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Thermal Performance of Double Skin Envelope in Full Scale Testing Module in Mexico City

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ABSTRACT

The study aims to understand the thermal performance of a double skin envelope system in a test cell by configuring a module that has thermal stability with little indoor temperature variations. A rooftop observation deck and laboratory was installed at the "J" Building of the Postgraduate Unit, National Autonomous University of Mexico campus, UNAM (19°18'33.59" N, 99°11'5.73" W). This platform was designed to test materials and construction systems under the Mexico City microclimate, which consists of two full-scale testing modules. Each cubic module measures 3m x 3m x 3m. All of its facades have several layers of insulation. Indoor and outdoor parameters such as thermal, lighting, acoustic and air quality were measured during the experiment. The study aimed to achieve indoor thermal stability, benchmarked to be close to zero during the 24-hour thermal gradient. Findings showed that during warmer months, between May 19 and June 21, 2016, the envelope played an important role in decreasing the indoor air temperature by 7°C. The diurnal thermal gradient was 3.87°C.

Keywords: Double skin envelope, Full Scale Testing Module, thermal performance, thermal stability

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INTRODUCTION

Mexico City has subtropical highland climate with mild winter and warm summer as well as seasonal variations in temperature. Despite this, efforts to reduce energy consumption and lower the indoor temperature are ongoing. Studies have shown that a good envelope material is an important to reduce heat gain and heat loss in a building (Garay, Uriarte & Apraiz., 2014; Kopp, Morrison, & Henderson, 2012; Nassif, Yoshitake, & Allam, 2014). Most studies on double skin envelope in the tropics and subtropical areas did not use testing modules. (Asdrubali, D'Alessandro, & Baldinelli, 2014)

A review of post graduate dissertations in UNAM between 1973 and 2015 revealed that majority of them (181 theses) have focused on Environmental and Energy issues, Material Development and ICT (2015-2, 2015). Most of these studies required evidence and verification of their arguments through experiments conducted in an experimental space (testing module) according to the specific needs of their projects. This situation where researchers have to design and build their own experimental space makes it difficult for them to continue their study. Thus, a Full Scale Testing Module is needed, which would meet the needs of thermal, lighting, acoustic and indoor air quality studies.

A full-scale testing module is capable of testing construction materials and building systems under normal conditions of use. There are several examples worldwide, such as the DOE's Flexlab in Berkeley, USA (Flexlab, 2016), and KUBIK a building by Tecnalia at the Technology Park of Bizkaia, Spain (Tecnalia, 2016).

In this study, the aim of the experiment was to reach indoor thermal stability through envelope material, and the testing module was to probe new materials and building systems in a full-scale space under normal conditions.

Aim

The study aims to measure the physical parameters inside the testing module, and establishes the baseline of the thermal performance of each of the full-scale testing modules. The experiment shows how heat wave passes through the envelope, how it affects the indoor conditions of the test modules and how the heat dissipates during the day. The experiment attempts to achieve thermal stability inside the Testing Modules; the maximum differential tit hopes to achieve is 1° Celsius diurnally. The objective is to configure a module that has little variations of temperature inside.

METHODS

A rooftop observation deck and experimentation laboratory is installed at the "J" Building of the Postgraduate Unit, National Autonomous University of Mexico campus (19°18'33.59" N,

Figure 1. Testing modules' location (Source: Google Earth, date: March 4, 2016)

99°11'5.73" W) as shown in Figure 2. This platform was designed to test materials and construction systems under the Mexico City microclimate, which consists of two full-scale testing modules. Each cubic module measures 3m x 3m x 3m (Figure 2). All of its facades have several layers of insulation.

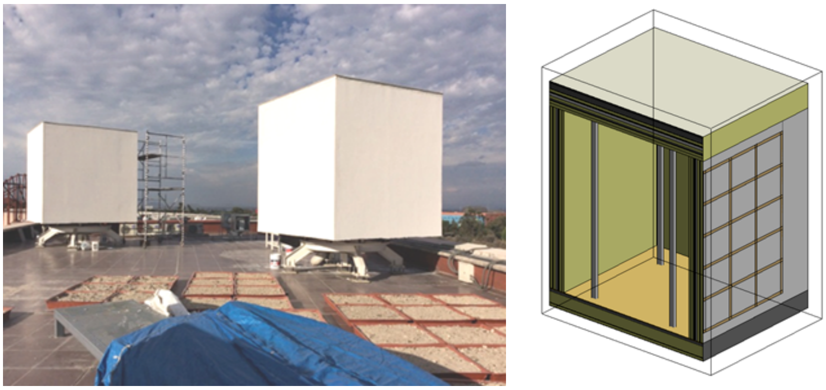

Figure 2. Full scale testing modules

In order to reach temperature stability inside the test module, outdoor meteorological data was compared with those from inside the Full Scale Testing Module. This study evaluated the performance of the double skin envelope.

Each module could rotate 360° and so the "Experimental Façade" can be positioned at different orientations to understand the behaviour of certain facades throughout the year.

These tests were conducted on the "Experimental façade", composed of 15 slots, which can be interchanged with various wall materials in order to analyse their performance. Table 1 shows the different layers of insulation applied in the experiment, where the different "U" values for every façade are tabled.

Instruments that measure meteorological variables on the outside are installed, which are used as a reference for comparison with measurements obtained inside. Table 2 shows a list of equipment installed for this research, according to exterior and interior equipment.

The measurements of the variables were recorded every minute such as where the outdoor air temperature, relative humidity, barometric pressure, wind, rainfall and Global Radiation. . Inside the modules, the air temperature, Relative Humidity, Mean Radiant Temperature and surface temperature of internal panels of the envelope were measured.

Table 1
"U" values of the envelope components for the system

Description		Thickness	Mean Density	"K" value	Thermal Resistance	"U" Value
		(m)	(Kg/m3)	(W/m2 °K)	R = thickness / k	U = 1 /? R
Vertical Double Skin Envelope Area (m^2)	10.24	0.3044	662.85	0.19	8.256	0.11916
Experimental Façade Area (m^2)	5.56	0.30	661.34	0.25	9.317	0.10578
Bottom Area (m^2)	9.00	0.22	444.70	0.13	6.037	0.16328
Cover Area (m^2)	10.24	.036	568.12	0.17	10.629	0.09331

Table 2
Installed equipment

	Equipment	Trademark	Model	Parameter	Unit
	Pyranometer	Kipp & Zonnen	CMP-21	Global Radiation	W/m^2
	Photometer	Licor	210-LS	Global Illuminance	Klux
Outside	Weather Station	Vaisala	WXT 520	Air Temperature	°C
				Relative Humidity	%
				Atmospheric Pressure	mbar
	Weather Station	HOBO	U-30	Air Temperature	°C
				Relative Humidity	%
				Atmospheric Pressure	mbar
				Global Radiation	W/m^2
	Data Acquisition System	Campbell Scientific	CR-1000	-	-
	Multisensor	HOBO	U-12	Air Temperature	°C
				Relative Humidity	%
	Temperature Probe	Campbell Scientific	107	Air Temperature	°C
Inside	Surface Mount Thermistor	Campbell Scientific	110 PV	Surface Temperature	°C
	Type "E" Thermistor. Inside Globe Thermometer.	Campbell Scientific	Type E	Mean Radiant Temperature	°C
	Data Acquisition System	Campbell Scientific	CR-1000	-	-

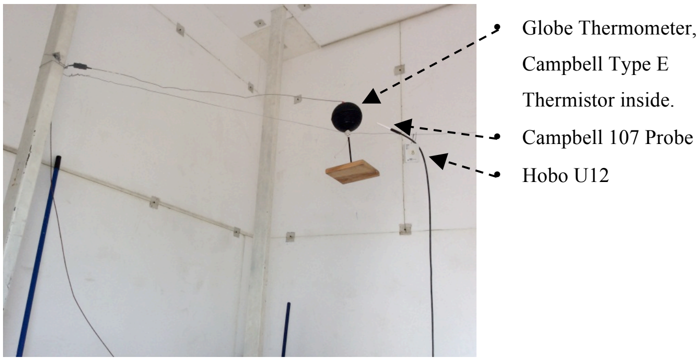

Figure 3. Equipment inside the Testing Module

Figure 3 shows the equipment (Globe Thermometer, Hobo U12, and Campbell 107 Probe) installed inside the testing module. It also shows the inner layer of insulation, where the surfaces are covered by insulation panels to avoid heat gain or losses from infiltration. All the panel joints are filled, in order to prevent heat gain or losses.

RESULTS AND DISCUSSION

The results of field measurements between 20 May and 20 June 2016 are shown in Figure 4. The measurements were conducted during the end of spring, when the outdoor conditions were warming up. Data was recorded every 5 minutes. When the mean average temperatures are plotted every

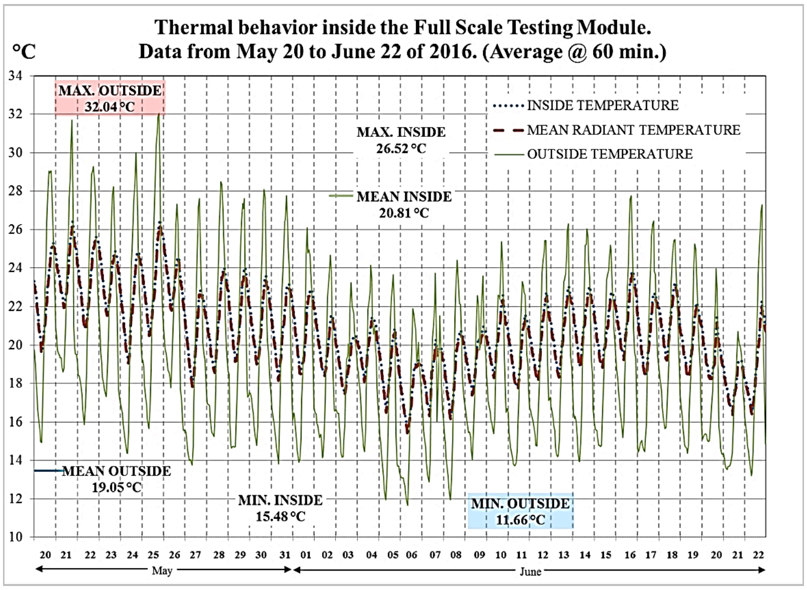

Figure 4. Thermal performance outside and inside the Testing Module

60 minutes, the graphics representing this data are virtually identical. Figure 4 shows the mean data, the broadest temperature ranges are the outdoor air temperatures, and the central ranges show the performance of the air temperature inside the module (temperature probe and mean radiant temperature). The maximum outdoor air temperature was 32.04°C and the average for the period was 19. 05°C.In this graph, the lower recorded internal air temperature was evidently due to insulation material installed on the envelope which slowed the heat gain from outside. Furthermore, it is important to mention that the thermal gradient is reached within the range between 3.87°C and 6.01°C during the warmest day.

Figure 5 shows the thermal performance during the warmest day of the field study on May 25, 2016. The maximum outdoor temperature was 32.73°C, and the average was 22.66°C. Inside the module, the maximum air temperature was 26.55°C, the average was 23.48°C. The indoor temperature gradient during the day was 6.01°C. A small difference between the temperature measured by the probe and that recorded with the globe thermometer was noted. The difference in temperature on average recorded between these two instruments was 0.21°C on average. It was noted that the time lag or the duration between the peaks (for outdoor air temperature to reach a peak indoor air temperature) was about 130 minutes.

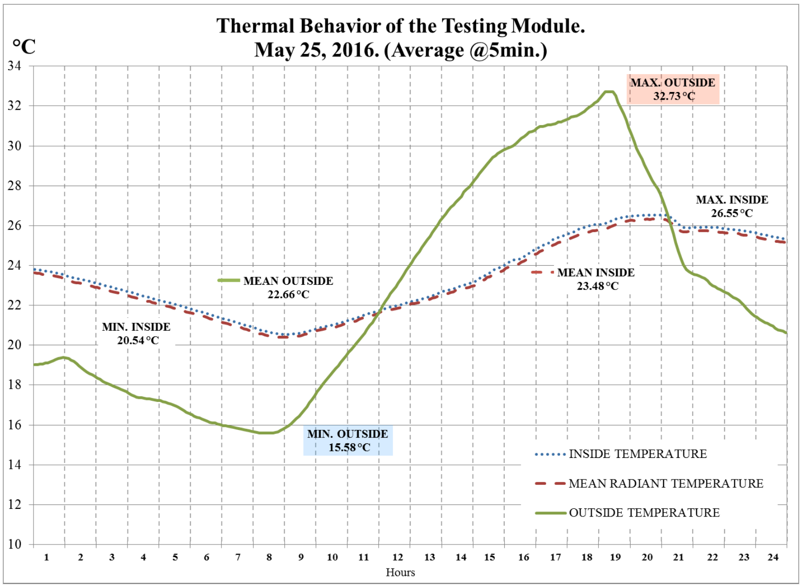

Figure 5. Thermal performance outside and inside the Testing Module, May 25, 2016

Figure 6 shows the thermal performance during a slightly cooler day on June 6th, 2016. The maximum outside temperature was 22.11°C, and the average was 16.71°C. Inside the module, the maximum air temperature reached was 19.25°C, and the average was 17.66°C. Thermal gradient was 3.87°C, which was very close to the target of this research. The time lag was approximately 450 minutes (7.5 hours)

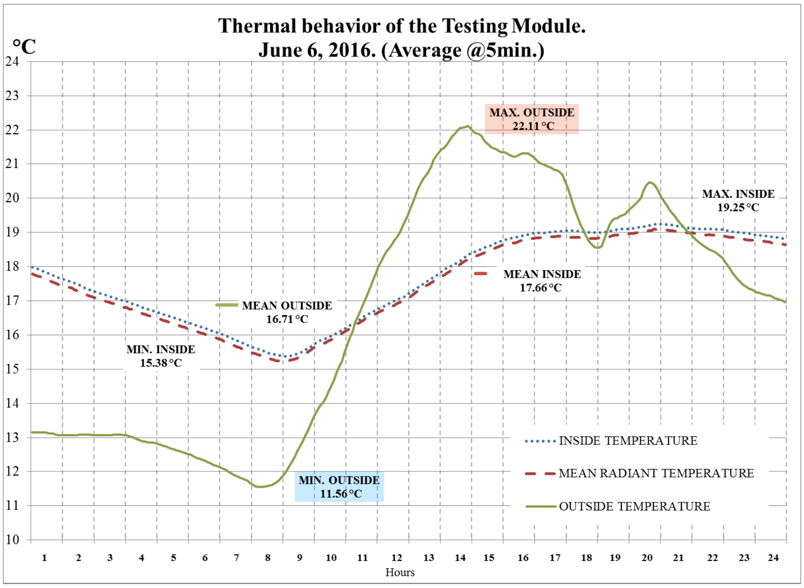

Figure 6. Thermal behaviour outside and inside the Testing Module, June 6, 2016

CONCLUSION

The experiment has shown that air temperature inside the module decreased substantially compared with the outdoor temperature due to the thermal resistance of the double skin material of the module envelope. The lowest differential was reached when the outside temperature did not exceed 22°C. Records obtained from the Globe thermometer and temperature probe were very similar whereby the differential between the two were less than 0.5°C. Building envelope conditions resulted in lower thermal gradient of less than 5°C during the day.

May and June are the warmest months in Mexico, and hence, these findings are important to reduce indoor heat during this period.

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