Passive cooling of telecom shelter using solar chimney with Earth-air heat exchanger

BOUBEKEUR DOKKAR[1,a], BELKHIR NEGROU[1], NASREDDINE CHENOUFF[1], NOUREDDINE SETTOU[1], ABDESSLEM BENMHIDI[2]
[1]Laboratoire de Valorisation et Promotion des Ressources Sahariennes
University of Kasdi Merbah
BP 511 Route Ghardaia 30000 Ouargla
ALGERIA
E-mail: Boubekeur.ogx@ gmail.com.
[2]Linde Gas Algeria, centre of Ouargla,
Z.I Route Ghardaia 30000 Ouargla
ALGERIA.

Abstract:- Passive ventilation systems are being increasingly proposed as an alternate to mechanical ventilation systems because of their potential benefits in terms of operational cost, energy requirement and carbon dioxide emission. This paper presents passive cooling system for base transceiver station (BTS) in neighboring Ouargla city (south of Algeria). There are numerous ways to promote this cooling technique, and in the present study the use of solar chimney together with earth-air heat exchanger (EAHE) is introduced to remove undesirable interior heat from telecom shelter. Consequently, theoretical analyses have been conducted in order to investigate the cooling and ventilation through combined solar chimney and underground air channel. In winter, only solar chimney is used for shelter cooling. In summer, the solar chimney can be perfectly coupled with the underground cooling system. CFD commercial code (Fluent 6.3) is used to predict the thermal performance, and fluid flow in two-dimensional solar chimney and underground channel. The obtained results show that flow increase at shelter inlet causes a marked improvement in cooling in all Shelter area, which indicates that we can design a shelter without conventional air conditioning.

Key-words:-Telecom station, passive cooling, solar chimney, heat exchanger.

1 Introduction

Cellular mobile service is a rapidly expanding and a very competitive business worldwide, including developing countries. Mobile network operates by connecting between Base transceiver stations which contain sophisticate electronic components; however, significant improvement in the microelectronic devices performance requires development of very efficient cooling systems. Generally, dissipating heat rates (ranging from 500 to 10,000 W depending on the size and type of equipments) is removed by using conventional air conditioners which consume large amount of electrical energy. In addition in remote areas large engine generators are required to supply power to air- conditioner. A large variety of passive cooling techniques have been proposed. They include standard ventilation and novel methods that use sensible and latent heat storage systems. Standard ventilation includes natural convection and forced air cooling. Natural convection is the transport of heat by buoyancy induced flows. The literature on natural convection within enclosures is vast and the selected few are available in Refs. [1–3]. This is the simplest and most cost effective cooling method. However, in remote desert with high ambient temperatures, this method proves its inability to maintain the desired internal temperature. Forced air convection is also of relatively low cost and simple in design, but it provides about 56% as maximum surface temperature reduction [4], so does not achieve the satisfactory results for cooling systems with high heat flux.

Concerning cooling systems using phase change heat transfer where the latent heat transfer of working fluid is used for removing heat. In this technique, A. Shammuga et al. [5] were developed and experiment two-phase closed thermosyphon heat exchangers to provide thermal management in telecom shelters. This thermal system absorbs the equipment dissipated heat during the hottest part of the day, stores it as latent heat and releases it through thermosyphons during the night to the ambient. It is seen from the ambient temperature curve for the month of May that the maximum temperature is 40.90 ◦C. The enclosure temperature is maintained at an average temperature of 37.67 ◦C and the maximum reaches 38.70 ◦C. It is seen that the phase change temperature of PCM increases above its melting temperature (29 ◦C) during the period 11.00 a.m. to 5.00 p.m. This is due to the fact that the storage capacity of the PCM is insufficient to take all the heat loads of the day during the month of May.

In the same way, A. Samba et al. [6] were investigating the impact of the thermosyphon loop by comparing two types of cooling system: the traditional cooling system (air convection) currently used by France Telecom and the thermosyphon loop cooling. They conclude that the maximum heat load of the telecommunication equipment is limited about 250 W for the traditional cooling system, while it is about 600W for the thermosyphon loop cooling system.

Another technique, commonly used in green building, remedies the inconvenient of natural and forced convection systems. It is composed of solar chimney and earth-air heat exchanger which is characterized by its simplicity and high removed heat rate [7-10]. In addition, it has low electricity consumption, so it is very convenient in remote area where photovoltaic is used to provide shelter [11]. The present paper investigates the possibility of using solar chimney and earth-air heat exchanger system to cool mobile telephone BTS in the neighboring of Ouargla city (south of Algeria).

2 Mathematical model

2.1 Computational domain

Fig. 1 shows the base case computational domain which is assumed as bi-dimensional, it includes shelter and solar chimney placed on the south side at an angle α equal to Latitude. For the Earth-air heat exchanger is taken only as shelter inlet boundary condition. The size of solar chimney is similar to that adopted by Z. Akchiche [10]. The shelter mesh consists of (240 × 225) and the chimney as (120 × 60).

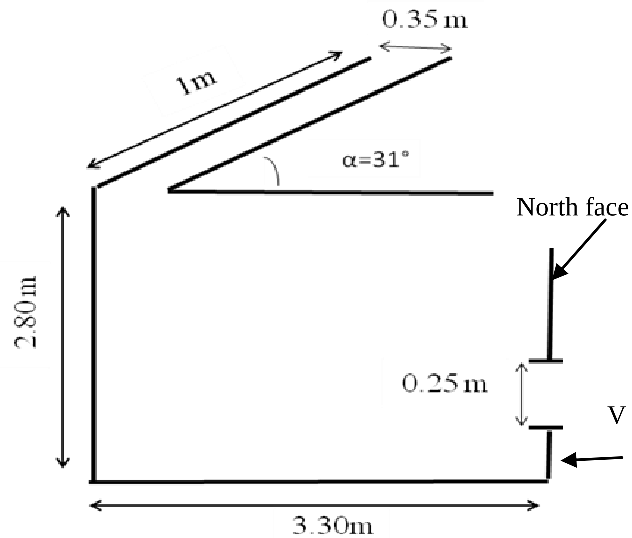

Fig. 1: Computational domain

2.2 Governing equations

Air flow across the shelter is carried by both air input velocity and the temperature gradients. Heat and mass transfer are then partly due to natural convection and forced convection. In this work, we consider the laminar regime, air as Newtonian fluid and neglecting viscous dissipation. Internal gain is assumed as heat flow at bottom shelter border. The phenomenon is governed by the conservation equations (mass, momentum and thermal energy) which are respectively written in condensed form as follows [10]:

$$\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x_i}(\rho U_i)=0 \tag{1}$$

$$\rho\frac{\partial U_j}{\partial t}+U_i\rho\frac{\partial U_j}{\partial x_i}=-\frac{\partial p}{\partial x_j}+\mu\left[\frac{\partial^2 U_j}{\partial x_i^2}\right]+\rho g \tag{2}$$

$$\frac{\partial T}{\partial t}+U_i\rho\frac{\partial T}{\partial x_i}=\frac{1}{\rho}\frac{\lambda}{c_p}\left[\frac{\partial^2 T}{\partial x_i^2}\right] \tag{3}$$

With: ρ density (kg/m^3), μ cinematic viscosity (kg/m.s), c_p calorific capacity (J/$kg.K$), λ thermal conductivity J/m^2.

Natural convection effect is considered in the momentum equation by varying the density expressed according to thermodynamic reference state (density ρ_0 and temperature T_0) by the Boussinesq approximation as follows:

$$\rho = \rho_0[1 - \beta(T - T_0)] \quad (4)$$

With β is the isobaric expansion coefficient of the fluid:

$$\beta = -\frac{1}{\rho} + \left(\frac{\partial \rho}{\partial T}\right)_{P=cst}$$

The flow in the Earth-air exchanger is similar to flow in circular pipe; it is governed by the conservation equations (continuity, momentum, energy). In order to simplify calculation, we consider only velocity and temperature at the exchanger outlet as shelter input conditions.

2 Numerical procedures

The shelter energy audit without cooling system is simulated by Trnsys 16 software. In order to fix the boundary conditions, this software simulation is used to determine shelter indoor temperature (lateral walls and zone) for the worst state which reaches the highest temperature.

By introducing the passive cooling system, the governing equations of flow across the shelter are solved by using a general-purpose CFD code (Fluent 6.3). Upwind scheme is chosen for numerical discritization and coupling betweens velocity field and pressure is insured by the SIMPLE algorithm [12]. Under relaxation is activated to accelerate convergence up to reaching steady state at 10^{-6} as residual error.

3 Results and discussions

3.1 Indoor temperature of shelter

For shelter without cooling system, Trnsys software is used to plot shelter indoor temperature curves at instantaneous state along the year. Fig.2.illustrates temperature curves of lateral walls and zone which shows that the worst case occurs in the day of 21/07/2013. The high indoor temperature reaches 83 °C which is taken as boundary conditions on the lateral walls.

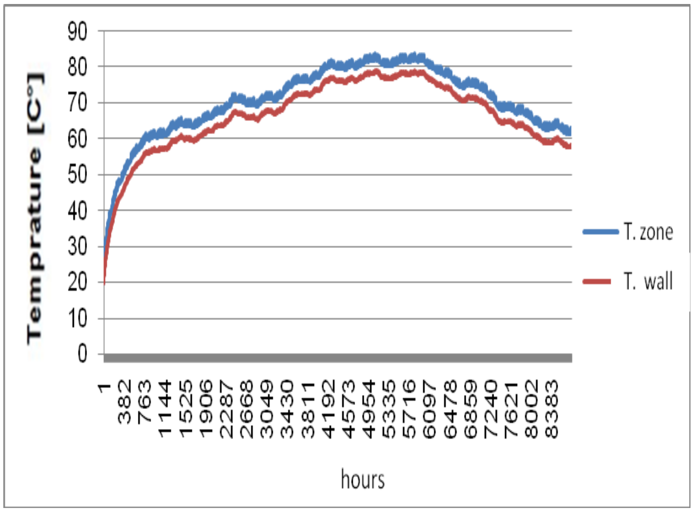

Fig. 2: Shelter indoor temperatures along year 2013

3.2 Effect of Earth-air heat exchanger

For shelter with passive cooling system, Fluent software is used to plot shelter indoor temperature contours. Fig. 3 shows that temperature remains high in whole zone its maximum fall is not greater than 2 °C, this is due to the lack of pushing system to facilitate the passage of air flow within Shelter. So, at shelter inlet, natural convection does not give a significant result for passive system. In Fig. 4, we see that the temperature in the zone records a significant fall. This shows that the flow with 0.009 m/s and temperature at 15°C caused by earth-air heat exchanger at shelter inlet gives a positive effect on improving cooling.

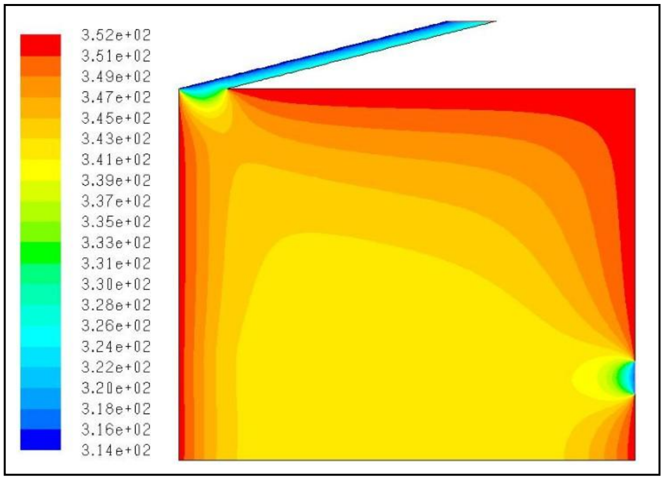

Fig. 3: Temperature contours for shelter without EAHE

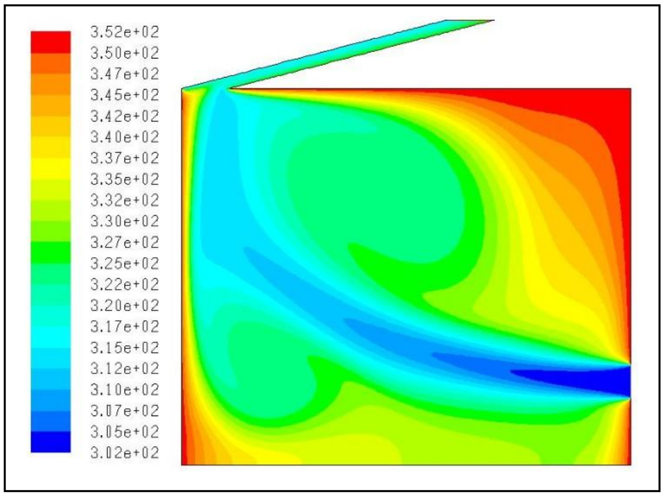

Fig. 4: Temperature contours for shelter with EAHE, V=0.009 m/s, OS=0.25m

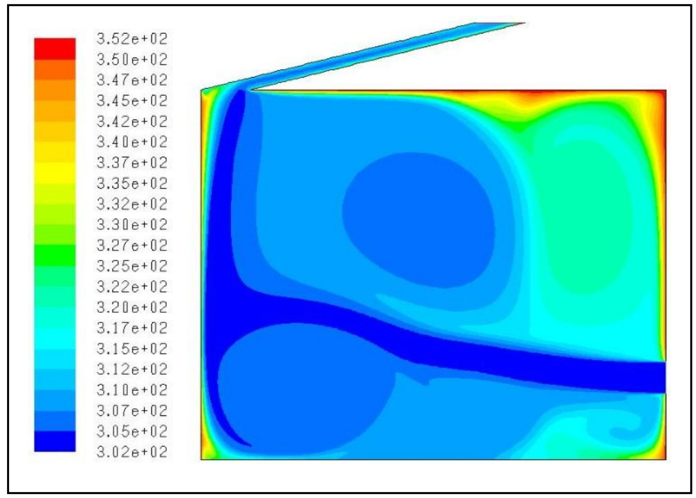

Fig. 5: Temperature contours for shelter with EAHE, V=0.1 m/s, OS=0.4m

3.3 Effect of flow rate and velocity

Fig. 4 shows that the temperature in the zone reported a very significant drop. This shows that increased flow by increasing the inlet open space at the shelter and the solar chimney have a positive effect on improving cooling.

Fig. 5, there is a marked improvement in cooling covers almost any shelter space. This is explained by the effect of the flow rate increase by the simultaneous increase in the velocity and the open space (OS) at shelter inlet to reach respectively V=0.1 m/s and OS=0.4 m. Temperature in the middle of the shelter does not exceed 29 °C. It indicates that we can design a shelter without conventional air conditioning with condition that we use batteries operating at temperatures up to 29 °C because the batteries currently used on the site are designed to a maximum temperature of 25 °C.

4 Conclusion

A passive cooling system incorporating solar chimney and earth-air heat exchanger system for cooling telecommunication enclosures is viable and reliable for shelters installed in desert and tropical regions. It requires less power; therefore it is a highly efficient system for remote areas where there is no power grid and the maintenance is minimal. In addition, it is a low cost cooling system and eco-friendly.

Temperature in the middle of the shelter does not exceed 29 °C. It indicates that we can design a shelter without conventional air conditioning with condition that we use batteries operating at temperatures up to 29 °C.

For future work, we plan to integrate other techniques to further reduce of temperature. It consists by combining the present cooling system with vertical chimneys placed on the outer sides of the shelter lateral walls to minimize external gains of sun radiations.

References :

[1] K.R. Kirchartz, H. Oertel, Three dimensional cellular convection in rectangular boxes, *Journal of Fluid Mechanics* 192 (1998), pp. 249–286.

[2] T. Fusegi, et al., Transient 3-D natural convection in a differentially heated cubical enclosure, in: Proc. *ASME/JSME Thermal Engineering Conf, Nevada*, 1991, pp. 83–88.

[3] S.B. Sathe, Y. Joshi, Natural convection liquid cooling of a substrate mounted protrusion in a

square enclosure: a parametric study, *Journal of Heat Transfer* 114 (1992), pp. 401–409

[4] C.W. Argento, et al., *Forced convection air cooling of a commercial electronic chassis: a experimental and computational case study*, IEEE Transactions on Components Packaging and Manufacturing Technology Part A 19 (2) (1996), pp. 248–257.

[5] A. Shanmuga Sundaram, R.V. Seeniraj, R. Velraj, An experimental investigation on passive cooling system comprising phase change material and two-phase closed thermosyphon for telecom shelters in tropical and desert regions, *Energy and Buildings* 42 (2010),pp. 1726–1735

[6] Ahmadou Samba, Hasna Louahlia-Gualous , Stéphane Le Masson b, David Nörterhäuser, Two-phase thermosyphon loop for cooling outdoor telecommunication equipments, *Applied Thermal Engineering* 50 (2013) ,pp.1351-1360

[7] Akchiche Zineb, Étude de comportement d'une cheminée solaire en vue de l'isolation thermique, Magister thesis in energetic and process, university of Ouargla Algeria, 2011.

[8] M. Maerefat, A.P. Haghighi, Passive cooling of buildings by using integrated earth to air heat exchanger and solar chimney, Renewable Energy 35 (2010), pp. 2316-2324.

[9] Ramadan Bassiouny, Nader S.A. Korah, Effect of solar chimney inclination angle on space flow pattern and ventilation rate, Energy and Buildings 41 (2009), pp. 190–196.

[10] Alemu T. Alemu, Wasim Saman, Martin Belusko, A model for integrating passive and low energy airflow components into low rise buildings, Energy and Buildings 49 (2012), pp. 148–157.

[11] Pragya Nema, R.K. Nemab, Saroj Rangnekar, Minimization of green house gases emission by using hybrid energy system for telephony base station site application, *Renewable and Sustainable Energy Reviews* 14 (2010), pp. 1635–1639.

[12] Patankar Suhas. Numerical heat transfer and fluid flow. *Washington D.C*: Hemisphere; 1980.