Construction and Building Materials 52 (2014) 59–70

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Thermal resistances of local building materials and their effect upon the interior temperatures case of a building located in Ghardaïa region

S.M.A. Bekkouche [a,*], T. Benouaz [b], M.K. Cherier [a], M. Hamdani [a], N. Benamrane [a], M.R. Yaiche [c]

[a] *Unité de Recherche Appliquée en Energies Renouvelables, URAER, Centre de Développement des Energies Renouvelables, CDER, 47133 Ghardaïa, Algeria*
[b] *University of Tlemcen, Laboratory of Automatic, BP. 119, R.p. 13000 Tlemcen, Algeria*
[c] *Centre de Développement des Energies Renouvelables, CDER, BP 62 Route de l'Observatoire, Bouzaréah, 16340 Algiers, Algeria*

HIGHLIGHTS

- The heat gain through the walls is the main cause of overheating during warm period.
- Air cavities are bounded by a thin reflective material layer.
- An optimized building envelope takes into account thermal properties and building materials.
- Hollow bricks provide the best compromise of thermal comfort.

ARTICLE INFO

Article history:
Received 4 January 2011
Received in revised form 10 October 2013
Accepted 31 October 2013
Available online 30 November 2013

Keywords:
Temperature
Hollow brick
Cinderblock
Stone
Thermal resistance
Thermal insulation

ABSTRACT

In desert regions, the heat gain through the walls is the main cause of overheating during warm period. In the present work, we carry out a study on the influence of the buildings envelop on the internal temperature by using local building materials. The main objective is to determine the temperatures of the mentioned building with various exterior wall configurations. This study aims at assessing also the Grashof number Gr of air layer which is arises throught the study of situations involving natural convection, providing a variety of results.

As a result, this work proves that an optimized building envelope takes into account thermal properties and building materials. The major concept of the thermal rehabilitation is based on the wall composition especially on the calculation of the walls thermal resistances. In the literature, values of thermal resistance of air spaces are very different. In this regard, other factors must be taken into consideration in these measurements such as the mobility of air in all wall elements which contributes as an insulating effect. Indeed, the numerical simulation save a great deal of time and effort in computational terms and showed that the horizontal position of the hollow brick gives the best results. In this sens, a building envelope, as a passive source of energy, is a critical factor. In conclusion, to achieve a better thermal comfort in arid and semi arid regions, a new configuration of the wall has been proposed, it allows to enhance the thermal insulation of the envelop while eliminating thermal bridges.

1. Introduction

With environmental protection posing as the number one global problem, man has no choice but to reduce his energy consumption. One way to accomplish this is to resort to passive and low-energy systems to maintain thermal comfort in buildings [1]. The Ecology of Building Materials explores key questions surrounding sustainability of building materials. Bjorn Berge [2] provides technical data to enable design and building professionals to choose the most appropriate materials for a project: those that are least polluting, most energy efficient, and from sustainable sources. Progress may be enabled by the deployment of materials which are adapted to the local climate within buildings, and the adoption of building-integrated renewable energy conversion technologies.

JA Clarke et al. describe the integration of cooperating passive and active renewable technologies within a major building refurbishment in Glasgow [3]. In Ref. [4], Enrico Fabrizio et al. show that increasing interest is currently being addressed to multi-energy systems in buildings. These systems integrate different techniques and energy sources, in order to cover the thermal and electrical loads of a building. However, the design and operation of such systems are very complicated; it is of the foremost importance to provide tools to select the best system configuration. The conclusions

---

* Corresponding author. Address: URAER & B.P. 88, ZI, Gart Taam Ghardaïa 47000, Algeria. Tel.: +213 661 31 76 29; fax: +213 29 87 01 52.
E-mail address: smabekkouche@yahoo.fr (S.M.A. Bekkouche).

0950-0618/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.conbuildmat.2013.10.052

Nomenclature

ρ_{air}	air density (kg m^{-3})
C_{air}	the specific heat of air, it is assumed constant and estimated at 1008 (m^2 s^{-2} K^{-1}, J kg^{-1} K^{-1})
V_{air}	air volume (m^3)
T_{air}	air temperature (K)
T_{Surf}	air temperature walls inner surfaces (K)
S	surface (m^2)
Q_{Gain}	direct solar gain due to openings (W)
Q_{Surf}	thermal power due to exchange between the air and, (i) walls inner surfaces and (ii) windows and doors (W)
$Q_{Heating}$	thermal power provided by heating equipment (W)
$Q_{Cooling}$	thermal power provided by cooling equipment (W)
Q_{Inf}	thermal power gain due to air infiltration (W)
Q_{Vent}	thermal power gain due to air ventilation (W)
m_{Inf}	the air flow due to infiltration (kg/s)
T_{out}	air temperature outside the building (K)
C_p	specific heat (J kg^{-1} K^{-1})
$T_{Vent,out}$	air temperature at the ventilation outlet (K)
$T_{Vent,int}$	air temperature at the inlet ventilation (K)
i	tilt angle (degrees)
Gr	Grashof number
h_{Conv}	the convective transfer coefficient (W m^{-2} K^{-1})
ρ	density (kg/m^3)
g	acceleration due to Earth's gravity (m/s^2)
β	volumetric thermal expansion coefficient (equal to approximately $1/T$, for ideal fluids, where T is absolute temperature)
L	length (m)
$\Delta\theta$	the temperature difference between surface and fluid (K)
μ	dynamic viscosity (Pa s)

in Ref. [5] stress the importance of creating common patterns of design for a better performances achieving of buildings, owing to the fact that traditional models have been inherited and already exist as valid references. In [6] the purpose is to appraise alternative building materials and technologies for wall and roof construction. The replacement of a conventional technology with an alternative material must be measured against the cost of the building as a whole. However, some simple experiments were carried out at the Building Physics Laboratory of the Engineering Faculty of Porto University FEUP. A sensibility study was performed with LFC's equipment to evaluate how measurements are influenced by emissivity, environmental conditions, color and reflectivity [7]. For the selection of construction materials and taking into account the thermal aspect, the chemical analysis of building materials such as gas concrete, cement, sand, marble, brick, roofing tile, lime and gypsum used in Turkey were carried out to assess the chemical components of these samples [8].

On the other hand, predictive numerical models have been widely used. The accomplished task in the current paper has as goal on one hand to develop an energy balance model and on the other hand to contribute to the creation of corresponding simulation tools. A developed model consisting of an elaborated computing program appropriate to the current application was proposed. This paper discusses and analyses some walls configuration, that propose energy savings and the use of local material revalidating the envelop of the Saharan construction. In Ghardaïa region, stone cinderblock and hollow brick are the most used construction materials due to their availability. A typical most commonly used construction in the region had been chosen.

2. Location, climate and descriptive of typical house plan

Ghardaïa region (32.4°N, 3.8°E) is located 600 km from the coast, at an altitude of 450 m above sea level. It is influenced by a dry climate, characterized by very low precipitations (160 mm/year), very high temperatures in summer and low temperatures in winter (frosty from December to mid-February). The climate is hot and dry in the summer with temperatures variation between a maximum of around 45 °C and a minimum of 20 °C, thus giving a large diurnal temperature swing. Winter temperatures vary between a maximum of 24 °C and a minimum of 0 °C. Its normal temperature in January is 10.4 °C; it is 36.3 °C in July. The average annual range is about 12.2° amplitudes of monthly average temperatures. They are more moderate in winter than in summer (average 11° in winter cons 13.5° in summer). The monthly maximum amplitudes are larger in summer than in winter fluctuates around 20 °C. Solar radiation is intense throughout the year with a maximum of 700 W m^{-2} in winter and 1000 W m^{-2} in summer, measured on the horizontal surface. This Saharan climate result that insulation is necessary, some requirements have been identified by Fezzioui et al. [9]. Chelghoum et al. [10] paper discusses adaptation for climate change through a local adaptation strategy at a variety of scales, showing how to manage high temperatures.

In Ghardaïa region, stones are the most used construction materials. It is has been used for centuries (since the foundation of the town at 1200 J) due to their availability and also due the lack of other construction materials such as wood (Vegetation are low due to the climate). A typical most commonly used construction in the region had been chosen. Fig. 1 is a schematic outline of real apartment building situated whether at the ground or at the first floor of two storey building. The house has an area of 88 m^2; wall heights are equal to 2.8 m while the other dimensions are shown in detail in Fig. 1. This apartment includes the following elements:

- Building envelops or outer wall consisting of a heavy structure generally constituted of stones (40 cm thick) jointed and surrounded by two layers having thickness of 1.5 cm of mortar cement. The most inner face is coated with 1 cm thick plaster layer.
- The inner walls (or splitting walls) whose sides are in contact only with the internal ambient are considered to be of heavy structure constructed of stones of 15 cm width jointed and surrounded by two mortar cement layer of 1.5 cm thick and two layers of 1 cm thick of plaster.
- 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 inter-imposed, it is an end coating resisting to corrosion and chemical agents.
- The roof is composed of cement slabs and concrete slab made so that it handles the load and be economical. A roof sloping of 5° allows water evacuation through several openings. Until now the flat roofs are considered as nest infiltration and 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.