

THE EFFECT OF THE THERMAL INERTIA ON THE TEMPERATURE OF A HEATING SLAB.

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Abstract

The paper presents the influence of the thermal inertia on the temperature of a heated concrete slab. This is a solar sensor provides a solar heating system floor, which the energy input.

The concept of thermal inertia is not easy to grasp. It is defined as the speed that helps a system ((building in our case) reacts to the change in operating conditions. The response of the building facing to the stresses is largely depending on the thermal properties of constituent materials. This feature is related to good performance, good use, and comfort of the thermal machine which is called “habitat”.

The objective of this work aims to study the influence of the inertia on the surface temperature of the floor, to design the future of homes with high inertia and very low energy consumption with satisfactory comfort conditions.

Keywords: *thermal inertia, solar heating, solar collector, floor, Forte inertia habitat.*

Résumé

L'article présente l'étude de l'influence de quelques facteurs de l'inertie thermique sur la température d'une dalle construite en béton. Il s'agit d'un système de chauffage solaire par plancher dont l'apport d'énergie est assuré par un capteur solaire.

La notion d'inertie thermique n'est pas facile à appréhender. Elle est définie comme étant la vitesse avec laquelle un système (bâtiment) réagit à un changement de régime de fonctionnement. La réponse du bâtiment face aux sollicitations dépend en grande partie des propriétés thermiques des matériaux qui le constituent. Elle participe au bon rendement, à la bonne utilisation et au confort de la machine thermique qu'est aussi l'habitat.

L'objectif de ce travail est justement d'étudier l'influence de nombreux paramètres de l'inertie sur la température superficielle du plancher, qui puisse permettre à l'avenir de concevoir des bâtiments à forte inertie et à très faible consommation énergétique avec des conditions de confort satisfaisantes.

Mots clés: *Inertie thermique, Chauffage solaire, Capteur solaire, Plancher, Forte inertie, L'habitat.*

ملخص

تقدم هذه الدراسة تأثير بعض عوامل الجمود الحراري على درجة حرارة أرضية من الخرسانة. هو عبارة عن نظام تدفئة شمسية بواسطة أرضية من الخرسانة موصولة بلاقط شمسي. إن مفهوم الخمول الحراري معقد نوعا ما، حيث يعرف بأنه سرعة استجابة النظام (البناء) للتغير في ظروف التشغيل. إن استجابة المباني إلى الضغوطات والتغيرات يرتبط إلى حد كبير بالخصائص الحرارية للمواد المكونة لها، فتشارك في مردودها الجيد واستعمالها كجهاز حراري (بناء) آمن ومريح. والهدف من هذا العمل هو على وجه التحديد دراسة تأثير العديد من عوامل الخمول الحراري على درجة حرارة سطح أرضية الخرسانة. والذي يمكن أن يساعدنا في المستقبل على تصميم مباني ذات خمول حراري عالي و استهلاك منخفض جدا للطاقة مع توفير شروط الراحة المرضية.

الكلمات المفتاحية: الخمول الحراري، التدفئة الشمسية، لاقط شمسي، أرضية، بناء.

I. INTRODUCTION :

Today, the construction industry goes into a new era. The energy consumption of buildings representing Algeria, almost 47% of the energy produced and they are responsible for over 25% of greenhouse gas emissions must be reduced by economic and energy solutions respect to the environment. For this, improving the building's envelope which is reinforced by insulation and better treatment of thermal bridges which introduce lower thermal requirements in air conditioning and heating should be taken into consideration. Further research should focus on efficient building heating systems to control the atmosphere of living with a lower energy cost. Certainly, maintaining the atmosphere is entrusted to the heating system whose quality depends greatly on the design, the design and implementation of the facility. At the same time, technological development in the field of current heating needs to go parallel to the direction of reducing the negative environmental impact through the use of renewable energy sources and to ensure also the security of our energy supplies facing the depletion of fossil energy resources.

In this approach, the heated floor has a particular place in technology. It provides optimal heat distribution vertically and horizontally, perfectly compatible with renewable energy sources. It is one of the flow temperature systems which reduces the energy consumption through its use.

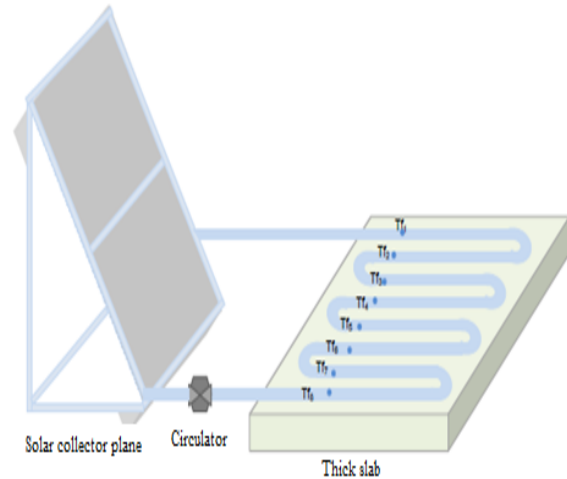
Research has been undertaken on this heating technology and several designs were studied. A. Mokhtari et al (1992) demonstrated in a theoretical and experimental study of a storage room with a direct solar floor a capture ratio of 8 to 10% is more than enough according to the Algerian climate. The authors also noted that a sensor surface equal to 10% of the heating floor's surface can be used without fear of overheating [1].

For the dimensions that are suitable for our climate, and to avoid the overheating phenomenon and have some thermal comfort. Kharchi A. (2000), used a report in his experimental study, capture area / exchange area (slab) equal to 0.5, for a slab thickness of 10 cm above the grid [2].

I. THE HEATING SYSTEM

A direct solar floor consists essentially of three elements:

- The solar panel captures that convert transforms sunlight into heat.
- A slab wherein in which the heat transfer fluid heated by the sensors. The latter simultaneously serves to store the heat generated by the sensors and to return in the same way as a conventional low-temperature floor heating, but with a certain time lag.
- A transfer group that manages the heating of the PSD [3].



II. MATHEMATICAL FORMULATION SYSTEM

The system is modeled according to a nodal method, based on the heat balances of each element which constitutes the heating system: sensor, coolant, floor consisting of a concrete slab.

A. Simplifying assumptions

- the physical properties of materials are assumed to be constant.
- The flow regime is transitional.
- The different solid media have a uniform temperature in a plane normal to the direction of flow.
- The heat flows are of one-dimension.
- The heat transfer fluid used is a pure water.
- the heat losses between the solar collector and the floor are negligible.
- The temperature of the water leaving the solar collector is equal to that of the water at the inlet of the under floor heating.
- We limit ourselves only to study the exchange of heat from the top of the coil (the floor is well isolated from the ground side).
- The heat transfer fluid circulates on the velocity u in the tube.
- The floor temperature is considered uniform.

B. Heat balance

1) Useful power recovered by the fluid

The useful power recovered by the heat transfer fluid is governed by the equation [4], [5]:

$$P_u = F_R \cdot ((\tau\alpha)_{\text{eff}} \cdot P_g - U_g \cdot (T_{fe} - T_a)) \cdot S_c \quad (1)$$

Or :

$(\tau\alpha)_{\text{eff}}$: Effective coefficient of absorption.

F_R : Overall efficiency of the thermal exchange of the sensor.

T_{fe} : Entered temperature of the coolant.

P_g : Overall power.
 U_g : overall heat loss.

2) Heat balance at the hot slab

By performing a heat balance at each node, we obtain a system of two equations describing the behavior of the floor.

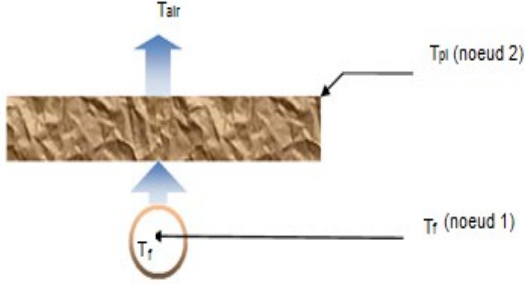


Fig.2. Nœuds considered in the floor

• Nœud 1 : (the heat transfer fluid)

$$\begin{aligned} M_f C_{p_f} \frac{\partial T_f}{\partial t} + U_f C_{p_f} \frac{\partial T_f}{\partial y} \\ = h_{vplf} S_{plf} (T_{pl} - T_f) \\ + h_{cplf} S_{pl} (T_{pl} - T_f) \end{aligned} \quad (2)$$

Dividing by $M_f C_{p_f}$, we obtain:

$$\begin{aligned} \frac{\partial T_f}{\partial t} + \frac{V_f V_{fmax}}{M_f} \frac{\partial T_f}{\partial y} \\ = \frac{h_{vplf} S_{plf}}{M_f C_{p_f}} (T_{pl} - T_f) \\ + \frac{h_{cplf} S_{pl}}{M_f C_{p_f}} (T_{pl} \\ - T_f) \end{aligned} \quad (3)$$

• Nœud 2: (the floor)

$$\begin{aligned} \frac{dT_{pl}}{dt} \\ = \frac{h_{vplf} S_{plf}}{M_{pl} C_{p_{pl}}} (T_f - T_{pl}) \\ - \frac{S_{pl}}{M_{pl} C_{p_{pl}}} (\phi_{vpla} \\ + \phi_{rpl}) \end{aligned} \quad (4)$$

With:

ϕ_{rpl} : Exchangeradiantwith air.
 ϕ_{vpla} : Exchangeconvectionwith air.

This equation completed by the initial conditions and system boundary, forms a system of nonlinear equations and coupled. The resolution is performed by the finite difference method using the descending implicit scheme for the convective term fluid and an explicit scheme for the transient term.

III. RESULTS AND DISCUSSION

The thermal inertia imposes a certain time delay between the moment when the water is introduced into the tube and the temperature of the surface varies.

The thermal inertia associated with conduction's phenomenon depends on the thickness of the slab and the thermo physical characteristics of the materials which consist of (volume, mass thermal conductivity, thermal emissivity) [2].

A. Temporal variation in useful power of the sensor

It is evident that the useful power recovered by the fluid closely depends on the global solar radiation. Thus, and as shown in Figure 3, the useful power (heat supplied to the floor) has a bell shape, it is between 120 and 300 watts.

This result has a good agreement with what was found in the literature [2].

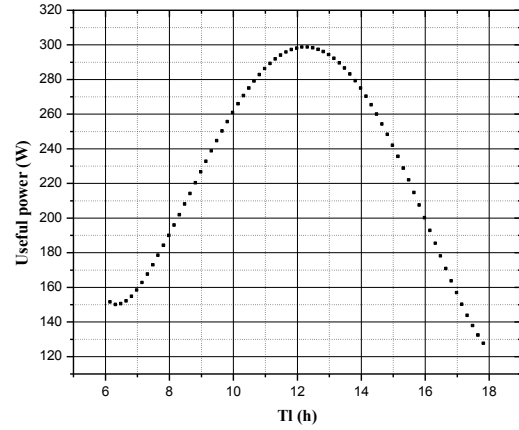


Fig .3. Variation temporal of the useful power of the sensor

B. Assessment of the role of inertia on the floor temperature

1) Influence of the thickness of the concrete

a)-Effect of the thickness of the concrete on the floor temperature

Figure 4.a illustrates the evolution of the floor's maximum temperature as a function of time for different thicknesses of the concrete's layer. It is clear that the maximum temperature of the floor decreases when the thickness of the layer of concrete increases.

The floor temperature will be even weaker than the concrete mass is important.

b) Effect of the thickness of the concrete over the useful power

In Figure 4.b we can find that the consumption of useful power decreases when the thickness of the upper concrete layer is increased (the thermal losses

between the sensor and the slab being assumed negligible, the heat transferred to the slab is thus equal to the energy captured by the "power output" sensor).

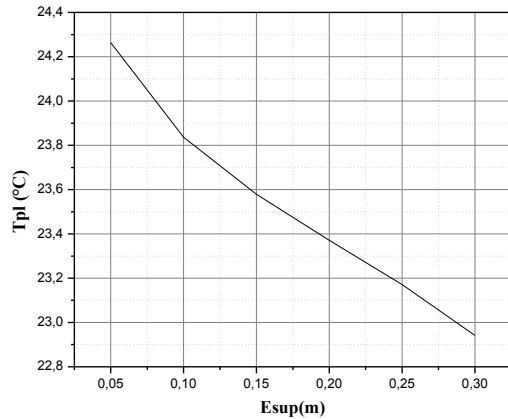


Fig .4.(a) Influence of the thickness of the concrete on the floor temperature.

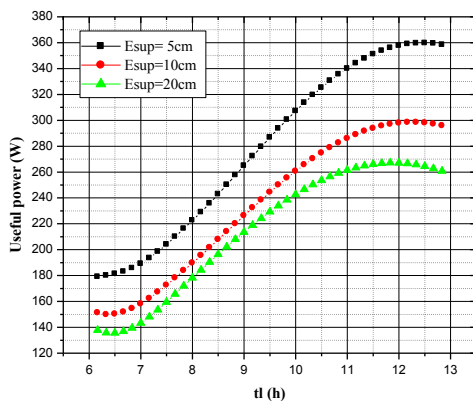


Fig .4.(b) Effect of the thickness of the top layer of the useful power .

2) Influence of the thermal resistance of concrete

It is evident that the floor's temperature is highly dependent on the thermal resistance of the top layer of concrete. Thus, and as seen in Figure 5, the increasing of the thermal's resistance of concrete leads to lower of the heat exchange with the atmosphere which directs to a reduction of the floor temperature.

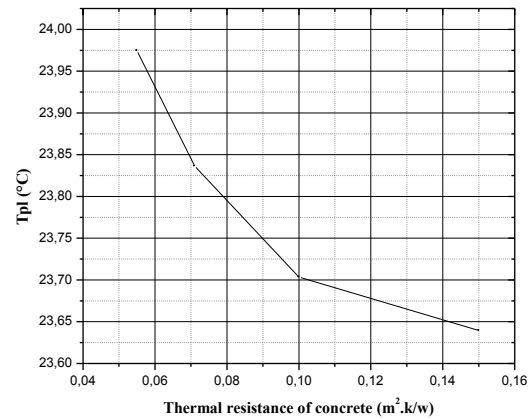


Fig .5. Evolution of the floor temperature in function of the thermal resistance of the top layer of concrete

3) Influence of emissivity of concrete

The examination of the curves in Figure 6 allows saying that the floor temperature is more important in the case where the radiation is not taken into consideration; in this case the amount of heat transferred to the air will be considerably larger.

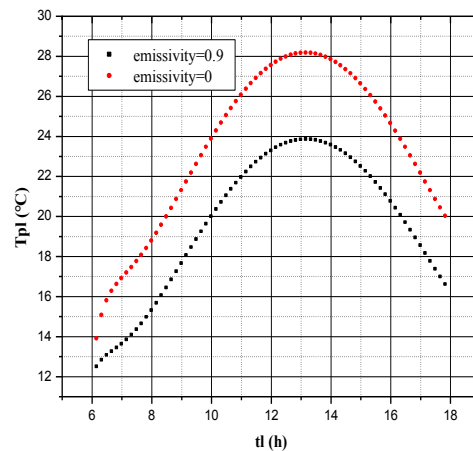


Fig .6. Temporal evolution of the temperature of a radiant floor and a non-radiant floor

CONCLUSION

Thermal inertia is thus a complex phenomenon. Multiple criteria should be taken into account to obtain the same comfort for less consumption.

The result of the study conducted the following conclusions:

The inertia of the floor is directly related to the thickness of the concrete layer located above heating pipes. With this configuration, it has been shown that the floor temperature was even lower than the concrete mass increased.

Therefore, it is recommended to increase as much as possible the thickness of the top layer of concrete. Nevertheless, we cannot afford to have too thick floor. Indeed, the "National Building Code" sets the minimum thickness of concrete floors of homes to 75 mm for the slab itself, and the use of a greater thickness is not necessary. A slab 10 cm thick may be a compromise quite interesting. Furthermore, the nature of the floor covering affects the thermal power emitted by the floor and its surface temperature.

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