The Effect of Configuration on Heat Transfer and Air Flow of Ventilation Concrete Block

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Abstract

This paper presents a study of heat transfer and air flow through ventilation concrete block with reverse V-shape(Λ) opening of different configurations, by a two dimensional numerical method. The air flow pattern was computed using the finite element method based on the standard k-ε turbulence model. A steady state, incompressible and turbulent flow was assumed throughout the calculation. In theory, through the consideration of two main parameters, angle (α) and air gap (h), results obtained from the model developed show a capability of providing a prototype of ventilating concrete block. In practic, the numerical method designed in the model can enhance the corporate sector, as a simulation tool supporting decision making in concrete block production.

Keywords: Finite element method; k-ε turbulence model; numerical simulation model; reverses V-shape (Λ) opening

1. Introduction

Thailand has a hot and humid climate, resulting in high energy consumption in buildings by air conditioning systems. A solution to reduce the consumption of energy is increasing the ventilation. Thus the topic of energy performance is considered simultaneously as a part of the 'optimized building' designing. One of the important components of the building is the wall. Brick material types and configurations of bricks are an important part of saving energy in buildings. Nowadays in Thailand, we construct walls for buildings from clay brick or concrete blocks. The concrete block is most commonly used as it can significantly reduce heat into the buildings. On the other hand, it can reduce energy consumption.

A number of models and computer codes of design of concrete block have been developed and validated worldwide by many researchers [1-11]. However, they considered only the concrete blocks that have passive cooling that maximizes and increase natural ventilation. Therefore, the application is limited to specific places where humans do no need to see inside rooms. In order to resolve this issue, Khedari et al., 2004[3] developed a new prototype of concrete block that cannot be seen from outside and inside and permits natural ventilation. This configuration of brick is named "Reverse V-shape (Λ)". In their work, compressive strength testing, indoor temperature, natural ventilation, and daylight contribution were considered experimentally. Many of the parameters that affect heat transfer and fluid flow inside the concrete block and room have not been investigated yet. These investigations can either be answered with the help of extensive experiments or by numerical simulations.

This work is extended from Klinbun et al., 2012 [12] and aims to present a numerical simulation model of heat transfer and air flow through a ventilation concrete block with reverse V-shape (Λ) opening. The considered parameters are angle (α) and air gap (h).The computation is simulated based on the finite element method in 2 dimensions. The flow field inside a domain is described by the Renolds averaged Navier-Stokes equations. The simulation results have been performed for a new prototype of ventilation concrete block. This numerical method might be useful tool for making decisions to produce commercial blocks.

2. Numerical simulation

Fig.1 shows a vented concrete block with reverse V-shape (Λ) opening. The dimensions are standard: 39 cm length, 19 cm height, and 9 cm width. The surface area of each opening is 34×h cm^2. In this work, the fluid and thermal properties are assumed as constants. Air in the vented concrete block is considered as incompressible, in steady turbulence state. The governing equations are the following [12]:

$$\nabla \cdot U = 0 \tag{1}$$

$$\rho U \cdot \nabla U = \nabla \cdot \left[\left(\eta + \rho \frac{C_\mu k^2}{\sigma_k \varepsilon} \right) \cdot \left((\nabla U) + (\nabla U)^T \right) \right] - \nabla P \tag{2}$$

where ρ is density of fluid [kg/m^3], U represents the average velocity [m/s], η denotes dynamics viscosity [$N{\cdot}s/m^2$], P is the pressure [Pa], k is the turbulence energy [m^2/s^2], and ε is the dissipation rate of turbulence energy [m^2/s^3]. The k-ε model describes turbulent flow in domain. The turbulence energy equation is given by:

$$\rho U \cdot \nabla k = \nabla \cdot \left[\left(\eta + \rho C_\mu \frac{k^2}{\varepsilon} \right) \nabla k \right] + \frac{1}{2} \rho C_\mu \frac{k^2}{\varepsilon} \left((\nabla U) + (\nabla U)^T \right)^2 - \rho \varepsilon \tag{3}$$

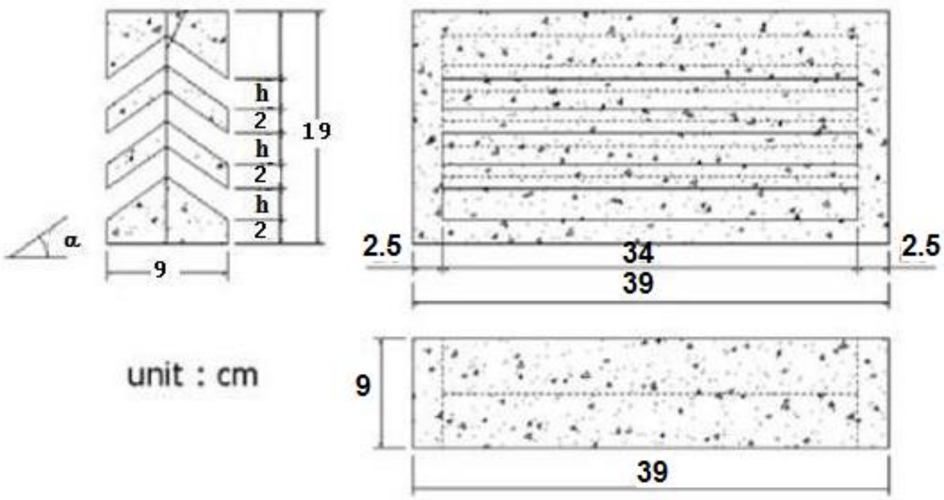


Fig .1. Dimensions of the vented concrete block with reverse V-shape (Λ) opening [3].

and the dissipation equation by:

$$\rho U \cdot \nabla \varepsilon = \nabla \cdot \left[\left(\eta + \rho C_{\mu} \frac{k^2}{\varepsilon} \right) \nabla \varepsilon \right] + \frac{1}{2} \rho C_{\varepsilon 1} k \left((\nabla U) + (\nabla U)^T \right)^2 - \rho C_{\varepsilon 2} \frac{\varepsilon^2}{k} \qquad (4)$$

Where $\sigma_k, \sigma_\varepsilon, C_{\varepsilon 1}, C_{\varepsilon 2}, C_\mu$ are standard values, suggested by Spalding and Launder (1972). $\sigma_k = 1.00, \sigma_\varepsilon = 1.30, C_{\varepsilon 1} = 1.44, C_{\varepsilon 2} = 1.92, C_\mu = 0.09$

Theenergyequationcanbe statedasfollows:

$$\rho c_p (U \cdot \nabla T) = \lambda (\nabla^2 T) \qquad (5)$$

2.1Boundaryconditions

Fig. 2 shows calculation domain and boundary conditions for this study.

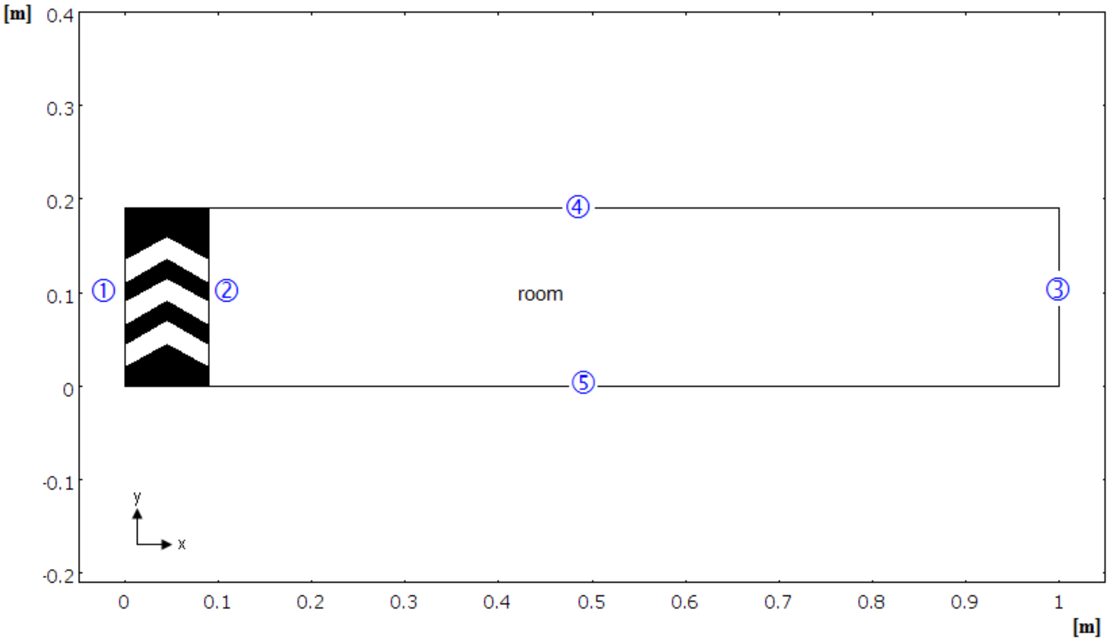


Fig .2. Calculation domain [12].

where		
①	Inlet BC	$u = 2.0$ m/s, $v = 0.0$ m/s $T_0 = 25^\circ C$
②	Continuity/interface BC	$U_1 = U_2$ $T_1 = T_2$
③	Outlet BC	$P = 0$ Pa $\nabla T = 0$
④	Upper wall	No slip $T = 40^\circ C$
⑤	Lower wall	No slip Convection flux

2.2 Calculation procedure

The finite element method (FEM) was used to analyze the steady state problems. In order to obtain a good approximation, a fine mesh was specified in the sensitive areas (as shown in Fig. 3). All computational processes were implemented using COMSOL™ Multiphysics, to demonstrate the velocity field and temperature is distribution that occurs within the vented concrete block. The number of elements considered for the mesh through the whole domain was 8723.

3. Results and Discussion

The simulation results of the new prototype of concrete block aimed to present air flow, vortices, and heat transfer inside the room. Two scopes were considered here: sight and loading limitations. The sight limitations mean that air gaps do not allow sight from the outside and inside while permitting natural ventilation (α≥ 10°).The loading limitation is described as a wall thickness to be larger than 2.5 cm, and rib thickness to be larger than2.0cm.Therefore, investigation configurations of a new prototype of concrete block were as follows:

(a)= h=2.5 cm, α=20°

(b)= h=2.5 cm, α=30°

(c)= h=2.5 cm, α=40°

(d)= h=3.0 cm, α=10°

(e)= h=3.0 cm, α=25°

(f)= h=3.0 cm, α=35°

The strategy to provide a certain thermal comfort to decrease the temperature of air and of object around occupants and to increase the velocity of the room air[13].The simulation results are shown in Fig. 5 toFig.8.

Fig.5 to Fig.7 show the streamlines of the recirculation zone, the velocity vector, and temperature contour, respectively. They show simulation results for six cases of concrete block. The simulation results of streamlines appear good agreement with the velocity vector distribution. All cases are not much different in pattern. The recirculation zone occur a t the corner of the upper part of the room. However, for block (b), the recirculation zone, was larger than the other cases. This is because of the effects of air gap and angle. The velocity of air inside the room induced ventilation systems was similar in all cases.

The decreasing velocity of air was a result of a large recirculation zone. From fig.7, the temperature contour is displayed. The inside room has good ventilation. The room temperature inside is reduced for block (d). The air gap and the angle have effects on the recirculation zone, velocity field, and temperature. If the recirculation zone is small, the speed will increase as a result of increased ventilation, and temperatures are reduced.

Finally, Fig.8 (a) and 8(b) show the velocity field and temperature in the room for all analyzed cases. It is observed that the best block from this point of view is block (d). Also, we can see that the velocity field and passive cooling are increasing with decreasing angle while the air gap increases.

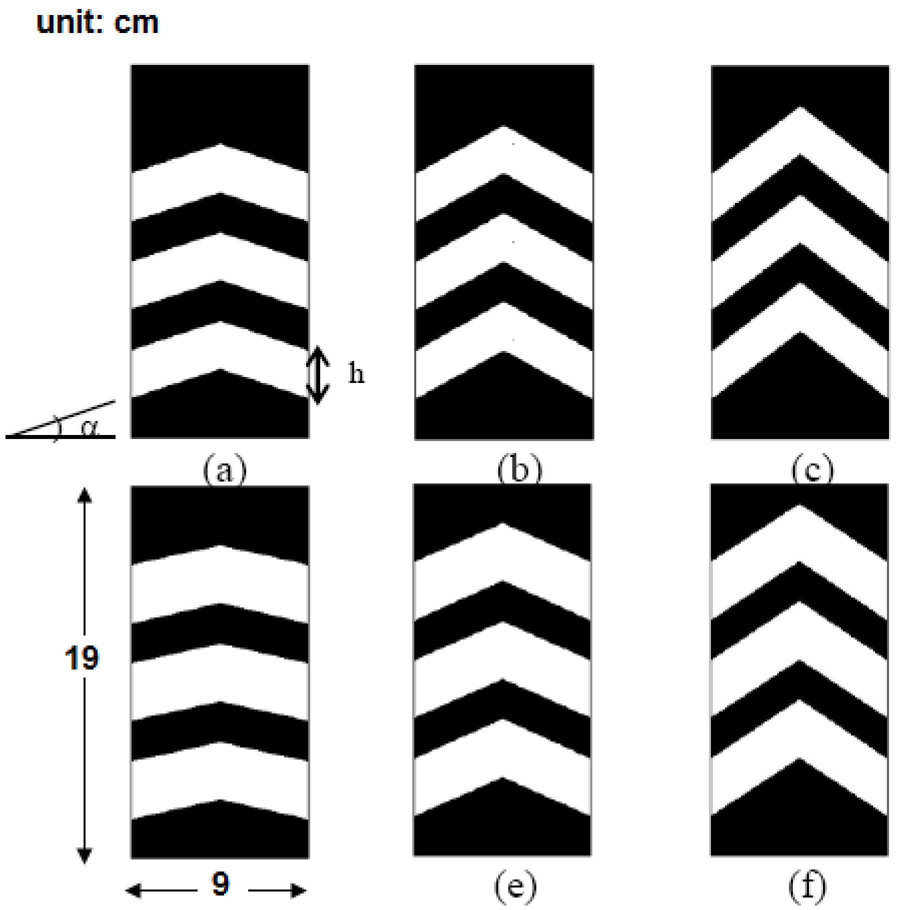


Fig. 3. Schematic of a new prototype of concrete block [12].

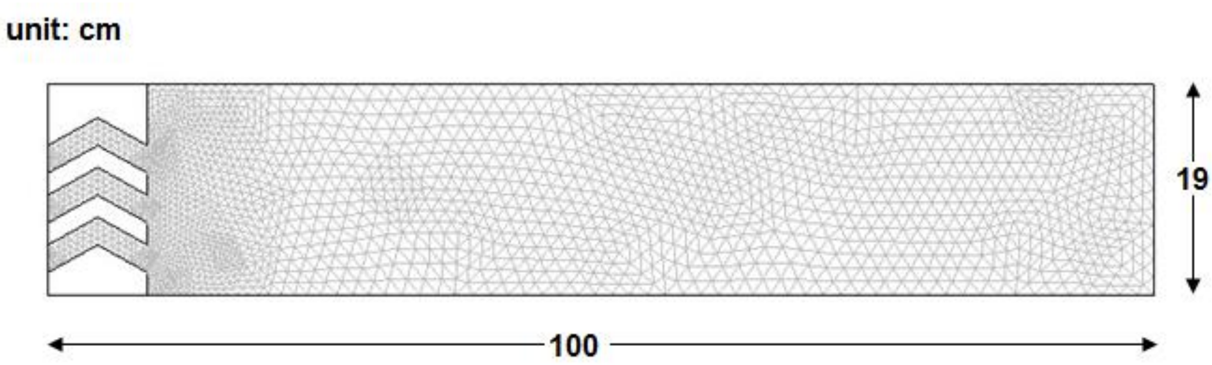


Fig .4. Mesh generation [12].

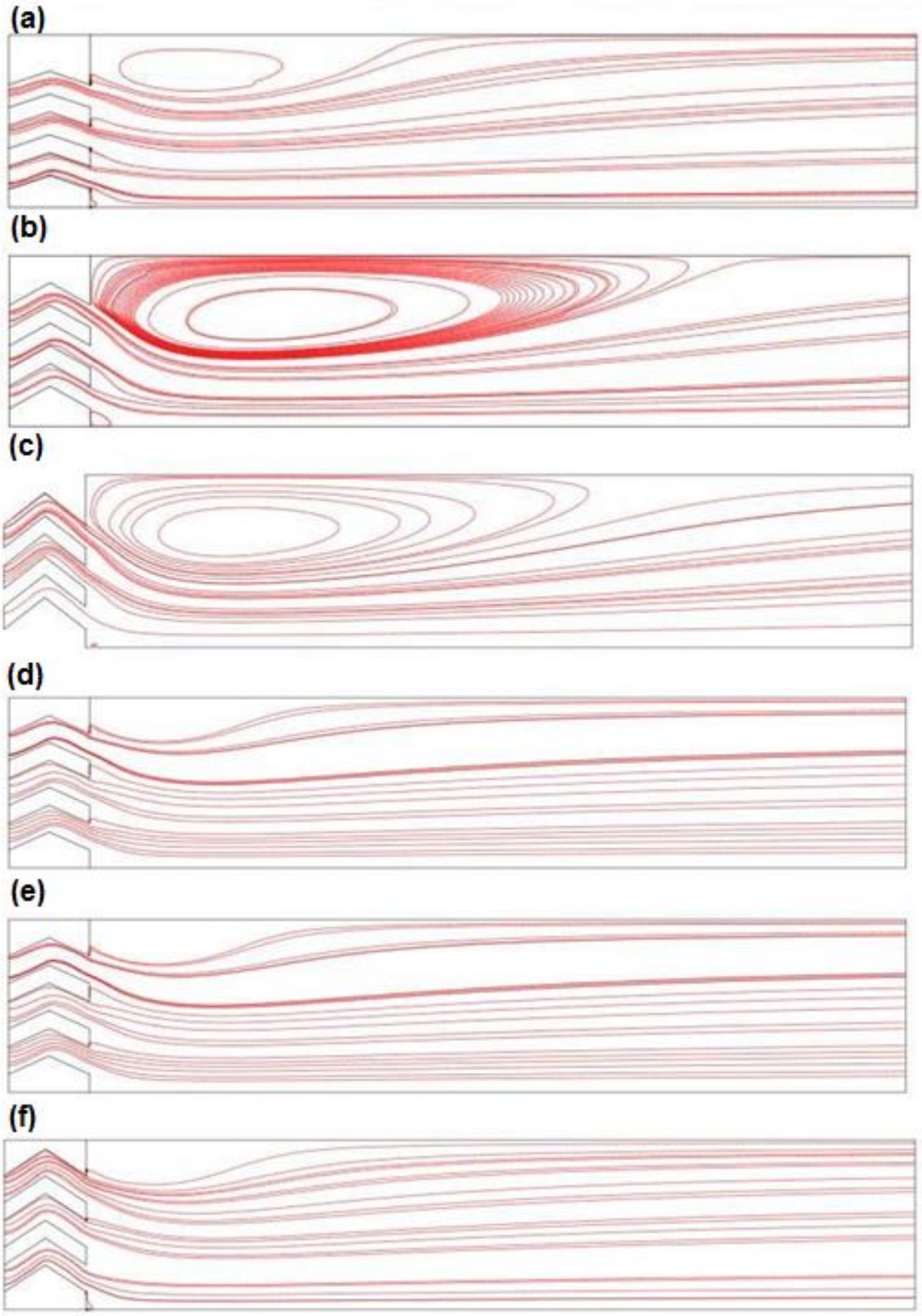


Fig. 5. Streamlines within concrete block and room with different blocks.

(a) (b) (c) (d) (e) (f)

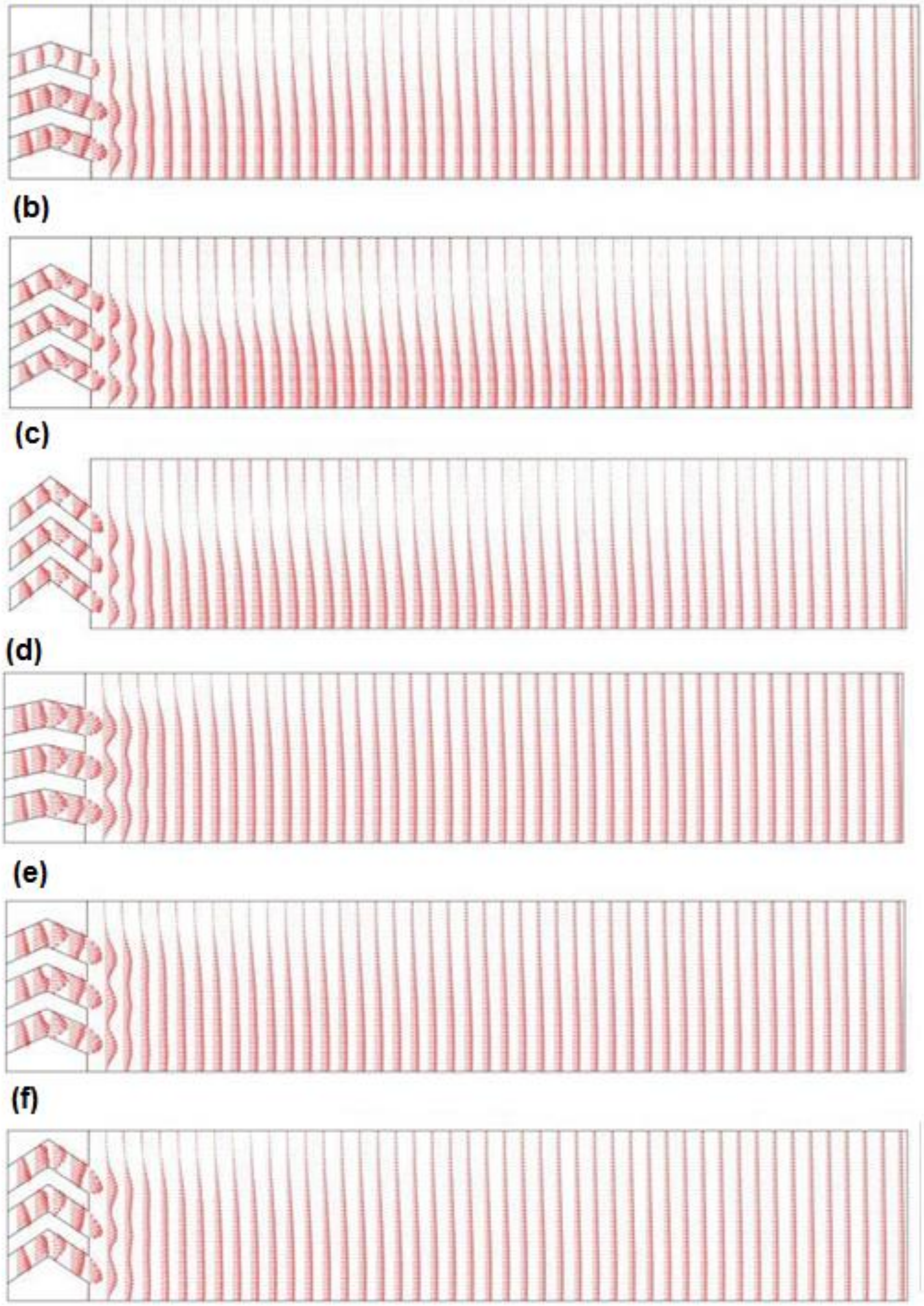


Fig .6. Velocity vector within concrete block and room with different blocks.

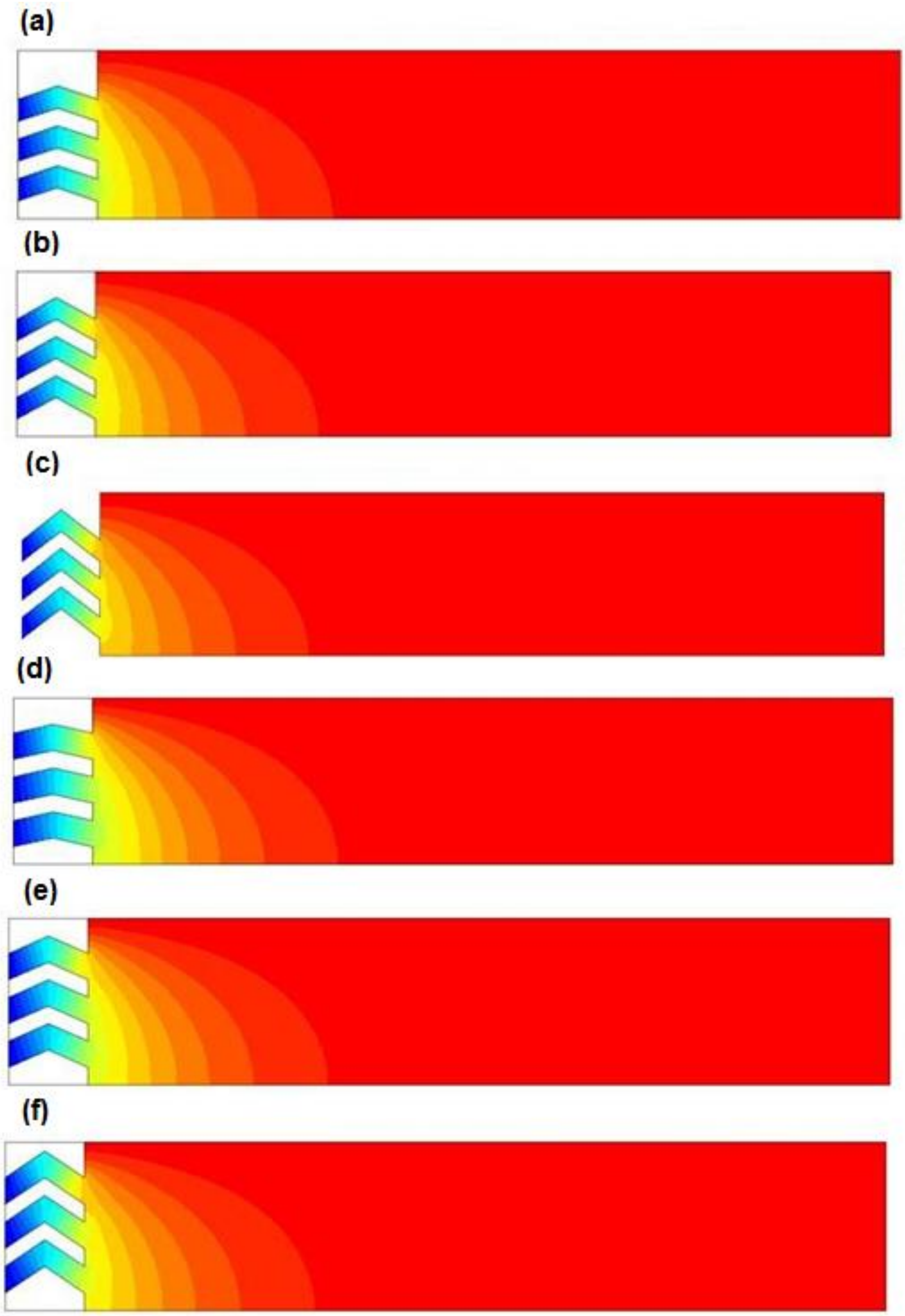
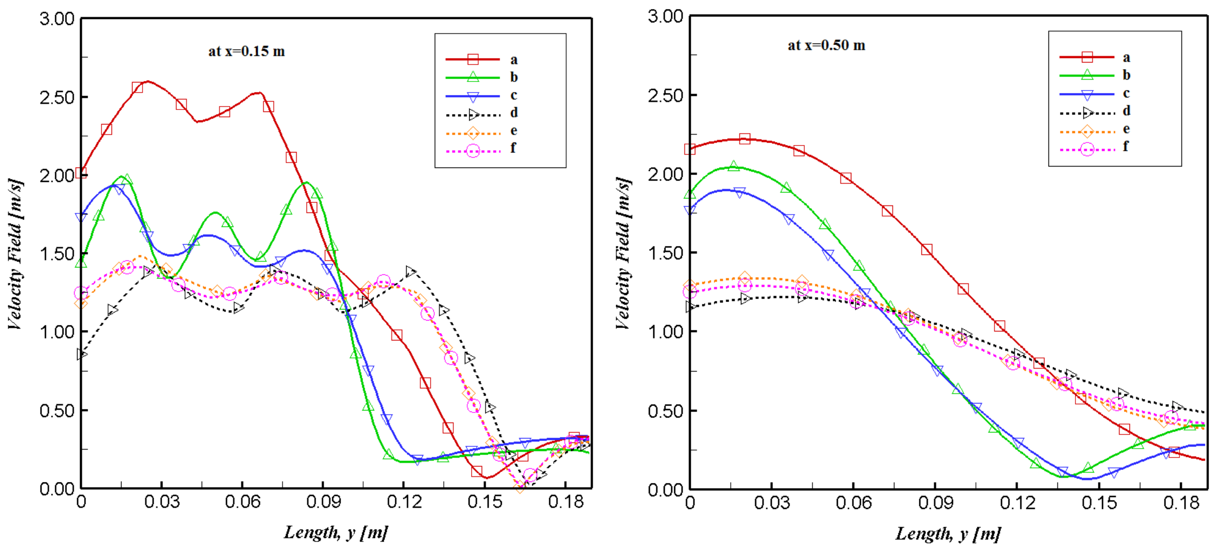
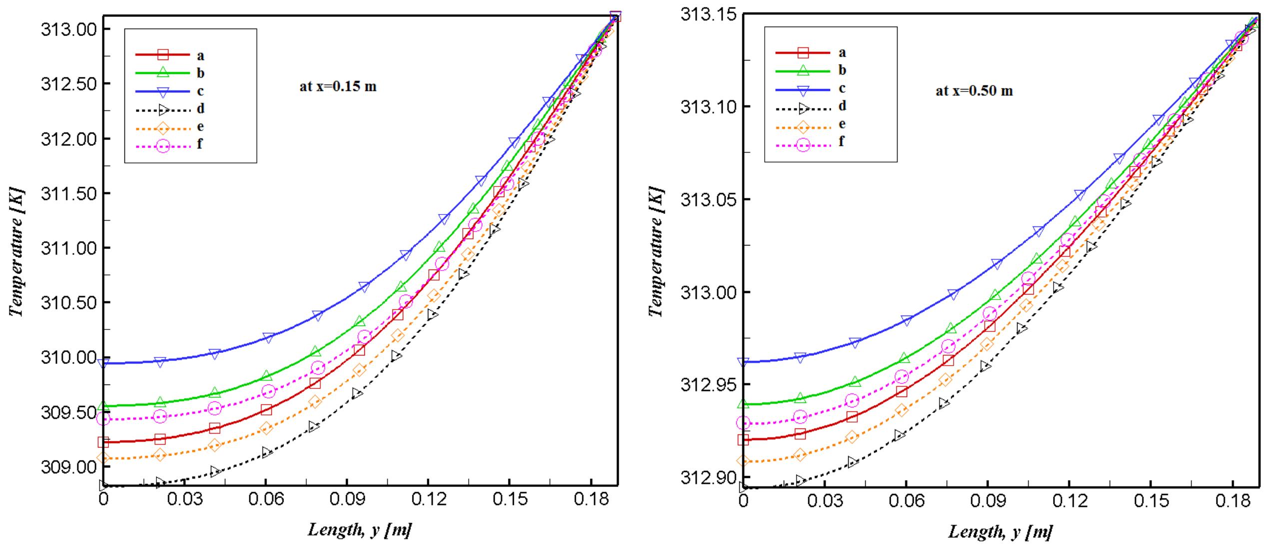


Fig .7. Temperature contour within concrete block and room with different blocks.



(a)



(b)

Fig. 8. (a) Velocity field (b) Temperature in the room for all analyzed cases.

4. Conclusions

The finite element method (FEM) was used as a tool to study fluid flow and heat transfer within a new type of concrete block, with variations in structure. Useful information generated by using these techniques will lead to a better design. The main points can be summarized as follows:

1. The air flow streamlines within the new prototype of concrete block with reverse V-shape (Λ) opening can be simulated by the finite element method.
2. Increasing the air gap (h) with decreasing angle (α), corresponding to block (d), still maximizes passive cooling and increases natural ventilation.

Users can choose which concrete block, depending on their specific purpose of application.

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Nomenclature

C_1, C_2 constant value in dissipation rate equation
C_0 constant value in k-ε model
k turbulence kinetic energy
h height of air gap
P pressure
u velocity in x-axis
ν velocity in y-axis
x coordination in x-axis
y coordination in y-axis

Greeksymbol
ε dissipation rate of turbulent kinetic energy
η dynamic viscosity
ρ density
α angle
T temperature
∝ Thermal diffusivity

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