Thermal Insulating Material for Low-Income Housing

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ABSTRACT: To improve the energy conservation conditions of low-income housing, it is proposed a cheap thermal insulating material based in the use of cane (arundo donax). This insulation material is applied in a preexistent wall in a frame, horizontally rather than vertically; located in the exterior side of the wall to account with its own thermal mass towards the interior of the spaces improving the thermal inertia of the building. Insulation properties have been evaluated resulting in 0.209 °C.m²/W for each row of cane. When applied to typical low-income houses it is obtained near 40% of savings in the necessary annual energy for heating and a reduction of 32% in power devices for heating.

Conference Topic: Materials and Building Techniques
Key Words: insulation, cane, technology, low-income

1. INTRODUCTION

The use of solar energy is strategic for people with low resources whose life depends fundamentally on the consume of Liquefied Petroleum Gas (LPG) or firewood, in template climates for house heating as well as for water heating and cooking [1]. Or even though having the natural gas installation, because of their situation of unemployment or the diminution of the employment's quality, they have a hard situation to maintain a minimum quality [2]. The use of wind energy is important in those places where exists an appropriate resource in velocity and frequency.

There are two problems with this houses: first, the existing low income housing tends to be far below acceptable standards [3] respect to insulation of walls and roofs; and people do not have money to pay for heating. If they combine energy conservation strategies, potential solar energy is more utilizable and people can heat home spaces and partially fill their heating needs.

In Argentina, there are 8927291 homes, 8.3% of this figure do not have natural or liquefied gas, 45.1 % of which belong to rural area and 3.5 % to urban area [4]. The cost of natural gas is cheaper than liquefied gas, but people do not have enough money in order to pay for heating, water heating and cooking costs. Most of they are consuming firewood in order to provide the necessary energy. This situation can produce health effect to users and negative impact to the environment.

Current practices in low-cost housing in the province, show definite tendencies. From the typological viewpoint: small, compact shaped, detached or paired units predominate. They cover a range of areas from 45 to 90 m² and they enclose volumes from 115 m^3 to 225 m^3 according to the number of bedrooms. Multifamily housing accounts only for 5 % of the total production and are up to three stories high, usually with only two units per floor. The commonly used technology in the region for most low-income buildings include: heavy masonry walls and reinforced concrete roof slabs; a construction type which provides adequate storage mass for passive solar energy use.

From the point of view of energy conservation, low-cost houses built with FONAVI funds, should take into consideration the climatic situation of their specific locations, following the standards set by the norms IRAM (Argentine Institute of Rationalization of Materials) [3]. The requirements are not too strong and worst of all, their are not actually enforced. As a consequence, almost all houses presently built in the province do not achieve satisfactory levels of thermal comfort throughout a typical winter day. Moreover, users normally utilize less than one third of the necessary energy for space heating [5].

It is necessary to use and incorporate conservation strategies in order to reduce the impact of this problems in house heating and where possible, to use the "heat pot" to complete foods, cheap solar water heating and cheap solar cookers [1] and make use of solar energy for space heating [6].

The use of traditional insulating materials (expanded polystyrene, expanded polyurethane, glass wood, volcanic granulated, etc), it is impractical because of the cost.

To improve the conditions of energy conservation, it is proposed to use a thermal insulating material based in canes (arundo donax). The stem of this plan is a hollow cylindrical element between knots with a good resistance to flexion and compression. They have variable diameter of 2 or 3 cm and 2 or 3 meters of height.

Figure 1: canes adjoining city canals.

Figure 2: canes adjoining rural routes.

In Mendoza, (32.88º south latitude, 68.85º west longitude and 827 m.a.s.l.) it is a material that grows in the margin of the city canals (acequias). Figure 1 shows this aspect and Figure 2 shows canes that grow adjoining rural roads. Canes have been utilized in the past as a roof construction material and in vertical closings. In general they were used tied one to another with wire, been the whole supported by a pillar structure; and then covered with soil in order to give them a proper finish.

2. INSULATION SYSTEM

The insulation material is applied to preexistent walls (brick, stone or adobe) in an unconventional manner in which the canes are put in a frame horizontally rather than vertically. This provides some advantages: this attachment is easier and more positive since it permits to reduce the heat transfer caused by air turbulence because of density differences and permits the improvement in the sealing of the space between them.

Figure 4 shows the manner in which canes are placed in the frame. Canes have 2 or 3 cm and are placed in 3 or 4 rows depending on the climate. The frame is made with 2" of popler wood, that is very cheap in this zone. It is nailed or screwed to the wall.

The insulation covers the outer walls of the house and permits to account with the thermal mass of the walls towards the interior of spaces, incrementing the thermal inertia of the building. This is important because the climate of Mendoza´s province has a thermal amplitude from 10°C to 14°C and it is necessary to reduce it in order to have better natural air comfortable conditions in interiors.

3. INSULATION PROPERTIES

In order to know the approximate conductance of the insulation system, work has been done with an experimental test. Figure 4 shows a warm box built in order to measure the heat flux that goes out of the box when the interior temperature is higher than the exterior temperature. The box has been calibrated with 5 cm of expanded polystyrene which thermal conductivity is known. The insulation system is placed in the shadowed side of the box and have been measured: interior and exterior surface temperature, exterior and interior air temperature.

Heat that leaves the box, Q, is computer as:

$$Q = hi.\ Aa.\ (Ti - Tsi) = Ua\ .\ Aa.\ (Tsi-Tso) =$$
$$Q = ho\ .\ Aa\ .\ (Tso - Ta) =$$

Where:
hi = inner heat transfer coefficient [W/m².°C]
ho = outer heat transfer coefficient [W/m².°C]
Aa = perpendicular area to heat flow [m²]
Ua = thermal conductance of insulation system [W/m².°C]

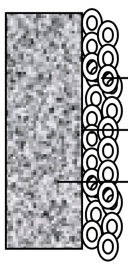

Figura 4: cross section of wall with insulation

Ti = inner temperature of the box [°C]
Ta= exterior temperature of the box [°C]
Tsi= inner surface insulating material temperature [°C]
Tso= outer surface insulating material temperature [°C]

The outer heat transfer coefficient (ho) is variable with temperature and wind velocity, but, when the experiences were made in the interior of the laboratory, velocity was near 0.
If we know Q, it is easy to calculate Ua:

Ua = Q / Aa. (Tsi-Tso) =

When Ua it is known, it is possible to compute the thermal resistance Ra = 1/Ua [m².°C/W]

The work with the warm box has been the following:

3.1- Determination of ho (outer heat transfer coefficient) with the expanded polystyrene box: in Figure 5 it is shown the determination of ho = 19.5 W/m².°C.

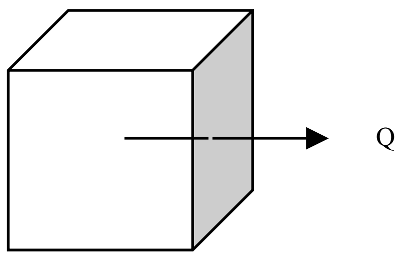

Figure 4: warm box for conductance measures.

3.2- Determination of Ra1: this is the thermal resistance of canes surfaces between two sheets of cardboard. Figure 6 shows the results of this experiment. We can see that Ra1 is 0.3373 m².°C/W.

3.3- Determination of Ra2: thermal resistance of the sheets of cardboard without the canes. Figure 7 shows this experiment and Ra2 results equal to 0.128 m².°C/W.

The determination of Ra of one row of canes is obtained computing Ra1-Ra2 = 0.209 m².°C/W. This value is equivalent to 7 mm thickness of expanded polystyrene.

4. ENERGY SAVING

In order to study the possibilities of this thermal insulation, it is considered a typical house with 2 bedrooms, a bathroom, a kitchen and a living room, with 64 m² of floor area. It is possible to calculate its thermal properties with and without thermal insulation in all brick walls. The roof is of concrete

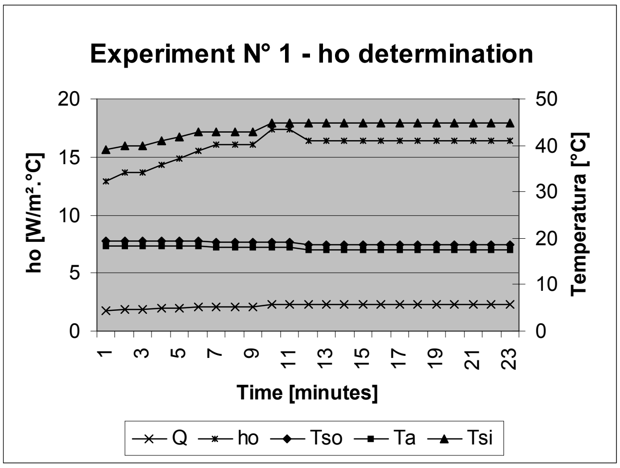

Figure 5: Determination of ho

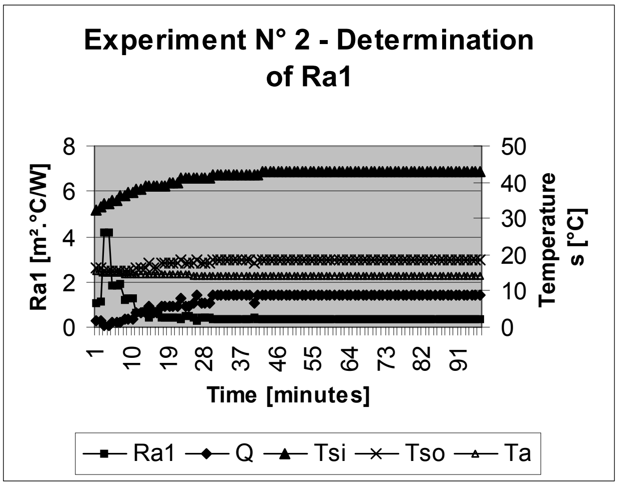

Figure 6: determination of Ra1

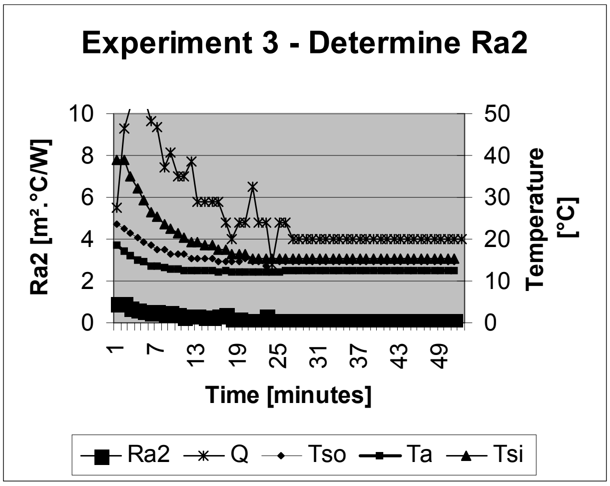

Figure 7: Determination of Ra2

slab, insulate with 2" of expanded polystyrene (preexistent), windows have one sheet of glass and steel frame. The house is solar heated by a direct gain system in the two cases.

The study was carried out in Mendoza City. The climate of Mendoza has 1384 °C.day/yr day heating degree (18°C base temperature) and 17.9 MJ/m².day as annually daily mean solar radiation for the year and have 300 clear day per year.

The annual thermal results reveal important benefits in the performance of this thermal insulation. Table I indicates the annual SSF, calculated according the SLR method [7]. The results show that without the insulation system in walls SSF is 9.7 %. When thermal the insulation system is added to walls, SSF is 14.0%. The relevant energy performance predicted values are presented also in Table I. The Net Loss Coefficient and the Load Collector Ratio (LCR) of the building are 36.2 % less with insulation; while SSF is 44.3% high. Annual building performance with insulation results 39.3% lesser in annual heating energy than it would without insulation. The power of the heating device results 32% lesser in buildings with insulation.

Table I: thermal values of building with and without insulation system.

Thermal values of building	Without insulation	With Insulation
Net Loss Coefficient [W/°C]	355.3	226.5
Load Collector Ratio [W/°C.m²]	44.4	28.3
Solar Savings Fraction [%]	9.7	14
Auxiliary Energy [kWh/yr]	14215	8625
Auxiliary Energy [kg/yr liquefied gas]	1091	662
Auxiliary Energy [kg/yr of firewood]	4084	2478
Heating power [KW]	9.19	6.24

Technologically the low income housing building makes full use of the traditional local practices: heavy concrete roof slabs, solid masonry or adobe walls and slabs on grade, thus providing the necessary thermal mass in order to reduce the inner thermal amplitude and to obtain more comfortable interior spaces.

5. CONCLUSIONS

This paper analyzes the possibility of thermal insulation with canes to be applied in low-income housing. The thermal resistance of each row of canes is 0.209 m².°C/W when put horizontally and it is necessary to use 3 or 4 rows depending of the climate of the site.

In the case of using 3 rows of cane in walls of a typical low-income house in Mendoza City, we can obtain near 40% of annual energy savings and to increase the effect of thermal inertia of walls improving thermal comfort of inner spaces.

These savings allow the improvement of the economical situation of unemployed people that use liquefied or natural gas for heating their houses and the reduction of the environmental impact from the firewood use.

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