Analysis of the Thermal Behavior of Architectural Covers with Semi - Insulation and an Overlaid Green Layer System In Temperate Climates.

Juan Manuel Rodriguez[1] and Juan-Carlos Baltazar[2]

[1] Department of Architecture, University of Guanajuato, Guanajuato, Gto. Mexico.

[2] Department of Architecture, Texas A&M University, College Station, TX, United States of America

Abstract

This study evaluates experimentally the thermal behavior of architectural elements of insulate roofs, including semi-insulation material with overlaid green elements on vertical and horizontal planes, also known as green roofs, for temperate climates. The results of the study showed that the flux of heat transfer on the roof was reduced and provide a better controlled temperature in the interiors all the yearlong. Difference between the outside and inside temperature up to 4 Celsius degrees were observed frequently specially in the early and late hours of the days, which generate a steady comfort.

Keywords: *Building integrated green roof, Climatic Year Type, Thermal performance*

1. Introduction

Hot and humid climates demand significant electricity for cooling. In 2001, Texas implemented the Texas Emissions Reduction Plan (TERP) program that aims to diminish the pollution in the state by energy efficiency

The use of green architectural elements started to have presence in some types of buildings in Mexico, specifically the residential architecture is beginning to see some examples in general without a definite specific purpose, such as a fashion phenomenon in its alleged desire of being "sustainable", though these elements do not consider relevant aspects regarding the structural behavior of the decks, and less its thermal effects or behavior.

This study present a preliminary analysis of the recorded results from an example of this type of solution built it in order to identify the possible advantages and disadvantages that can be identified specifically in the overall thermal behavior in external conditions and interiors.

The Mexican housing type has been subordinated to the economic system, and consequently to prevailing economic conditions. In general, since beginning of the twenty century, it has widely avoid using insulating material and misuses the climate advantage of the region, being more marked in the country central region. This phenomenon primarily identified by change of more economic construction systems, but with fewer advantages in climate use. In earlier times, the constructive system comprised materials such as stone and adobe and more complete solutions based on those systems, which unfortunately with the pass of the time were disappearing. Because of the area climatic conditions, this phenomenon did not represent major problem, the differences between external and internal temperature have minimal variations as it will be shown in this study.

2. Methods

There are several concepts for defining the green roofs covers on buildings. Two categories are very well recognized, the ones called extensive, comprising covers where the plant substrate is not exceeding 0.1 m, also called by some "ecological cover", characterized by small plants and some grasses, and the intensive ones with distinguished thicknesses greater than 0.2 m., where it is possible to plant some type of trees. There is some ones in an intermediate case they have been called semi-intensive, employing features of both. The latter classification is the case analyzed in this study.

Another concept used to define this field of study is "Urban Naturalization", which includes the concept of "green roofs" employed by several research groups including the compilation by Spanish Society for the Promotion of Urban and Rural Naturalization (PRONATUR).

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The base of this study is the work done by Minke on reference to "Green roofs" research in Germany, a country to which he is regarded as one of the fastest developing and implementing these elements. Since 1974, Minke; has conducted research and development in the field of green buildings, affordable housing and especially in the field of earth constructions His works are not only in Europe but also in South America, Central America and India. Minke stated that in areas with cold climates, in winter the ground is frozen and kept for long periods at 0°C, even when the outside temperature is considerably lower. With a temperature of + 20°C inside and -20°C outside and soil temperature 0°C decreases the transmission heat loss of the roof (Minke 2004: 16).

According with the Minke´s hypothesis, in a climate with more solar radiation green roofs would have major advantages (Minke 2004: 17), however global climate conditions are contrasting, since in most places with solar radiation normally does not have conditions as those in cold areas and insulating characteristics therefore are not the same. Since in cold climates where water freezing functions as insulation, in temperate zones hardly water will freeze the rooftop. Therefore these benefits will not be capitalized.

The study arises from the following stages:

a) A green roof 6.5 m long and 3.1 m wide is implemented, with a slab based partly insulated panel "W" supported with metal light beams and with a concrete compression layer 0.7m thick, which together with the panel does not exceed 0.18 m.

b) On the cover a membrane is placed as insulation of the humidity of the vegetable substrate placed over the cover with a thickness of 0.12 m; in the peripheral region of the substrate a fraction of gravel is set and between the gravel and the “tezontle” substrate, in order to filter out excess water without eroding the vegetable substrate. In a secondary zone of the cover with an area of 2.2 m long and 1.82 m wide the depth of the plant substrate has a minimum thickness of 0.12 m to a maximum rate of 0.55 m.

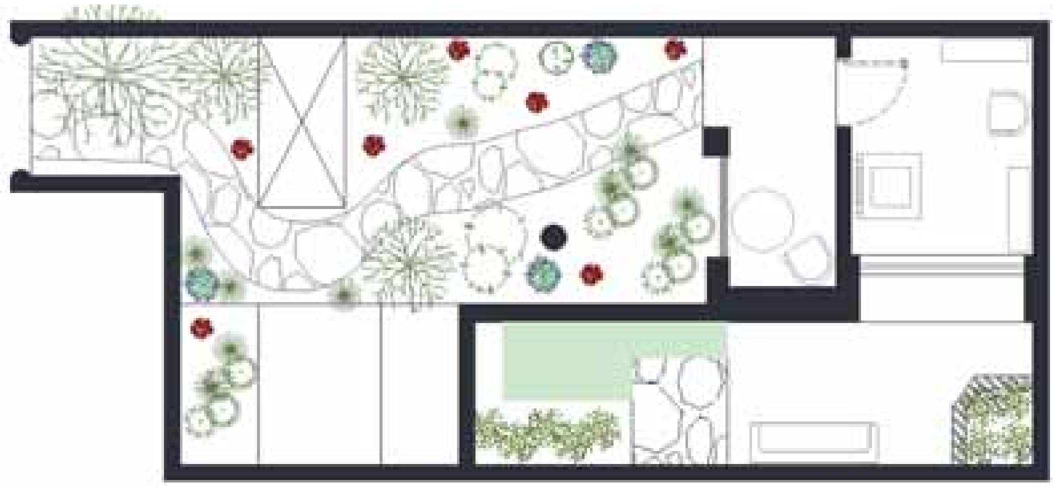
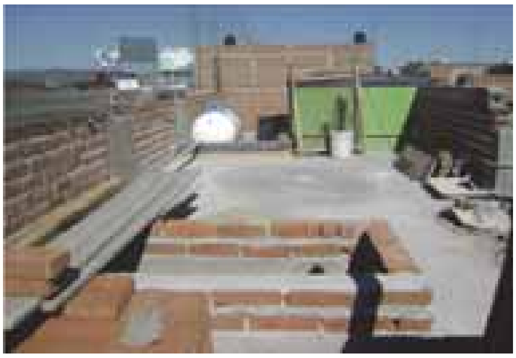


Fig 1: Plan view of the green roof.

The images below show some of the construction stages of the green roof:



Cover construction process | Cover basis completed

Implementation of vegetation cover | Integration of plant elements

Actual state of green roof

Fig. 2: Construction stages of the green roof

c) The plants used are native to the region, which has the characteristics of a semi-arid area. Specimens of mesquite (*Prosopis laevigata*), some specimens of huizache (*farnesiana Acacia, Acacia schaffneri*), a specimen of oak (*chihuahuensis Quercus*), a specimen of pine (*Pinus cembroides Zucc*.), a specimen of Garambullo (*Myrtillocactus geometrizans*), some specimens of Nopal (*Opuntia ficus-indica*), a couple sets of barrel cactus (*Echinocactus*), two specimens of rosemary (*Rosmarinus officinalis*), Evergreen (*Sedum praealtum*), Aranto (*Bryophyllum daigremontianum*) and wild grass.

d) For measuring some of the thermals performance a U30 HOBO weather station was installed where the outside and inside temperature is recorded, some case sensors are placed on the ground directly under the green roof cover, another in the upper part at 2.8 m and other at 1.65 meters high in the interior zone.

The Mexican normalization and certification organization for the construction, on reference to the decks in the

Mexican standard NMX-C-460-ONNCCE 2009 states that for Mexican thermal zones 1 and 2, the total thermal resistance of the enveloped must be at least 1.4 m^2K/W, and 2.1 m2K /W to achieve comfort and greater than 2.65 m^2K/W to save energy. Similarly, for 3A, 3B and 3C zones the values should be 1.4 m^2K/W, 2.30 m^2K/W to and 2.80 m^2K/W respectively. Regarding the indoor environment the NMX-AA-164-SCFI-2013 standard concerning sustainable building criteria and minimum requirements, it states that thermal comfort must be between reach between 18 and 25 °C.

With these benchmarks, the characteristics of the local microclimate are discussed from time records for a period longer than 50 years about 5 solar cycles, the comfort zone is determined by the model of Wakely which includes the definition of the scope comfort zone unlike other models, allowing you to adapt to different climatic zones, (Wakely,1979 in Tudela, 1982: 35-36), in this model the neutral temperature (*Tn*) it is called comfort center temperature *Tcc*, and is defined as follows: $Tcc = Tm/4 + 17.2$, where *Tm* is the annual average temperature. After the *Tcc* is determined, the temperature swing is identified from finding the range of the mean maximum and minimum extremes temperatures and from them the amplitude of the comfort zone.

The comfort zone, based on the period of the maximum and minimum temperature of 1959-2013 (for the city of Leon, Mexico), is determined to be 18.7 °C to 24.2 °C; next the Type Climatic Years are defined; for Maximum Activity (CYT-max) and for the Minimum Activity (CYT-min).

Figures 3 and 4 shows respectively the climatic years type for Maximum Activity (CYT-Max) and for Minimum Activity (CYT-Min) for the city of Leon, Mexico, for the period 1959-2013, comprising about 5 solar cycles.

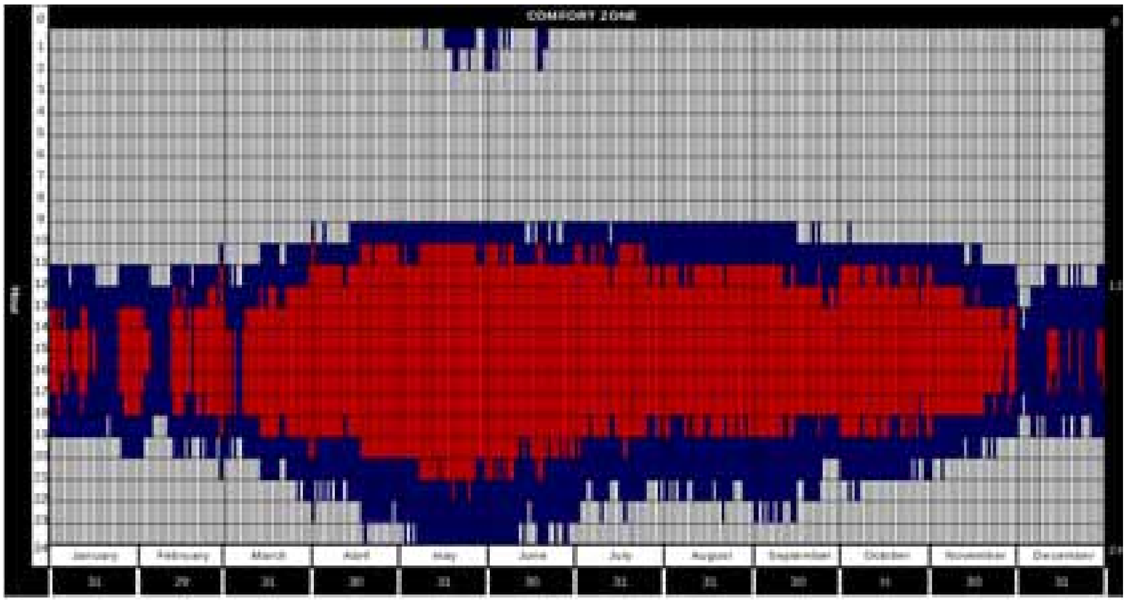


Fig. 3: Climatic Year Type for Maximum Activity (CYT-Max) for the Period 1959-2013. (Colors Represent Temperature Ranges: Greater Than 24.225 °C in Red, Between 18.725 and 24.225 °C in Blue, and Lower Than 18.725 in White)

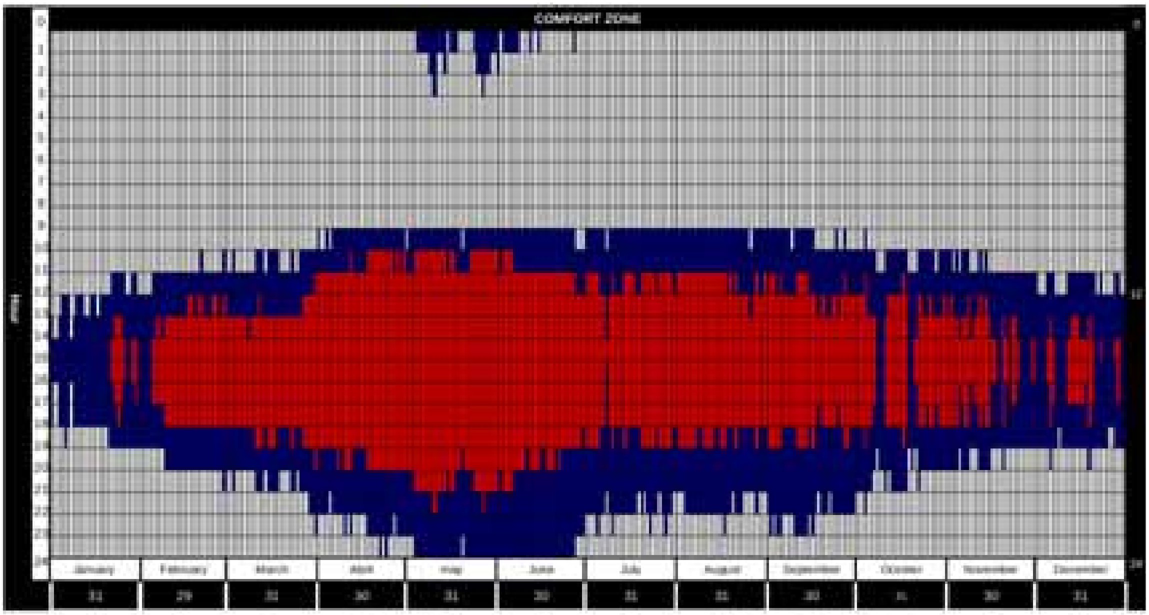


Fig. 4. Climatic Year Type for Minimum Activity (CYT-Min) for the Period 1959-2013. (Colors Represent Temperature Ranges: Greater Than 24.225 °C in Red, Between 18.725 and 24.225 °C in Blue, and Lower Than 18.725 in White)

3. Results

From the determination of the reference climate years types for major and minor solar activity considered from solar cycles of solar cycle number 19 to number 23, which covers the period of daily temperature of 1959-2013 and determining from this period CYT-MIN and CYT-MAX for the city of Leon Guanajuato. Based on these periods the behavior of the external temperature of the green roof cover is analyzed, and represented in a similar way to those of climate years as shown in the following figure.

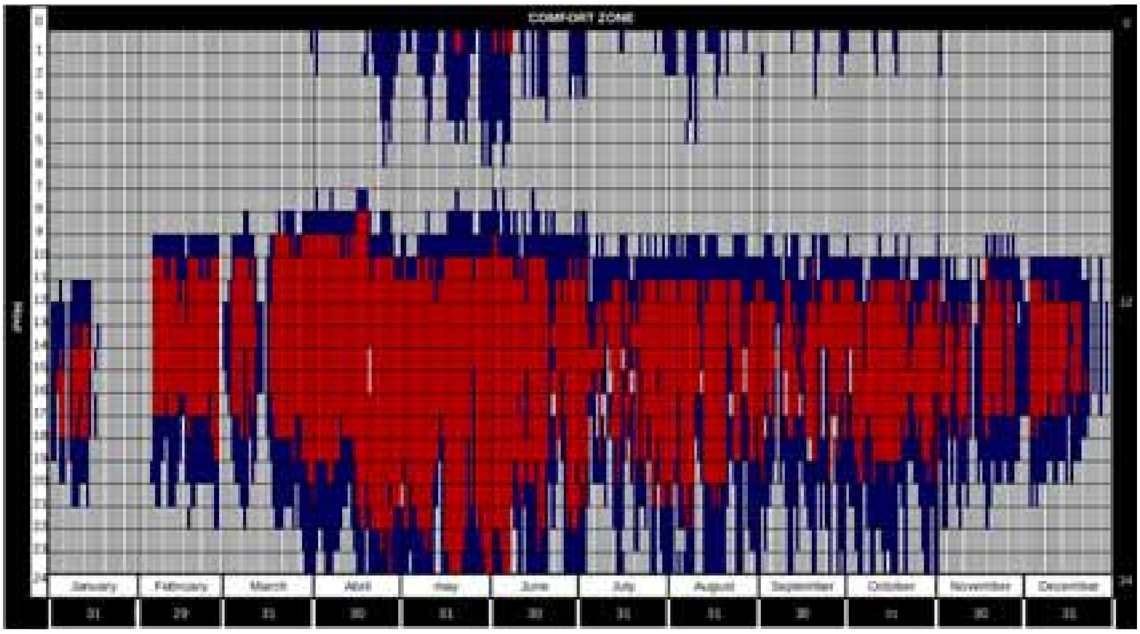


Fig. 5: Representation for the Comfort Zone with data for Outdoor Temperature over the Green Cover. (Colors Represent Temperature Ranges: Greater Than 24.225 °C in Red, Between 18.725 and 24.225 °C in Blue, and Lower Than 18.725 in White)

As for the results of the internal temperature in the two different positions of location sensors and 2.8 m and 1.65 m the results are presented in the figures below.

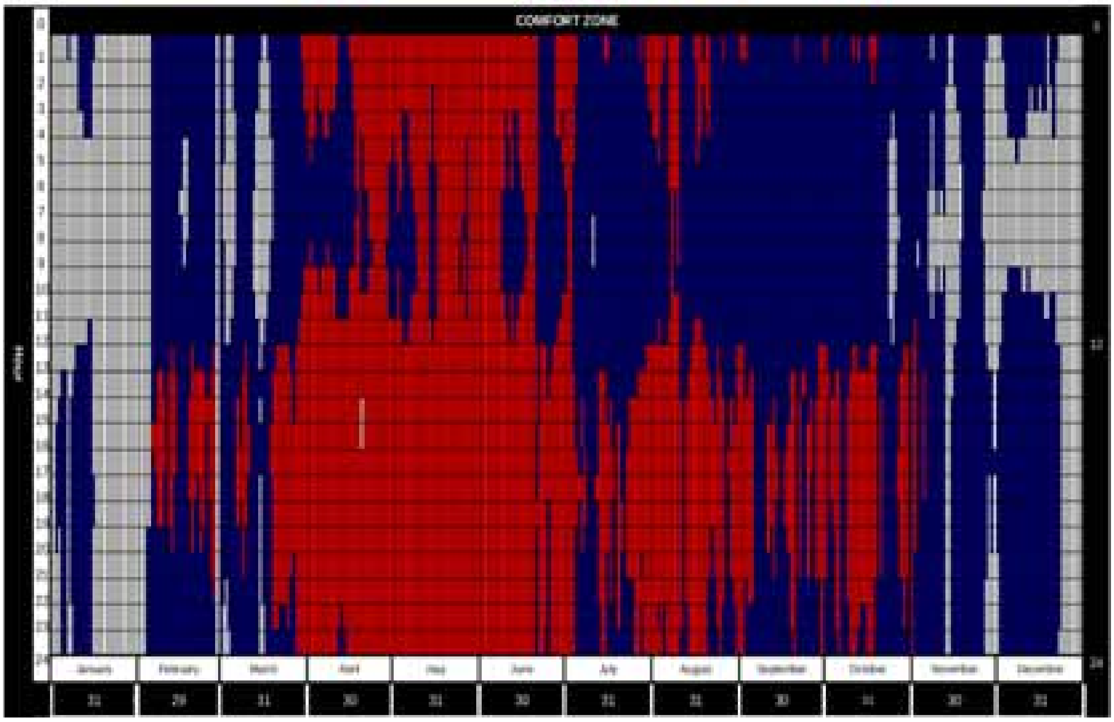


Fig. 6: Hourly Indoor Zone Temperature at 2.8 m Position. (Colors Represent Temperature Ranges: Greater Than 24.225 °C in Red, Between 18.725 and 24.225 °C in Blue, and Lower Than 18.725 in White)

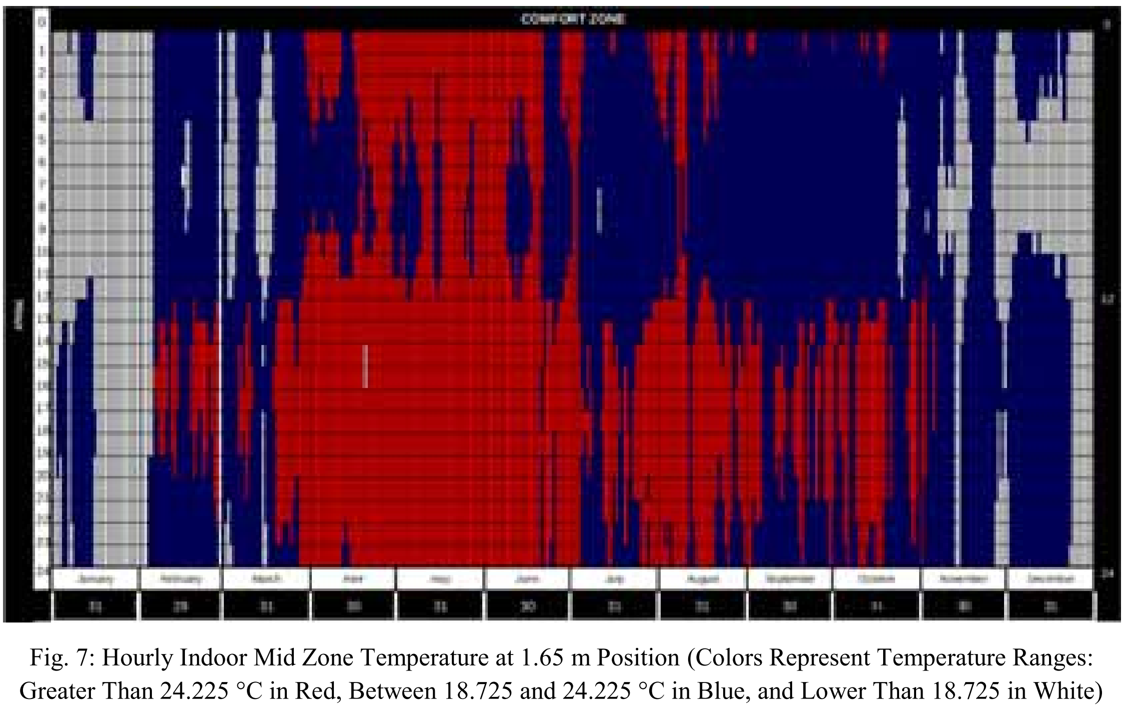


Fig. 7: Hourly Indoor Mid Zone Temperature at 1.65 m Position (Colors Represent Temperature Ranges: Greater Than 24.225 °C in Red, Between 18.725 and 24.225 °C in Blue, and Lower Than 18.725 in White)

In relation to the cover based on the Mexican standard NMX-C-460-ONNCCE-2009 and the method for estimating the thermal resistance of the envelope it was obtained a value of 2.16 m^2K/W, which is an equivalent to a global heat transfer coefficient of 0.464 W/ m^2K that when compared with those established by the standard for thermal zones the resulting value is in the range of comfort, Zones 1 and 2 are the zones defined for most of the areas comprising the center of the Mexico.

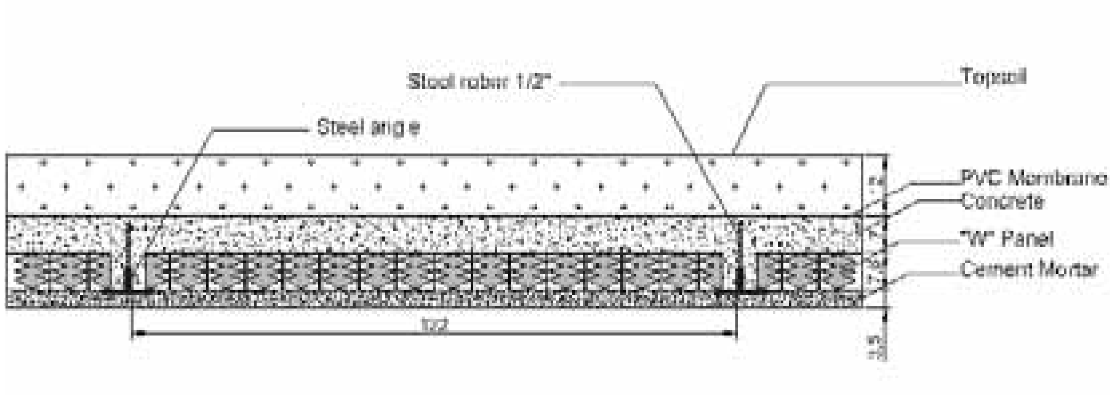


Fig. 8: Section of the deck structure

As for the overall analysis of the behavior of the temperature outside on the green cover and its correlation with the interior temperature shown in the graphs above; it can be seen that the overall difference is not significant, accounting for a difference between temperatures of approximately 2.6 °C and 2.5 °C, and presenting a difference between the exterior and interior extreme maximums within 5.2 °C and difference of 5.4 °C between high and medium internal sensors.

The analysis of historical temperature with reference to temperature measured on the green roof, it does not exceed 1.2 °C, yet if this historical temperature is analyzed with respect to the inner temperature the difference is even more significant of approximately 3.9 °C and a maximum temperature extreme of 6.8 °C.

Table 1: Daily behavior Historical Temperature for the period 1959-2013 and the outdoor temperature recorded over the green cover and indoor temperature for two different heights 2.8mts and 1.65 meters.

Higher Temperature Difference			Average Degree °C	Uncertainty relative	Standard deviation	%	Dispersion	Uncertainty random effects 90%	Uncertainty random effects 95%	Total Uncertainty 99.5%
Maximum	5.17 °C	Temperature Outdoor	20.6							
Minimum	2.7 °C	Temperature Indoor High 2.8 mts	23.3	-0.1	1.9	12.7	2.0	2.7	4.2	14.3
Maximum	5.4 °C	Temperature Outdoor	20.6							
Minimum	2.67 °C	Temperature Indoor Mid 1.65 mts	23.2	-0.1	1.9	12.6	2.0	2.7	4.2	14.2
Maximum	6.1 °C	Temperature Outdoor	20.6							
Minimum	1.13 °C	**Historical Temperature TCY-MAX**	19.4	0.1	0.8	5.4	1.3	1.8	2.8	9.4
Maximum	5.3 °C	Temperature Outdoor	20.6							
Minimum	1.17 °C	**Historical Temperature TCY-MIN**	19.4	0.1	0.8	5.7	1.3	1.8	2.8	9.4
Maximum	6.83 °C	Temperature Indoor High 2.8 mts	23.3							
Minimum	1.13 °C	**Historical Temperature TCY-MAX**	19.4	0.2	2.7	18.1	4.4	5.9	9.1	30.8
Maximum	6.4 °C	Temperature Indoor Mid 1.65mts.	23.2							
Minimum	3.8 °C	**Historical Temperature TCY-MAX**	19.4	0.2	2.7	18.0	4.3	5.8	8.9	30.3
Maximum	4.51 °C	Temperature Intdoor High 2.8 mts	23.3							
Minimum	1.7 °C	**Historical Temperature TCY-MIN**	19.4	0.2	2.7	18.3	4.4	5.9	9.1	31.0
Maximum	4.4 °C	Temperature Intdoor Mid 1.65 mts	23.2							
Minimum	1.6 °C	**Historical Temperature TCY-MIN**	19.4	0.2	2.7	18.2	4.4	5.8	9.0	30.5

4. Conclusions

Building systems in Europe and higher latitudes are different to tropical latitudes, as the ones covered in Mexico. In non-tropical latitudes the insulation is more stringent, while some tropical areas this is not critical; most of those regions is not considered at all.

The variations of the outside temperature to inside are not extreme so insulate buildings, and it is impractical and more costly to the general population. Mexican norms for housing construction begin to be more favorable especially in the minimum characteristics residences that could stress the need for climate protection conditions.

The overall average temperature decrease inside is not very high with reference to the outside temperature not exceeding globally 2.6 °C. Greater differences are found considering the historical temperature on climate year type for maximum activity, a difference of 3.9 °C.

The wall insulation process in the tropics is not rigorous, presenting significant infiltrations but they are not responsible of the changes on the outside temperature.

Solutions with green roofs called extensive, are intended to insulate the constructions of external weather conditions and care of the same is performed by the user; maintenance is secondary. Yet, the professional practice to implement green roofs are too expensive for widespread use, The thermal performance perhaps is not significant on temperate climates but there are other relevant aspects of their environmental use, that may have a greater impact and benefit for the environment, as the case of rainwater harvesting and soapy water recycling.

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