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Sustainable housing with block masonry with vertical cells and hollow horizontal ducts

Vivienda sustentable con mampostería a base de blocks con celdas verticales y conductos horizontales huecas

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Abstract

Gradually by anthropogenic actions, the temperature is increasing throughout the planet, and the same human being has been affected, requiring more and more air conditioning mechanisms to maintain their comfort in the spaces they use, Therefore, this article shows a new system of construction of real estate with masonry blocks with vertical hollow cells and hollow horizontal ducts, which mitigate the heat transfer inside the buildings after 8 hours of exposure to sunlight, reducing the temperature by 20 ° C compared to the traditional system. Therefore, this new proposal contributes to the reduction of climate change by requiring less electrical energy for the comfort inside the real estate, besides, it is available to all the inhabitants of the planet because it is a block material that integrates masonry.

Climate change, Masonry with vertical cell block and hollow horizontal duct, Heat transfer

Resumen

Paulatinamente por acciones antropogénicas, se está incrementando la temperatura en todo el planeta, y el mismo ser humano ha estado afectándose, requiriendo cada vez más, mecanismos de aire acondicionado para mantener su confort en los espacios del que hace uso, por lo que el presente artículo muestra un nuevo sistema de construcción de bienes inmuebles con mampostería a base de blocks con celdas huecas verticales y conductos horizontales huecos, mismos que mitigan la transferencia de calor en el interior de los inmuebles después de 8 horas de exposición a los rayos del sol, reduciendo en un 20 °C de la temperatura referente al sistema tradicional. Por tanto, esta nueva propuesta abona en la reducción del cambio climático por requerir menos energía eléctrica para el confort en el interior de los bienes inmuebles, además, está al alcance de todos los habitantes del planeta por ser un material de block que integra a la mampostería.

Cambio climático, Mampostería con block de celda vertical y conducto horizontal huecos, Transferencia de calor

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Introduction

In recent years we have witnessed drastic changes in global temperatures due to anthropogenic activities. According to the Intergovernmental Panel on Climate Change, the increase of greenhouse gases in the atmosphere influenced the global mean or land surface within the range of 0.5 to 1.3 °C during the period 1951-2010 (IPCC, 2013). The increase in global temperature has affected many physical and biological systems, including human systems (IPCC, 2001a; Rosenzweig *et al*., 2007). In Mexico, temperatures of up to 40 °C are recorded, according to data from the National Water Commission of the National Meteorological Service. (CONAGUA, 2020), Figure 1.

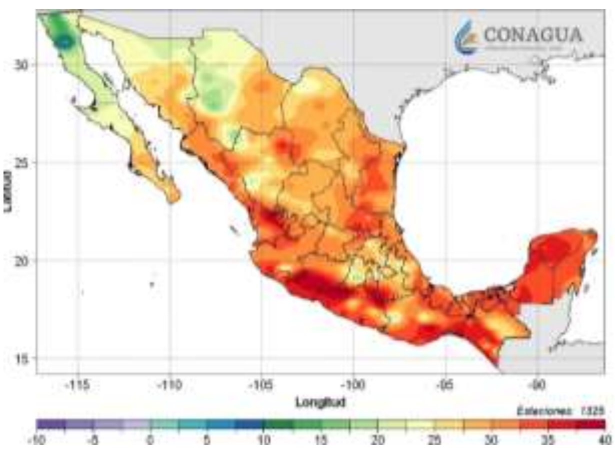

Figure 1 Average temperature in Mexico for the month March 2020, (CONAGUA, 2020)

High temperatures directly affect the condition and well-being of entire populations. Nowadays, industrial and commercial sectors, in order to reduce such temperatures inside buildings, offer the consumption of ventilation and cooling elements that contribute crucially to the greenhouse effect due to the energy used for their production, as well as the energy consumption for the operation of air-conditioning devices, thus causing a negative impact greater than the benefit (Bergeron and Strachan, 2010; de Munck *et al*, 2013; Hamilton *et al*., 2009; Ichinose, Shimodozono, & Hanaki, 1999; Klysik, 1996; Ohashi *et al*., 2007; Ramamurthy, Li, & Bou-Zeid, 2015; Sailor, 2011).

Based on statistics reported by the National Energy Balance, electricity consumption in the residential sector represents 23.3% of the total consumed in Mexico (de Planeación Energética y Tecnológico, 2009), with the highest demand when high temperatures occur, in which the user resorts to air conditioning to maintain comfortable conditions inside their real estate.

Particularly, in the State of Campeche, an average (dashed line) annual maximum temperature of 36.5 °C is observed. (CONAGUA, 2020), Figura 2.

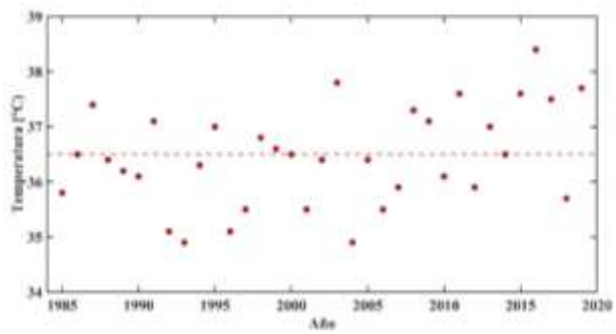

Figure 2 Average maximum temperature in the State of Campeche (dashed red line)

Background

Currently, houses in the State of Campeche are built with artificial masonry using conventional concrete blocks with two and three vertical cells, whose block dimensions including mortar joints in the already built wall (thickness x height x length) are 10x20x40 cm, 15x20x40 cm, and 20x20x40 cm (Rivera *et al*., 2008).

The 15x20x20x40 cm blocks, Figure 3, are the most commonly used in the region for structural purposes; the 10x20x40 cm blocks are mainly used for the construction of dividing walls or perimeter fences of houses; while the 20x20x40 cm blocks are generally used for architectural purposes (Rivera *et al*., 2008). Figure 3a shows the isometric of the piece of block with two and three cells whose size in built wall will be 15x20x40 cm, the dimensions and walls of the lower and upper faces are shown in Figure 3b and the lateral views in Figure 3c.

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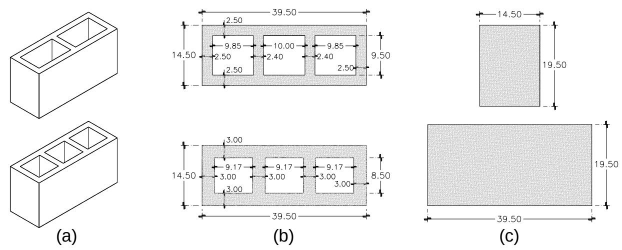


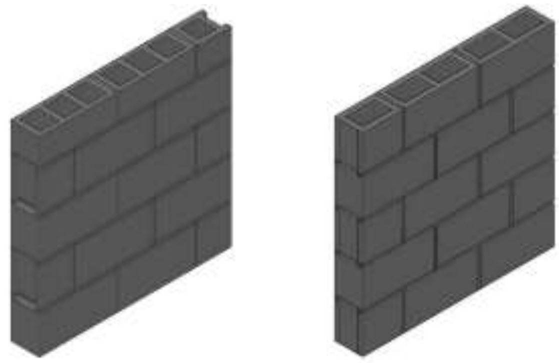
Figure 3 Masonry concrete block used in the State of Campeche, dimensions in cm, (a) isometric of two and three cells, (b) plan dimensions and (c) lateral dimensions

The efficiency of blocks with these characteristics has been observed, one of the advantages being the low weight of the blocks with vertical cells, but with a disadvantage: retaining the hot air resulting from exposure to solar radiation during the day, because there is no access to fresh air or air circulation, i.e. the air trapped inside the cells causes an increase in temperature inside the building that lasts until after the sun goes down.

That is, during the day, any building above the ground level inhabited by humans absorbs and stores a large proportion of heat in the walls and ceiling exposed to the sun's rays, and is released after sunset, which means that the temperature in the masonry remains and is transferred throughout the night to the interior spaces of the building (Grimmond and Oke, 1999b; Kotthaus and Grimmond, 2014a; Offerle, Grimmond and Fortuniak, 2005; Roberts, Oke, Grimmond and Voogt, 2006).

Traditionally, the masonry wall is formed with several pieces of block shown in Figure 3 with the arrangement indicated in Figure 4. The vertical voids are only serving the function of lightening the load-bearing walls without mitigating the heat transfer inside the rooms, moreover, being masonry it is confined with slab and load-bearing chains restricting the mobilisation of the flow of hot air or heat energy inside the wall.

Figure 4a shows the construction of the masonry wall with 3-hole blocks, and Figure 4b shows it with 2-hole blocks, both with the dimensions denoted in Figure 3, the dimensions of the constructed wall are 15x20x40 cm.



(a) (b)

Figure 4 Concrete block masonry with (a) three and (b) two vertical cells

Therefore, to expel the heat energy inside the masonry, the proposal described in the methodology section is presented to mitigate the heat coming from the outside, reducing the consumption of electrical energy through the use of non-conventional block with special characteristics that form a network of internal horizontal and vertical ducts, favouring the mobilisation of the hot air trapped inside the cells, expelling it through the roof of any building with the arrangement shown in the methodology section.

The study area is located in Ciudad del Carmen, Campeche, Mexico. It is located southwest of the Yucatan peninsula, in the western part of the Isla del Carmen, it is situated at 18 ° 38′18 ″ N and 91 ° 50′07 ″ W in the Gulf of Mexico, between the east and the Laguna de Términos, Figure 5.

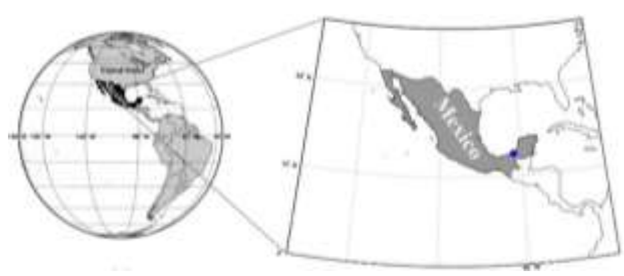


Figure 5 Location of the study area

According to information from the National Water Commission of the National Meteorological Service (CONAGUA, 2020) based on the FV3-GFS model of the National Oceanic and Atmospheric Administration (Kalnay *et al*., 1990; Kanamitsu 1989; Kanamitsu *et al.*, 1991) the temperatures registered in Ciudad del Carmen Campeche oscillate above 40 °C, Figure 6, being this magnitude the average, since in the month of May and June this temperature increases exceeding 43 °C and in winter below 30 °C.

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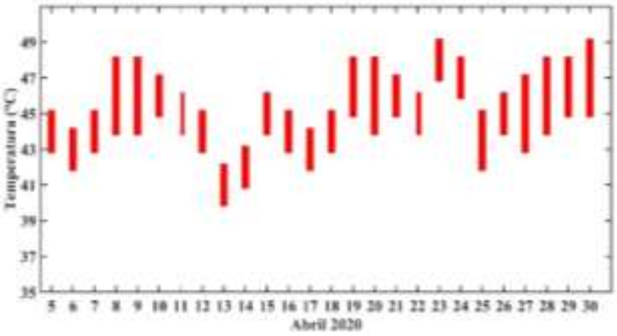
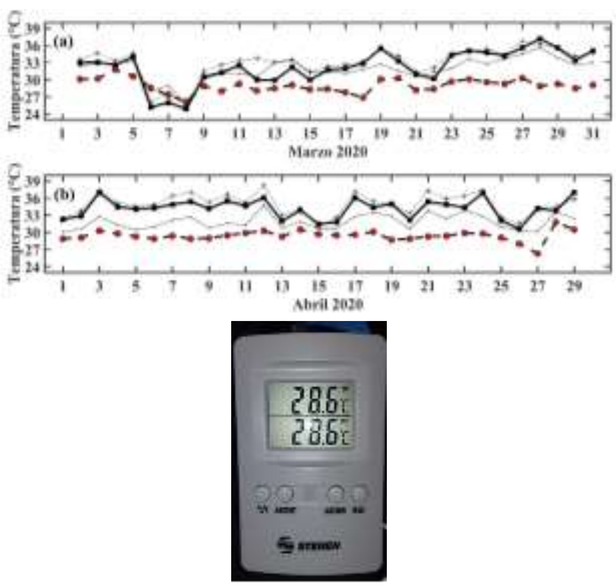


Figure 6 Climogram of Ciudad del Carmen for the month of April 2020

Figure 7 shows the temperatures taken in a house built with 15x20x40 cm hollow block, using a digital indoor and outdoor thermometer. The temperature record was taken on the second level of the building, measuring 5.61 x 4.86 m (27.2646 m2), supplied with light and brightness by two windows to the east of the room and 4 skylights in the roof. This room has a high exposure to the sun from the east, west and south of the room. During the morning, a gradual increase in temperature is observed in the masonry walls; this temperature remains in the walls until the end of the day when it slowly dissipates, causing a greater thermal sensation inside the house. Next, we can observe the graph mentioned above; it shows a dotted line with circles representing the temperatures measured at 10 a.m., a dotted line with small circles representing the temperatures measured at 12:00 p.m., while the dotted line with a + sign represents the temperatures measured at 15 hrs. Finally, the solid line with squares represents the temperatures measured at 19:00 hrs.



(c)

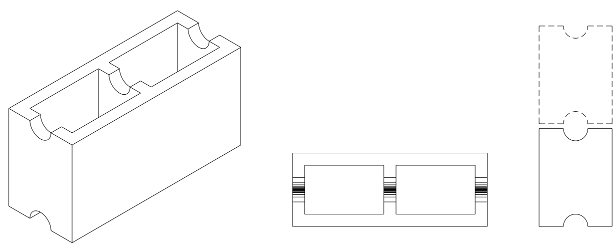
Figure 7 Graph of temperatures recorded in residential houses (a) March and (b) April and (c) equipment used for measurements

Excessive use of air conditioning due to increased heat transfer in buildings generates a high expenditure of electrical energy, therefore, greater ecological damage by increasing greenhouse gas emissions, due to the use of refrigerant gas and electricity consumption that emits more CO2 (carbon dioxide) into the atmosphere. Furthermore, it affects the lifestyle causing stress to the human being, leading to increased health risk (Rosenzweig *et al*., 2007).

Methodology

In order to materialise the proposal, this section will show the materials and arrangements to release the hot air, as well as the type of sensors that will be used to perform the temperature tests.

Figure 8 represents the design of the unconventional block, with two vertical openings and half reeds in the walls to form the ventilation network within the masonry wall. Figure 8a shows the isometric with the half reeds in the walls, Figure 8b the plan view and Figure 8c the profile of the block that will be used to allow the heat to flow through the presence of the half reeds which, when joined with other pieces, will naturally form a horizontal duct at each joint.



(a) (b) (c)

Figure 8. Masonry block, (a) two vertical holes, (b) half reeds for horizontal ducts and (c) forming a masonry wall

Once the masonry wall is built with the block described in Figure 8, we will proceed to record temperatures using a digital thermometer programmed with arduino, the temperature data is printed or displayed on the LCD screen as shown in Figure 9. (Figure 9); This LCD screen is connected to a temperature and humidity sensor (DHT11 sensor), this being one of the most suitable sensors for walls already built and in operation, having the great advantage of obtaining the temperature and humidity digitally filtering white noise. The pins of the PCB version of the DHT11 are: grounding (GND), data transmission (DATA) and power supply (VCC).

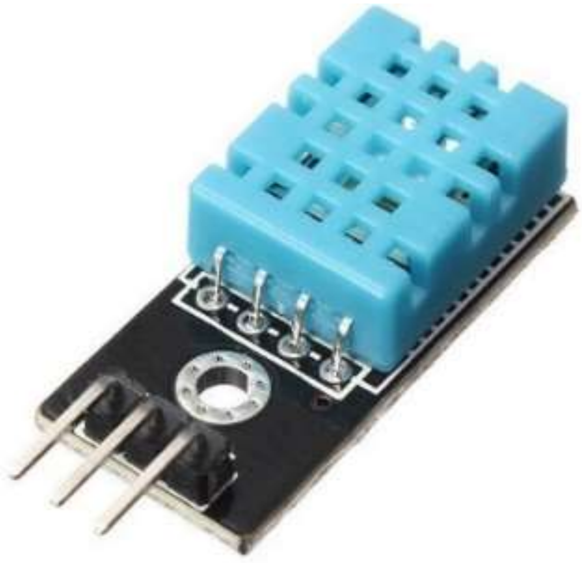
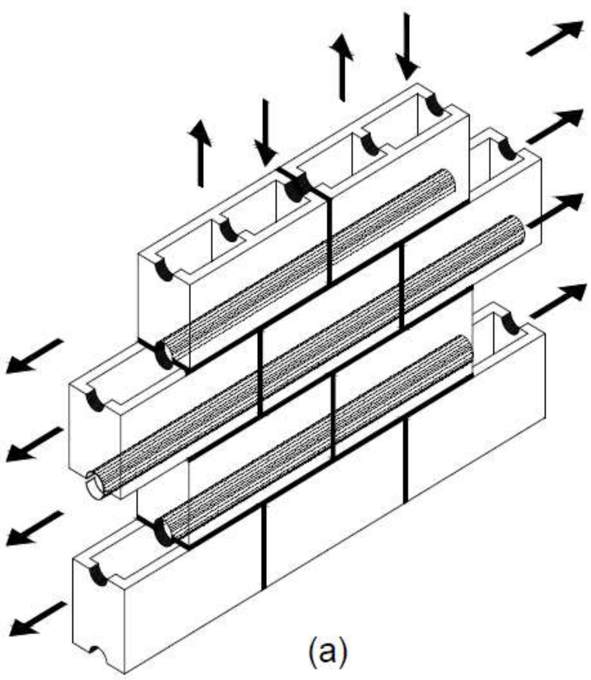


Figure 9 Digital Thermometer programmed with arduino

Results

The hollow block proposed in this work will form horizontal and vertical ducts inside the masonry wall, as shown in Figure 10, which shows a ventilation network by the design of the block inside the wall, thus allowing air flow in the horizontal and vertical direction, simultaneously releasing heat energy at the top of the roof by the constant exposure of the sun's rays.



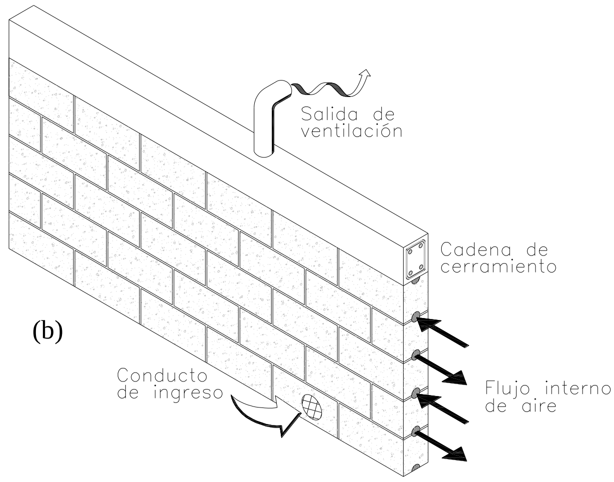


Figure 10 Masonry wall with (a) horizontal and vertical duct layout, (b) access located 1.40 m from finished floor level and ventilation outlet in enclosure chain

Figure 11 shows the full-scale three-dimensional layout of the dwelling house with masonry walls. The blockwork with hollow vertical cells and empty horizontal half-pipe ducts with roof vents to release heat energy are shown.

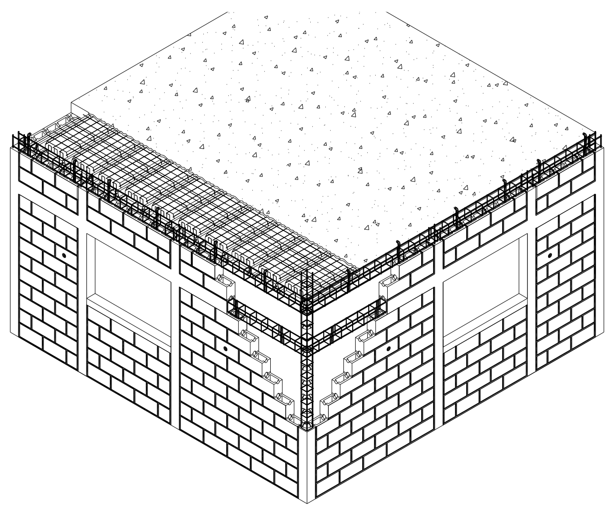


Figure 11. Overall masonry scheme with horizontal ducts and vertical cells

The temperatures were obtained on the walls of the house, recording them at two different times over the course of a day and up to a month, allowing us to know not only the temperature, but also the thermal sensation registered inside the house. These data were used to generate an average of the temperatures recorded, which were then compared with those of the conventional block wall. Figure 12 shows the temperature reduction after the construction of the conventional block walls in one area and in another area of masonry with hollow vertical block cells and hollow horizontal ducts.

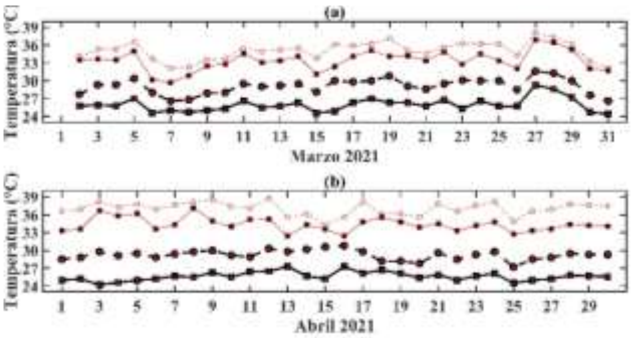


Figure 12 Temperatures inside the house, (a) with conventional block with red lines and (b) with block of the present proposal

The reduction with the proposal shown in Figure 10 is around 20% on average, which means less electricity use.

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Conclusions

In high-temperature areas, there are buildings with masonry walls made of solid pieces or blocks with vertical openings which, when they receive the sun's rays for 8 hours, transfer the heat to the interior spaces of the house. In the first hours of sun exposure to the walls, the masonry heats up and being constantly exposed to the heat, the pieces absorb it and transmit the heat to the interior, in such a way that when it gets dark the walls are still hot, spreading the temperature towards the interior of the building. The proposal of vertical and horizontal hollow block masonry reduces heat transfer to the interior of the rooms by 20%.

The network of horizontal and vertical ducts structurally weakens the resistance of the masonry, however, it is reinforced by slightly increasing the number of castles, in this case it is suggested to have a maximum separation of 3m with the type of block proposed, while, if block with only vertical hollows is used, the maximum separation is 4m.

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