Renewable Energy 71 (2014) 589–597

Contents lists available at ScienceDirect

Renewable Energy

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

Impact of passive cooling techniques on energy demand for residential buildings in a Mediterranean climate

K. Imessad [a,*], L. Derradji [b], N.Ait Messaoudene [c], F. Mokhtari [a], A. Chenak [a], R. Kharchi [a]

[a] Centre de Développement des Energies Renouvelables, Route de l'observatoire, BP 62, Bouzaréah, Alger, Algeria
[b] Centre National d'Etudes et de Recherches Intégrées du Bâtiment, CNERIB, Alger, Algeria
[c] The "Teacher Mohamed Binladin" Research Chair on Quality and Productivity Improvement in the Construction Industry, University of Hail, Saudi Arabia

ARTICLE INFO

Article history:
Received 31 October 2013
Accepted 4 June 2014
Available online 1 July 2014

Keywords:
Experimental study
Dynamic simulation
Thermal inertia
Night ventilation
Overhang
Energy saving

ABSTRACT

This study presents the thermal analysis of a building prototype, which was designed and built in accordance with energy efficiency measures to improve indoor thermal comfort, particularly in summer. The building prototype is located in Souidania (20 km southwest of Algiers, latitude 36°7N, Longitude 03°2E). The location is characterized by a temperate Mediterranean climate. In order to perform this analysis, various activities are carried out: a series of monitoring campaigns; dynamic simulations with TRNSYS software, calibration of the model with experimental data and comparative study with buildings that use different wall constructions. Based on a validated building thermal model, dynamic analysis is carried out in order to evaluate the impact of thermal mass and of eaves and night ventilation. The results demonstrate that cooling energy demand is more affected by thermal transmittance values than by the envelope thermal mass. A recommended guideline for the optimum overhang length for south-facing windows is proposed. Ultimately, it is found that the combination of both natural ventilation and horizontal shading devices improves thermal comfort for occupants and significantly reduces cooling energy demand.

1. Introduction

During recent decades, buildings energy consumption has significantly increased in Algeria. Nearly 42% of energy consumption of the country is allocated to this sector [1]. Most of this energy consumption is due to space heating and cooling. Due to rapid economic growth and growing desire for better indoor environment, energy demand for heating and cooling is expected to increase steadily. Thus, building sector has a significant potential for energy savings.

A previous construction program in Algeria has yielded the construction of 1,000,000 housing units from 2005 to 2009. Unfortunately, most of the houses constructed under this housing program exhibit a poor energy performance. This lack of performance could be avoided with a design that integrates energy efficient solutions for improving the thermal performance.

In the literature, there are many studies on different aspects of building energy efficiency [2–6]. Some studies analyze typical residential houses in the Mediterranean region and finds that specific energy consumption can be reduced once proper windows and shading devices are used in addition to insulating the roof and ceiling [7–9]. Ferrante et al. [10] consider local materials and traditional architecture as solutions for energy efficiency in buildings and show that it is possible to built dwellings with very low energy consumption and near-zero CO_2 emissions in the Mediterranean climate.

Beside thermophysical characteristics of the building envelope, other passive techniques such as ventilation rate and solar control allow a reduction in energy demand both for heating and cooling [11,12]. Rising conventional energy prices and environmental considerations have resulted in increased interest in the integration of energy efficiency solutions and the use of free and inexhaustible sources of energy [13].

The present article focuses on the energetic aspect of a prototype dwelling built in the framework of MED-ENEC Project (Mediterranean Energy Efficiency in the Construction sector). This dwelling is built for demonstrating best practices and new technologies as well as integrative approaches for efficient use of energy and use of renewable energies in the building sector. Thermal performances of the pilot dwelling are studied during the summer

* Corresponding author. Fax: +213 2 90 16 54, +213 2 90 15 60.
E-mail address: imessad@gmail.com (K. Imessad).

http://dx.doi.org/10.1016/j.renene.2014.06.005
0960-1481/

period. For this purpose, the study includes a series of experimental activities and numerical simulations in dynamic state. The main goal is to demonstrate that suitable energy performances can be obtained using low-energy design strategies in a Mediterranean climate.

2. Description of the pilot dwelling

The pilot dwelling is a low-energy house with 65 m^2 net floor area; 3 rooms, 1 kitchen, 1 bathroom, and lavatories. The prototype (Fig. 1) is designed as a typical single family home; it is built in accordance with Algerian building code [14,15]. The home is located at Souidania (20 km southwest of Algiers, latitude 36°7N, Longitude 03°2E). The location is characterized by a temperate Mediterranean climate with rainy and relatively mild winters and hot-humid summers. The dwelling is designed for good energy efficiency based on optimal insulation of the envelope and use of solar energy for space heating and domestic hot water production. Its enhanced thermal efficiency reduces energy demand for heating and cooling. The house is equipped with four thermal solar collectors with a total area of 8 m^2. This solar system provides domestic hot water and space heating through the floor.

The house has a compact shape and is oriented along the E–W axis. The living room and bedroom have medium size windows (12% of floor area) south oriented in order to gain heat from the winter sun in cooler months. A roof overhang of 75 cm is provided for south-facing windows in order to prevent direct solar radiation during summer. All openings are high efficiency double glazed PVC windows 4/6/4 (4 mm clear glass + 6 mm air-gap + 4 mm clear glass) with an overall specific heat transfer coefficient of 2.6 W/(m^2 °C). The wall facing west has no openings in order to prevent overheating. On the other hand, the house is cooled by passive techniques combining natural ventilation and high thermal inertia walls and ceiling slabs. Prevailing summer winds (sea breeze) are oriented N–E. Accordingly, openings are oriented for optimal exploitation of natural ventilation in accordance with the prevailing wind pattern. Moreover, occupants have the possibility of controlling the ventilation rate by operating windows.

Considering the environmental impacts caused by over exploitation of natural resources for the production of building

Table 1
U values of the building envelope.

	Composition	Thickness (m)	Thermal conductivity (W/m.K^{-1})	U (W/m^2.K^{-1})
External wall	SEB	0.14	1.3	0.36
	EPS	0.09	0.040	
	SEB	0.29	1.3	
Floor	Concrete	0.05	1.75	0.54
	EPS	0.06	0.040	
	Concrete	0.15	1.75	
	Mortar + sand	0.03	1.15	
	Tiling	0.02	1.7	
Ceiling	Mortar	0.03	1.60	0.23
	EPS	0.16	0.040	
	Concrete	0.08	1.75	
	Plaster	0.03	0.35	

materials, cement stabilized earth is used for load-bearing walls. Soil based construction blocks have been used in North Africa for centuries; especially in rural and Saharan regions [16]. Topsoil can be used for construction of walls in many ways. However, there are a few undesirable properties such as loss of strength when saturated with water, erosion due to wind or driving rain and poor dimensional stability. These drawbacks can be significantly eliminated by stabilizing the soil with a chemical agent such as cement [17]. In our case, the foundation soil was used to fabricate bricks of 29 × 14 × 9 cm dimensions by mixing it with cement (at around 5%) and then compressing it manually in adapted molds. External walls are made of a sandwich structure which consists of an expanded polystyrene insulation layer inserted between two block layers. In order to avoid any heat transfer through the roof, the ceiling is insulated with a 16 cm thick layer of polystyrene.

Thermal inertia is an important parameter in designing energy-efficient buildings. In order to incorporate this parameter, the inside layer is made 29 cm thick. The design of the blocks and the construction techniques are performed in accordance with the recommendations of the ministry of housing [18,19]. Table 1 gives U-values of external walls, ceiling and floor. Thermophysical properties of stabilized earth blocks (SEB) used in the construction have been determined by the hot wire method using CTMETER equipment [20].

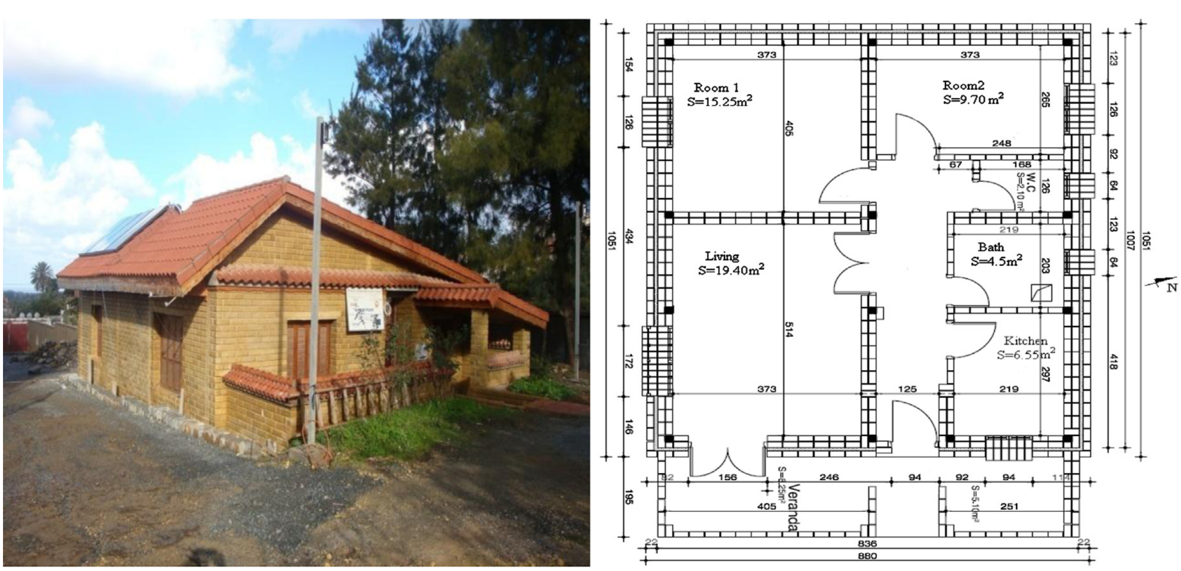

Fig. 1. The prototype dwelling.