CAM(B)BRIDGE | Calculation and Measurements in Buildings: Bridging the Gap

Conventions n° 2016 R 59a et 2016 R 59b

L.2.3.5 | Production et adaptation des métadonnées des sites démonstrateurs

Spécifications relatives au site Citydox

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1. GENERAL INFORMATION

1.1. Introduction

The present document collects all the notes, information and steps concerning the experiment undertaken within the framework of the project *Cam(b)bridge*. This specification is redacted with a dual purpose: sharing data sets enabling modellers to validate their simulation models and also information and process of the experiment to make future measurement campaigns easier and more efficient.

This research project is leaded by *Architecture & Climat* from *UCL University* and *Jacques Delens s.a. Company*. The purpose of the initiative is to develop methods that can be applied on site during the construction phase to assess the actual performance of buildings at a moment when it can still be improved to reach the target without entailing over costs. The measurements are performed in summer, during 9 days without occupancy.

1.2. Apartments

The experiment was undertaken in a building complex named *Citydox*. The site is located in Anderlecht, at the South-West of Brussels, in Belgium. The construction, accomplished by *Besix and Jacques Delens s.a. [EJD]*, is a part of a complex of a nursing home (180 beds), 71 service flats, 91 residential homes and an office complex. The measures have been taken in two apartment, illustrated in the following figures.

The apartments considered for the study are facing South-East and are located on the fourth and sixth floors. At the period of the test, the offices facing the units, near the principal road, were already constructed.

Figure 1 : Site Citydox

Figure 2: 3D view of the location of the Citydox complex (source : citydox.be)

Figure 3 : 3D view, presentation of the complex

The experiment has been undertaken in two bedrooms of two identical apartments, one located on the fourth floor and the other on the sixth floor, above the first one. The party walls and floors of the taller bedrooms (AI and BI) as well as their ceilings have been covered by insulation panels on their indoor side. The 4 units are named “AI”, “AU”, “BI”, “BU” according to their location in apartments “A” for B.1.4.1 (fourth floor) or “B” for B.1.6.1 (sixth floor), and according to the presence “I” or the absence “U” of internal insulation panels. AI and AU units are respectively identical to BI and BU units.

Figure 4 : 3D view with location of the units of the experiment

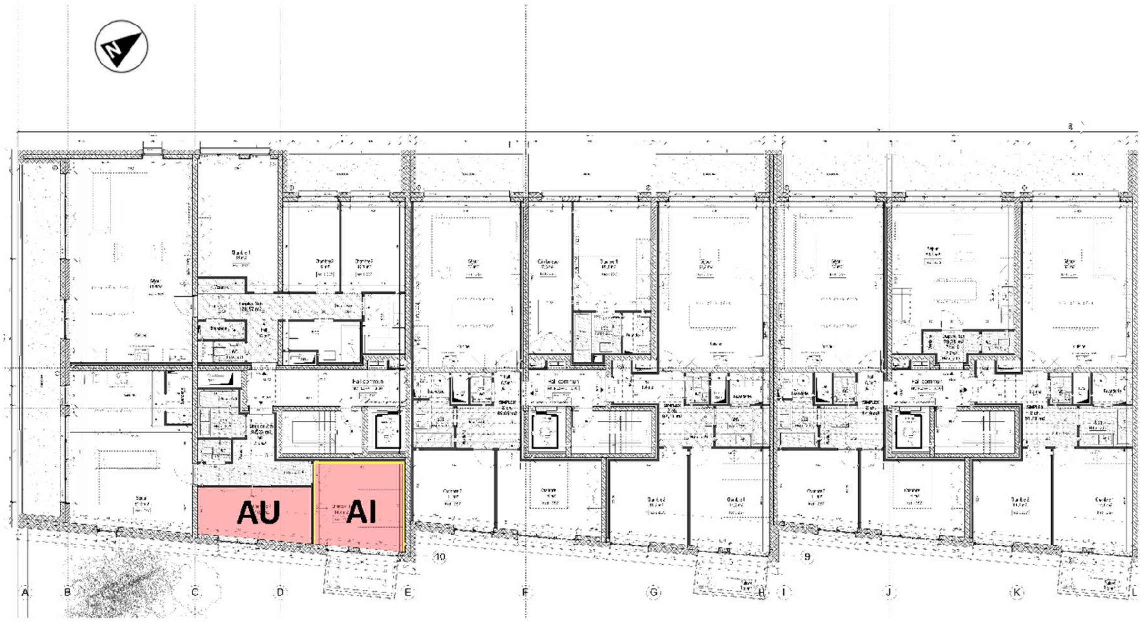

Figure 5 : Units location

Figure 6: Unit location, view of South-East façade

2. EXPERIMENT

The conventional measurement procedure for the assessment of the Heat Loss Coefficient (HLC) is based on a coheating test. The coheating test is currently limited to winter month, as a significant internal-external temperature difference is needed. We intend to expand the time window allowable for the assessment of the Heat Loss Coefficient (HLC) by performing measurements in summer. Measurements of Citydox units were performed from 13/07/2018 to 25/07/2018.

The measurement have been realized in identical units in parallel, in order to compare a co-heating test to a method based on the observation of the floating indoor temperature. A reference value of the HLC can be obtained by comparing the input powers and the difference of internal temperatures measured in two parallel identical units, one submitted to coheating and the other being in floating temperature mode, as they are submitted to identical solar heat gains (Figure 7).

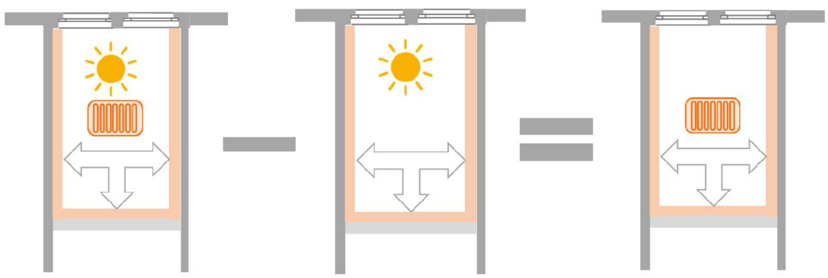

Figure 7 : Analysis process considering the temperature difference between two identical units provided with inside insulation panels: one of the unit is co-heated while both are submitted to identical solar heat gains

The heat loss by common walls and floor, shared with adjacent units, is hardly assessed as the surrounding spaces of the units are not accessible. For that reason, the placement of internal insulation on the party walls allows to focus on the heat loss coefficient of the external façade. It also reduces the heat losses to the neighbouring units and the thermal mass effect of the party walls, floor and ceiling. Moreover, the setup allows to reach higher values of internal temperatures and to obtain a sufficient internal-external temperature difference. Temperatures at the interfaces between inner insulation and original walls were monitored with temperature sensors, to assess the heat flow through the insulation layers.

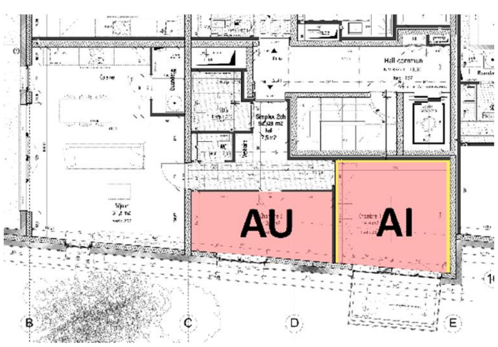

Figure 8: Plan layout of Units A, fourth floor

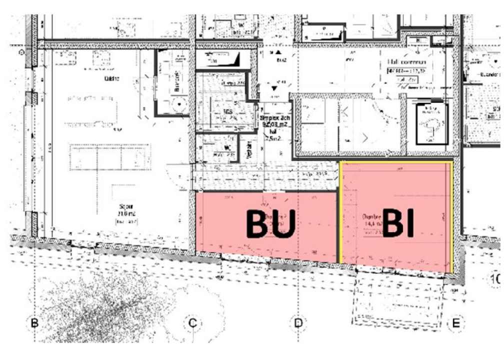

Figure 9: Plan layout of Units B, sixth floor

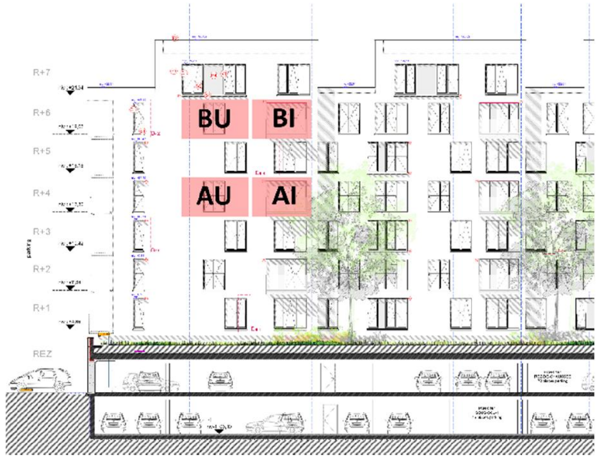

Figure 10: View of South-East façade

Four South oriented units have been tested (Figure 8 and Figure 9): two identical units with insulation panels and two other identical units without insulation panels. In both pairs, one unit is co-heated while the other is in floating temperature mode.

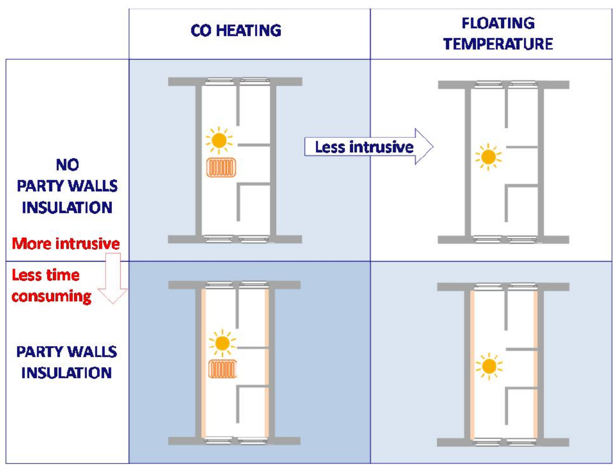

Figure 11 : Different boundary conditions and heat sources for the measurement of the Heat Loss Coefficient

The strong reduction of the thermal mass effect due to the placement of insulation enables to reduce the time period required to assess the façade HLC until 9 days of monitoring without occupancy.

Internal heat gains provided by electric radiators have been monitored. Access was denied during the monitoring. The door and the windows were closed during the whole process.

3. MODEL DETAILS

3.1. Location

The apartments are located in Anderlecht, at the South-West of Brussels in Belgium. There is a building with offices already constructed in front of the units. And a crane projected shadows on the windows at some times. It is shown on Figure 12. The latitude of the buildings is 50.830N and the longitude is 4.318E. The data were measured in local summer time, i.e. in Central European Summer Time (UTC/GMT+2h). They were averaged every 10 minutes and recorded at the end of those ten minutes intervals.

*Figure 12 : Panoramic view from apartment **B.1.4.1**, Unit AU*

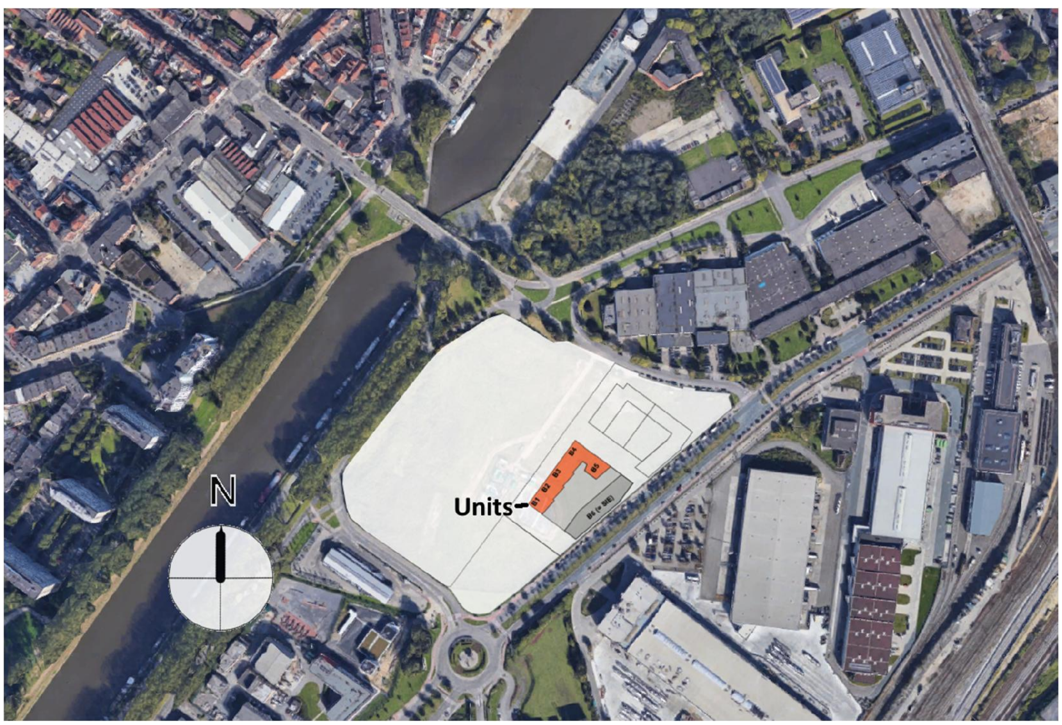

Figure 13 : Site Citydox

3.2. Geometry

Figure 14 shows the internal layout of one apartment (B.1.4.1). The studied places are both bedrooms. The second apartment (B.1.6.1) is located 2 floors above this apartment. The two apartments are exactly the same. The internal ceiling height is 2.57m for both apartments.

All the wall dimensions are specified in the annexes at the end of this document. The reference surface considered for the assessment of the wall dimensions is the layer of interior finishing.

Insulation layer panels has been attached to the three party walls, the party floor and the ceiling (in yellow on Figure 14). The façade of insulated apartments have a supplementary window than uninsulated units.

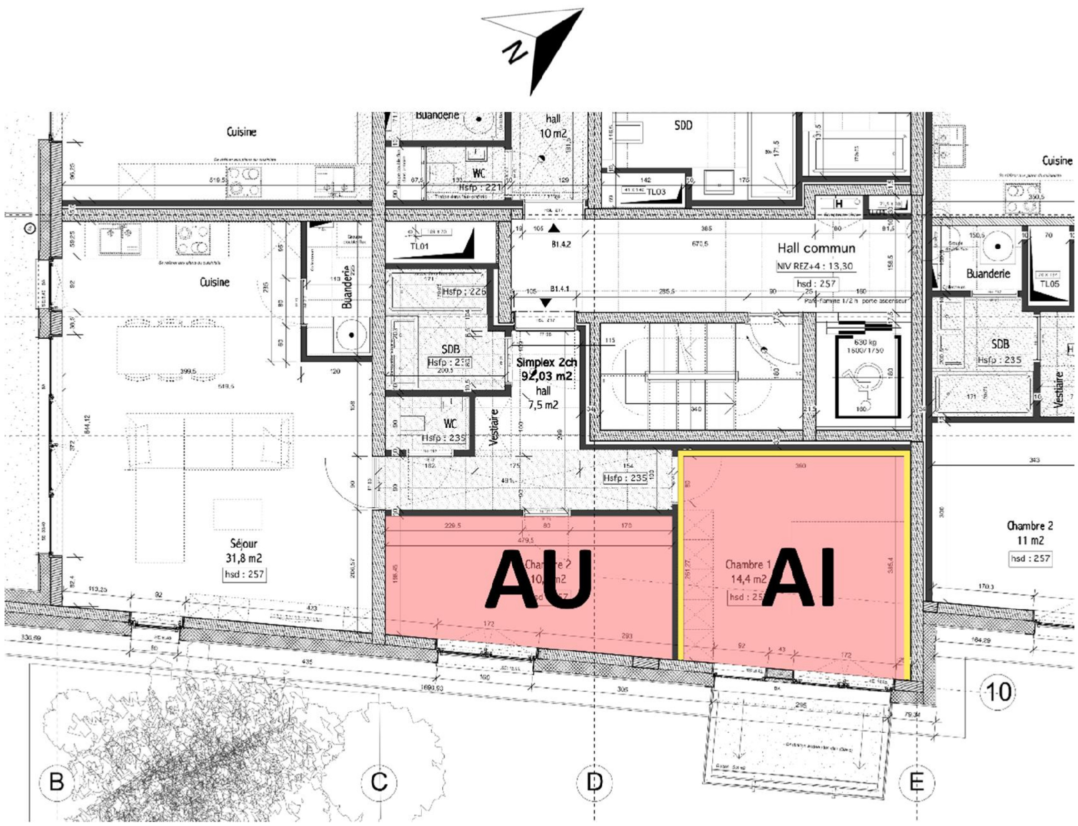

Figure 14 : Layout of apartment B.1.4.1[Furniture are not present in the apartment during the experiment/ in yellow: insulation layer]

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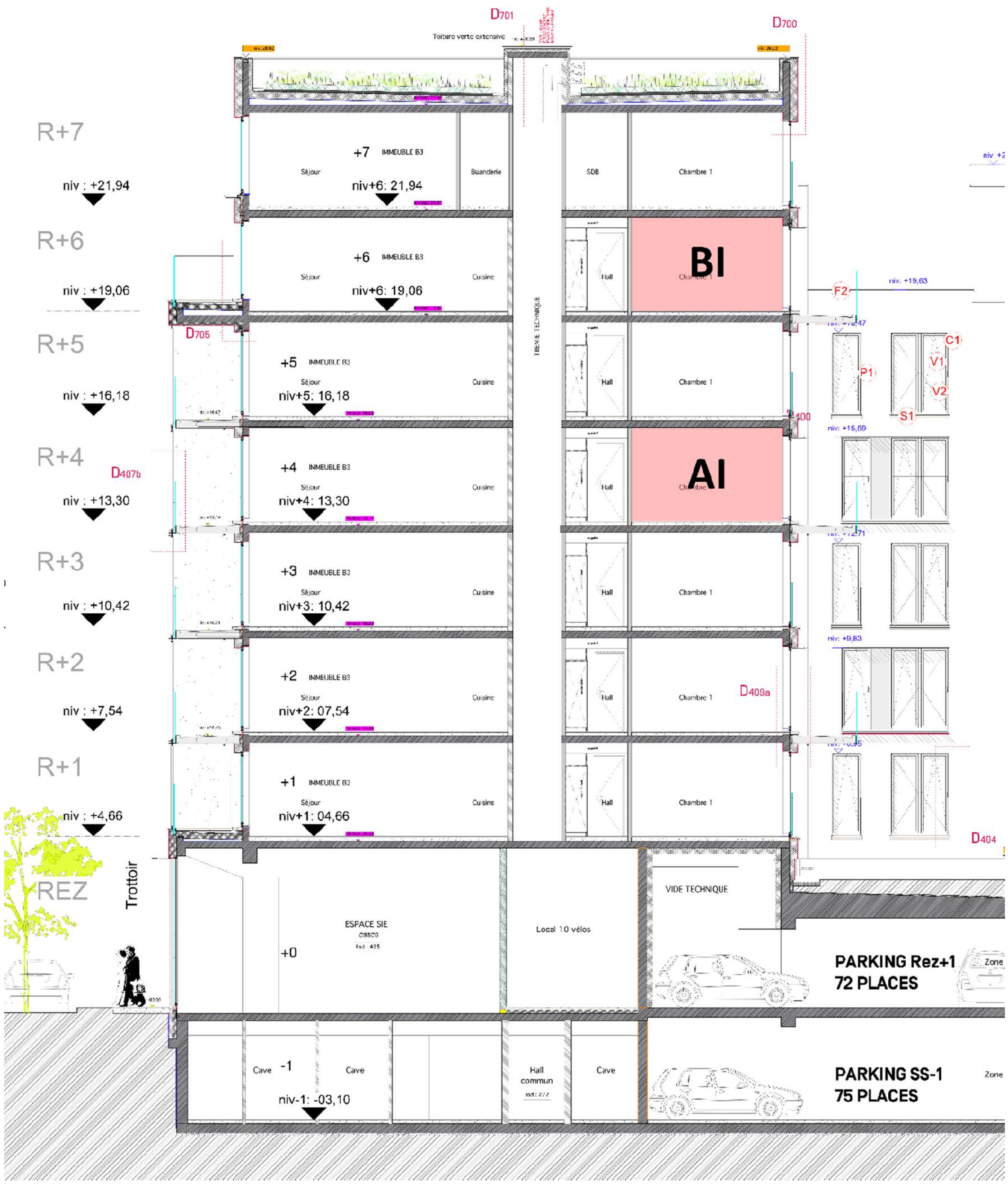


Figure 15 : Longitudinal section in the units

3.3. Glazing and frame areas

All units are equipped with a window shared into two parts: a turning window (G1) and a tilting and turning window (G2). Units AI and BI are equipped with another fixed window (G3). The windows are represented in Figure 16.

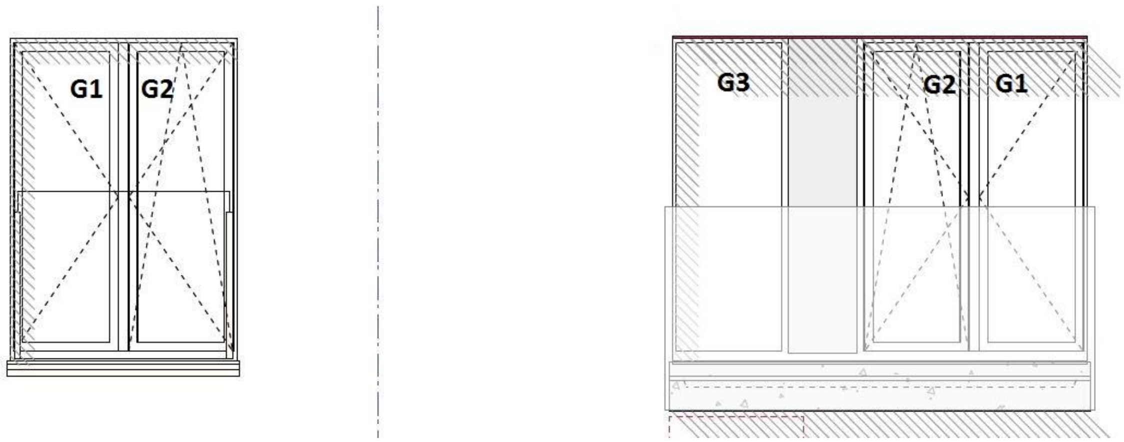


Figure 16 : Façade windows

Table 1 : Dimensions of the windows

Glazing ID	Overall dimensions			Window area	Glazing breadth	Glazing height	Visible Glazing area	Frame area
	l [m]		h [m]	[m²]	[m]	[m]	[m²]	[m²]
G1	80	x	2.20	1.76	0.60	2.04	1.22	0.54
G2	80	x	2.20	1.76	0.60	2.04	1.22	0.54
Total bedroom2				**3.52**			**2.44**	**1.08**
G1	80	x	2.20	1.76	0.60	2.04	1.22	0.54
G2	80	x	2.20	1.76	0.60	2.04	1.22	0.54
G3	80	x	2.20	1.76	0.74	2.14	1.58	0.18
Total bedroom1				**5.28**			**4.02**	**1.26**

3.4. Construction

The construction properties are presented in the Table 2 ***for the walls and the***

Table ***3*** : Floors construction thermo-physical properties (green color: Manufacturer's data or as built documents, blue color: assumptions)

Table ***3*** for the floors and ceilings. The Figure 17 and Figure 18 present the wall and floors numeration used in the tables.

Walls

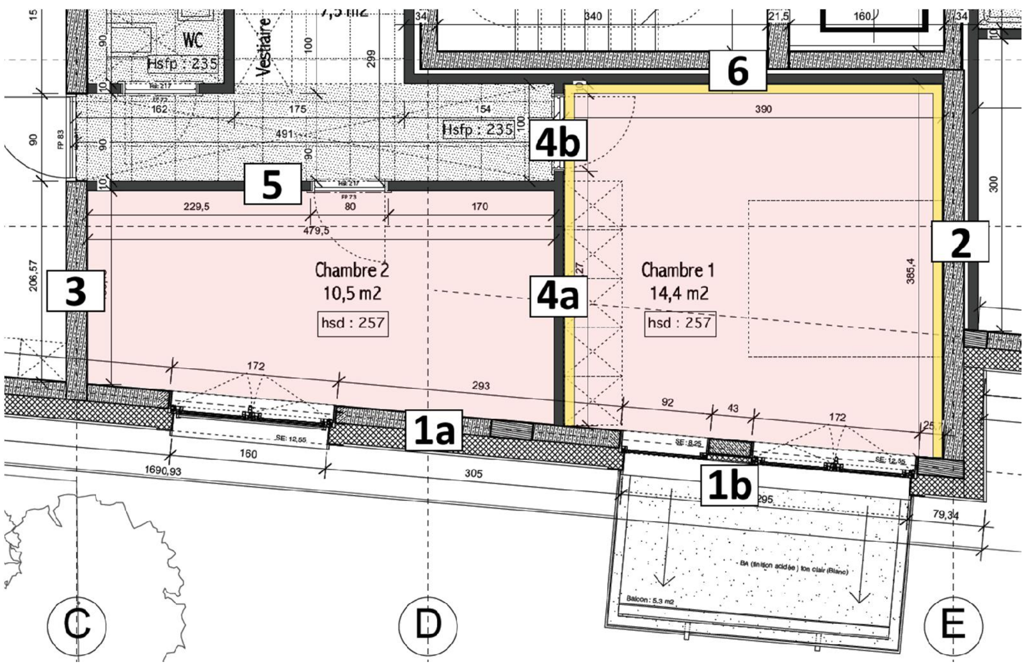


Figure 17 : Plan layout with wall numbering

Table 2 : Walls construction thermo-physical properties (green color: Manufacturer's data or as built documents, blue color: assumptions)

	Thickness	Thermal conduc.	Density	Sp Ht	Absorb	Emiss
Layer	m	W/mK	kg/m3	J/kgK	-	-
[1a] External façade wall - *from outdoor to indoor // Rse = 0.04 m²K/W , Rsi = 0.13 m²K/W*						
Roughcast	0.01	1.5	1500	1000	0.21	0.9
Insulation PSE	0.21	0.032	35	1450		
Silicablocks	0.175	1.7	1800	1000	0.25	0.9
Total	0.395			U =	0.146	W/m²K
[1b] External façade wall btwn windows - *from outdoor to indoor // Rse = 0.04 m²K/W , Rsi = 0.13 m²K/W*						

Roughcast	0.01	1.5	1500	1000	0.21	0.9
Insulation PSE	0.06	0.032	35	1450		
Silicablocks	0.175	1.7	1800	1000	0.25	0.9
Total	0.245			U =	0.46	W/m²K
[2] Party wall between bedroom 1 and adjacent apartment *// Rsi = 0.13 m²K/W*						
Plaster blocks	0.1	0.3	900	1000	0.25	0.9
Air	0.03	0.176	1800	1000		
Silicablocks	0.214	1.7	1800	1000		
XPS	0.1	0.0357	35	1450	0.55	0.9
Total	0.444			U =	0.27	W/m²K
[3] Party wall between bedroom 2 and living room *// Rsi = 0.13 m²K/W*						
Plaster	0.003	0.52	1200	1000	0.25	0.9
Silica blocks	0.214	1.7	1800	1000		
Plaster	0.003	0.52	1200	1000	0.25	0.9
Total	0.22			U =	2.52	W/m²K
[4a] Party wall between bedroom 1 and corridor *// Rsi = 0.13 m²K/W*						
XPS	0.1	0.029	1200	1000	0.55	0.9
Plaster blocks	0.1	0.3	900	1000	0.25	0.9
Total	0.2			U =	0.25	W/m²K
[4b] Party wall between bedroom 1 and staircase *// Rsi = 0.13 m²K/W*						
Silicablocks	0.175	1.7	1800	1000	0.25	0.9
Air	0.055	0.324	1800	1000		
Total	0.43			U =	0.23	W/m²K
[5] Party wall between bedroom 2 and corridor *// Rsi = 0.13 m²K/W*						
Plaster blocks	0.1	0.3	900	1000	0.25	0.9
Total	0.1			U =	1.69	W/m²K
[6] Party wall between bedrooms *// Rsi = 0.13 m²K/W*						
Silicablocks	0.175	1.7	1800	1000	0.25	0.9
Air	0.055	0.324	1800	1000		
Plaster blocks	0.1	0.3	900	1000		
XPS	0.1	0.029	1200	1000	0.55	0.9
Total	0.20			U =	0.25	W/m²K
[4b] Int. door between bedroom 1 & corridor						
Wood	0.05	0.14	1200	1000	0.25	0.9
Total	0.05			U =	2.80	W/m²K
[5] Int. door between bedroom 2 & corridor						
Wood	0.05	0.14	1200	1000	0.25	0.9
Total	0.05			U =	2.80	W/m²K

Floors and ceilings

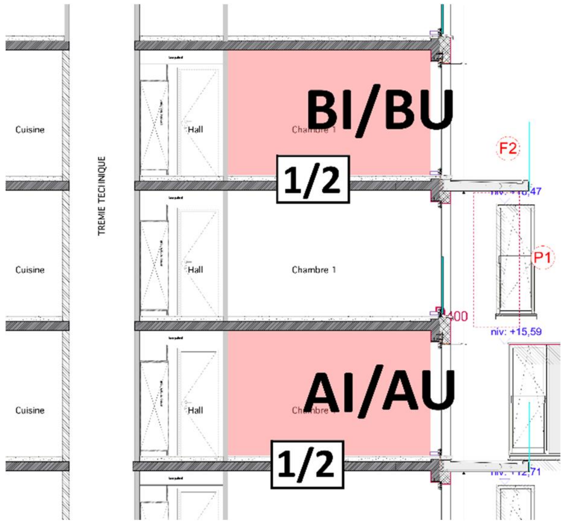


Figure 18: Section in units AI/AU and BI/BU with wall numbering

Table 3 : Floors construction thermo-physical properties (green color: Manufacturer's data or as built documents, blue color: assumptions)

	Thickness	Thermal conduct.	Density	Spec Ht	SW Absorbtion	LW Emission
Layer	m	W/mK	kg/m3	J/kgK	-	-
[1] Uninsulated floor – top down						
Wooden floor	0.005	0.102	1700	1600	0.44	0.9
Screed	0.13	1.3	1200	880		
Reinforced Concrete	0.175	1.7	2500	880	0.25	0.9
Total	0.31			U =	1.92	W/m²K
[2] Insulated floor – top down						
XPS	0.1	0.036	35	1450	0.55	0.9
Wooden floor	0.005	0.102	1700	1600		
Screed	0.13	1.3	1200	880		
Reinforced Concrete	0.175	1.7	2500	880	0.25	0.9
Total	0.41			U =	0.30	W/m²K

3.5. Glazing thermal and optical properties

The double glazing is composed by an external coated glazing of 6mm and an internal glazing of 4mm, separated by 15mm of gas (Argon), with low emissivity layer.

The main thermal properties are specified in the Table 4.

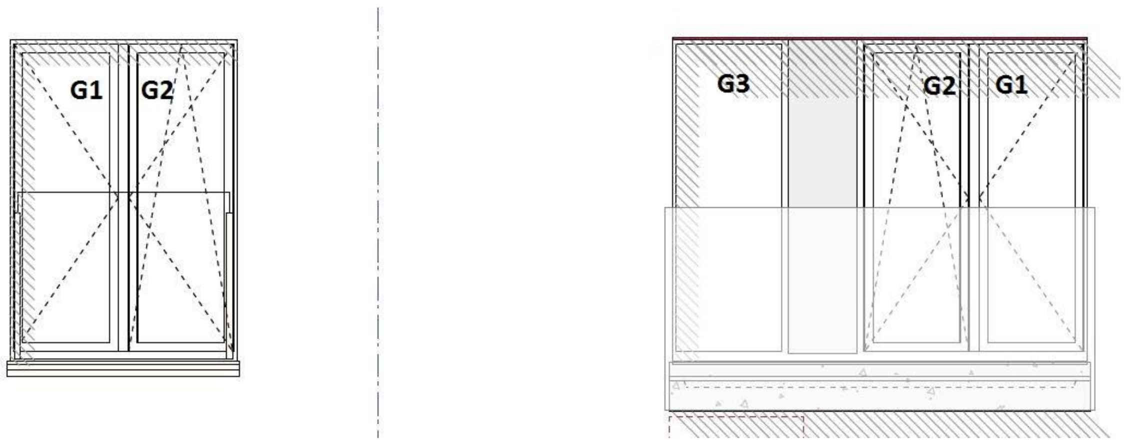


Figure 19 : Façade windows description

Table 4 : Windows main thermal properties

Glazing ID	UG	UF	Ψ glass edge	Uw	SF	LT
	W/(m²K)	W/(m²K)	W/mK	W/(m²K)	%	%
G1	1.00	2.30	0.05	1.55	40	72
G2	1.00	2.30	0.05	1.55	40	72
G3	1.00	2.35	0.05	1.30	40	72

Table 5 gathers other properties of the glazing:

Table 5 : Other window properties

Propertie	Value	
Light reflexion	12	%
Light absorption	16	%
Solar energy direct transmission	36	%
Solar energy direct reflexion	35	%
Solar energy direct absorption	29	%
Shading coefficient	46	%

3.6. Shade screen

During the experiment, a crane was present in front of the windows. It has an influence on the solar heat gains. The placement of pyranometers in front of the window, inside the unit BI and on the balcony of the unit BI, allows to assess the heat gains despite of these shade screen.

Figure 20 : View of the external crane from unit BU

Figure 21 : View from the unit BI

3.7. Thermal bridges

The thermal bridges Ψ values were assessed via the THERM software. The thermal loss calculation is performed on the basis of internal wall dimensions. The thermal bridge's location is illustrated in Figure 22 and its dimension and the heat loss are specified in Table 6.

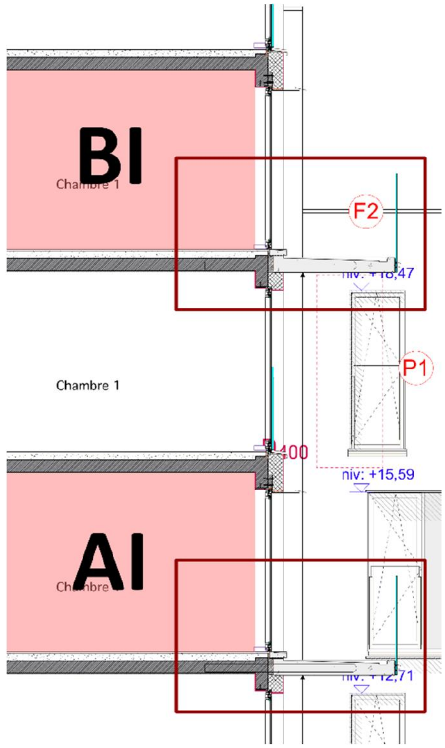


Figure 22 : Section drawing of the main thermal bridges

Table 6 : Thermal bridges dimensions and heat losses

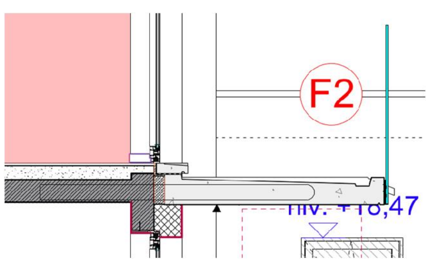
	Dimension	Ψ	TB heat loss
[A] Losses by the balcony edge in units AI and BI			
AI/BI 	2.95 m	0.35 W/Km	1.02 W/K

Table 7 : Total of thermal bridge losses for each unit

AI	AU	BI	BU
1.02 W/K	0.00 W/K	1.02 W/K	0.00 W/K

3.8. Ventilation

Mechanical ventilation was shut off during the whole measurement period. The ventilation inlets/outlets were sealed with tape to limit heat exchanges due to infiltration.

3.9. Heating

Co-heating was performed with an electric radiator, with the configuration shown in Figure 23. The power of the radiator is directly controlled by the indoor temperature measured by the temperature sensor located at the center of the room.

Figure 23 : Electric radiator in the insulated unit (AI)

The goal of the experiment is to perform side by side experiments with a time duration of 9 days. The units AI and AU were heated while units BI and BU were in floating temperature mode. The heating set point was 34°C.

3.10. Air leakages

Pressurisation tests (blowerdoor) were not carried out on construction site. Default air leakages values for each unit have been considered, based on an assumption of 12 acr/h .They are gathered in the following table:

Table 8 : Air leakage results

Blowerdoor test 50 Pa	AI	AU	BI	BU
V50 [m³/h]	234.5	222.7	234.5	222.7

3.11. Weather

The weather data during the experiment were collected on site with a weather station located on roof. This station collected the data of wind speed and direction (at approximatively 10 m above the ground), atmospheric pressure, air temperature, relative humidity, rain fall and intensity and global solar radiation on a horizontal plane. The data were recorded as average values every 10 minutes. One supplementary station was placed on the roof, just next to the first weather station, collecting global solar radiation on a vertical plane at the same frequency. One other pyranometer was placed in the BI unit, just behind the windows and one other on the balcony of unit BI, on a vertical plane to collect global solar radiation.

Figure 24 : Weather station on the roof (picture taken from another experiment but the configuration was the same)

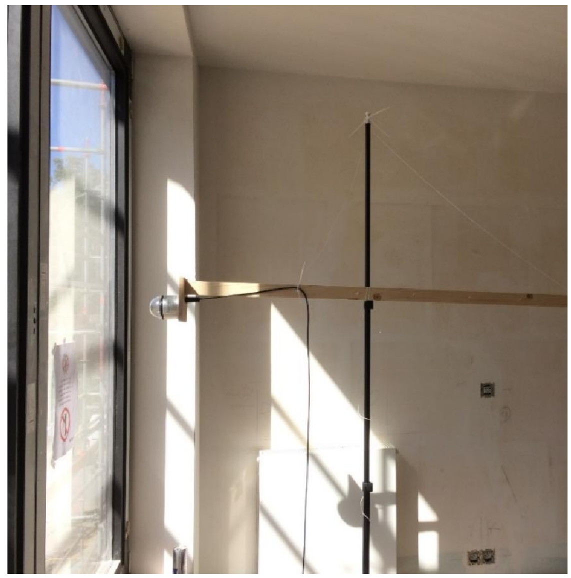


Figure 25 : Pyranometer in front of the window (picture taken from another experiment but the configuration was the same)

3.12. Ground reflectivity

The ground reflectivity wasn't measured. The crane and the balcony interfere surely with those data. In front of the building is another building and the reflectivity of the façade could also have an impact.

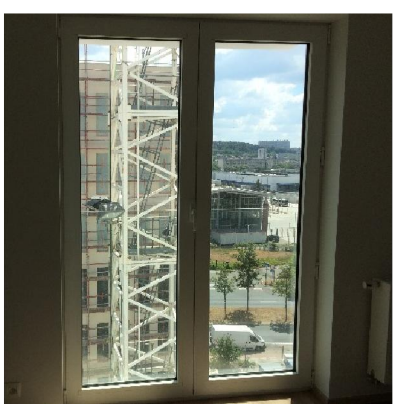


Figure 26 : View of the external crane from unit BU

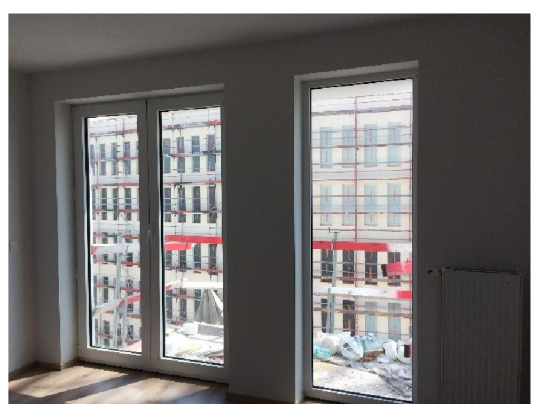


Figure 27 : View from the unit BI

3.13. Predicted HLC

The calculation of a theoretical heat loss coefficient is summarized in the following table. It takes into account:

- External wall heat loss coefficient: depending on the U-value of the external wall and windows
- Thermal bridges heat loss coefficient: the values were described in chapter 3.7
- Infiltration heat loss coefficient: assumption 12 acr/h.

Table 9 : Predicted HLC

Wall loss	AI Dimension	AI U	AI TB loss [W/K]	AU Dimension	AU U	AU TB loss [W/K]	BI Dimension	BI U	BI TB loss [W/K]	BU Dimension	BU U	BU TB loss [W/K]
External wall [1a]	6.80 m^2	0.15 W/Km^2	0.99	8.85 m^2	0.15 W/Km^2	1.29	6.80 m^2	0.15 W/Km^2	0.99	8.85 m^2	0.15 W/Km^2	1.29
Ext. wall btw windows	0.95 m^2	0.46 W/Km^2	0.44	0.00 m^2	0.46 W/Km^2	0.00	0.95 m^2	0.46 W/Km^2	0.44	0.00 m^2	0.46 W/Km^2	0.00
Window	5.28 m^2	1.47 W/Km^2		3.52 m^2	1.55 W/Km^2		5.28 m^2	1.47 W/Km^2		3.52 m^2	1.55 W/Km^2	
Window - glazing	4.02 m^2	1.00 W/Km^2	4.02	2.44 m^2	1.00 W/Km^2	2.44	4.02 m^2	1.00 W/Km^2	4.02	2.44 m^2	1.00 W/Km^2	2.44
Window - frame 1	1.26 m^2	2.31 W/Km^2	2.91	1.08 m^2	2.30 W/Km^2	2.48	1.26 m^2	2.31 W/Km^2	2.91	1.08 m^2	2.30 W/Km^2	2.48
Window - glazing edge	16.32 m	0.05 W/Km	0.82	10.56 m	0.05 W/Km	0.53	16.32 m	0.05 W/Km	0.82	10.56 m	0.05 W/Km	0.53
Total wall loss		[W/K]	9.18		[W/K]	6.75		[W/K]	9.18		[W/K]	6.75

Thermal Bridge loss	AI Dimension	AI Ψ	AI TB loss [W/K]	AU Dimension	AU Ψ	AU TB loss [W/K]	BI Dimension	BI Ψ	BI TB loss [W/K]	BU Dimension	BU Ψ	BU TB loss [W/K]
[A] Balcony edge	2.95 m	0.35 W/Km	1.02	-	-	-	2.95 m	0.35 W/Km	1.02	-	-	-
Total thermal bridges		[W/K]	1.02		[W/K]	0.00		[W/K]	1.02		[W/K]	0.00

Infiltration loss	AI V50 value [m^3/h]	AI ACH conversion [m^3/h]	AI TB loss [W/K]	AU V50 value [m^3/h]	AU ACH conversion [m^3/h]	AU TB loss [W/K]	BI V50 value [m^3/h]	BI ACH conversion [m^3/h]	BI TB loss [W/K]	BU V50 value [m^3/h]	BU ACH conversion [m^3/h]	BU TB loss [W/K]
	234.50	11.73	3.91	222.70	11.14	3.71	234.50	11.73	3.91	222.70	11.14	3.71
Total infiltration loss		[W/K]	3.91		[W/K]	3.71		[W/K]	3.91		[W/K]	3.71

	AI		AU		BI		BU	
Total heat loss	**[W/K]**	**14.10**	**[W/K]**	**10.46**	**[W/K]**	**14.10**	**[W/K]**	**10.46**

4. EXPERIMENTAL SCHEDULE

The experiment was undertaken in parallel in 4 similar units so that all units were submitted to the same weather conditions. The experiment lasted from the 2018/07/13 to 2018/07/25. There are some holes in the data recording. The data had to be interpolated for this reason.

The units AI and AU were heated (set point 34°C) while units BI and BU were in floating temperature.

5. INSTRUMENTATION

5.1. Internal sensors

Sensors are named with 5 letters, to identify in which apartment they are located and where precisely. The following table summarizes the meaning of letters composing the name of the sensors.

Logger zone	Unit	Sensor type	Sensor location - 1	Sensor location - 2
A *Apart. B.1.4.1* B *Apart. B.1.6.1*	I *Insulated* U *Uninsulated*	T *Temperature* R *Radiation*	B *Back* F *Front* M *Middle* I *Interface* S *Sanitary*	E *East* W *West* N *North* C *Ceiling* G *Ground* M *Medium* H *High*

Notes:

Sensor location 1:

- (B, F, M): according to the depth from the façade (B: back of the room, F: next to the façade, M: middle of the room)
- (I) : interface between wall and insulation
- (S) : neighbor Northern zone

Sensor location 2:

- (M,H): If air temperature sensor: at medium height (M) or near the ceiling (H)
- (E,W,N,C,G): If interface temperature sensor: at the East (E), West (W) or North (N) wall surface or at the ceiling (C) or floor (G) surface

Description of different sensors:

- 9 Temperature sensors per unit: 5 sensors located on the ceiling, floor and party walls either on the wall surfaces in uninsulated units, or at the interface between walls and insulation

- panels in insulated units, 2 air temperature sensors in the tested unit (in the center of the room, one high and the other at 1m20), 1 temperature sensor in the adjacent Northern zone in the same apartment.
- 1 pyranometer in the unit BI, named BIRFM. It was located in front of the windows as shown in Figure 28. It allows to collect the total amount of solar irradiance entering the units.
- 1 pyranometer on the balcony of unit BI, named I_V_S_balcon, recording global radiation data on a vertical plane.
- Co-heating consumptions were monitored in kWh. NOTE: The recorded powers are computed from the differences of the recorded consumptions. As data were recorded with a 10 minutes interval, recorded power must be multiplied by 6 to be expressed in Watt.

Figure 28 : Pyranometer in unit BI

5.2. Weather sensors

A weather station located on the roof collected:

- Solar radiation data: global on a horizontal plane W/m2 ;
- Wind: speed in m/s / orientation and maximal speed in degree from North ;
- Temperature in °C ;
- Relative humidity in % ;
- Atmospheric pressure in Pa;

A vertical pyranometer was let on the roof, near the weather station and south-east oriented, measuring the total solar radiation on a vertical plane in W/m²

6. PROVIDED MEASURED DATA

All the data are provided in three Excel files, with a10 minutes time step:

- L_3.3.3.9_Table_A_180713_180725.xlsx : for data in unit A (apartment B.1.4.1)
- L_3.3.3.9_Table_B_180713_180725.xlsx : for data in unit B (apartment B.1.6.1)
- L_3.3.3.9_Table_W_180713_180725.xlsx : for weather data

ANNEXES

INTERNAL DIMENSIONS

B.1.4.1 and B.1.6.1		Room			
		AI	BI	AU	BU
Floor area	m²	12.61	12.61	10.50	10.50
Interior ceiling height	m	2.57	2.57	2.57	2.57
Volume	m³	32.41	32.41	26.99	26.99

Walls

		AI	BI	AU	BU
[1a] External wall_S	m²	6.80	6.80	8.85	8.85
[1b] External wall_S between windows	m²	0.95	0.95		
[1] Windows	m²	5.28	5.28	3.52	3.52
Glass	m²	4.02	4.02	2.44	2.44
Frame	m²	1.26	1.26	1.08	1.08
Glass percentage	%	76.14	76.14	69.32	69.32
Glass edge	m	16.32	16.32	10.56	10.56
[2] Party wall btwn bedroom 1 and adjacent apartment	m²	6.94	6.94		
[3] Party wall between bedroom 2 and living room	m²			5.10	5.10
[4a] Party wall between bedrooms	m²	4.14	4.14	4.14	4.14
[4b] Party wall between bedroom 1 and corridor		0.83	0.83		
[4b] Int. door between bedroom 1 & corridor		1.74	1.74		
[5] Party wall between bedroom 2 and corridor	m²			10.59	10.59
[5] Int. door between bedroom 2 & corridor	m²			1.74	1.74
[6] Party wall between bedroom 1 and corridor	m²	10.02	10.02		

Floors and ceilings

		AI	BI	AU	BU
[1] Uninsulated floor - top down	m²			10.52	10.52
[2] Insulated floor - top down	m²	14.36	14.36		

LIST OF FIGURES

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