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Original Research Article

GREEN BUILDINGS IN THE SOUTH VALLEY OF EGYPT

Dr. George Bassili Hanna

Emeritus Professor, Building Physicist & Building Energy Efficiency Consultant
Housing and Building National Research Center
P. O. Box 1770, P. C. 12311Cairo, Egypt.

Abstract: This paper discusses how indoor air temperature is controlled by employing a passive solar technique able to limit the unbearable outdoor weather conditions in a New Urban desert community of Toushky. The passive system employing the “Rock Bed” integrated with a solar chimney to generate an air draft from a thermal tunnel in the ground. A thermal circuit model is developed to describe the complex patterns of heat exchanges. The Finite Difference Method (FDM) is used to estimate the cooling load and the temperatures at different surfaces.

Keywords: Passive technique; rock bed; solar chimney; thermal model; FDM; computer simulation.

1. Introduction:

Egypt lies between latitudes 22 and 32 with a daily 9 to 11 hours of sunshine. Solar energy is available in all regions with an average total solar radiation 1900-2600 kWh/m^2/year, while the direct solar radiation is 1970-3200 kWh/m^2/year. About two thirds of Egypt's total population of 90 million (year 2014) is living in urban areas. Egypt's population is concentrated in only 6% of the territory. About 30% of the Egyptian living in Cairo and Alexandria and about 65 % of total populations living in Great Cairo and Delta. Solving the housing problem in Egypt is a tremendous task due to the rapid population growth, 90 million. The housing construction rate in Egypt is not great enough to face the population growth. To solve this problem, new urban communities were started, specially in the south valley (Toushka region).

For Correspondence:
gbhanna44ATyahoo.com
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The Egyptian land consists mainly of desert (≅ 94% of the Egyptian land). Most of the Egyptian inhabitants live on the northern part that includes Delta and around the Nile Valley at the south of Cairo. Desert is mainly plain except for the Eastern mountain chain and Sinai Mountains. Water will be a problem in the next few years, since the maximum water allowed from the River Nile is about 55.5 billion m$^{3.}$

The high dam was constructed in the years from 1960 – 1971. A lake was created as result of the construction of the high dam, and was named as Nasser Lake. It has a maximum capacity of 168.8 billion m^3, with dimensions of approximately 500 km by 30 km, of the 500 km length, 350 km lie on the Egyptian soil, with the rest in Sudan.

The idea of expansion started to appear in the beginning of the sixties as a result of the tremendous increase in population which is thought that it will double every 30 years keeping in mind that the increase in land has increased by only 0.1% since 1930's. The idea is to make another Nile passes through the vast dessert from Toushka till Qatara depression (– 112 m under sea level). It started from the south of the High Dam Lake to transport the excess water arising from any large floods through a canal to Toushka Depression. Toushka canal is about 22 km and about 2000 acres could be cultivated on the banks of the Canal, in addition of 500000 acres on Toushka Depression and another 500000 acres till Qatara Depression, where new agricultural and industrial communities can be built to enhance people to move to this virgin area which will be full of job opportunities and many field to invest.

Control of indoor temperature could either be done positively by air conditioning, or passively by appropriate design technique. This paper presents a natural cooling system for residential buildings in TOUSHKY region in the western desert of the Egyptian Land. The essence is to create a maximum possible thermal comfort in the buildings without any particular cooling source, but employing all the passive devices able to limit the unbearable outdoor weather conditions during summer days. The first system used in Egypt is known as the Nubian technique applying natural evaporative cooling and ventilated roof. The second system is known as the "Rock Bed" coupled with solar chimney to generate an air draft from a thermal tunnel " thermal bus" at 5m depth in the soil. An earlier study[1] has been used and the computer programs were modified and redeveloped to estimate the cooling load and the temperature response to various forms of heat inputs. Previous studies by Hanna and Guirguis[2&3] investigated experimentally and theoretically the thermal performance of three passive rooms, the first coupled with a roof solar system, and the second with a solar wall system and the third with cavity walls for comparison.

The climate of TOUSHKY is characterized by very high day temperature, (47.7 ^{o}C- 30 ^{o}C); low night temperature, (26.6 ^{o}C- 5 ^{o}C); large diurnal and annual range, (15 ^{o}C- 29 ^{o}C); humidity, (10%-30%). The first figure of each range represents summer and the second for winter. The overheating period is about 7 months and the maximum direct solar radiation is about 1100 W/m ^{2}. The annual wind is about 8 m/s. The temperature during summer months was above 40 ^{o}C for more than 6 hours daily.

2. Materials and Methods

2.1 Building Construction

A residential house unit consists of six rooms, two with a common bathroom located in between, and another four rooms at right angle to form the L-shape system at 45 ^{o} with respect to the North/South axis with a south court yards. Cross-section diagrams N/S and E/W of the working principle for natural cooling system are shown in Figs.1 and 2. Vertical shading elements at an angle 45^{o} with respect to the wall are used for windows. Open ended ventilated roof enhance the natural ventilation. Shading the room ceiling helps draft air from the room through dampers to the solar chimney. The solar chimney are oriented in the direction of the main wind. The interior court yard lower than the ground level by 60 cm. Green areas in the interior court yards improves and lowering the court air temperature.

2.2 Passive Technique

The rock bed storage is designed to cover the cooling load period during the hottest hours from 12-17. The volume of the rock bed is about 4.0 m^{3} is required for about 50 m^{3} of building volume. During the day, the hot ambient air flows through the rock bed to cool the building mass through ducts and the indoor room air through dampers in the ceiling through ducts to the solar chimney, as shown in Fig.3.

It is assumed that the rock diameter is 0.04 m and the void ratio (e) is 0.4. The rock bed storage is designed to cover the cooling load during the hottest hours from 1200-1700 hours. The cooling load and the air flow rate are given as following equations:

$$Q=(\rho\ C_p)_{rook}\ V_{bed}\ (1-e)\ \Delta T_r \qquad (1)$$

$$Q=(\rho Cp)air\ V\ \Delta T \qquad (2)$$

2.3 Thermal Circuit Diagram

A thermal circuit diagram is shown in Fig.4 represents the 21 thermal resistance's and 7 thermal capacitates and 5 forms of heat inputs. Resistance's R19, R20 and R21 are only used with rock bed and solar chimney. Table 1 summaries the thermal resistance's and Table 2 summaries the thermal capacitance's used in the simulation.

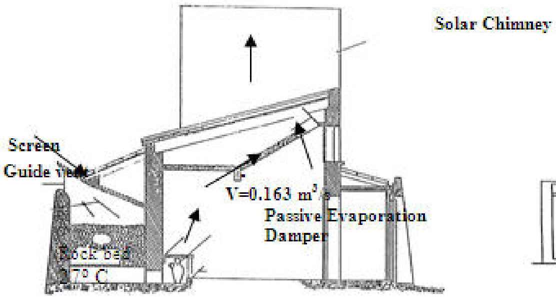

Fig.1 Cross-section view (N/S)of natural cooling System .

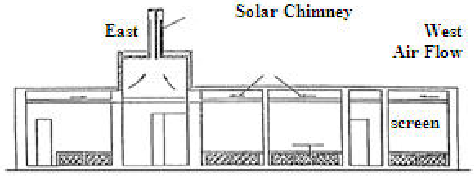

Fig.2 Working principles of the solar chimney and rock bed.

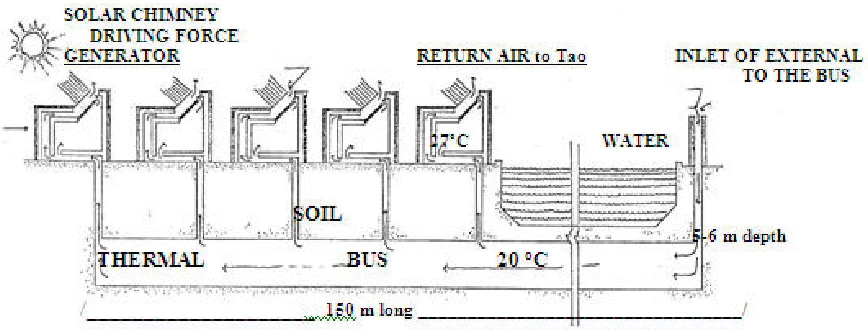

Fig.3 Thermal Bus concept for Passive Solar Cooling Network

3. Results and Discussion

It was found that a bed of $4m^2$ and height of 1.0 m is quite satisfactory. The thermal bus is a tube at 6 meter depth in the ground and is about 150 m long. The hot ambient air entering the thermal bus is exchanging the sensible heat with the soil temperature which at lower and constant temperature (≅ annual temperature mean at the site) by conduction by and convection with the surrounding air. The air velocity depends on the draft given by the solar chimney and on the tunnel surface friction. The aim of the solar chimney is to create the air draft through the thermal bus and helps cool air to enter the room through rock bed to the ceiling cavity, as shown in Figs. 1 and 2. The solar chimney faces both east and west orientation to extend the solar period. The dimension of the solar chimney is about 7 m x 1.8 m for each room of about 50 m^3 volume. Figure 3 shows thermal bus principles for passive cooling system suggested for the whole settlement. Its shows solar chimney acting as driving forces passive solar generator connected to the room air through a ceiling dumber and to the walls thermal mass. The thermal bus is embedded in the ground at a 6 m depth where the hot ambient air is entered from a wind catcher to the bus passing underneath a water basin to cool the ground temperature.

Table 1 Types of Resistance's of the Thermal Model

Res.No	Type of Resistance	Res. No.	Type of Resistance
R0	Ventilation =1/3nV	**R11**	**Ceiling=2/h_iA_5+$\sum(x_5/k_5A_5)$**
R1	Door =(1/Ah_o+x/Ak+1/Ah_I)	**R12**	North wall =1/h_iA_6
R2	South film =1/h_o A_1	**R13**	Out- film, north wall=1/h_oA_6
R3	Indoor film =1/A_1h_o	**R14**	North =x_6/k_1A_6
R4	South wall=x_1/k_1A_1	**R15**	East & west=1/h_iA_7+x_7/2k_1A_7
R5	Glass=1/h_oA_2 +1/h_iA_2	**R16**	Floor=1/h_iA_8
R6	Partly south =1/h_o A_3	**R17**	Ground=1/πL_1 k_g
R7	South =x_3/A_3 k_3	**R18**	Roof radiation loss
R8	South film = 1/h_iA_3	**R19**	Rock-bed air flow=3/mV
R9	Roof =1/h_iA_4+1/.5A_4/k_4A_4	**R20**	roof air vent=3/(m+n)V
R10	Roof film =1/h_oA_4+.5x_4/k_4A_4	**R21**	=R20

Table 2 Types of Capacitance's

Symbol	Relation	Description
Q =	αAI	
V =	50 m^3	
V=	0.036 m^3 /s	
C1, C2 =35224400	½ (ρ C x $A)_1$	Wall
C3, C4 =1254998	½ ρ C(x A)3	
C5 = 1254998	ρ C x A	Roof
C6, C7 =9056925	½ρ C (x $A)_7$	North
C8 =2875911	½ρ C (x $A)_7$	E & W
C9 =8486400	(ρ C x A) $_8$	Floor

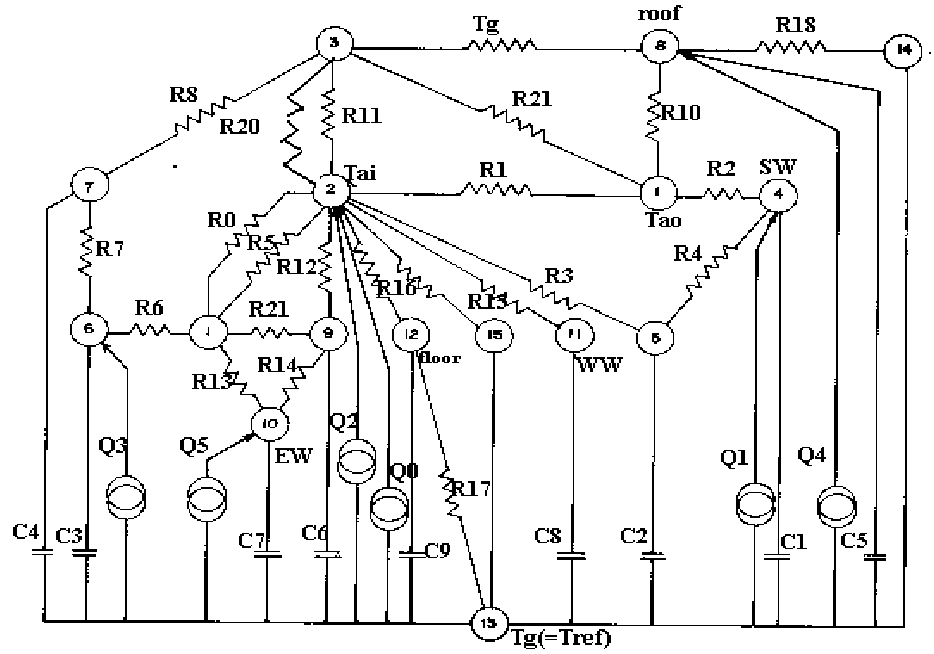

Fig.4 Thermal Circuit Diagram of the Passive Residential Unit

Figure 5 shows a comparison between the indoor air temperatures of five different cases. QUICK[4] computer program has been used to carry out this simulation. It is clear that , the indoor air temperature of case I with outer walls of hollow concrete blocks and 12 cm RC roof slab is higher than case V (HB43 and shaded roof) by bout 8 °C at the hottest period of a summer day, which is above the comfort temperature in the region by about 9 °C. A passive unit of 3.5x4x3 m of the passive system is investigated as follows: i) without rock-bed as shown in Fig.5; ii) with rock-bed operated 24 hours as shown in Fig.6 and; iii) with rock-bed and is operated from 1200 to 1700 hours. The swing in the indoor air temperature is between 35 and 38 °C which is nearly equal to case V in Fig.5. T3 is the air temperature above the ceiling and roof and T8 is the solar roof temperature.

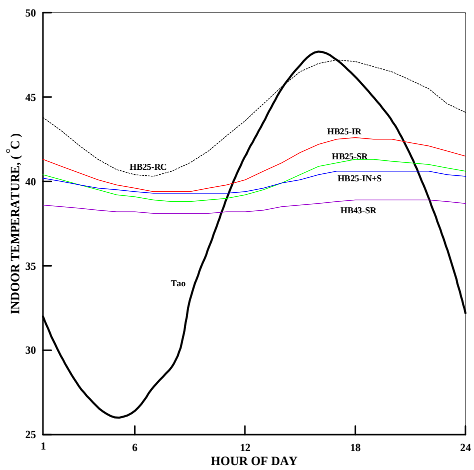

Fig.5 Comparison between four cases fo different roofs and walls constructions.

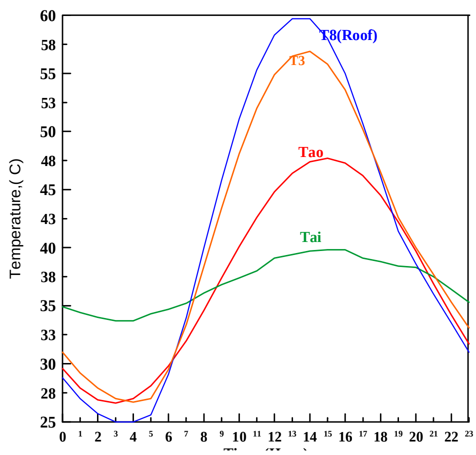

Fig.6 Temperature variation of indoor Air above ceiling and roof without rock-bed.

The cooling load during the day hours from 1200-1700 reaches its maximum and is equal about 2000 W to maintain a constant indoor temperature at 27 ^{o}C, as shown in fig. 7. Figure 6 shows the temperature variation of the solar roof, space above ceiling, and the daily cooling load. A range of air flow rate between 0 .04 to 0 .163 m^3/s during day and night is needed to create an air draft to circulate the ambient air in the rock bed (4m^3) to the room air to be maintained at 27 ^{o}C. The rock bed is cooled in about 9 hours at air flow rate of 0.163 m^3/s.

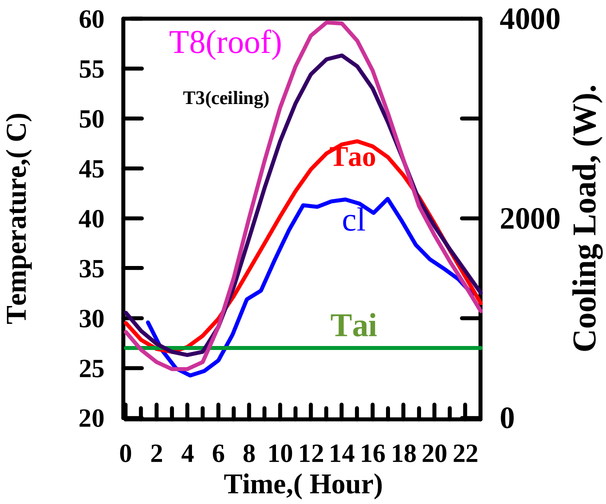

Fig.7 Temperature variation and

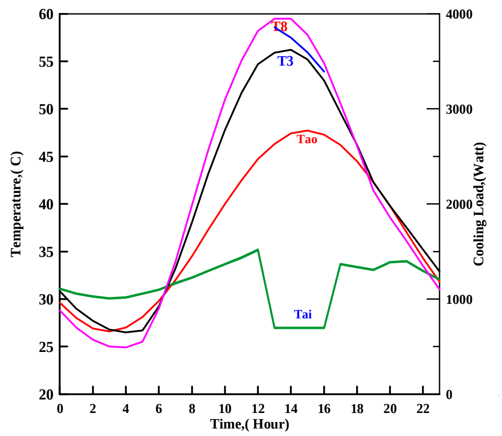

Fig.8 Temperature variation and

4. Conclusions

The aim of this study was to investigate the possibility of using passive solar technique in lowering the indoor air temperature in a new residential building in TOUSHKAY region. The preliminary theoretical results could be summarized as follows: 1) this study has shown that the shaded and ventilated the building roofs is essential to reduce the direct solar effects; 2) the present data further point out that the use of Passive Solar Technique is strongly recommended to reduce the indoor air temperature significantly during the hottest period of the summer days. Further experimental work is necessary to promote definite results.

Acknowledgement

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