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# Improvement the winter space heating by the effect of rotating thermal wall storage

**M. Moghiman[a], M. Hatami[b], M. Boghrati[c]**

[a,b] *Ferdowsi university of Mashhad, Mashhad, Iran, mmoghiman@yahoo.com*
[c] *Qaen Faculty of Engineering, Birjand University, Qaen, Iran, mboghraty@yahoo.com*

## ABSTRACT

In this study a monolithic thermal storage wall has been replaced by a set of rotable wall segments which can rotate around their vertical shafts. The study has been carried out to improve the classical Trombe wall design. In order to allow for some natural lighting into the room, air gaps are used between wall segments. The distances between the wall segments aid both air convection and direct radiation into the room. One face of each wall segment is painted black for day time absorption, and the other side of the segment finished with white color. The rotating wall segments can be a good absorber during the day and a good radiator during the winter nights. When no further useful solar radiation is available the hot surfaces of the wall segments are rotated inwards. The results show that in comparison with classical solar walls the rotable storage walls can provide much more percentage of the heat even in cold climates. The results also show that for each square foot of floor area in climates with average winter temperatures about 32°F, at least 0.38 square feet of south facing rotable wall is needed

**Keywords:**
solar energy, Trombe wall, rotating wall, winter space heating

# 1. INTRODUCTION

Passive solar systems are playing an increasing role in air conditioning of modern buildings. Many of the passive solar heating walls are operating based on the principle of the Trombe solar collective Wall. A Trombe wall is a static monolithic vertical thick masonry wall designed to absorb the sun's energy during the day, store it, and radiate heat evenly. This wall is built of a material such as stone, concrete and usually placed between the solar collecting glazing and the interior space to be heated. The Trombe wall is permanently fixed in position and do not track the sun. The main performance problems associated with the Trombe wall are the lack of direct radiant heating and natural lighting into the interior space to be heated during the day, and the transfer of most their thermal storage energy into the green house during the night, thereby decreasing the amount of heat transfer into the room to be heated.

There has been made different types of modification to Trombe's original design to produce more advantages and reduce its disadvantages. The standard Trombe wall has the drawback of low thermal resistance, which leads to significant losses at night-time or during periods with no sun. Faiman [1] has used a rotating prism wall located on the inside of a south facing (or north-facing in the southern hemisphere) glazed window. Zalewski and co workers [2] have investigated four different types of solar wall: standard Trombe wall, the insulated Trombe wall, the non-ventilated solar wall and the composite solar wall. The concept of composite Trombe wall is similar to the traditional Trombe wall except there is an insulating wall at the back of the massive wall to overcome the heat loss from the inside to the outside of building. Chen and Liu [3] have studied numerically the effects of the porous absorber on the temperature distribute and airflow in the two types of the composite solar wall. They found that the possibility of insufficient in the heating system decreases greatly and the thermal resistance of composite wall increases at night or on a cloudy day, if a convective porous layer is used as a solar absorber inside composite wall. They found that the influence of the particle size, the porosity, the thermal conductivity of porous layer and the porous absorber position in the solar composite wall on the air temperature in the heated room is significant. Nwachukwu and Okonkwo [4] discussed that by the application of a coating of superior absorption vigour on the exterior of storage wall, the absorption and storage capacity of the Trombe wall can be improved. Fang and Li [5] numerically found that a lattice passive solar heating wall can remarkably improve the heating efficiency of the Trombe wall for passive solar heated. The effect of height on the performance characteristics of a passive solar air heater has been experimentally investigated by Ryan and Burek[6]. They found that thermal efficiency is a function of the heat input and the system height, but not of the channel depth.

As mentioned above, one of the main performance problems associated with the Trombe based solar walls is the transfer of most their thermal storage energy into the green house during the night time, thereby decreasing the amount of heat transfer into the interior room. In this study, a passive solar heating mechanism is described which operates on the principle of the Trombe wall but which overcomes the performance problem associated with the transfer of most thermal storage energy into the green house during the night. The rotating wall consists of a set of rotable vertical rectangular cross section wall segments which can rotate around their vertical shafts. The purpose of the present paper is to compare thermal effects of classical and rotating wall systems on winter space heating.

## 2. THE ROTATING WALL SEGMENTS

There are three approaches to passive systems: direct gain, indirect gain and isolated gain. In direct gain system, the actual living space is a solar collector, heat absorber and distribution system. Thermal masses inside the interior absorb that strikes them during the day time and radiate the heat at night time. In an indirect gain system (Fig. 1(a)) thermal mass is located between the sun and the living space. The thermal mass absorbs the sunlight and transfers it to the living space by conduction. Operable vents at the top and bottom of a thermal storage wall permit heat to convert from between the wall and the glass into the living space. When the vents are closed at night radiant heat from the wall heats the living space. Sunrooms (or solar greenhouses) employ a combination of direct gain and indirect gain system features. Sunlight entering the sunroom is retained in the thermal mass and air of the room. Sunlight is brought into the interior room by means of conduction through a shared mass wall in the rear of the sunroom, or by vents that permit heat transfer from the storage area by opening vents that access the storage by mechanical means (fans) into the living room.

In this study the problem of bringing sunlight into the interior room by means of conduction through solar wall, or by vents that permit the air between the sunroom and living space to be exchanged by convection has been solved by using rotable wall segments (Fig. 1(b)). The solar house contains a south facing double glazed solar window of net area 306 square feet. The floor area of the sunroom is 102 square feet. An interior insulated blind reduces heat loss at night time during the winter and reduces unwanted heat gain during the day time in summer. The number of rotable wall segments is 5 with a 15 cm gap between the wall segments. The removable insulated curtains can be incorporated to reduce heat losses during winter nights. The rotating wall segments have a net area of 235 square feet. One face of each wall segment is painted black for day time absorption, and the other side of the segment finished with white color. The investigation has been performed in city of Mashhad where, December is the coldest month. The transmission coefficient of the roof living room is 0.2 Btu/(hr)(sq ft)(deg F). Different insulations have been used at walls to reduce heat loss from the building. The wall segment construction materials are stone and concrete with a specific heat of 0.20 Btu/(lb)(deg F).

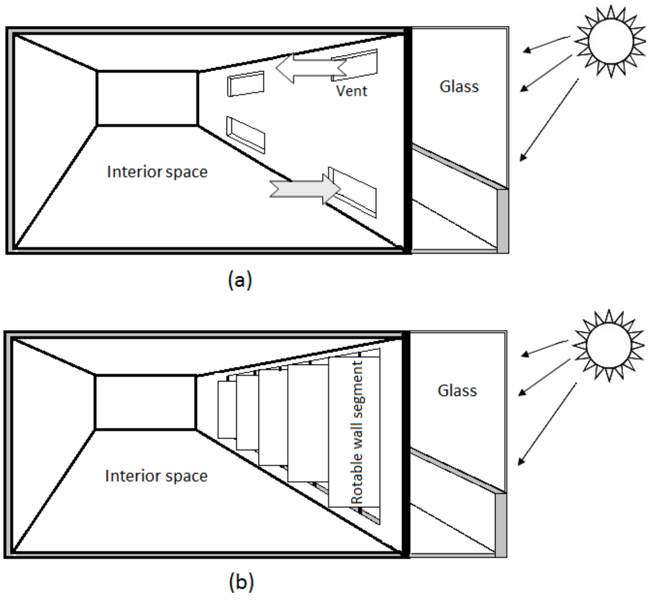

*Fig. 1. a)Trombe solar wall,  b) rotable wall segments.*

# 3. RESULTS

Fig. 2 shows the effect of outdoor air temperature on average room temperature for day time heating under two solar wall conditions: fixed wall and rotable wall. The results have been obtained for adequate insulation of walls with transmission coefficient value of wall structures U= 0.1. For fixed wall condition, heat from solar greenhouse into the interior room converted by means of mechanical fans, whilst for rotable wall condition, this is done by natural convection through air gaps between the wall segments. The comparison between inside average temperatures from fixed wall and rotable wall reveals that inside temperatures obtained for fixed wall condition, are higher than those of rotable wall. This occurs because air natural convection through air gaps of rotable wall segments between the greenhouse and the interior room is lower than forced venting of fixed wall. The results show that on a clear December day with outdoor air temperatures higher than about 40 º F, acceptable indoor average space temperature of about 68°F over a 12-hour period is provided.

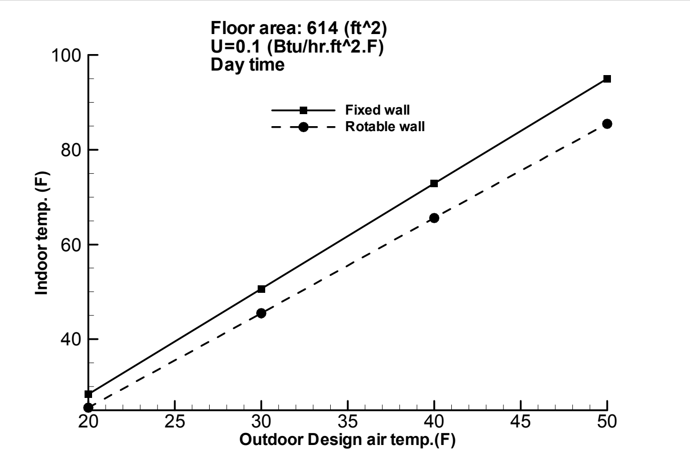

*Fig. 2. Effect of outdoor air temperature on average room temperature.*

Fig. 3 presents the effect of outdoor air temperature on average room temperature for night time heating under two solar wall conditions: fixed wall and rotable wall. The results again have been obtained for adequate insulation of walls with transmission coefficient value of wall structures u=0.1. At the end of day time the wall segments have been rotated 180°. The removable insulated curtains have been used to reduce heat losses during winter night time. For fixed wall condition, heat from solar greenhouse into the interior room converted by means mechanical fans. The comparison between inside average air temperatures from fixed wall and rotable wall shows that inside temperatures obtained for rotable wall condition are much higher than those of fixed wall. Rotable wall segment procedure has the ability to maintain an average space temperature of about 60°F over a 12-hour period of a cold winter night (outdoor air temperature = 20 ºF).

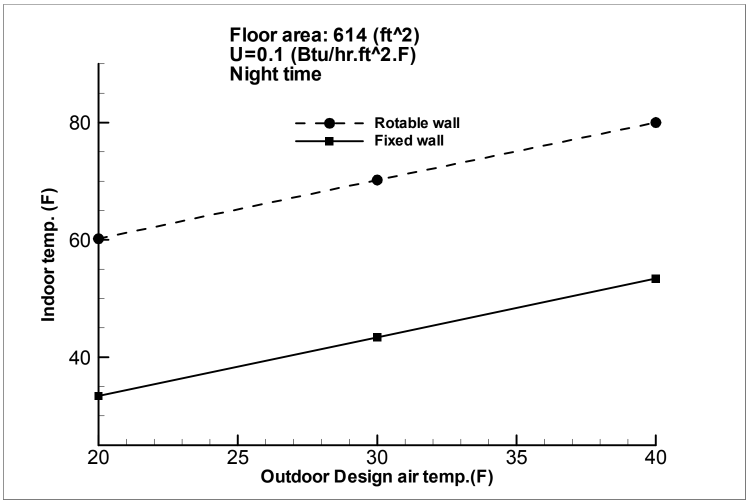

*Fig. 3. Effect of outdoor air temperature on average room temperature.*

Fig. 4 shows the effect of wall transmission coefficient U on inside average room temperature for night time heating under two solar wall conditions: fixed wall and rotable wall. The results have been obtained for outdoor air temperature 32 ºF over a 12-hour period. It is seen that for average outdoor air temperature 32°F, the rotable wall provides average space temperatures of about 57°F to 72 °F whilst the average space temperatures of fixed wall are low even for lowest values of U coefficient.

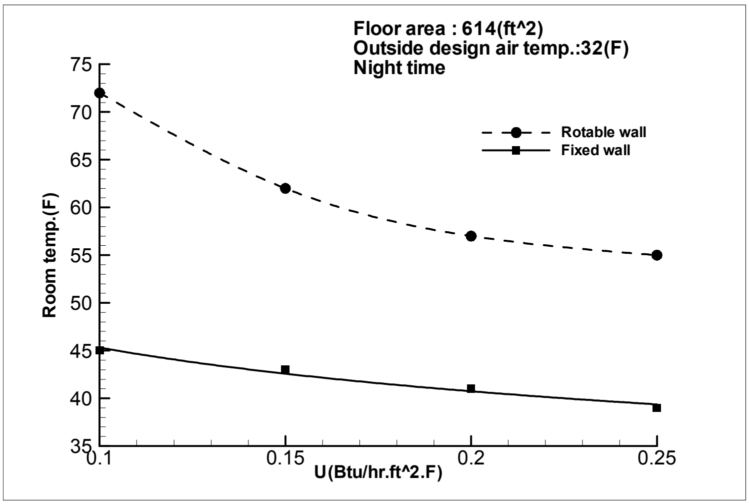

*Fig. 4. Effect of U coefficient on inside average room temperature.*

Fig. 5 shows the effects of floor area and wall transmission coefficient on inside average room temperature for fixed solar wall. The results have been obtained for outdoor air temperature 32 ºF. It can be seen that an increase in living room floor area or an increase in wall transmission coefficient both decrease the inside average room temperature. The Fig. reveals that the inside average room temperatures provided by fixed wall for different floor surface areas and wall transmission coefficients are low.

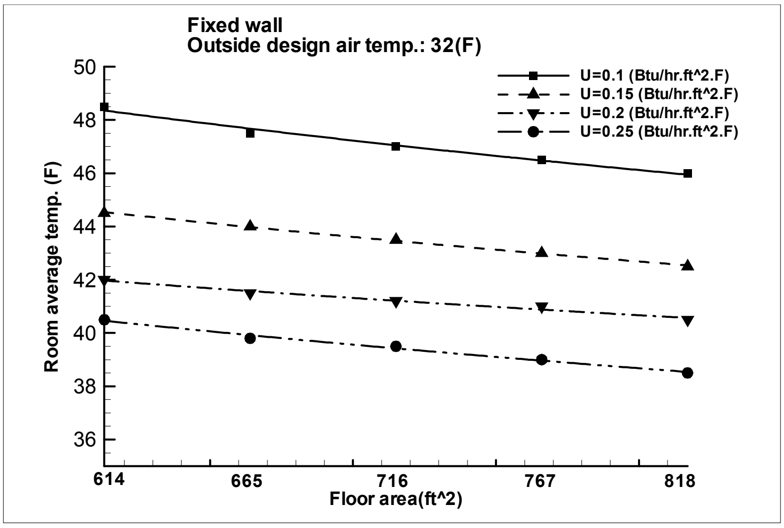

*Fig. 5. Effect of floor surface area on inside average room temperature.*

Fig. 6 shows the effects of floor area and wall transmission coefficient on inside average room temperature for rotable solar wall. The results have been obtained for outdoor air temperature 32 ºF. It is seen that an increase in living room floor area or an increase in wall transmission coefficient both decrease the inside average room temperature. The comparison between inside average temperatures provided by fixed wall (Fig. 5) and rotable wall (Fig. 6) reveals that inside air temperatures provided by rotable wall segments, are much higher than those of fixed wall.

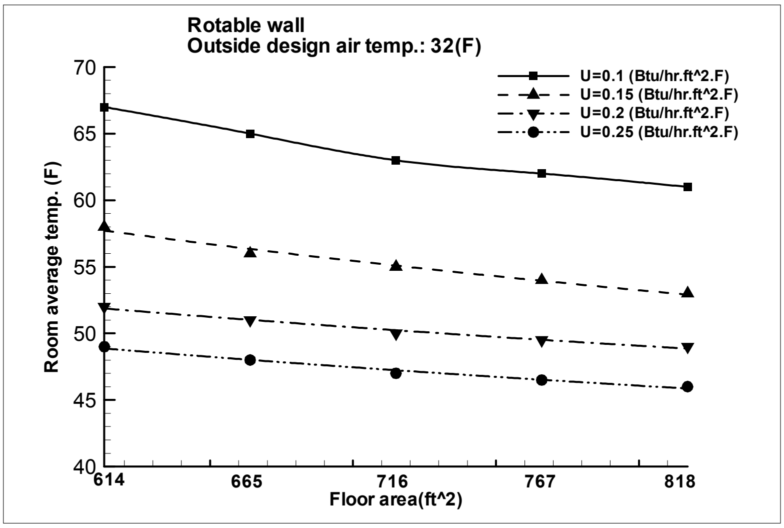

*Fig. 6. Effect of floor surface area on inside average room temperature.*

# 4. CONCLUSION

An indirect gain rotating masonry wall design has been used to improve the classical Trombe wall design. The classical Trombe wall design absorbs solar energy at its face and radiates only a small portion of its thermal storage energy at its back to the interior space. By using rotating thermal storage wall segments aside from the night time direct radiation by the energy absorber face, the solar room temperature can be decreased during the night which reduces the heat loss through glazing. In order to allow for some natural lighting into the room the air gaps have been used between the wall segments. Because of the distance between the wall segments, natural convection between the greenhouse and the space to be heated aids the venting for day-time heating. Based on the presented results, the following conclusions may be drawn.

The most important advantage of rotable wall design is its high capability winter night space heating.

The rotable wall segment design needs not vents of the wall for night time heating.

For a better design of day time heating of rotable wall segments, vents of the wall are needed.

Adequate insulation of interior room walls is needed for winter space heating rotable of wall .

For each square foot of floor area in climates with average winter temperatures about 32°F, at least 0.38 square feet of south facing rotable wall is needed.

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