INSULARIS

SINGLE FAMILY HOUSE THERMAL STUDY IN BOGOTA

Comfort study – "La Calera House"

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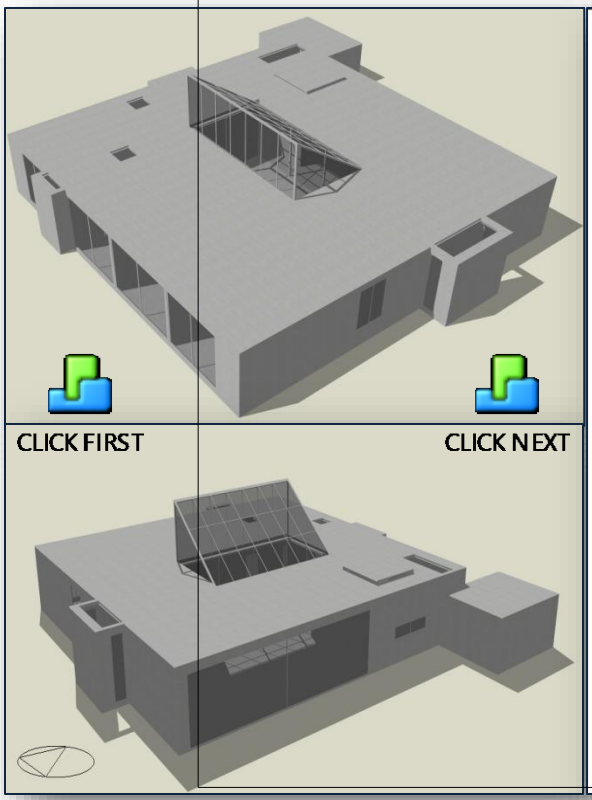
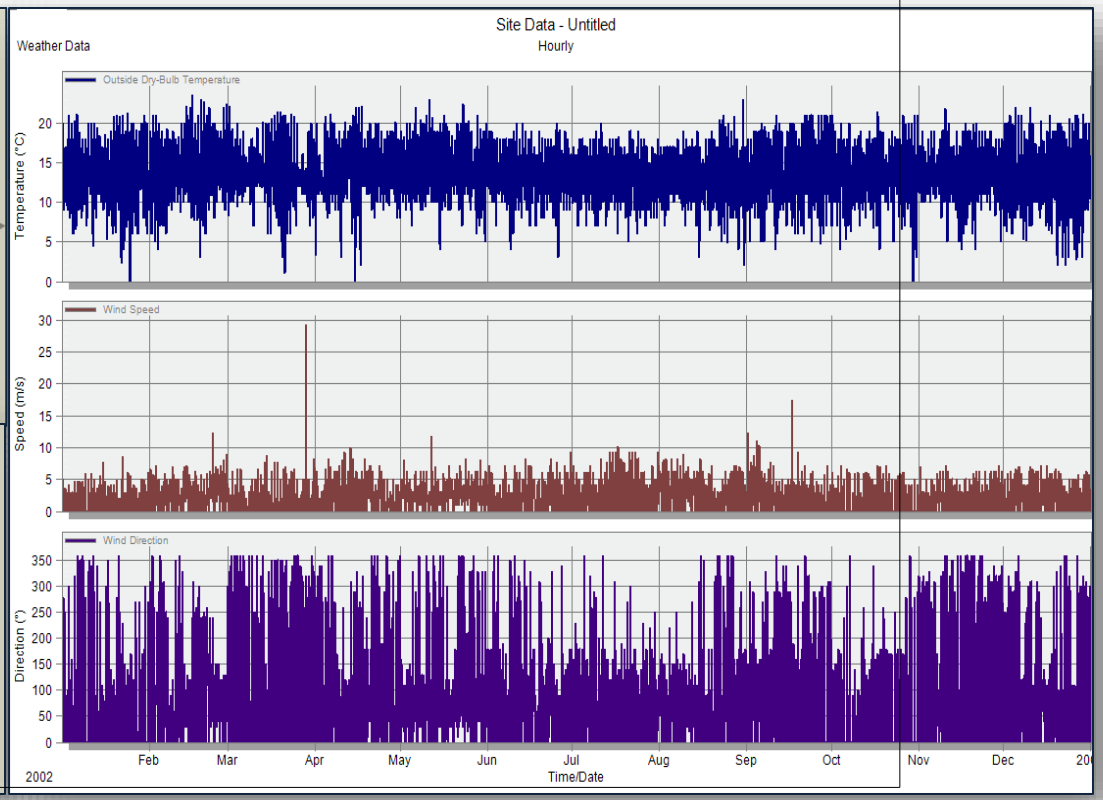
INTRODUCTION

Introduction

Climatic Zone

This report will study the single family housing building "La calera" ,use the weather data of La Calera extracted form Meteonorm and evaluate the thermal comfort along the whole year…





… by means of the software DesignBuilder. In general, La Calera and Bogota's climate is tempered cold along the year. Temperatures fluctuate between 3 and 22 °C.

Introduction

Climatic Zone

These are the main temperature values and wind flows on site. The average temperature inside the baseline house along the year is 19.6 °C. The architecture of the building shows a …

BASELINE		January	February	March	April	May	June	July	August	September	October	November
Extreme external T°	Coldest day	3.2	3.6	5.4	6.3	6.0	5.9	4.8	5.6	3.7	4.7	4.5
	Hottest day	22.7	22.0	22.2	6.3	21.2	5.9	22.0	20.2	3.7	21.0	4.5
Extreme internal T°	Coldest day	14.38	13.84	13.10	14.29	14.40	13.06	13.12	13.32	12.85	13.20	13.67
	Average	19.30	19.11	18.94	20.81	18.69	21.64	18.28	18.50	20.58	18.77	21.80
	Hottest day	26.11	25.04	25.26	24.34	24.10	23.74	23.80	24.55	24.98	25.02	24.70
Wind direction and speed	Avrg wind direction	95.77	93.58	88.30	91.19	95.86	93.69	90.16	94.82	91.19	104.68	92.59
	Avrg wind speed (m/s)	2.50	2.59	2.39	2.40	2.29	2.69	2.92	2.80	2.60	2.39	2.30

…charming and personal character but, unfortunately, with a permanent cold thermal feeling. An insulation strategy should be focused to avoid/reduce heating if applied or discomfort hours if not.

Introduction

Materials Considered in the simulation

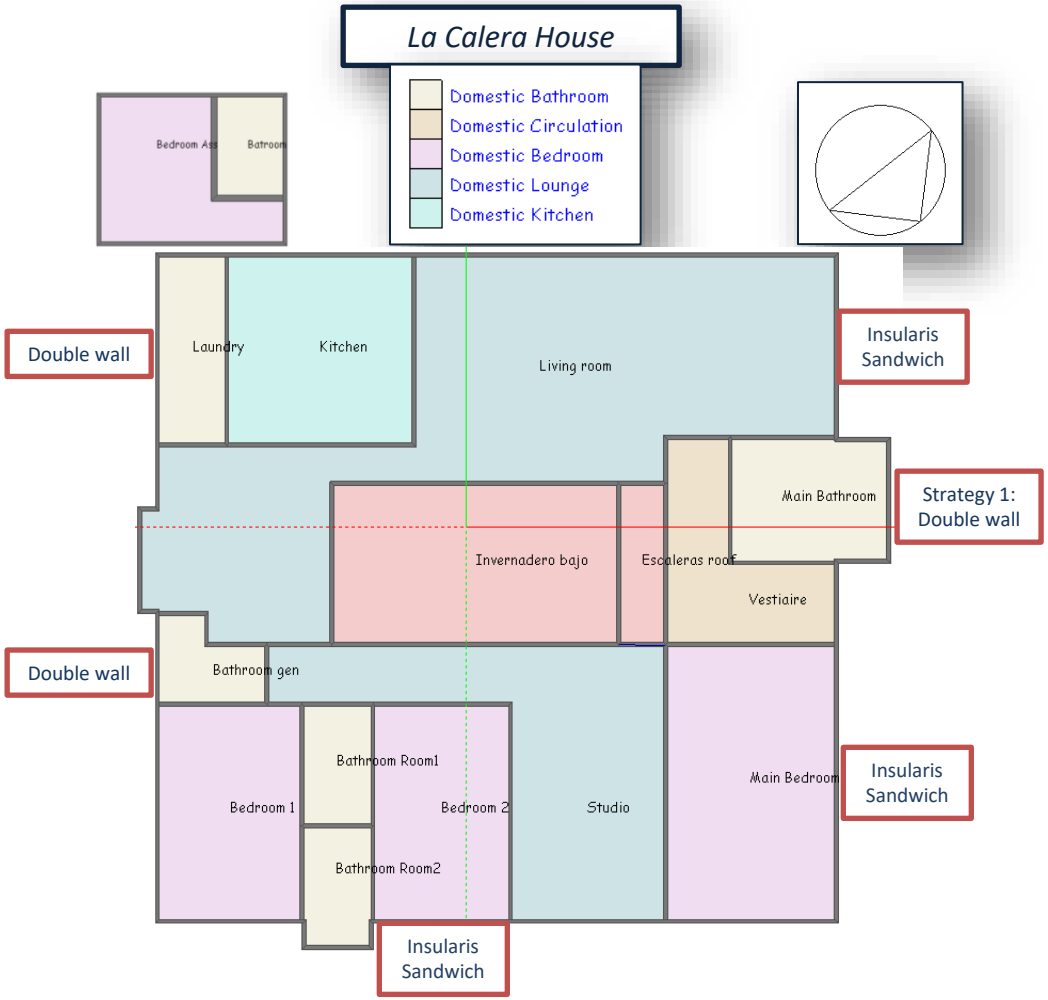
No insulation
Baseline
Walls Exterior & Interior: 10 cm conventional concrete (CC) without insulation.
Ground slab: 15 cm conventional concrete slab (CC)
Roof slab: 15 cm conventional concrete slab (CC)

Strategy I: Insularis Colombia
Walls Exterior : 10 cm Insularis colombia (the whole envelope except comments the wall next to the red boxes)
Double Walls Exterior : 20 cm Insularis colombia
Insularis Sandwich Walls Exterior : 10 cm Insularis colombia + High density EPS (Icopor) + 8 cm Insularis colombia
Walls Interior: 10 cm Insularis colombia
Ground slab: 15 cm Insularis colombia
Roof slab: 15 cm Insularis colombia

Exterior Windows
Glazing:Standard 4-12-4 low-e, air filled
Generic Low-E 4mm glass + 12 mm air + Generic Low-E 4mm glass
Frame: Aluminium window frame (with thermal break)
Aluminium window frame (with thermal break)

Interior Windows (greenhouse)
Single glazed, no low-emissivity coating, 4 mm thick glass.
No frame

Window's natural ventilation set point: **24 °C**



We are going to analyze 5 different strategies to show how insulation will significantly increment comfort hours during the year and modify this specific design with higher living standards.

Introduction

Model Description

The Fanger Comfort model was first published in 1967 and is currently used. Fanger proposes a procedure to evaluate comfort on a 7 points thermal feeling scale...

FANGER	
PMV Below -4	Extremely cold
PMV between -4<x<-3	Very cold
PMV between -3<x<-2	Cold
PMV between -2<x<-1	Cool
PMV between -1<x<0	Slightly cool
PMV between 0<x<1	Slighty warm
PMV between 1<x<2	Warm
PMV between 2<x<3	Hot
PMV between 3<x<4	Vey Hot
PMV over 4	Extremely hot

•The Fanger model follows an energy analysis that considers all forms of energy loss of the body:

- ***the convection and radiant heat loss from the outer surface of the clothing,***
- ***the heat loss by water vapour diffusion through the skin,***
- ***the heat loss by evaporation of sweat from the skin surface,***
- ***the latent and dry respiration heat loss***
- ***the heat transfer from the skin to the outer surface of the clothing***

•Fanger conducted a study with volunteers, introducing them to a climatic chamber and inducing them several thermal feelings. Out of the results he established a comfort equation relating a "Predicted Mean Vote" classification from -3 to +3 . Although the Fanger model provides just 7 points, Energy + Design Builder allows an unlimited classification.

•Each thermal feeling has an associated:

- ***Operative Temperature :*** *Average between Air Temperature (Ta) and Mean Radiant Temperature (Tr)*
- ***Windows openings:*** *Relative air velocity inside the house*
- ***Clothing factor:*** *as an example 0 would be completely exposed, 0.5 light sports wear, 1 winter wear, 1.5 business suit (maximum value)*
- ***Relative Humidity:*** *How dry or humid the air is.*
- ***Activity:*** *What kind of activity is happening (static cycling, reading, taking a shower, sleeping…), also affected by the occupancy per m2, the use electronic devices or ligths.*

... along with numerous human experiments in various environments. He related subjects in response to the variables that influence the condition of thermal comfort.

COMFORT EQUATION

$$(M-W) - 3{,}05\cdot10^{-3}\ (5733 - 6{,}99\ (M-W) - p_a) - 0{,}42\ \{\ (M-W) - 58{,}15\ \} - 1{,}7\cdot10^{-5}\ M\ (5867 - p_a) - 0{,}0014\ M\ (34 - t_a) =$$
$$3{,}96\cdot10^{-8}\ f_{cl}\ \{(t_{cl} + 273)^4 - (t_r + 273)^4\} - f_{cl}\ h_c\ (t_{cl} - t_a)$$

$$PMV = (0{,}303\,e^{-2{,}100\,M} + 0{,}028)\{58{,}15(M - W) - 3{,}05\cdot10^{-3}\,[5733 - 406{,}7(M - W) - p_a] - 24{,}42[(M - W) - 1]$$
$$- 10^{-3}\cdot M(5867 - p_a) - 0{,}0814\cdot M(34 - t_a) - 3{,}96\cdot10^{-8} f_{cl}[(t_{cl} + 273)^4 - (\bar{t}_r + 273)^4] - f_{cl}h_c(t_{cl} - t_a)\}$$

$$t_{cl} = 35{,}7 - 1{,}628(M - W) - 0{,}155 I_{cl}\{3{,}96\cdot10^{-8} f_{cl}[(t_{cl} + 273)^4 - (\bar{t}_r + 273)^4] + f_{cl}h_c(t_{cl} - t_a)\}$$

$$h_c = \begin{cases} 2{,}38\ (t_{cl} - t_a)^{0{,}25} & \text{for } 2{,}38(t_{cl} - t_a)^{0{,}25} > 12{,}1\sqrt{v_{ar}} \\ 12{,}1\sqrt{v_{ar}} & \text{for } 2{,}38(t_{cl} - t_a)^{0{,}25} < 12{,}1\sqrt{v_{ar}} \end{cases}$$

$$f_{cl} = \begin{cases} 1{,}00 + 0{,}2\cdot I_{cl} \text{ for } I_{cl} < 0{,}5 \text{ clo} \\ 1{,}05 + 0{,}1\cdot I_{cl} \text{ for } I_{cl} > 0{,}5 \text{ clo} \end{cases}$$

$$\bar{t}_r = \sqrt[4]{F_{p-1}(t_1 + 273)^4 + F_{p-2}(t_2 + 273)^4 + \ldots + F_{p-n}(t_n + 273)^4} - 273$$

where t_n = temperature of surface n, °C
F_{p-n} = angle factor between person and surface n
ΣF_{p-n} = 1

PMV = Predicted Mean Vote

M = Metabolism, met (1 met = 58 W/m²)

W = External work, met. Equal to zero for most metabolisms

I_{cl} = Thermal resistance of clothing, clo (1 clo = 0,155 m² K/W)

f_{cl} = The ratio of the surface area of the clothed body to the surface area of the naked body

t_a = Air temperature, °C

$\bar{t}_r$ = Mean radiant temperature, °C

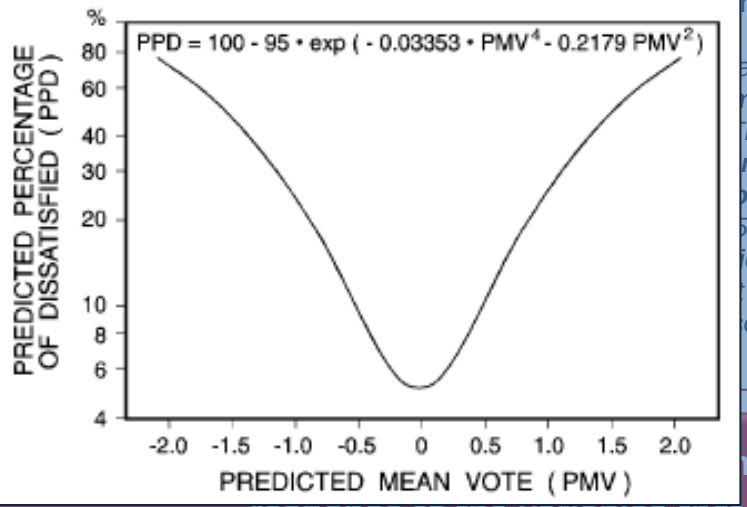
v_{ar} = Relative air velocity, m/s

p_a = Water vapour pressure, Pa

h_c = Convective heat transfer coefficient, W/m²K

t_{cl} = Surface temperature of clothing, °C

BSR/ASHRAE Standard 55P, *Thermal Environmental Conditions for Human Occupancy*
Most Current Draft Standard



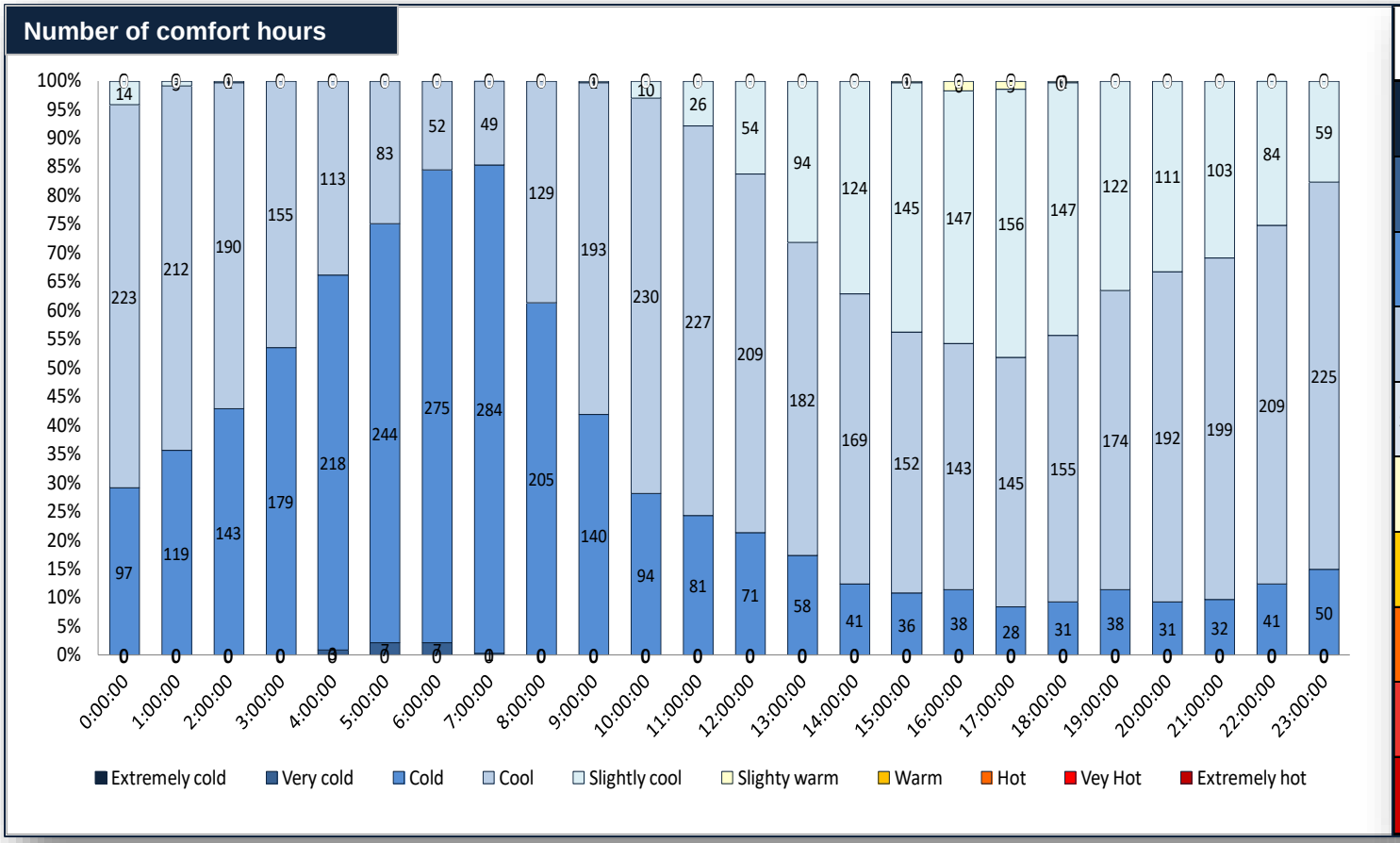
The Predicted Mean Vote (PMV) model uses heat balance principles to relate the five key factors for thermal comfort listed previously to the average response of people on the above formulation (the PMV). **The PPD (predicted percentage of dissatisfied)** index is related to the PMV as defined in the ASHRAE Figure. It is based on the assumption that people voting +2, +3, -2, or -3 on the thermal sensation scale are dissatisfied, and the simplification that PPD is symmetric around a neutral PMV.

He related subjects in response to the variables that influence the condition of thermal comfort.

ANNUAL RESULTS - BASELINE

Baseline la Calera

Annual Results – Comfort hours

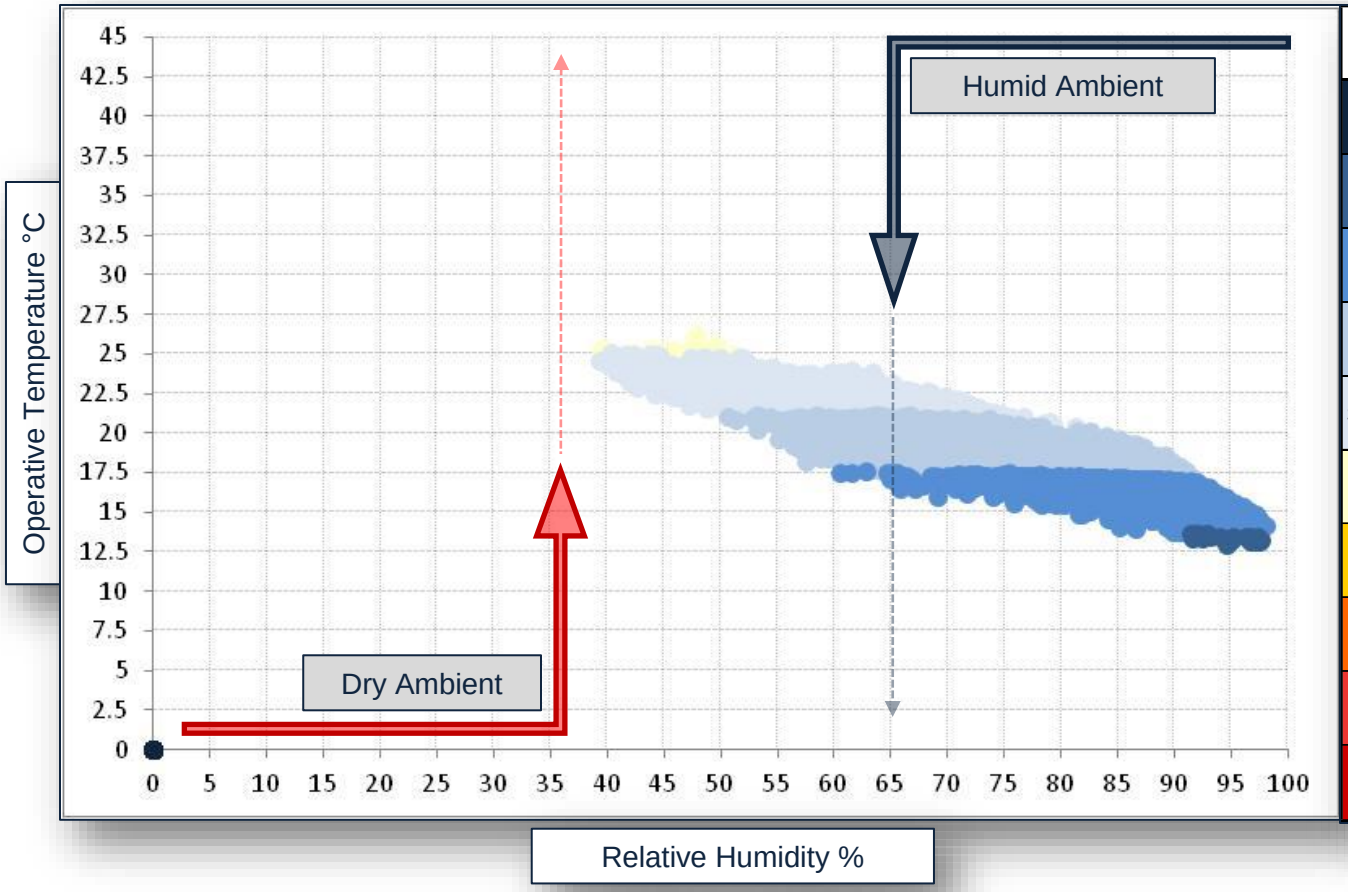


FANGER	% hours/month
Extremely cold	0.0%
Very cold	0.2%
Cold	32.1%
Cool	49.5%
Slightly cool	17.9%
Slighty warm	0.2%
Warm	0.0%
Hot	0.0%
Vey Hot	0.0%
Extremely hot	0.0%

Following the graph an absolute 18.1 % comfort hours are obtained along the whole year, mainly between 1PM and 11 PM. “Chilly” nights are forecasted in the house.

Baseline la Calera

Annual Results – Temperature vs Humidity



FANGER	% hours/month
Extremely cold	0.0%
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Slighty warm	0.2%
Warm	0.0%
Hot	0.0%
Vey Hot	0.0%
Extremely hot	0.0%

5 variables affect comfort- Humidity, T°, Activity, Ventilation and Clothing. Clothing will be the same the whole year (winter wear). Activity thermal loads result from lighting, occupancy & the room's use.

Baseline la Calera

Annual Results – Comfort Report

During 77.5% of the year, temperatures inside the house will fluctuate between 13 and 20.4 C°.

Comfort hours:

18.1%

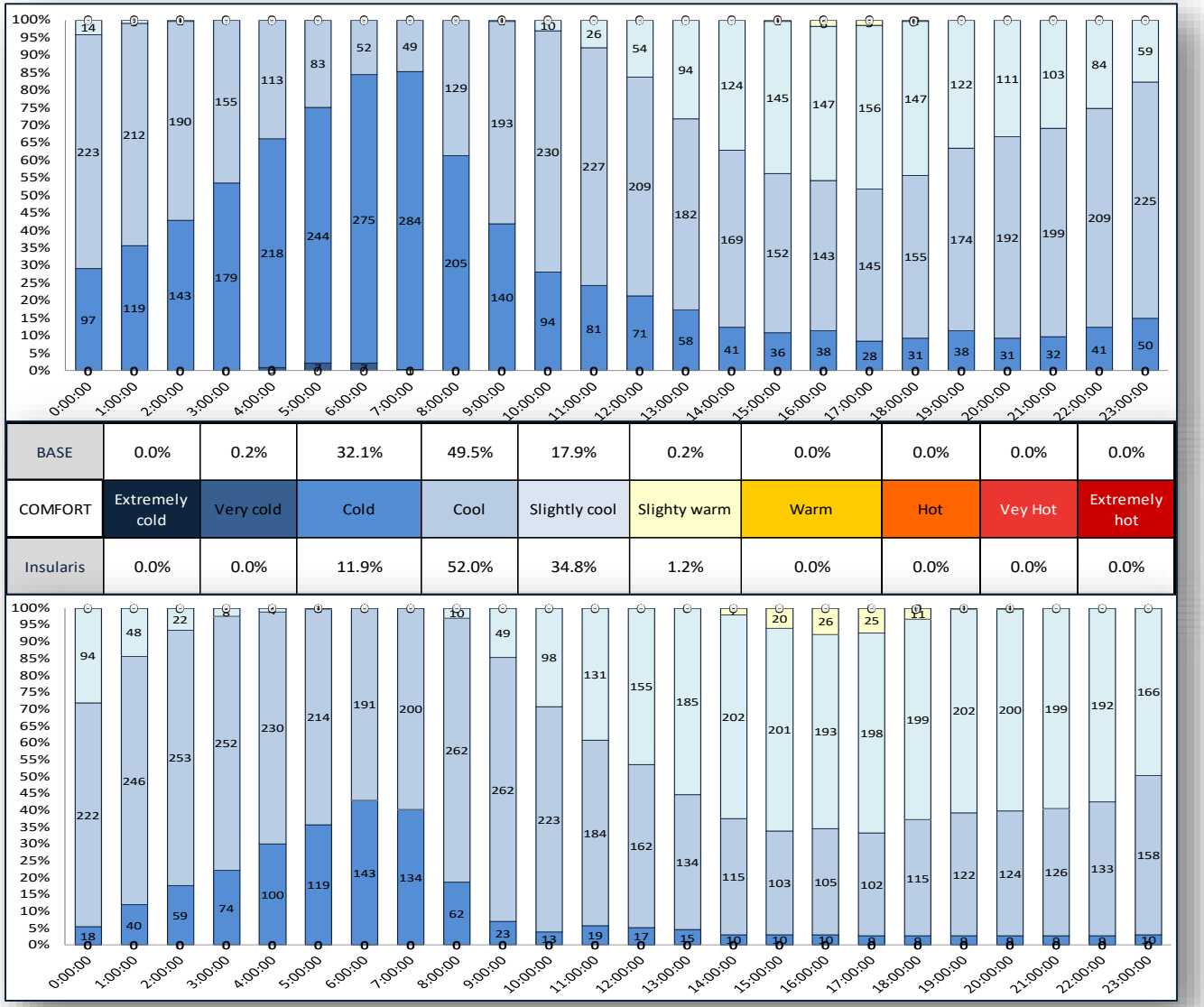
COMFORT REPORT			Very cold			Cold			Cool			Slightly cool			Slighty warm		
TEMPERATURE	% of comfort hours (Out of 8760 hour/year)		**0.2%**			**32.1%**			**49.5%**			**17.9%**			**0.2%**		
	TOTAL N° Hours		**21**			**2816**			**4337**			**1570**			**16**		
	N° Hours		0.0	19.0	2.0	1.0	2550.0	265.0	638.0	3321.0	378.0	180.0	1386.0	4.0	6.0	10.0	0.0
	Temperature MIN		0.0	12.9	13.6	13.6	13.6	17.0	17.0	17.6	20.4	20.4	21.1	24.8	24.8	25.0	0.0
	Temperature MAX		0.0	13.6	13.6	13.6	17.0	17.6	17.6	20.4	21.1	21.1	24.8	25.0	25.0	26.1	0.0
	% Hours		0%	100%	67%	33%	100%	29%	71%	100%	68%	32%	100%	40%	60%	100%	#DIV/0!
ACTIVITY	LOW Use	% Time	0%			9%			19%			31%			50%		
	Mid term USE	% Time	100%			66%			45%			41%			50%		
	Intensive USE	% Time	0%			25%			36%			29%			0%		
WINDOWS	CLOSED	% Time	100%			100%			100%			51%			0%		
	HALF OPEN	% Time	0%			0%			0%			19%			0%		
	Full OPEN	% Time	0%			0%			0%			30%			100%		

It is up to the client's judgment to select the range of the comfort scale he would like to enjoy, and CEMEX responsibility to satisfy him by offering constructive solutions that fits all the requirements.

INSULATION STRATEGY I

Insulation Strategy I

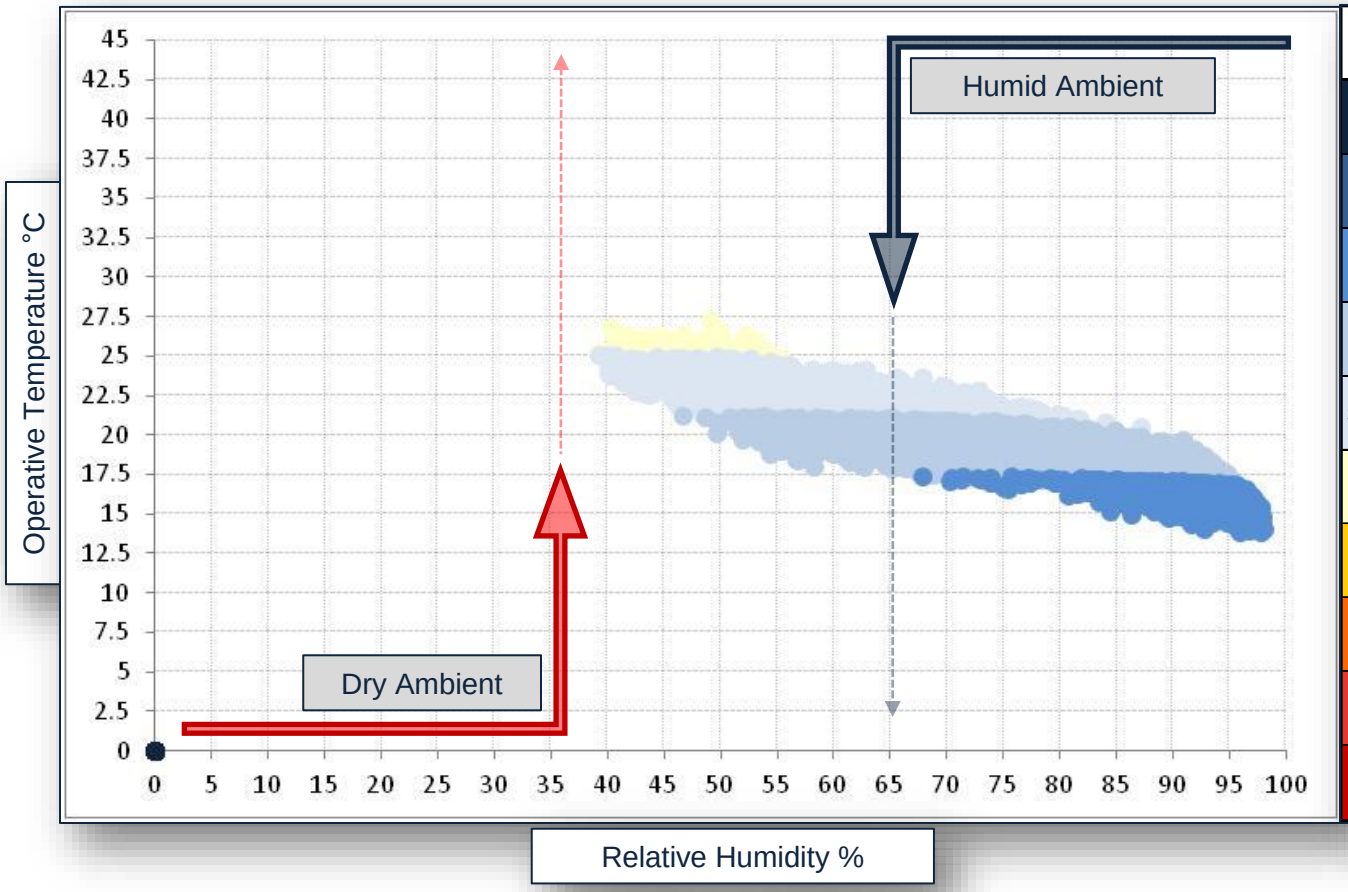
Annual Results – Comfort hours



BASE	0.0%	0.2%	32.1%	49.5%	17.9%	0.2%	0.0%	0.0%	0.0%	0.0%
COMFORT	Extremely cold	Very cold	Cold	Cool	Slightly cool	Slighty warm	Warm	Hot	Vey Hot	Extremely hot
Insularis	0.0%	0.0%	11.9%	52.0%	34.8%	1.2%	0.0%	0.0%	0.0%	0.0%

Insulation Strategy I

Annual Results – Temperature vs Humidity



FANGER	% hours/month
Extremely cold	0.0%
Very cold	0.0%
Cold	11.9%
Cool	52.0%
Slightly cool	34.8%
Slighty warm	1.2%
Warm	0.0%
Hot	0.0%
Vey Hot	0.0%
Extremely hot	0.0%

Results show a 36% of the total hours falling into the Slightly cool/warm, generally stated as "comfortable parameters" with a high degree of acceptance among the house users.

Insulation Strategy I

Annual Results – Comfort Report

During 88 % of the year, temperatures inside the house will fluctuate between 17 and 27.3 C°.

Comfort hours:

36%

COMFORT REPORT			Cold			Cool			Slightly cool			Slighty warm		
TEMPERATURE	% of comfort hours (Out of 8760 hour/year)		**11.9%**			**52.0%**			**34.8%**			**1.2%**		
	TOTAL N° Hours		**1044**			**4559**			**3048**			**109**		
	N° Hours		0.0	934.0	110.0	292.0	3913.0	354.0	319.0	2709.0	20.0	23.0	86.0	0.0
	Temperature MIN		0.0	13.8	16.9	16.9	17.4	20.5	20.5	21.2	24.8	24.8	25.1	0.0
	Temperature MAX		0.0	16.9	17.4	17.4	20.5	21.2	21.2	24.8	25.1	25.1	27.3	0.0
	% Hours		-	100%	27%	73%	100%	53%	47%	100%	47%	53%	100%	-
ACTIVITY	LOW Use	% Time	7%			13%			27%			49%		
	Mid term USE	% Time	77%			54%			37%			50%		
	Intensive USE	% Time	16%			32%			35%			1%		
WINDOWS	CLOSED	% Time	100%			99%			41%			0%		
	HALF OPEN	% Time	0%			1%			30%			0%		
	Full OPEN	% Time	0%			0%			29%			100%		

Along the whole year, the number of comfort hours are raised by a factor 2 compared with the Baseline house (18.1%). In other words, an extra 17.9% of total comfort is obtained with this strategy.

FINAL REPORT

Final Report

Annual Results Table

Annual summary		
Strategies Summary	Baseline	Insularis Colombia
Extremely cold	**0.0%**	0.0%
Very cold	**0.2%**	0.0%
Cold	**32.1%**	11.9%
Cool	**49.5%**	52.0%
Slightly cool	**17.9%**	34.8%
Slighty warm	**0.2%**	1.2%
Warm	**0.0%**	0.0%
Hot	**0.0%**	0.0%
Vey Hot	**0.0%**	0.0%
Extremely hot	**0.0%**	0.0%
% TOTAL COMFORT HOURS	**18.1%**	36.0%

Insularis Concrete

Characteristics of Design

- **Foundation and Top Slab:**
  - Compressive Strength: 210 Kg/cm2
  - Slump: 13 cm +/- 2.5 cm
  - Aggregates Maximum Size: 12.5 mm
  - A/C ratio : 0.36
  - Density of concrete: 1677 kg/m3
- **Walls, beams and columns – Architectural Insularis Hidratium White Cream**
  - Compressive strength: 210 kg/cm2
  - Slump:18 cm +/- 2.5 cm
  - White Cement – Type III
  - Aggregates Maximum Size: 12.5 mm
  - Density of concrete: 1734 kg/m3

Insularis Concrete

- Conventional building system with walls, beams, columns and slabs. All are Insularis concrete.
- The thickness of the walls is 10 cm. In some cases there is a layer of Insularis Concrete of10 cm, then a polystyrene of 5 cm and finally a layer of 8 cm of Insularis Concrete. The top slab has a thickness of 15 cm.
- For architectural concrete, it used a plastic formwork with no texture.
- Specifically contemplated the use of a retarder admixture due to prolonged transport time (3 hours) and placement (1 hour).
- Concrete compaction was performed with rod and tapping with rubber hammer.