HYDRONIC COOLING OF THE THERMAL MASS ON HOUSE DWELLINGS

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ABSTRACT

This article features an analysis of the active radiant hydronic system as a thermic mass cooling system of concrete and the time which this cooling process is being made on the sub-humid mild climate temperature (Mexico City, Mexico) and the warm humid climate temperature (San Pedro Sula, Honduras). The research develop two concrete prototypes, a hydronic system and the another one as a reference to compare the system functionality. On Mexico City's weather, the concrete thermic mass diminishes 6.73 °C in comparison with the environment temperature. At San Pedro Sula, the concrete thermic mass diminishes 3.32°C in comparison with the environment temperature as well. Reason why this system's functions works better on sub-humid mild climate temperature because of the high dew temperature is lower than the warm humid climate temperature, so that the water temperature circulation is lower, leveling up the heat absorption from the concrete thermic mass.

Keywords: radiant cooling; hydronic system; energy save; thermal mass; thermal comfort; hot and humid weather.

1.- Introduction

In Honduras, as other Latin American countries on development, uses an energetic matrix dependent to Oil. San Pedro Sula, located in the north part of the country, is considered as an industrial city because of the amount of textile industries in the city, making it the second city on importance from its country. On the last years, an energetic crisis is being happened due to the rising demand of electric energy, leaving to its maximum capacity the power plants that supply with electricity the cities; the main consequence is the constant power rationing. One of the reasons of the increasing of this demand of energy is the excessive use of air conditioning equipment because of the high temperatures and humidity from the city and due to the bad design of buildings, not caring of the weather just copying models from other cities without noticing the climate specifics.

Lozano (2008) explain that the facade is one of the most important components that the use of energy affects, the gain and the loss of heat is given through the –skin of the building; this represents a significant percentage in the demand of electric energy consume from 40%. Due to the effort that the equipment requires to generate comfort in the space interiors. As a consequence, the following questions appear: the thermic mass of the ceiling can be cooled in order to diminish energetic consume generate b the use of air conditioning systems? Is it possible to accomplish this cooling using water, as a heat absorption element of the thermic mass?

Europe, Asian countries and United States uses the hydronic system as a complement of air conditioning systems in order to acclimatize interior spaces, this represent energy savings from 25% to 40% in comparison with the spaces that only utilize the air conditioning system. This saving depends of the climate conditions of the place. Hydronic cooling system is refer as a pipe net made of PEX attached to a cement layer which is below the surface of the building where the cold water flows.

This research goal is to diminish mass thermic temperature of concrete with the use of the hydronic system to minimize the heat transference from the exterior to the interior. Among the objectives of the research is to analyze the percentage of the concrete mass thermic cooling according to weather conditions, the analysis of the required time to cool the thermic mass and to avoid condensation within the skin of the building

The experimental part of the research consist to develop two scale prototypes with high thermic mass, the chosen material was concrete. One prototype will have installed a pipe system in its interior to leave cool water to pass under it; the other prototype will be used as a reference. This stage’s goal is to analyze the hydronic system functionality to get to know the cooling percentage of the concrete thermic mass and the time in which this process develop in the sub humid mild climate temperature (Mexico City, Mexico) and the warm humid climate temperature (San Pedro Sula, Honduras). The experiment will take place in the postgraduate unity building in the Mexican Autonomous National University, due to its facilities are capable and efficient to develop the experiment and the lab measure materials; and in the San Pedro Sula city, Honduras, because is the case study.

2.- Radiant hydronic system

Among the active radiant systems that uses water as a acclimatize system, the most utilized are the warm systems. These systems have being evolved until the time they can be hybrid systems, warming and cooling accordingly to the season of the year. It defines as a pipe web system attached to a concrete layer located on the surface of the building. This pipe system leaves hot and cold water to circulate, so the heat and the cold from water transmit through the pipes to the concrete, and at the same time the concrete give up and leave the heat and cold to pass to interior space from the building [1].

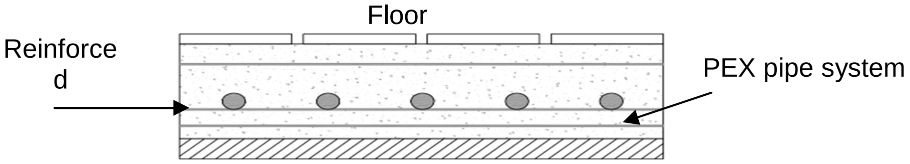
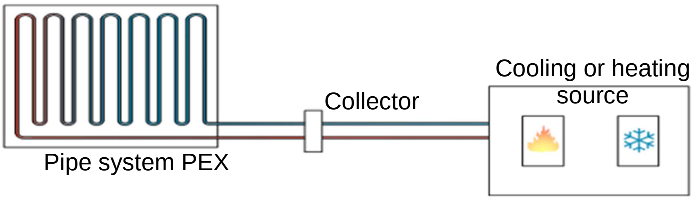


Fig. 1 “Radiant hydronic system scheme on the floor”. Source: the author.

This system has its basis on the roman warm system called “Hypocaust” and the Korean system “Ontol”, which consisted in a series of conduits under the surface of the floor where hot water circulated (that was generated in stoves) and the warm air was transmitted to the ground and then to interior space [2].
The basic principle of the system is that water is 832 times denser than air, so that the energy density has a direct relation with the material density and can be captured and canalized quicker with water than air. The process is similar to the human body functionality, due to the radiant transfer that the body uses to change most of the thermic energy, that’s why it is a thermally active system that can change from warm to cold with the transference of energy through skin. Modified buildings under this logic change its energetic consume and human comfort patterns due to its high energy saving potential rather than the convective air conditioning systems.
Common system installation consists in high density PEX pipes which finds under the concrete slap. The system can be configured to make the flow of water be constant, at the same time it can change the water temperature according to the environment temperature [4]. To make the system works it require a bomb, a mixer valve to get different temperature from water and hot/cold water suppliers systems to get the system functioning.



Water cooling methods:
-Subterranean water.
-Night air.
-Underground collector.
-Chiller.
-Heat bomb.

Fig. 2 “Cooling system and radiant heating scheme”. Source: the author.

2.1.- Condensation

One of the problems from this system is the condensation generation in concrete. There are strategies to avoid condensation, one of the most important consist in supply cold water to an elevated temperate than the dew temperature on the space [5]. On warm humid climate temperatures, the differential between dew temperature with the environment temperature is lower, contrary case from the dry climate temperature; that’s the reason of the limitations of the system to diminish the temperature of the concrete thermic mass on this climate types.
Another strategy to avoid condensations is to diminish the filtration of the humidity from exterior to interior, because there is a high range of filtrations that can make the sensitive heat to increase, leveling up the dew temperature, so the security margin of the temperature decrease to condensation happen. To decrease the filtration is important to isolate the dwelling of the building. Other strategy is to put an air dehumidifier on the entrance [6].

2.2.- Design

There is different software to simulate the radiant system, these allow to evaluate the different alternatives of finishes to know its behavior, slab depth, temperature combinations, water flow and heat absorption quantity.

Before calculation, is important to understand the building thermic behavior where this radiant system will be installed, to know how much heat will be needed to eliminate or absorb form interior to generate desire comfort. The system design criteria say that the PEX pipe circuit must be distributed with a maximum wide of 6 inches (150 mm). The rank of separation is from 8 to 10 inches (200 mm to 250 mm) with the objective to have an optimal economic balance with the required pipe. To cheap the cost of the system, many countries use pipe with low diameter, between ½” to 5/8” (12mm to 15mm) with the separation of 6” (150 mm) [7].

2.3. - Advantages and disadvantages

Between the advantages and disadvantages that the system has, we introduce and short abstract of them [8]:

Advantage	Disadvantage
Lower maintenance costs (because of inherent system simplicity—no space conditioning equipment is needed in outside walls, and a common central air system can serve both interior and perimeter zones).	The system don´t move the air around the space.
The manipulation of the concrete thermal mass to cool it and slow the transfer heat to the spaces.	Lower the water temperature too much can create discomfort to the people (feet too cold and head too warm) or cause condensation in the surface.
Better indoor air quality (because ventilation air is not recirculated and there are no wet surface cooling coils, thereby reducing the likelihood of bacterial growth).	The inappropriate installation of the system and/or the wrong design can create different temperature in the surface or don´t get the enough cooling capacity to cold the space.
The facility to use the hydronic system with others systems.	The limited experience in the installation and the lack of the knowledge of how the system works.

Table 1 “Advantage and disadvantage of hydronic system”. Souce: Olsen, 2008.

3.- Comparison of the cooling of the hydronic system of thermic mass

The first part of the experiment took place in the postgraduate unity building of the UNAM in Mexico City, with a sub humid mild climate temperature. To analyze the hydronic system as a mass thermic cooling system were develop 2 concrete prototypes of 30 cm in length x 30 cm in width x 15 cm in thickness. On one of the prototypes is installed the internal pipe system to water flowing and the other prototype is being used as a reference. The concrete prototype has a PEX pipe of a half inch with a separation of 15 cm between pipes.

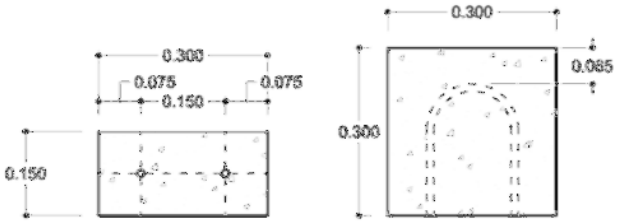


Fig. 3 “Concrete prototype with hydronic system scheme”. Souce: the author.

To take measurements, thermistors register temperature from prototypes and the in/out water temperature. The measurements took place from the 21 and the 27 of November of 2014 inside the lab to analyses the system functioning in interior spaces. Then, measurements were taken from 24 and 25 of January of 2015 and from 2 to 6 of March of 2015, on the roof of the building to analyses the sun radiation incidence on the system; the results are shown choosing a significant day. To this phase of the experiments is used a water flow from 1 litter per minute.

Because of the lack of water cooling equipment, the process is manual, so that the water is cooled stabilizing it with a differential degree, from 1°C to 2°C over the dew temperature.

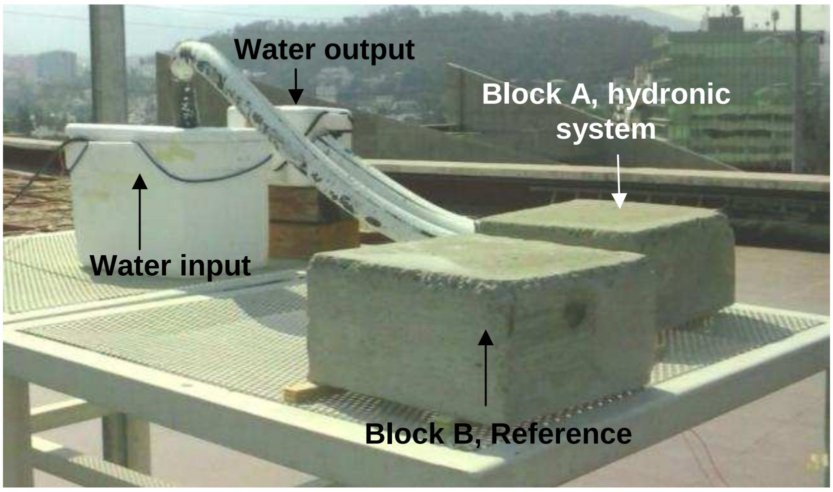


Fig. 1 “Experiment on the roof. Source: own elaboration”.

On March 5 of 2015, the hydronic system worked from 10:30 am to 6:00 pm. Sensors check the temperature from the block’s interior surface, to compare the temperature from the superior surface (the one that receives full solar radiation), interior temperature and the temperature from the lower surface of the block. To get the superficial temperature from all the block’s faces, the faces are divided in six parts, the lateral surfaces: north, south, east and west; and the superior surface of the block in 9 parts. Measurements took place every ten minutes per hour with FLUKE infrared thermometer en every division, to get the average temperature on every surface and compare them with the thermistor temperature (see fig. 5)

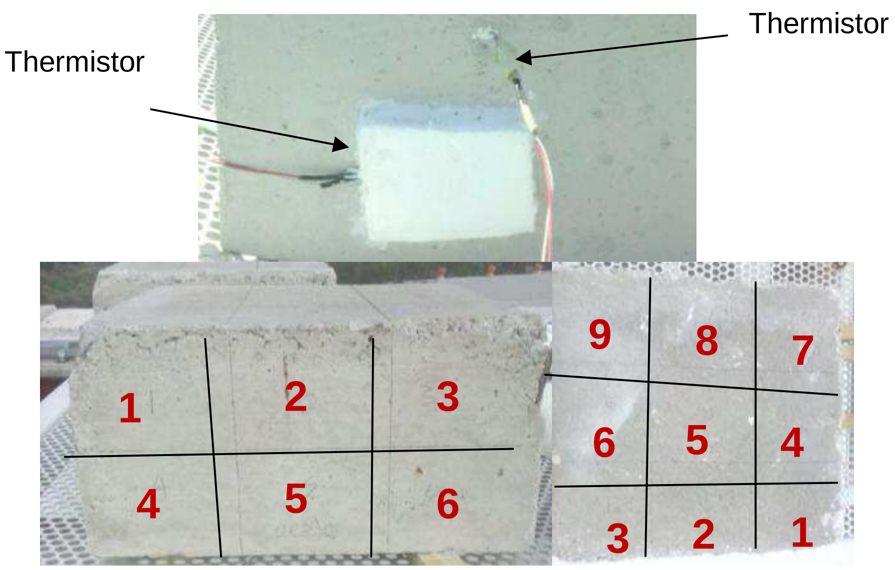
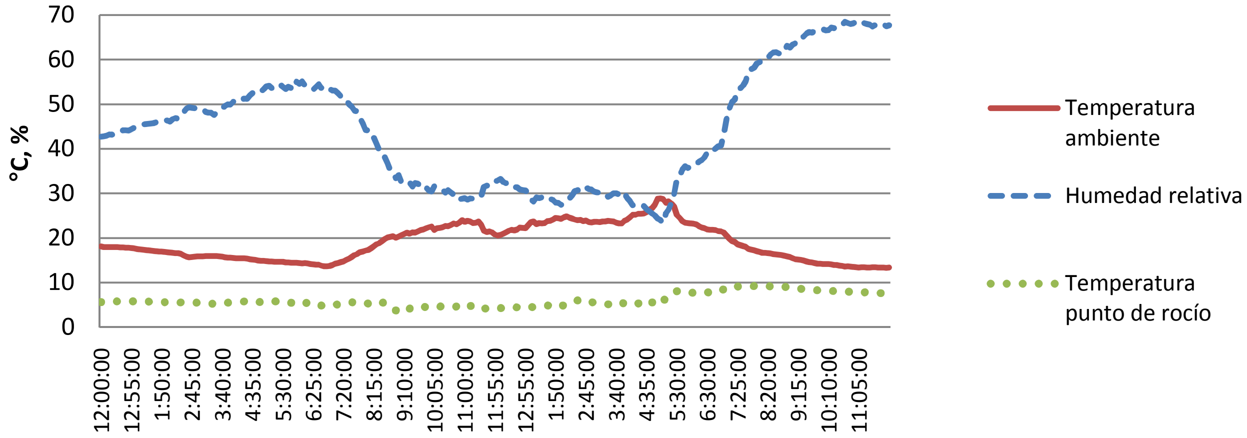
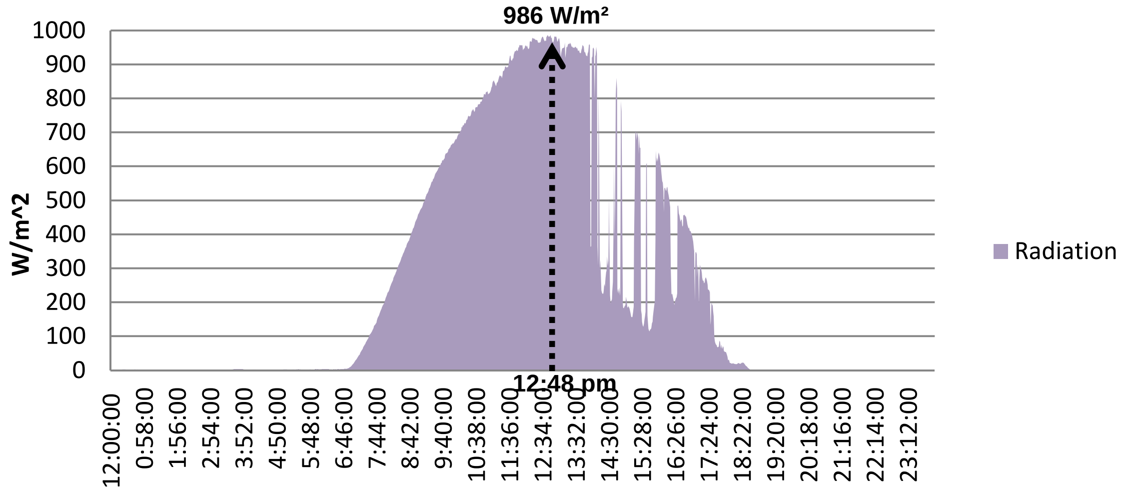


Fig. 2 “Location of the sensors and the Surface división on the face of the block”. Souce: the author.

On graphic 1, is shows the environment temperature, the relative humidity and the dew point temperature that feature the day 5 of March of 2015. The environment temperature rounds between 13.30°C and the 28.84°C; the relative humidity rounds between 23.34% and 68.47% and the range of dew point temperature stays between 3.76°C and 9.29°C. Maximum radiation shows at 12:48 pm with W/m², on graphic 2 we observe that after 1:30pm is cloud so that the radiation diminishes.



Graphic 1 “Temperatura ambient, relative humidity and dew point temperatura on March 5, 2015”.



Graphic 2 “Solar radiation on March 05, 2015”.

	Temp, °C	RH, %	Punto de rocío, °C	Bloque referencia	Superficie inferior bloque referencia	Bloque hidrónico	Superficie inferior bloque hidrónico	°C agua entrada	°C agua salida
Mínimo	13.305	23.348	3.76	12.58	14.489	12.70	14.282	4.94	6.18
Máximo	28.841	68.471	9.29	30.733	30.407	23.94	25.683	15.22	18.66
Promedio	18.97	44.21	6.07	20.71	24.25	18.19	20.99	2.62	12.57

Table 1 “Test results on March 05, 2015”.

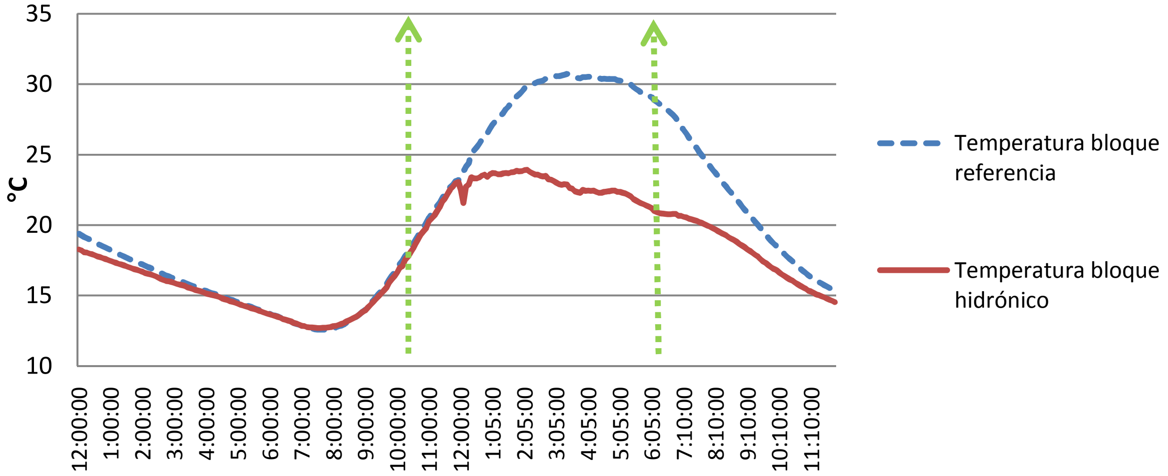
On table 2, it shows that the reference block presents a maximum temperature in the interior of the block with 30.73°C. at 3:25pm, at the same time, the hydronic system block has a 22.88°C temperature at the interior, having a difference between both blocks of 7.85°C. The temperature from the inferior surface of the reference block in that time was 30.078°C so that there is a difference of 0.65°C between the interior temperature and the lower surface.

On the hydronic system block, in that hour the temperature at the interior of the block was 22.88°C and the inferior surface temperature was 24.45°C, with a difference of 1.57°C. The interior temperature of the block is lower due to the water circulation of the hydronic system. The maximum difference between the temperatures of the interior from both blocks was 8.14°C (see graphic 4), it was given at 4:25pm; with the following results:

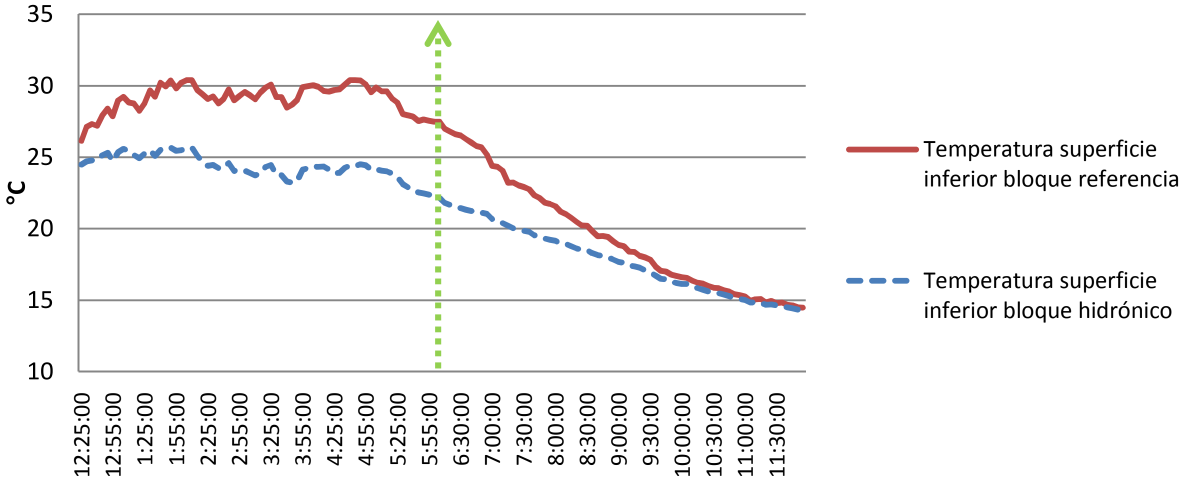
- Block of reference
  - Interior temperature: 30.42°C
  - Inferior surface temperature: 29.70°C
  - Difference between both temperatures: 0.72°C
- Block with hydronic system:
  - Interior temperature: 22.28°C
  - Inferior surface temperature: 23.89°C
  - Difference between both temperatures: 1.61°C

The difference between the inferior temperatures from both blocks was 5.81°C at 4:25 pm, so that the hydronic system reduces the heat transference to the extreme side of the block, showed on graphic 4.

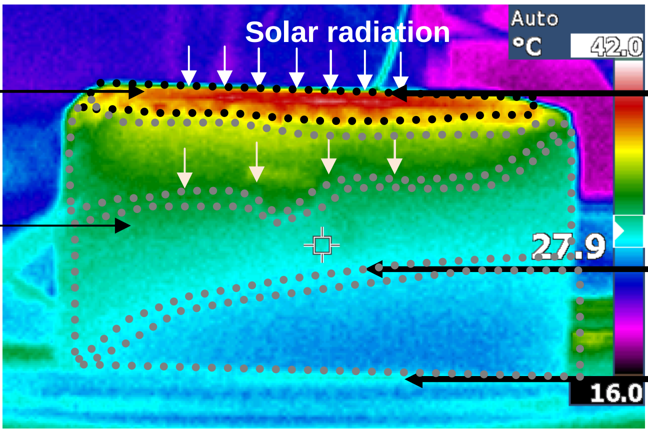
In the fig. 6 we can see the block heat flux and the different areas according to the temperature, having as a result the inferior surface lower temperature than the superior.



Graphic 3 “Comparison of the temperature inside the blocks”.



Graphic 4 “Comparison of the temperature of the bottom surface of both blocks”.



Surface warmer due to solar radiation

Heat transfer by the thermal mass of concrete to the lower surface.

Temperature measurements with the infrared thermometer FLUKE every 10 minutes on the upper surface

Thermistor

Thermistor

Fig. 3 “Thermal image of the reference block”.

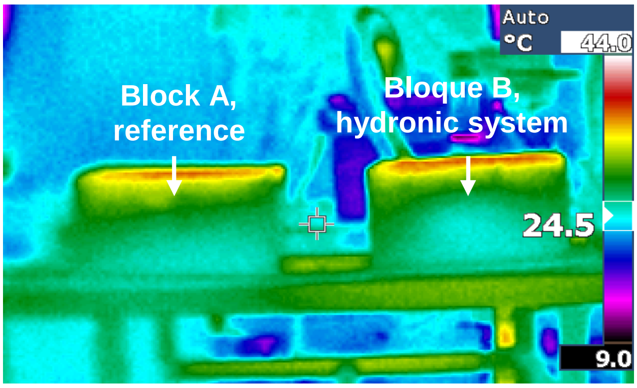
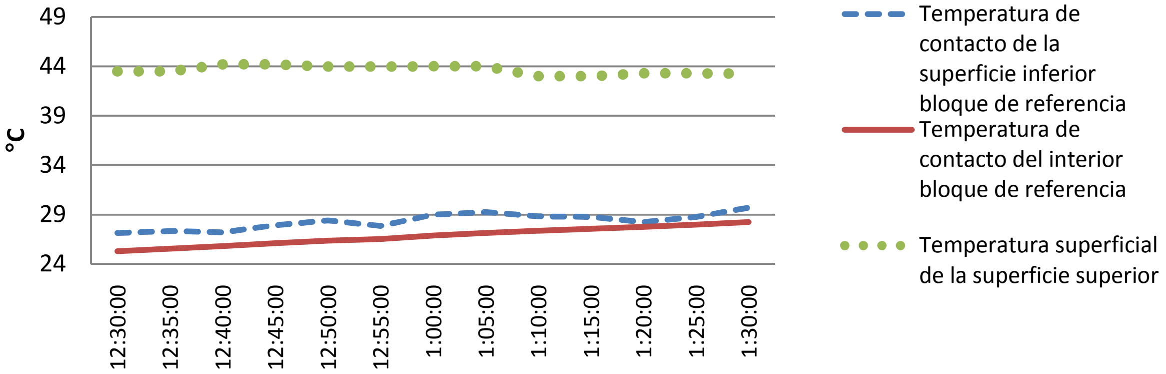


Fig. 4 “Thermal image of the blocks”.

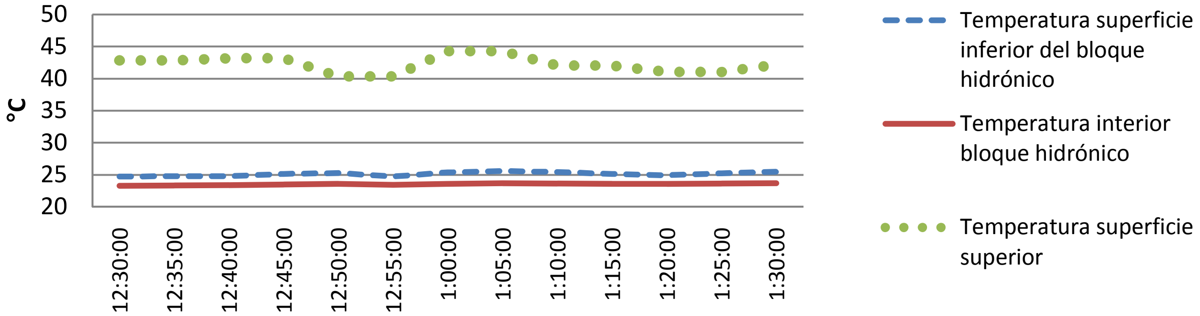
On Fig.7 there’s a thermic image from both blocks at 12:30pm, block B presents a bigger area with lower temperatures at its center than block A, which happen due to the hydronic system cold water flow.

Hora	Temperatura superficies Bloque referencia					Temperatura superficies Bloque hidrónico				
	Superior	Norte	Oeste	Este	Sur	Superior	Norte	Oeste	Este	Sur
12:30:00 p.m.	43.48	25.68	26.17	33.72	34.87	42.83	26.92	26.70	33.88	34.65
12:40:00 p.m.	44.21	25.20	25.38	32.78	34.62	43.17	24.83	25.60	32.15	34.37
12:50:00 p.m.	43.98	23.47	24.95	31.28	34.03	40.31	30.03	26.27	30.03	31.20
01:00:00 p.m.	44.00	24.77	26.02	31.10	34	44.27	25.25	25.80	31.83	33.93
01:10:00 p.m.	43.01	24.90	25.83	29.65	34.57	42.00	24.75	25.48	30.65	34.62
01:20:00 p.m.	43.28	24.30	25.67	29.23	35.70	41.02	24.50	25.60	28.60	35.00
01:30:00 p.m.	43.24	24.62	25.95	29.18	36.22	42.17	25.58	26.62	28.83	35.60

Table 2 “Average temperature in the faces of the blocks”.



Graphic 5 “Temperature compared on the reference block on March 5, 2015”.



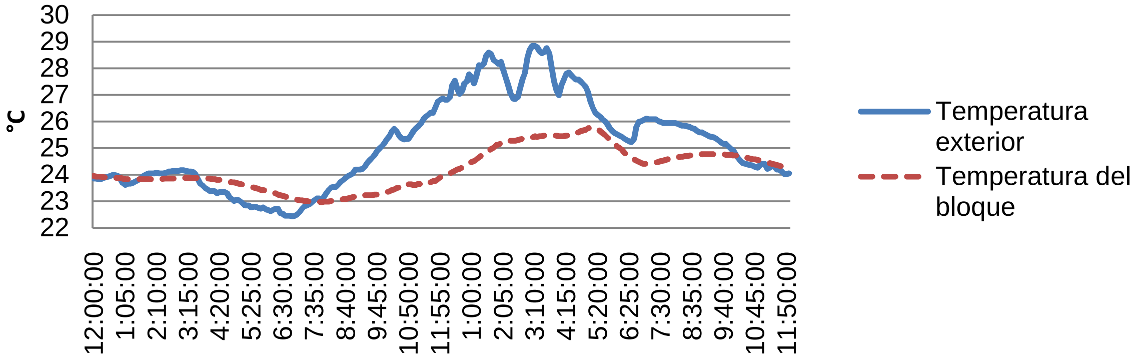
Graphic 6 “Temperature compared on the hydronic system block on March 5, 2015”.

On table 3, we see the average temperatures in an hour; the measurements were taken every 10 minutes on the different divisions on the faces of the blocks with FLUKE infrared thermometer. On graphic 5 and 6 shows a comparison, between 12:30 pm and 1:30 pm, of the temperature behavior between superior surface, inferior and interior of the blocks. The superior surface temperature from the reference block was constant from 43°C and 44°C. The temperature from the inferior surface of the block rounds between 27°C and 29°C; and the temperature from the interior of the block was between 25°C and 28°C. There is a difference of the average temperature of 15.29°C between the temperatures of the inferior and superior surfaces.

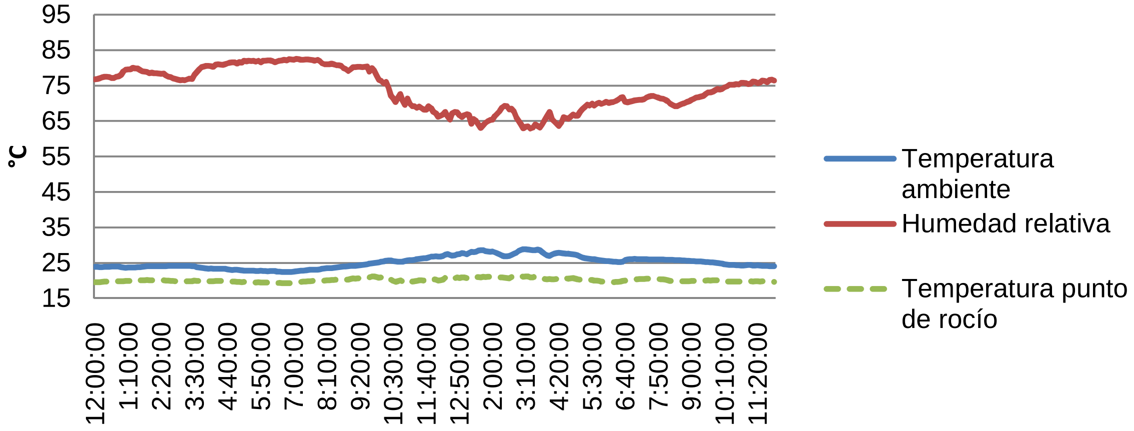
On graphic 6 there is a difference of temperature from the surfaces with the interior of the hydronic system block. The temperature of the interior surface of the block rounds between 41°C and 44°C; the temperature of the inferior surface of the block rounds between 24°C and 25°C; and the temperature of the interior of the block was between 23°C and 24°C. There is a difference of the average temperature of 17.13°C between the temperature of the superior surface and inferior temperature and a difference of 18.71°C with the temperature of the interior of the block. With this results, we can prove that the hydronic system, besides of cooling the mass from the interior of the block, it can reduce the heat transference to interior spaces; in this case we got a difference of 3.21°C between the inferior surfaces of both blocks in the hour that presents the most solar radiation incidence, between 12:30pm and 1:30pm.

On the second part of the experiment we make a replica of the experiment in San Pedro Sula city, Honduras; with a warm-humid weather. On this part of the experiment we make a block with the radiant system because of the lack of measurement equipment. The measurements took place from 8 to 18 January of 2015. The equipment of the experiment is a HOBO U12-013, to take measurements of the temperature, relative humidity and temperature of dew point. Sensors TMC6-HD were connected to the equipment to register water and block temperatures. On graphic 7, we can see the behavior of the temperature from the thermic mass of the concrete block comparing it to the environment temperature during the measurements of 10 of January of 2015. The environment temperature rounds between22.44°C to 28.84°C, relative humidity rounds between 62.88% and 82.51% and the dew point temperature was between 19.27 and 21.23°C.

The water temperature of the entrance remained between 1°C and 2°C of difference with the dew point temperature. During the measurements was registered that the temperature of the concrete mass thermic can achieve a lower difference to the environment temperature of 3.32°C between 1:00pm and 2:00pm. The minimal temperature that can cool the concrete thermic mas is from 1.3°C between 9:00am and 10:00 am, in an hour from the starting point of the water circulation.



Graphic 7 “Comparison between environment temperatures with concrete thermic mass with the functions of the hydronic system”.



Graphic 8 “Environment temperature, relative humidity and dew point temperature on January 10, 2015”.

4.- Conclusions

It can conclude that the hydronic system can cool the skin of the building thermic mass; with the experiment we prove that the system can cool 6.73°C the concrete mass thermic in comparison with the environment temperature in a sub humid weather and 3.32°C in a warm humid weather. It is considered that it can increase the cooling temperature isolating the prototypes in order to get the desire weather conditions, especially with a low dew point temperature to achieve a lower water temperature to cool the thermic mass and to get a bigger difference.

On the sub humid weather, the hydronic cooling system reduce the heat transference generated by the solar radiation over an exterior surface of the other surface in the interior, getting a temperature difference of 5.81°C. This heat reduction decreases the consumption of the air conditioning systems.

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