Recycled packaging material as an upper deck ventilation system in buildings

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ABSTRACT: This research analyses the thermal improvement occurred in an indoor space, from the use of an upper deck ventilated system through the reuse of packaging material. This experimental research shows the comparison of obtained data between two climate test modules, one case where the roof is protected by an upper deck ventilated system throughout the employment of reused wood pallets and other case where the roof is completely unprotected as it is usual in buildings of the studied area. A typical day was modelled using the average temperatures from the climatic season measured. The theoretical trend of the results in the performance indicated a potential of 6% of thermal improvement.
Keywords: Shading devices; Ventilation system; Thermal Improvement.

INTRODUCTION

Mexico is a country facing a complex process of social transformation, in which the housing and living conditions are truly relevant. The country has more than 112 million people and 77% of its population is concentrated in urban centres. According to official data, the current housing demand in Mexico is approximately 8.9 million households, in which 54% of them will be developed in just five metropolitan areas that concentrate more than 48 million people.

The National Housing Commission estimates that such demand will be built on a system of social production of low cost. This with a development scheme involving a standardized architectural configuration and a lack of consideration to climatic conditions, regardless of the fact that Mexico is a country with 60 different types of climates according to Köppen-Garcia's climatic classification system. Added to this, there is a variation in annual rainfall ranging from 182 mm to 2010 mm that also impacts roofs usages.

Applicable regulations in larger metropolitan areas of the country established to use declines from 1.5 to 3% on the decks. This allows the use of flat slabs, which generate a large gain in solar radiation, reducing by this way, thermal comfort of the inhabitants. This evidence impedes to ensure satisfactory living conditions, as the architectural envelopes do not meet basic premises such as the proper handling of solar radiation.

On the other hand, the supply of lumber, laminated and bonded wood used in the construction industry in Mexico is much lower than consumer demand for social housing production. Although Mexico has a 33% of forest areas in its territory and is part of the 3% of the world's primary forests, the United Nations for Food and Agriculture Organization (FAO) says there is a deficit of approximately 14.5 million m3 in national forest industry in 2009.

Given the above, the recycling of supplies in the construction process, is a timely response to the problems described since about 25% of total round wood harvested in Mexico is used as timber, laminated and bonded.

The panels employed in this experimental study are dunnage pallets that are normally used as packaging material, and for purposes of the present investigation, they would be used as an upper deck ventilation system in buildings.

Figure 1. Pallet used in this research

Environmental problem

The pallets represent an environmental problem for developing countries; example is what happens in the state of Colima. Agribusiness companies settled in Colima require a significant amount of wood, both for the production of containers of fruit, and the development of platforms that can be stowed and carried by forklifts.

As reported by J. Ramirez (2008), the consumption of fig wood for the production of containers of fruit is approximately of 35,000 square feet annually, whereas the consumption of pine and pitch wood for the production of pallets is 60,000 square feet per year.

Another of the issues with the wood production described above is that some part of it comes from non-regulated sources. About 80% of fig wood is illegal, and comes from rural and suburban areas of the State of Colima; and about 50% of the pinewood illegal comes from the mountainous area of the volcanoes through clandestine loggers settled in the valley of Zapotlán, Jalisco.

Fruit containers have a useful life of four to six applications. The platforms have a shelf life of about a year. After that time, the platforms are destined for firewood, fences in animal cages or in marginal batches in irregular settlements located in flood zones. In most industrialized areas such as Mexico City, Guadalajara and Monterrey, the discarded pallets are ground in machines specifically designed for that purpose, and the product of milling is intended as input for the production of particleboard wood panels. This product is also intended as fuel in industrial boilers.

The pallets or panels have pesticide treatments to increase their durability, but this quality makes them pollutants. The ground product that will be generated from the combustion boilers, which are also inefficient and highly polluting releases chemicals from treated wood. With the proposed use in this investigation, the life of the platforms would be extended and the exposed elements would last for at least 3 years if treated with burnt motor oil, which is cheap and helps solving other environmental problem.

Technical antecedents

Some literature has, experimentally and analytically, investigated the performance and heat transfer characteristics for the introducing air movement behaviour within parallel roof; such as, the comparison of full-scale ventilated roof component under real climatic conditions which was proposed by Dimoudi et al., air gap height (6 and 8 cm) and application or not of a layer of a radiant barrier, were examined.

The thermal performance of the component was assessed by direct comparison of conventional constructed roof during the summer period. In the ventilated roof component a circular solar chimney was positioned in order to facilitate the extraction of the hot air from the ventilated gap. A constant room temperature (27 ± 0.2 ºC) was applied in the interior of the test cell during the whole testing period.

Only qualitative results comparison of ventilated and typical roof performance was analysed. During daytime the upper slab of the typical roof was 1-3 K higher than ventilated roof upper slab (without a radiant barrier). During the nighttime upper slab of typical roof was 0.5 K warmer than ventilated roof upper slab (with radiant barrier). Measurements of heat fluxes through the inner surface of the roof showed that, the typical roof presented gains 1-3 h earlier than the ventilated (with a radiant barrier). In both day and nighttime, the ventilated roof had less gains than the typical one, thus, the overall performance of the ventilated roof during the summer period can be considered as highly efficient. On the effect of the air gap height assessment, the measured data showed that a decrease (from 8 to 6 cm) of the air gap height might improve the performance of the ventilated roof under summer conditions, around 15% compared to the typical roof.

The addition of a radiant barrier was an improvement on the system's performance under daytime summer conditions; on the other hand, the layout without radiant barrier performed better under summer nighttime conditions. Heat transfer experiments were carried out to find the optimal spacing for double-skin roofs (Lai et al. 2008). They found that an average of 7.54 cm of space for double-skin roofs for a pitched roof is the optimal value. Regarding heat transfer in double-skin roofs, Biwole et al., proposed a bi-dimensional numerical simulation of the heat transfers through the double skin wherewith most important parameters for the system's efficiency were revealed. They found that the double-skin width must be over 6 cm and under 10 cm.

In Colima, Gomez-Azpeitia et al installed a double-deck system, based metal and cement board, to reduce direct solar gain on the roofs of a classroom. They evaluated the thermal performance of the double-deck system by the values of temperature and humidity, recorded inside. The results were compared with those recorded in a classroom without modification and another with white painted cover. These measurements were made during the warm-humid season. The results indicated a reduction of four degrees Celsius in temperature by cement panel system compared with other without treatment and a degree with respect to the roof painted white.

METHOD

Placement

The experiment was conducted in three experimental test modules placed within the University of Colima Campus, located in Coquimatlan, Colima: a suburb of Colima City, (103º48’W, lat. 19º12’N long, 365m alt.) with a sub humid warm climate.

Figure 1. Colima City Localization

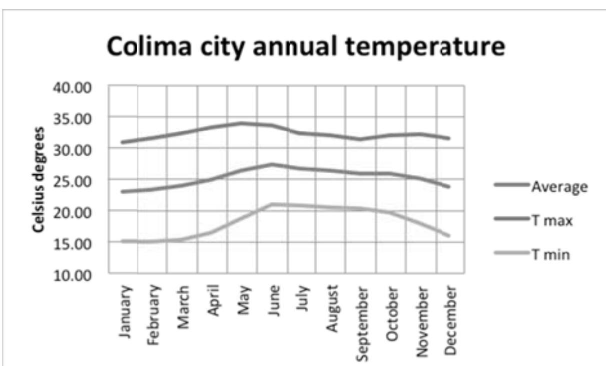

Figure 2. Annual temperature conditions in Colima city. Source: Conagua: (National Water Commission)

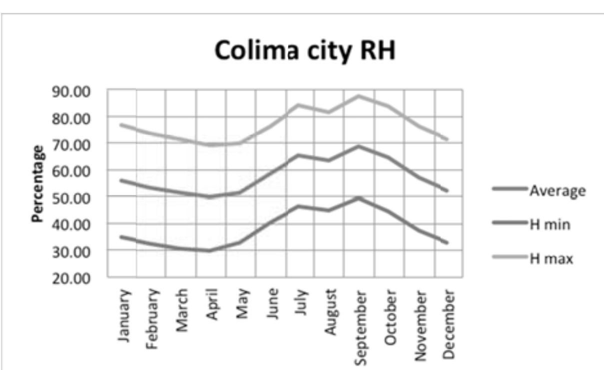

Figure 3. Relative humidity conditions in the city of Colima. Source: Conagua: (National Water Commission)

Test Modules

Modules are square, with internal dimensions of 1.35mts long x 1.35mts wide x 1.35mts high. These dimensions are 1:2 scale replica of a minimum room according to the construction rules of the town. Roof and walls also respond to the same scale. The materials employed are conventionally used in the region: Clay brick walls and concrete slab on the roof. The module has parapets 0.10m tall and the top colour is light grey, the walls are painted white. The modules are physically separated from other buildings, and therefore their four walls are exposed to outdoor conditions, however the rooms of the houses at most have only two exposed walls.

Tests modules have a door located on the north side of 0.50 by 1.10m, which remained open throughout the experiment, and the walls were not any type of insulation.

Figure 4. Test modules, location Coquimatlán, Colima. Source: Authors

Monitoring Equipment and Data Logging

In the experiment it was used Data Loggers (HOBO type), U12-012 model Onset Company. The sensor was placed indoors in the geometric centre of each module, and it recorded dry bulb temperature and relative humidity. Data logging was collected each half hour for Forty-five days from November 26th 2011 to January 9th 2012, which corresponds to the mild season of the site.

Experiment

Panels were placed on two tests modules and other test module was allowed to proceed under normal conditions as a control manner. The panels used were dunnage pallets discarded by a local store; they measure 1.06 meters per side and are made of wood strips 0.079m wide spaced at a distance of 0.042m. The wood strips rest on four crossbars with 0.081m high and separated 0.27m average away.

The wood has no additional surface finish. Treatment received does not alter colour or texture. The natural colour of the wood goes from yellow to light brown. Tablet width is 0.012m, and the separation of the upper ceiling is 0.09m.

Two experimental configurations were evaluated, one panel over second test module and two perpendicular panels over third module to add shade area. Panels were arranged so that allowed best performance of shading and ventilation (see Fig. 6). Given the separation of the wood strips in the panels, shading is 78% of the total panel area. On the roof of modules, a single-panel shades 54% of total roof area and the double-panel covers 63% of the total roof area.

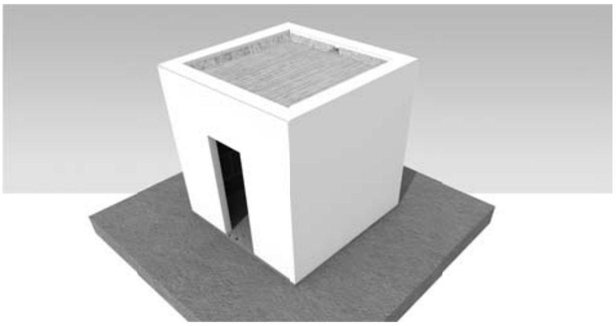

Figure 5. Control test module. Source: Authors

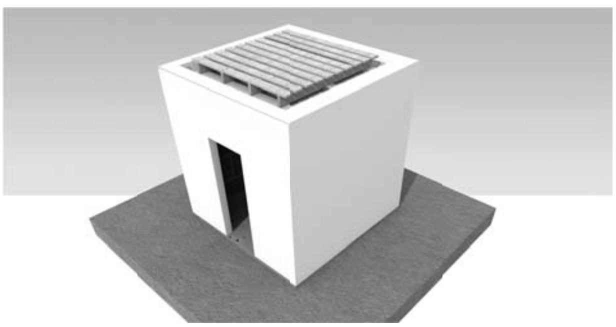

Figure 6. Test module with a single-panel device. Source: Authors

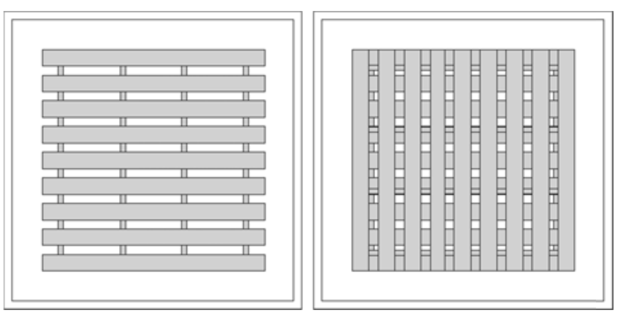

Figure 7. Arrange of panels on test module with a single-panel device (left) and double-panel device (right). Source: Authors

RESULTS

From 45 days of monitoring in the three modules, 6480 temperature data were obtained also an equal amount of relative humidity. We selected a temperature´s representative day, the closest to the annual average: The selected day was February 9. By comparing the temperature and humidity data, it was observed that in relative humidity there was no phenomenon worthy of analysis, since the differences were easily explained by the differences in temperature exclusively.

Temperature behavior was obtained, also the differences between the experimental modules with control test module to identify the effect of the device in each of their versions. (See figure 8). After this analysis it was found that the effect is relatively proportional to the quantity of panels. The 54% shaded from single-panel device was a difference of 1.13 ° C compared with 63% shade with two panels device that produced a difference of 1.43 °.

While the double-panel occurred greater effect, in the device with a single-panel had a more prolonged effect: the double-panel equals its temperature with control chamber at 2 o'clock in the morning, the simple-panel equals its temperature with control module two hours later. Although the double-panel device begins to cool one hour before the single-panel does. This indicates that a denser and more extensive platform could improve performance significantly.

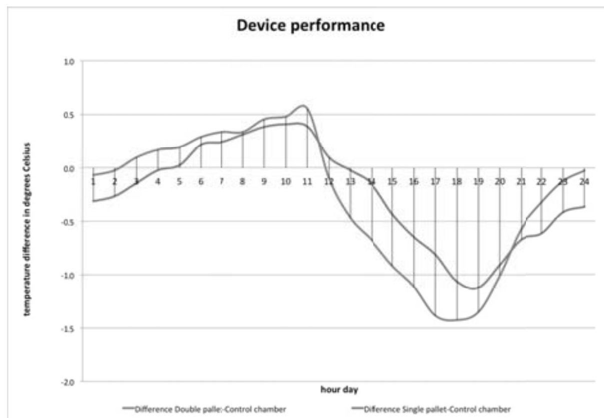

Figure 8. Compared performance of both devices (single and double panel, graphic shows differences of experimental test modules and control module

Moreover, the analyzed season does not correspond to the hottest in the city; to determine the maximum potential of the system was a correlation between the temperature data from the control module and the simple-panel system. A theoretical trend of the results of the single-panel device indicated a potential of 7% in the performance of thermal improvement, it means that when the greatest expectation of outside temperature raises 39.4 °C in summer for the city of Colima, the use of the upper deck ventilated system provides an equivalent decrease to 2.43 °C.

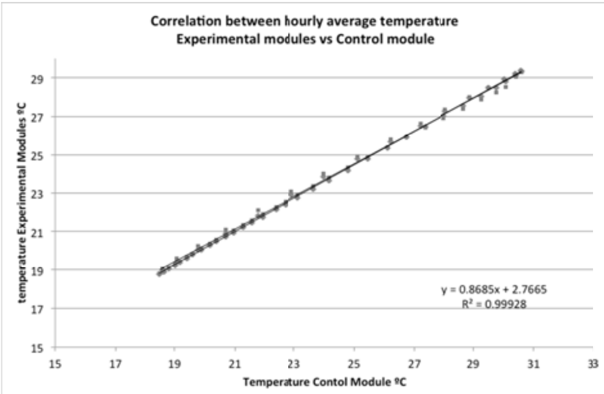

Figure 9. Relationship between temperatures in control module and experimental modules

CONCLUSION

It is feasible the use of simple solutions for problems such as mass housing in emerging countries. Reuse of pallets is a direct application that contributes to improve the comfort of the residents of such housing, while responding to an environmental problem. Such is the case of the pallets, which can provide a decrease in temperature at a very low cost.

Recycled materials such as pallets do not imply relevant changes to the home, and can be applied after its construction; it does not alter the use or resistivity of the roof. The proposed system has potential to be used selectively or massively. Although the results are lower than those achieved in other studies with devices based on the same principle, are not negligible considering that the material is available virtually free.

Reviewing the results and the experimental conditions we can say that the potential may be greater than the results achieved, considering that this experiment did not isolate walls and the door was kept open permanently. Because of this, experiment could have a higher exposure to which would have actual construction spaces, reaching poor results that an actual building.

ACKNOWLEDGEMENTS

Thanks to the Institutional Strengthening Program (PIFI) and Ministry of Public Education of the Mexican federal government for supporting the participation in this conference PLEA 2013.

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