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Influence of the compactness index to increase the internal temperature of a building in Saharan climate

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ABSTRACT

Some variables that are related to building shape and which influence heating and cooling requirements are the following: compactness index, the height of walls, climate, and the characteristics of the building envelope. These characteristics are crucial variables that should be taken into account because they are relevant to the energy requirements for maintaining the building at a comfortable temperature.

This paper introduces a new approach to the description and modelling of multizone buildings in Saharan climate. Therefore, thermal nodal method was used to apprehend thermal behaviour of air subjected to varied solicitations. The result proves that proper use of compactness index and building geometry parameters will noticeably minimize building energy and improve the internal temperature of the building. The compactness is better when the compactness index is lower.

1. Introduction

Optimized architectural design in the initial conceptual phase would help reduce the energy consumption of buildings in an efficient way. This is because architectural qualities extensively affect the energy performance of a building in terms of orientation, compactness, building morphologies, building envelopes, materials, functions, etc. The shape of the building has a significant impact on both construction costs and energy costs of buildings. The main impact of building compactness from the indoor climate point of view is its effect on the envelope's surface area, relative to the floor's area, or the space volume, and hence, the rate of heat exchange of the building with the outdoors.

Some studies have investigated the impact of the building shape on its thermal performance for selected climates in Europe [1–3]. The reported studies used rather simplified building thermal models. For instance, Jedrzejuk et al. [4–6] used a degree day based method to model the thermal performance of buildings. Givoni [7] mentions that the ability of a building to save energy aside from thermodynamic and heat retention qualities of materials depends on its shape, orientation, layout of transparent envelopes, size, measures of protection from the sun, and the facade colour. Parasonis et al. [8] note that manipulation of the shape of the building alters its energy use value, even though the physical characteristics of the envelopes remain unchanged. That means that this factor influences the energy demand of buildings.

In very cold climates, more heat escapes through the building envelope than the amount of heat that can be gained by increasing the surface receiving solar radiation. Therefore, the increase in the shape factor (more external building surface for the same volume, lower compactness index) is proportional to the increase in the energy required for heating [9]. In warm climates, this proportion is not direct, and a fixed type of building performance cannot be determined [10]. However, A favourable compactness ratio is considered to be one were the A/V ratio $\leq 0.7\ m^2/m^3$. In some parts of the UK with poor winter insulation very small detached dwellings may require even lower A/V ratios in order to achieve the Passivhaus specific heating demand [11].

The compactness of a building, indicated by the S/V ratio (S: area of building envelope surface, V: volume of the building) has a considerable influence on the heating energy demand of buildings, regardless of the level of fabric insulation. This paper provides a simplified analysis method to predict the impact of the shape (compactness index) for a building on its instantaneous temperature. A proposed model is developed based on detailed simulation

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Nomenclature

C_W	diagonal matrix for thermal capacity ($J\,K^{-1}$)
T_W	temperature (K)
A_W	square matrix for thermal conductivity ($W\,m^{-1}\,K^{-1}$)
B_W	vector
e	thickness (m)
n	number of node
m	the number of interior surface walls, window and door which exchange heat by radiation with the wall surface i
α	absorption coefficient
ε	thermal emissivity
G	the incident global irradiation on the surfaces ($w\,m^{-2}$)
S	surface (m^2)
λ	thermal conductivity ($w\,K^{-1}\,m^{-1}$)
C_p	specific heat ($J\,kg^{-1}\,K^{-1}$)
ρ	density ($kg\,m^{-3}$)
$F_{Surf\text{-}i}$	form factor between the exchange surfaces
σ	Stefane–Boltzmann constant ($W\,m^{-2}\,K^{-4}$)
V_{vent}	wind speed ($m\,s^{-1}$)
h_{conv}	coefficient of heat flux exchanged by convection (w)
$\dot{m}_{Inf}$	the air flow due to infiltration (kg/s)
$\dot{m}_{Vent}$	the air flow due to ventilation (kg/s)
T_i	air temperature inside the building (K)
T_{out}	air temperature outside the building (K)
$T_{Vent,out}$	air temperature at the ventilation outlet (K)
$T_{Vent,in}$	air temperature at the inlet ventilation (K)
T	temperature (K)
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)
$Q_{heating}$	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)
Q_{Surf}	thermal power due to exchange between the air and, (i) walls inner surfaces and (ii) windows and doors (W)
Q_{Gain}	direct solar gain due to openings (W)
T_{Surf}	air temperature walls inner surfaces (K)
h_{Conv}	the convective transfer coefficient ($w\,m^{-2}\,K^{-1}$)
Gr	Grashof number
Pr	Prandtl number
L	length of the plate (m)
ΔT	temperature difference between the surfaces and volumes exchange (K)

analyses utilizing several combinations of building geometry, orientation, thermal insulation level, glazing type, glazing area and climate. The present paper wants to emphasize the importance of this factor in the estimation of a building energy performance on the base of an analysis of a building in hot climate.

2. Diagrammatic example of building: design aspects of traditional Mzab settlements and their decline

The built response of the Mzab community to their socio-cultural and surrounding environmental requirements is expressed by two concepts: centrality and barriers. Centrality, in the arrangement of the Mzab settlements reflects traditional Islamic town planning in general, in that it does not dissociate the material and

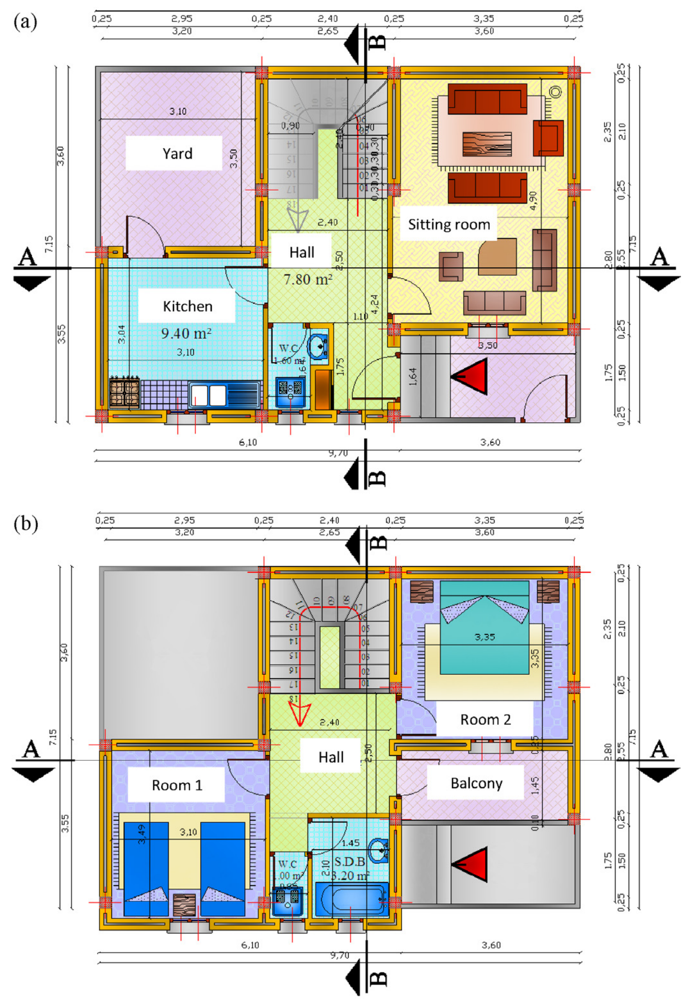

Fig. 1. Typical plans produced by professionals (a: ground floor plan, b: first floor plan).

spiritual aspects of life, as does much of modern town planning. The centrality of the towns and dwellings was, to a degree, symbolic of the society's cosmology. Barriers are the boundaries between settlements and their hostile environment, which could be human or climatic. A rampart around a settlement is a barrier against a hostile surrounding population. Vegetation, heavy buildings, compact buildings with winding streets are also barriers against a harsh climate [12].

It is clear that modernization has had a negative effect on the evolution necessary to provide a harmonious way of life for Mzab people. Planning and urban design processes and regulations applied by professionals and government agencies are based upon modern ideas imported from different cultures. This contradicts in many respects traditional practices in Mzab area. It is thus important that planners and designers should take traditional practice as a source of inspiration and make balanced integration between technological advances and traditional practices [12]. Other paper [13] is oriented towards creating a strategic vision and developing action plans for environmental protection.

The study was carried out on a building in Ghardaïa. The exterior envelope, apart from contributing to the energy savings during the entire life span of the building by controlling the energy exchange between indoor space and environment, also promotes the development of a comfortable indoor environment. Fig. 1 is a schematic outline of apartment building, the house has a habitable area of 68.3 m^2, and wall heights are equal to 3 m while the other