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Interior Insulation of Walls Exposed by Polystyrene in South Algeria

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Abstract

Objectives: This article presents a theoretical and experimental study aimed at demonstrating the valuable role of the indoor thermal insulation of a building located in arid climate region. **Methods/Statistical Analysis:** Mathematical model is proposed to evaluate the effect of thermal insulation on the energy performance of the building envelope. The different temperature values of the walls and indoor air provided by the simulations are compared to those measured. It was revealed that the proposed mathematical model able to apply the real temperatures, and it is possible to carry out a study that allows showing the role of the thermal insulation. **Findings:** According to this study, the exposed walls provided with insulation give better results compared to the case where one or two walls isolated. The thickness of the polystyrene significantly affects the efficiency of the insulation and allows a remarkable damping of the fluctuations of the indoor air temperatures of the building. The results also show that the wall layer of polystyrene plays the role of a thermal barrier. The results indicate that in arid climate zone, heat gains through the walls certainly the main cause of overheating of buildings. One of the most important solutions of a passive house is to give high priority with regard to the performance of the thermal envelope, such as high insulation of walls. **Application/Improvements:** Through this model, we have been able to review some phenomena already mentioned, such as thermal storage, and to prove the effect of interior insulation on the temperature profile of walls and indoor air.

Keywords: Indoor Air Temperatures, Interior Insulation, Mathematical Models, Polystyrene, Walls Exposed

1. Introduction

The built environment has always been influenced by the climatic context to which it belongs, and often the architectural design strives to present the best fit with the environment. At this level a question arises: what will be the passive architectural tools likely to provoke this alliance? We propose in this present work to know the thermal insulation of the building.[1] The development of the cities of southern Algeria has been done in the same way as northern cities, thus marginalizing the very harsh climatic characteristics of these regions. For many years, following a crisis due to a high demand for housing, the state is victim of this approach that does not reflect the socio-cultural aspirations of the Algerian citizen and does not meet the climatic and economic requirements of these regions: buildings with arbitrary orientations, and facades including picture windows anyhow, the inappropriate choice of the use of building materials, the exposure of buildings to solar constraints (non-use of sun breezes), the majority of people build their own homes in their own way, ... etc.[2] This contribution confirms that thermal insulation is the simplest and most common solution to limit heat loss and promote solar gains in winter and to pro-

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tect against overheating in summer.[3] We will also study the influence of the thermal insulation of the building on indoor temperatures, in summer or in winter.

Thermal insulation aims to limit the losses of homes. The role is to preserve the comfort by reducing the thermal exchanges with the external environment: if this one is cold, the insulation keeps the heat; if it is hot; the insulation preserves the freshness. The insulation can be placed in a variety of ways in a wall (outdoors, sandwiched or indoors) without affecting the thermal insulation quality of the wall. However, its position modifies the inertia of the wall as well as the risk of condensation. The insulating power of a material is expressed by its thermal conductivity. Space vacuum prohibits convection and conduction, and only radiation remains. Air has, in fact, a great thermal resistance as long as the convection movements are prevented. To overcome thermal losses in the design, it is essential to choose construction methods and materials that minimize these losses through the walls. As a rule, you need excellent thermal insulation. The problem of thermal insulation and in particular of thermal bridges seems to have found the answer according to the literature: the external insulation, everything is possible if the insulation and the facings are efficient. For exterior insulation, environmentally friendly materials will be used if the installation is well done. It is therefore necessary to calculate losses by thermal link bridges and therefore to know the lengths of these links. The main role of insulation is to limit the conduction of heat, and sometimes thermal radiation. A good insulator is obviously a bad conductor of heat.[4,5] In order to reduce energy consumption in the building sector, research is increasing to aim for better insulation of the building envelope and minimize thermal losses through the walls, floors, and roof and glass walls of the building. The interior is heated or air conditioned.

For this and in order to limit the spread of heat from the inside to the outside and vice versa, it is essential to use the use of thermal insulation. Traditional insulators, called “Mass”, are the most common. Fibrous mineral insulators (glass wool, rock wool) and cellular plastic products (polystyrene, polyurethane foam) are examples. These insulators, used in the roof, walls and floors, limit thermal transfer only by conduction due to their low thermal conductivities.[6] In general, increasing the average outdoor temperature will help raise the average indoor temperature as we have seen before in projects has been achieved by our group in the research unit applied in renewable energy , increasing discomfort, this is also verified when observed developments of the inner and operative temperatures of the different thermal zone in both stages (DRC over the first floor) with different orientations. We have already done thermal studies, whether with program Python 7.2 code. This experience gave me an overview of the methods used by researchers which may help to improve the quality of my studies. We ask ourselves the question of the ideal location of a structure to lower the energy costs related to air movement.

2. Mathematical Model

The mathematical model is based on the mass and enthalpy balance equations (1, 3), which can be written as:

$$\tilde{n}_{\mathrm{air}} C_{air} V_{air,i} \frac{dT_{air,i}}{dt} = \sum_{i=0}^{N} [Q_{mas}^{trans}(i,n) C_{air} (T_{air,n} - T_{air,i})] + Qcv_{(air,i),j} + Ps_{\mathrm{int}} + Ps_{air} \tag{1}$$

We obtain a system of N equations with N unknowns; the main variables are the air temperatures in each zone. Superficial exchanges, especially convective exchanges are complex phenomena governed by the fluid mechanics laws:[7]

$$Qcv_{(air,i),j} = \sum_{j=1}^{k} \left[S_j h_{cvij} \left(T_{j,i} - T_{air,i} \right) \right] \tag{2}$$

To calculate the temperature of surface j in zone i, we can base on the conduction model given in references.[8-12] The proposed approach allows representing the multilayer system by a model based on an electrical analogy.[13] It is often used when we interest to the determination of the temperature of any node inside a wall. The working assumptions are as follows:

a. The heat transfer is unidirectional and perpendicular to the wall.
b. The air is considered a perfect transparent gas.
c. The thermo-physical properties of building materials are constant.
d. The air temperature inside the zones is uniform (nodal method).
e. The contribution of the occupant’s energy and other internal gains are negligible.

For more clarification, consult the work in the articles given in references.[6-9] As the sensible balance, with using the conservation equation of the dry air mass and considering that temporal variations in mass are very low amounts, we get the following equation:

$$m_{air}(i)\frac{d\,Hs_{air}(i)}{dt}=\sum_{i=0}^{N}\left[Q_{mas}^{trans}(i,n)\left(Hs_{air,n}-Hs_{air,i}\right)\right]+\frac{Pl_{int}}{Lv}+\frac{Pl_{air}}{Lv} \qquad (3)$$

A system of N equations with N unknowns is obtained; the main variables are the specific humidities in each zone. We can use the empirical formulas of specific humidity may be expressed as a function of relative humidity by the relationship:[6]

$$Hs=\frac{0.622P_{sat}(T)\,Hr}{101325-P_{sat}(T)\,Hr} \qquad (4)$$

$$P_{sat}(T)=e^{23.3265-\frac{3802.7}{T}-\frac{2.2343\ 10^{5}}{T^{2}}} \qquad (5)$$

3. Presentation and Building Modelling

The study was carried out on a building in Ghardaïa. The exterior envelope, apart from contributing to the energy savings during the building life by controlling the energy exchange between indoor space and environment developed a comfortable indoor environment.[10,14,7] Figure 1 is a schematic outline of apartment building, the house has a net area of 71.3 m^2, and wall heights are equal to 2.8m while the other dimensions are shown in detail in Figure 1. The flooring is placed on plan ground to lodge the ground floor. The concrete of the flooring is directly poured on the ground thus minimizing losses. Floor tiles are end coating resisting to corrosion and chemical agents[7]. The roof is composed of cement slabs and

(a) (b) (c) (d)

Figure 1. **(a)** Descriptive plans general real, **(b)** 3D view, **(c)** Interior surface of non-isolated chamber, **(d)** Interior surface of the isolated room.

concrete slab made so that it handles the load and be economical. A roof sloping of 5° allowed water evacuation through several openings. The flat roofs are considered the air infiltration in it as architectural solution. Windows and doors contribute significantly to the energetic balance. Their contribution however depends on several parameters as: local climate, orientation, frame, relative surface (window-flooring), and concealment performance during night and sunny days. In this case focus is made particularly on windows and doors dimensions and all are made of woods. The apartment has a surface of 95.74 m^2 with an occupied space of 71.3 m2.[7] In our model, the openings are on both north and south surface for the building with a main door on the East side, during the day the temperature of the outside air is greater than that of the interior. To eliminate the exchange ventilation with outdoor air, the windows and the door will be closed during the day, opened the night (the window and the door will be closed is the time or $T_{ai} < T_{ao}$ and be opened $T_{ai} > T_{ao}$) [10] by numerical simulation of the model is determined corresponding to each case. For better ventilation of the interior during the night, the door and the window will be on two different opposite wall, it is necessary to seek their guidance for minimized heat gain. During the day the windows and the door will be closed. Heat transfer is carried out as the case of an opaque member. To calculate the temperature in the inside faces of the window and the door, the same method and the same steps in the case of wall are followed.[13]

4. Validation Setup

The most commonly used indicator of thermal comfort is air temperature and relative humidity. These two basic factors should always be considered in relation to other environmental factors such as radiant temperature, air velocity, clothing insulation and metabolic heat. The advantage of our proposed model is that these four factors were taken into consideration. In this section, we will focus only on the validation of these two basic factors using Python 7.2 software. The digital model has become an indispensable tool in which we can test the assumptions imposed. These numerical models also enable the prediction to be short term by periodically injecting new values into the model. Moreover, it is for this reason that we first worked the model and then tested its internal consistency in order to validate it experimentally. A measurement companion was carried out throughout the year, we chose for validation two different days. A cold day that corresponds to January 08 2017 and another hot (July 11, 2017), the primary purpose is to test the reliability of the approach under the influence of distinct climatic conditions. In this regard, we will test results on an existing a room located in the DRC of a semi-collective residential building which consists of two blocks, each block retains 2 floors (ground floor + 1st floor) in the Applied Research Unit on Renewable Energies. The envelope is exposed to environmental changes on the north and east facade.

It means that this room is characterized by poor compactness, so it has the index equal to 1.0867. Window area represents around 8% of the total surface of the south wall. The door is plain wood, has an area of 2.2 m^2 which represents a percentage of 13.37% of the north wall surface. The previously developed mathematical model is formulated by a set of nonlinear ordinary differential equations. These were solved by using Runge Kutta fourth order numerical method, this simulation aims at computing the two basic comfort parameters and then introduce the thermal nodal method for the dynamic modeling of buildings. Information fields are connected to a node, traducing for instance the allocation of a node to a zone or also the topology of the global electrical network associated with the building. We have been induced to assign a type to each node.[6,14,7] The validity of the model was tested through the comparison of theoretical results with experimental parameters. Data were collected by 3 consoles with high precision for weather stations in such a way to consider the air stratification phenomenon. The obtained final values represent the average of the measured parameters.

5. Methodology and Confrontation of Results

For the recording of the data we used a Linseis LPD 12 acquisition unit with a digital screen of an interface of two English and German languages and a programmable menu. It has twelve individual programmable channels in mV, V and mA and can be connected to a computer for recording data.[14,7.]For the measurement of wall temperatures, five thermocouples were placed at different points on each wall. Similarly, we collected the values internal temperatures of the ambient air by placing the five thermocouples in different points. The experimental values plotted in the figures are obtained by averaging those saved. We will proceed by the figures drawn below to the validation of the model intended for the description of the thermal behavior of the part in absence and in the presence of the internal thermal insulation. The curves plotted in Figures 2, 3 respectively represent the air temperatures, and for the day of January 08, 2017 and July 11, 2017 and this before the thermal insulation the temperature profiles obtained generally show the same scenarios. The difference in the scenarios for this case also lies in the estimated and experimental temperatures. It is noted that the given temperatures by the digital model decrease then increase gradually between 6 hours and 10 hours. On the other hand, experience shows that the temperatures in this range remain practically stable. These results confirm once again the valuable role of the thermal inertia of the stone, which favours the stability of the interior temperatures of the habitat. From the point of view of comparison, it can be seen from these statements that the gap between theoretical and experimental data is quite encouraging.

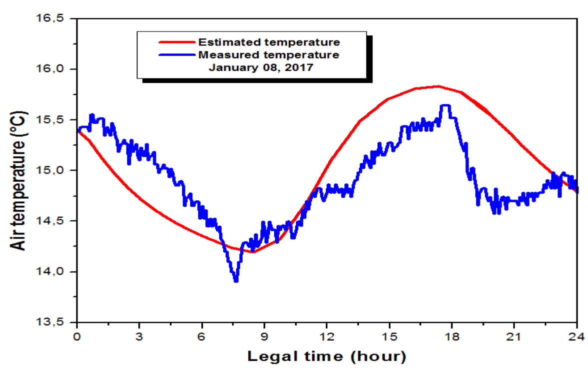

Figure 2. Air temperature inside the room, without insulation, Ghardaïa 08 January 2017.

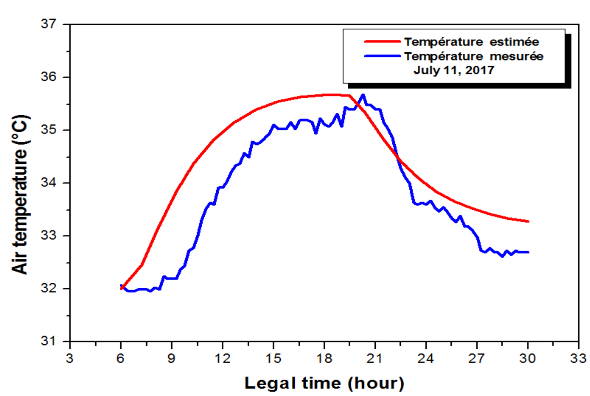

Figure 3. Air temperature inside the room, without insulation, Ghardaia 11th of July 2017.

6. Results and Numerical Simulation Presents the Role of Thermal Insulation

This study allows us to describe the evolution of the internal temperatures of our isolated room of the building considered during summer or winter. The initial conditions of all surfaces and air were chosen from the experimental values. Numerical simulation makes it possible to predict the thermal behavior for both situations; without and with thermal insulation. Figures 4 and 5 deliver the indoor air temperature and exterior surface temperature curves of the room wall for both days (hot and cold). In the case of insulation, we isolate all the surfaces of the room by 4 cm polystyrene. In this context, the day of January 2nd and 6th June 2017 to carry out this study.

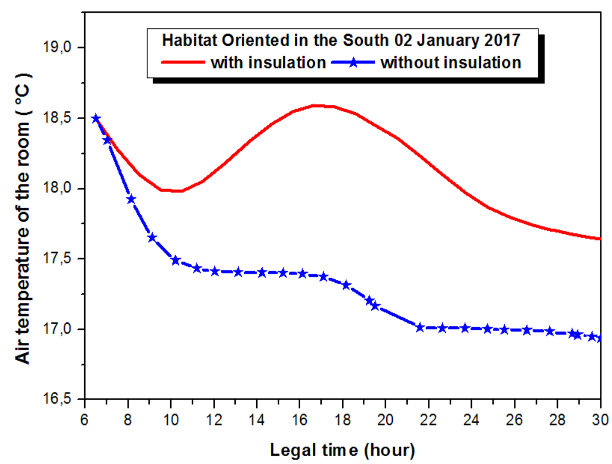

Figure 4. Indoor air temperature of the Room, 02 January **2017.**

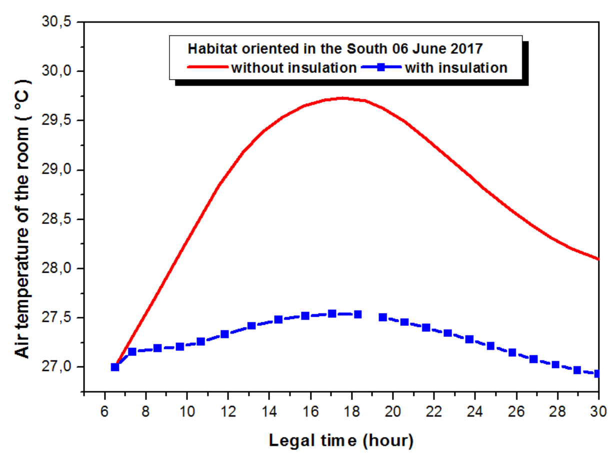

Figure 5. Indoor air temperature of the Room, 02 June 2017.

7. Conclusion

The thermal insulation of the walls and roof reduces the feeling of cold that may exist in winter. The current question that inevitably arises: to what extent does theory and practice correspond? The concordance is so encouraging given the equipment and materials used. We presented the effect, impact and influence of thermal insulation on thermal comfort. These works and research activities make it possible to draw some standards and criteria that are very interesting to act and to acquire a perfect and admirable insulation.

8. References

1. Lajimi N, Boukadida N. Numerical study of the thermal behaviour of bi-zone buildings. Comptes Rendus Physique. 2015 Oct; 16(8):708–20. Crossref.
2. Jaffal I, Inard C, Bozonnet E. Toward integrated building design: A parametric method for evaluating heating demand. Applied Thermal Engineering. 2012 Jul; 40:267–74. Crossref.
3. Tsoutsou S, Ferreira CI, Krieg J, Ezzahiri M. Building integration of concentrating solar systems for heating applications. Applied Thermal Engineering. 2014 Sep; 70(1):647–54. Crossref.
4. Mosaffa H, Ferreira CAI, Rosen MA, Talati F. Thermal performance optimization of free cooling systems using enhanced latent heat thermal storage unit. Applied Thermal Engineering. 2013 Sep; 59(1-2):473–9. Crossref.
5. Chidambaram LA, Ramana AS, Kamaraj G, Velraj R. Review of solar cooling methods and thermal storage options. Renewable and Sustainable Energy Reviews. 2011 Aug; 15(6):3220–8. Crossref.
6. Bekkouche SMA, Benouaz T, Hamdani M, Cherier MK, Yaiche MR, Benamrane N. Judicious choice of the building compactness to improve thermo-aeraulic comfort in hot climate. Journal of Building Engineering. 2015 Mar; 1:42–52. Crossref.
7. Hamdani M. Choix de l'Orientation et des Matériaux de Construction en Vue d'Améliorer les Performances Thermiques des Bâtiments. [Thèses]. University of Tlemcen; 2016 Jun. p. 1–190.
8. Rumianowski P, Brau J, Roux JJ. An adapted model for simulation of the inter-action between a wall and the building heating system. Proceedings of the Thermal Performance of the Exterior Envelopes of Buildings IV Conference; Orlando, USA; 1989. p. 224–33.
9. Bekkouche SMA, Benouaz T, Cherier MK, Hamdani M, Yaiche MR, Benamrane N. Influence of the compactness index to increase the internal temperature of a building in Saharan Climate. Energy and Buildings. 2013 Nov; 66:678–87. Crossref.
10. Bekkouche SMA, Benouaz T, Cherier MK, Hamdani M, Benamrane N, Yaiche MR. Thermal resistances of local building materials and their effect upon the interior temperatures case of a building located in Ghardaïa region. Construction and Building Materials. 2014 Feb; 52:59–70. Crossref.
11. Hamdani M, Bekkouche SMA, Benouaz T, Cherier MK. A new modelling approach of a multizone building to assess the influence of building orientation in Saharan climate. Thermal Science. 2015; 19(2):591–601. Crossref.
12. Cherier MK, Bekkouche SMA, Benouaz T, Hamdani M, Benamrane N, Halloufi O. Studies and choice of local building materials for improving interior temperatures of a building located in Ghardaïa region. Proceedings of the 13th International Multidisciplinary Scientific Geo Conference SGEM Renewable Energy Sources and Clean Technologies; Albena, Bulgaria; 2013 Jun. p. 235–42.
13. Bekkouche SMA, Benouaz T, Cherier MK, Hamdani M, Yaiche MR, Benomrane N. Influence of the compactness index to increase the internal temperature of a building in Saharan climate. Energy and Buildings. 2013 Nov; 66:678–87. Crossref.
14. Hamdani M, Bekkouche SMA, Benouaz T, Belarbi R, Cherier MK. Minimization of indoor temperatures and total solar insolation by optimizing the building orientation in hot climate. Engineering Structures and Technologies; Taylor & Francis. 2014 Dec; 6(3):131–49. Crossref.