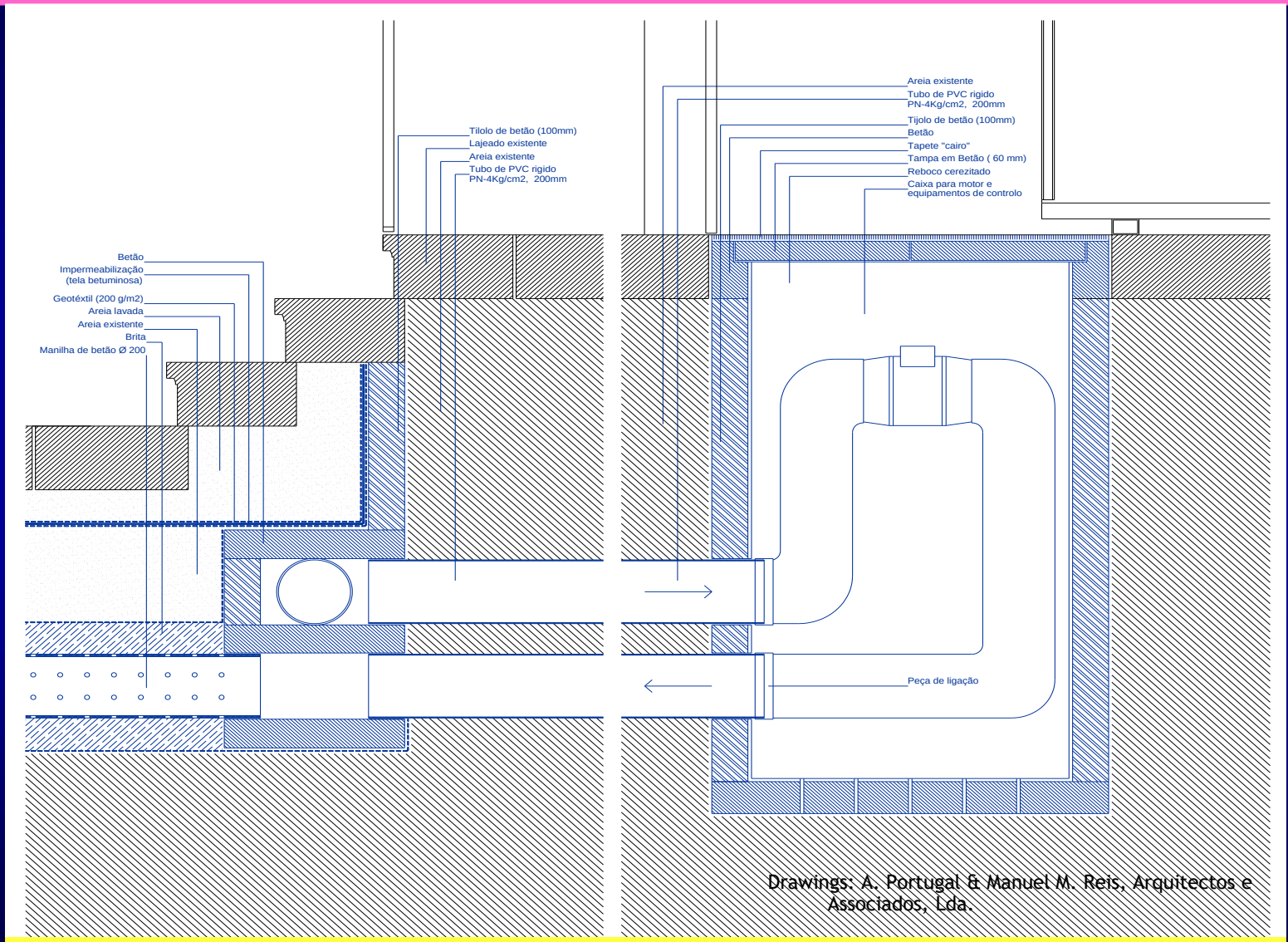
Channel



CHANNEL

U.PORTO
FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
CONSTRUCT
LFC

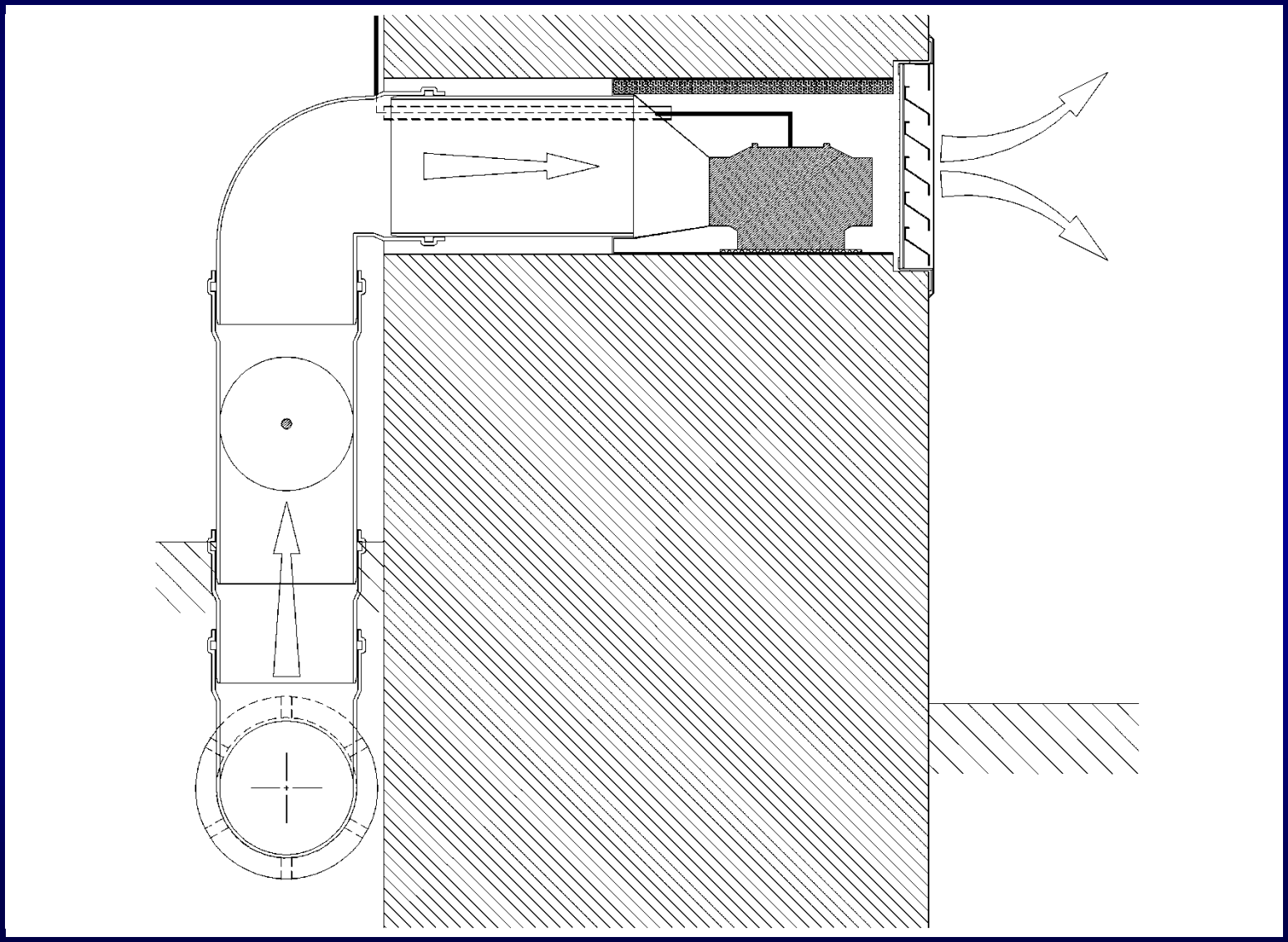
FAN - UNDERGROUND



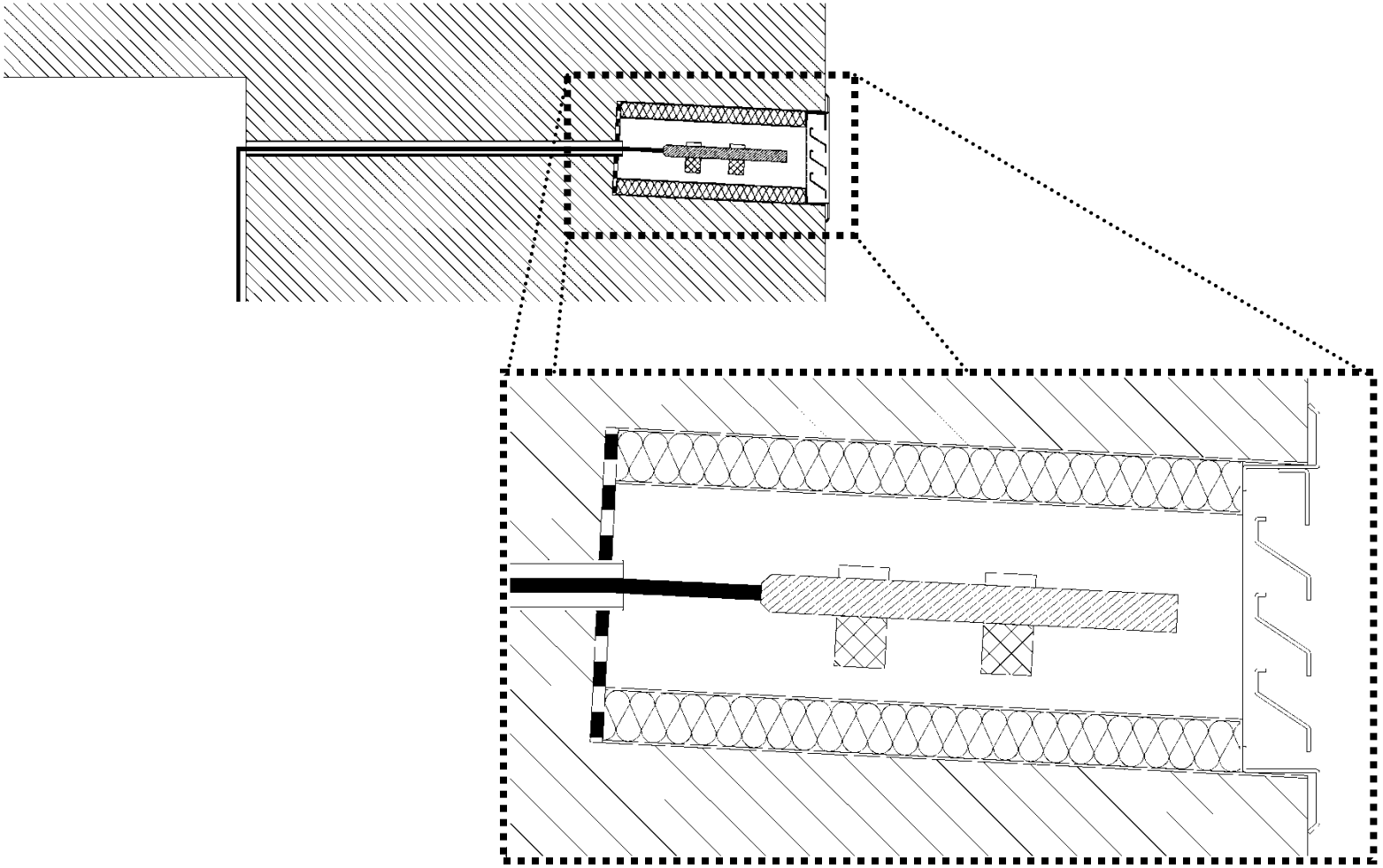
Drawings: A. Portugal & Manuel M. Reis, Arquitectos e Associados, Lda.

HUMIVENT SYSTEM

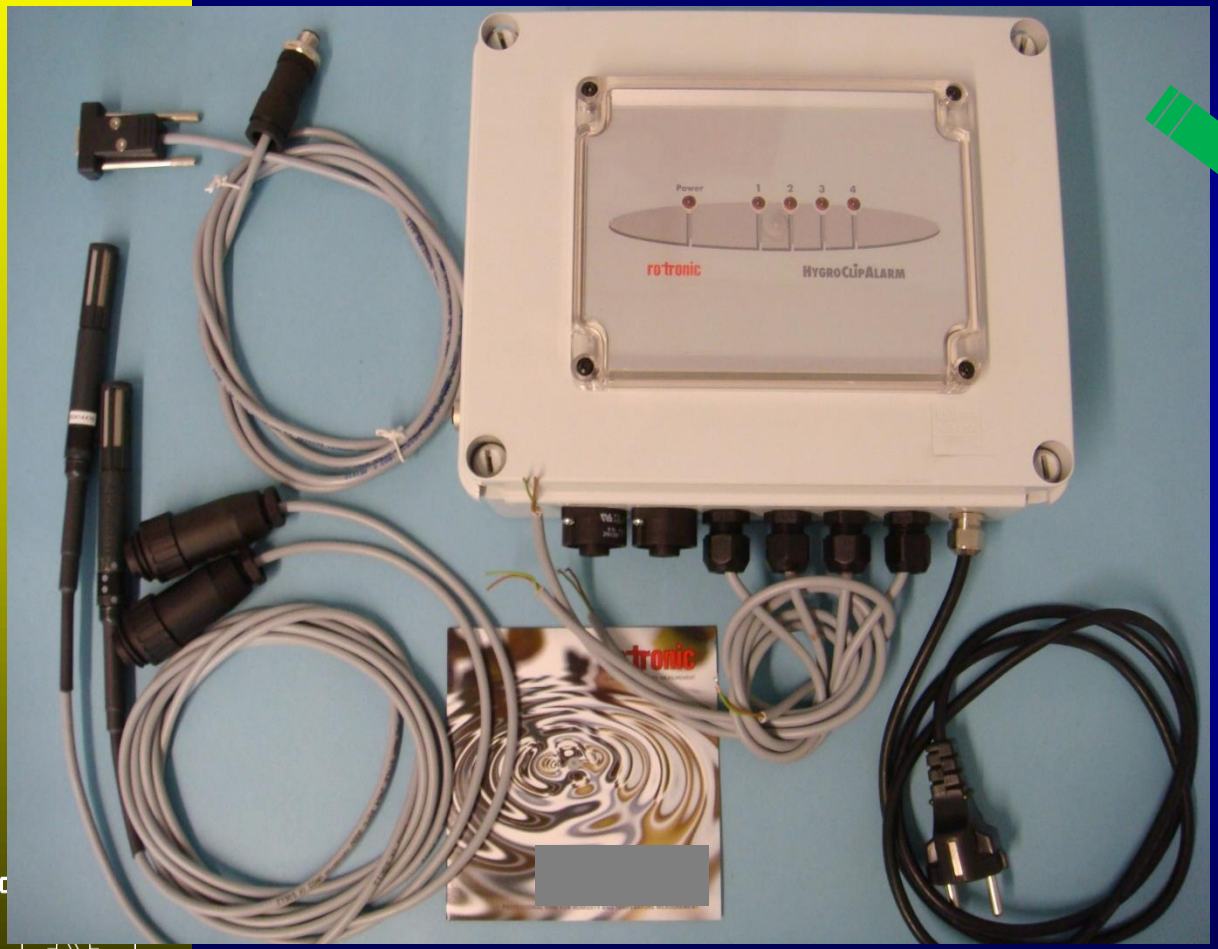
FAN - IN THE WALL

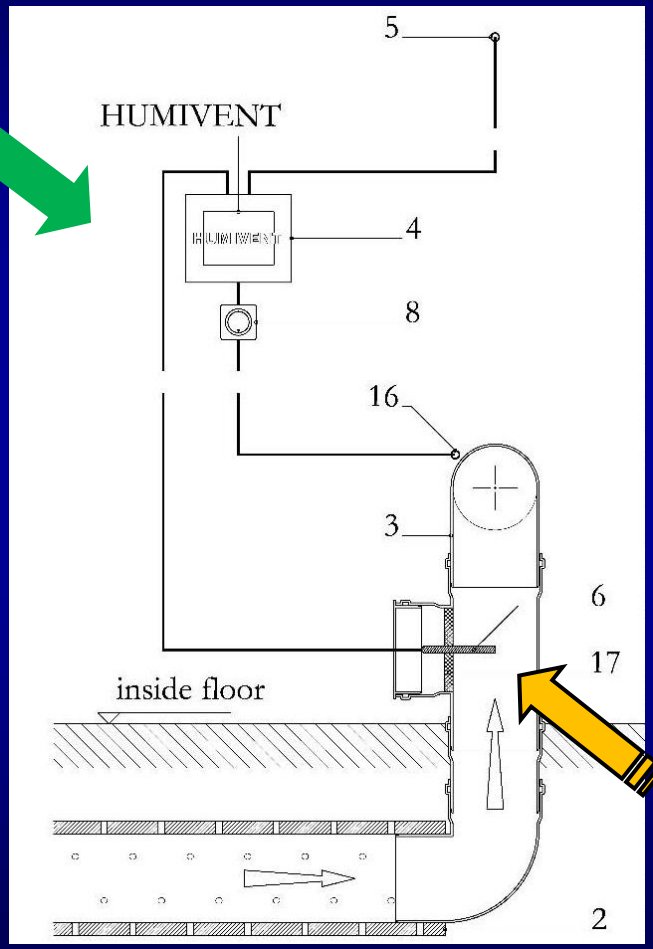


OUTDOOR PROBE (T and RH)



HUMIVENT DEVICE





After the channel implementation

U.PORTO
FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
CONSTRUCT
LFC


imperium
imperium
imperium
imperium

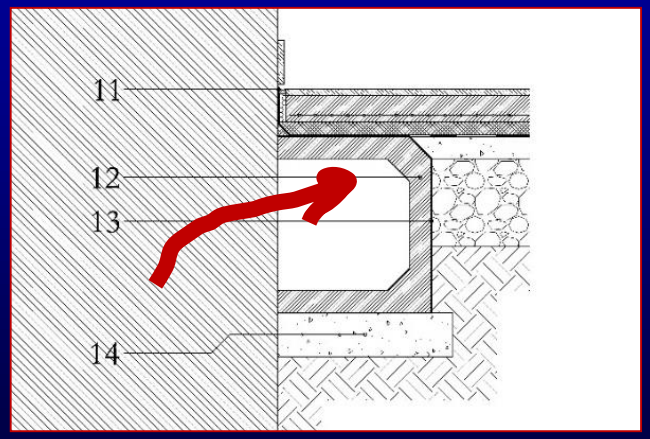
BEFORE... AND AFTER...

7.

CONCLUSION

1

The treatment of rising damp is a problem difficult to solve. We consider that the use of air with controlled relative humidity is the most suitable treatment principle.



U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

CONSTRUCT

LFC

2

The hygro-regulated wall base ventilation device optimizes the overall efficiency of the system.

The most suitable criterion is to turn off the ventilation if the vapor pressure at the air outlet is lower than the vapor pressure at the air inlet . The HUMIVENT device was developed.

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

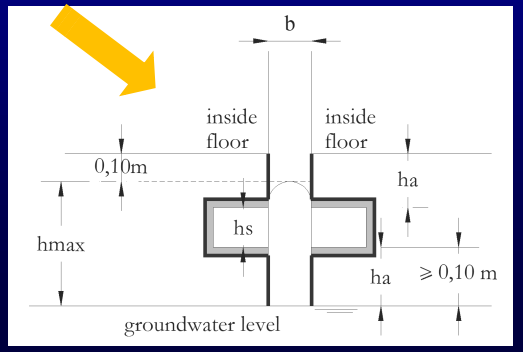
CONSTRUCT

LFC

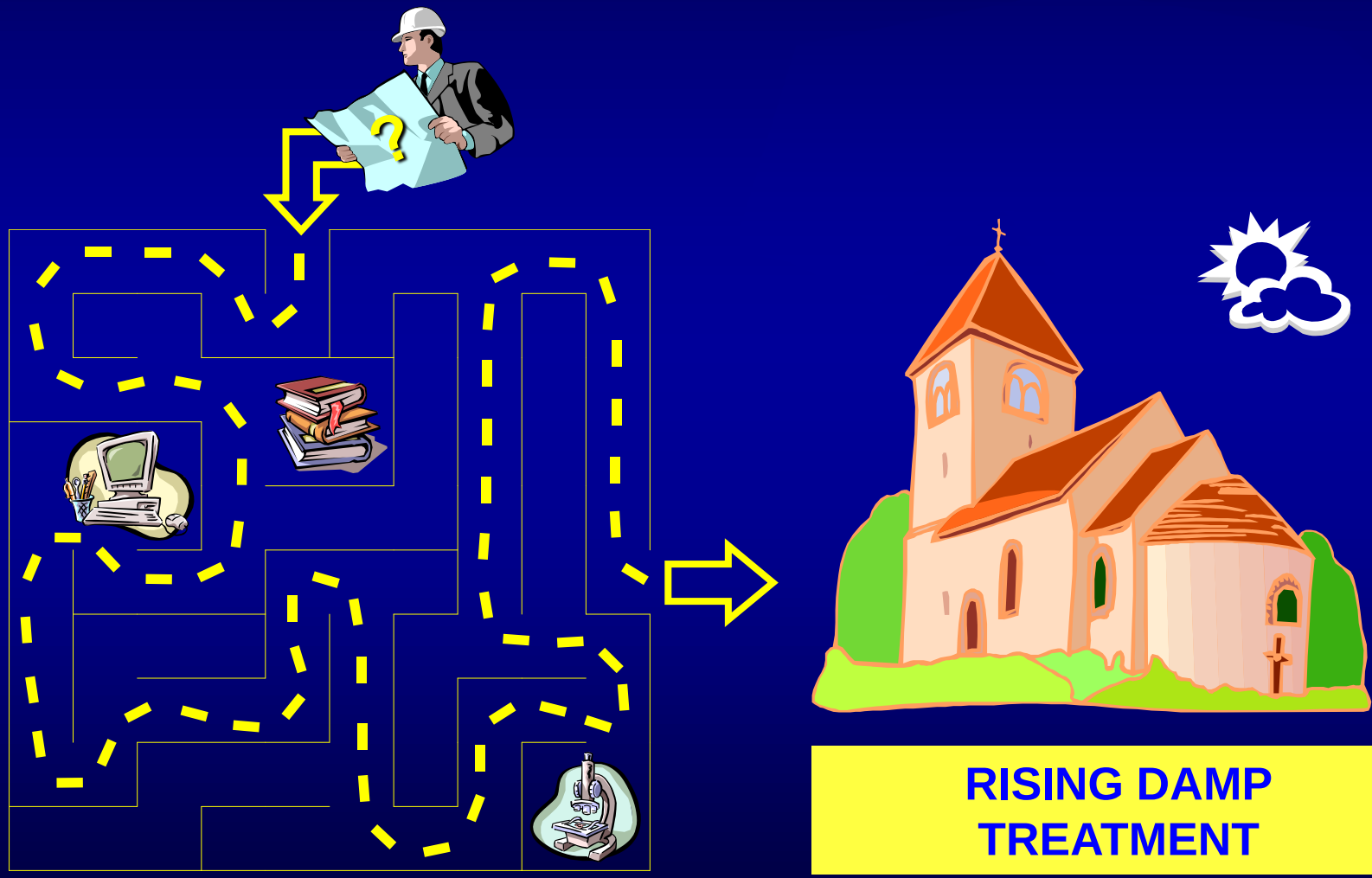
3

We developed a simplified methodology for designing the wall base ventilation system and presented an application.

The first step is to define the maximum acceptable level of the damp front in the wall, h_{max}, below the floor level.



The innovation asks for research
and the research must benefit the practice



U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

CONSTRUCT

LFC


THANK YOU FOR YOUR ATTENTION...
Vasco Peixoto de Freitas
vpfreita@fe.up.pt
mail@vpfreitas.com
Vasco Peixoto de Freitas