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Numerical Analysis of Natural Ventilation in Double Skin Facades to Feasibility of Reducing the Use of Air Conditioning Systems in winter

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ABSTRACT: Nowadays implementation of natural ventilation is one of the essentials considered when designing buildings to provide comfort for the residents. Taking advantage of natural ventilation reduces the need and the irregular use of HVACs in buildings. In doing so, Dual Skin Facades allows a natural air conditioning while controlling noise, wind and rain. A dual skin can offer other advantages in protecting the building from the elements such as changes in climate. It allows the residents to benefit from their open windows without being exposed to the hazards of single layer structural wall. Dual Skin Facades also provides the ability to adjust and to compensate for heat, cold, light, wind, and the exterior noise in a way that result in comfort for the residents without energy wastes. The article below is to conduct an analysis of natural air conditioning in different Dual Skin Façade systems and a numerical analysis of double skin facades in "Hot and Arid" climate of Iran and it is to benefit from natural air conditioning in winter. In doing so, we will rise to better option and higher preference with compare the two models of air ventilation in double skin façade's air gap.

Keywords: Dual Skin Façade, Hot Arid Climate, Natural Air Conditioning.

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INTRODUCTION

Reduction in energy consumption in buildings began first by the user's supervision and control and then by maximizing the heating-cooling insulation of the building. Energy consumption of buildings was reduced largely in this way. But the problem of sick building syndromes or lack of air and the shortage of ventilation in the building were brought up. This was caused as a result of new methods of HVAC and closure of spaces for the purpose of minimizing the temperature drop via the air leakage. Complete closure of spaces regulated the temperature, but caused the sicknesses related to shortage of natural air ventilation. Such sicknesses which were unknown or ignored at the beginning became familiar as sick building Syndromes later (Saberi, 2001)

Nowadays the demand for natural air conditioning is on the rise which results in an increased demand for air conditioning through open windows. Perhaps this is the response to irregular use of HVACs which repeatedly has been referred to as "Sick Building Syndrome" (Latifi and Alizad gohari, 2012).

In doing so, Dual Skin Facades allows a natural air conditioning while controlling noise, wind and rain. Dual Skin Facades also provides the ability to adjust and to compensate for heat, cold, light, wind, and the exterior noise in a way that result in comfort for the residents without energy wastes (Kalantar Mehrjardi, 2006).

The technology at first pioneered in cold climate; however, a noticeable expansion of dual skin technologies took place in Europe, North America, and Japan starting in 1980s. In the light of recent economic developments, the implementations of dual skin facades in areas with very hot summers and cold winters (Hot and Arid Climate) are on the rise (Juan and Youming, 2010).

Although double skin faced has many advantages but there are also challenges in their functionality. Correct designing with respect to climatic parameters can make the double skin facade effective and efficient and resolve such challenged to a reasonable extent. Using this technology in developing countries such as Iran is based on the western concepts and ignoring the regional climatic conditions. Therefore paying attention to the domestication of the double skin faced with respect to the climatic parameters seems important when designing those (Salehi et al., 2011).

Dry and hot climate is the dominant climatic condition in Iran. Therefore study and optimization of convenient conditions in buildings located in these regions are of prime importance. With respect to the warm weather in most months of the year and cold weather in winters the problem of natural air condition and thermal convenience are very important. The article below is to conduct a numerical analysis of double skin facades in "Hot and Arid" climate of Iran and it is to benefit from natural air conditioning in winter.

Review of literature

Natural ventilation in double skin facades: With reference to Belgium's National Institute of Building Research, Dual Skin Facades are defines as:

Active Façade (Dual Skin) is the type of façade that covers a floor or more of a building by multiple clear skins, whether the layers are air isolating or not. The air gap in-between the two skins could be ventilated either naturally or mechanically. The ventilation strategy of the gap is time dependent. To enhance the inner environment the facilities and the systems to the façade, whether active or passive are made integrated. In most cases such complexes are managed by automated control systems (Poirazis, 2004).

In addition to providing the needed light within, indeed the external glass of the dual skin systems is capable of absorbing the light and storing heat in the winter, also induces natural ventilations in the summer to reduce the same sun light related heat. This is how the dual skin system helps in reduction of the heating and air conditioning load also with the internal air quality (Hashemi et al., 2010).

Tolerance of the temperature above 24 degree Celsius in the buildings without natural air condition such as closed HVAC is difficult. While in buildings with natural air conditions the temperatures of even above 27 degree Celsius is pleasant. This reduces the energy consumption in the building (Geratia and Deherde, 2004).

Overall, the air gap size, windows, construction material types, the structure type, the direction of air current, shading devices, and the intelligent controlling systems are some of the key elements in designing the dual skin facades (Pappas and Zhai, 2008).

Plans for the Direction of Air Current

There are three suggested air ventilation plans to the façade:

-Type A; to ventilate inward: The air tends to drift from within the building to the air-gap, and the fresh air to the facility is replaced / supplied from outside. In the A type, the air from the rooms enters the air-gap and continues to move passing above the rollers to the awnings. In some designs, the air is guided out or through the duct is returned to central heating or A/C systems of the building.

-Ventilation Combo (Type B and C): The air is guided outward through the air-gap or vice versa. In cold climates, the B and C types can have a pre heating effect on the air before it enters the rooms.

-The ventilation system of A, B, and C are mechanical that could be implemented in conjunction with the HVAC system of the building.

-The air is ventilated out of the building (Type D): The fresh air from outside is guided inward through the air-gap and it is ventilated outside too. The D type as a breather to the dual skin façade is implemented along with natural ventilation mechanism. The system may allow the fresh air inward through open windows and when closed may function as a thermal insulator providing a suitable thermal stability (Salehi et al., 2011; Taghi and Montazer Motamedi, 2006; Juan and Youming, 2010).

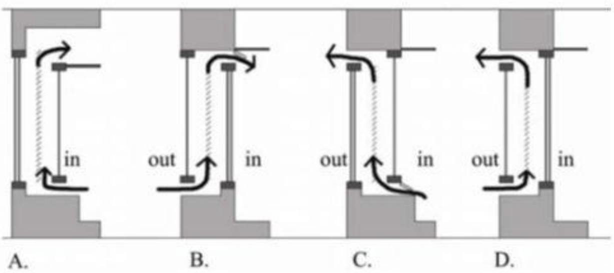

Figure1. Plans for the Direction of Air Current (Taghi and Montazer Motamedi, 2006)

MATERIAL AND METHODS

Boundary conditions and numerical methods: With reference to the conducted research and the contributing parameters, the numerical analysis of natural ventilation in dual skin façades is as follows:

In order to achieve the most optimum performance of the dual skin façades with regards to the characteristics of hot and arid climate and the suggested specifications, for natural ventilation in the said type of climate, a dual skin façade sample is designed. The numerical analysis of the sample design generated by special software is as shown below:

The two implemented software are by GAMBIT and FLUENT and through them the numerical analysis of the dual skin façade is conducted.

The geometry and Mesh design of the dual skin is done implementing GAMBIT software. It is followed by boundary condition designations which are to figure out values for the air intake and output, the inner and outer surfaces, and also the surrounding walls. The resulting Mesh value is entered into FLUENT software.

The most important parameter needed to plug into FLUENT software is to select the appropriate value on boundary condition lines. In doing so, must define the elements such wind velocity and temperature. Based on the element values then can define conditions on the windows designated for inward flow of air. To analyse the environment, it requires setting the equations for Conservation of Mass and Energy, Pressure and Momentum of the sample model. Then with regards to the already mentioned elements can proceed with calculating for a 24 hour period in an hourly segment. Eventually the values for wind and thermal dispersion are achieved. At this stage, the important issues are the heat transfer rate of the inner wall and the temperature of vented out air which we will define.

Now is the time to analyse the sample. To begin with, must come up with different geometrical values, reconfigure the Mesh and to re-plug it into FLUENT software, re-define the boundary condition values, and solve it for the given parameters.

Next step is to calculate for the heat transfer rate of the inner surface for every single case, and ultimately it is to compare them with the size of the air inflow / out flow windows, and determine the best values.

Case Study

The intended case study is an imaginary 3 story high building in which there is a single room allocated to each floor. The allocated air-gap size of the dual skin façade is 50cm. There is a window to each floor allocated to both the inner and the outer skin with 1.0 meters dimension.

The specifications of the implemented glasses to the inner and the outer skins of the façade set as default are per Table 1.

Climate Data

The current case study is analysed in hot and dry climate of Kerman city located on 30° 17’ 38” N. Latitude and 57° 5’ 3” E. Longitude. The inflow air temperature of the exterior windows is 3 degree cooler than the air temperature outside and the inflow air temperature of the opener at the lower part of the air-gap is 1 degree cooler than the temperature outside. The velocity of the air entered through the openings is intended to be $2.5^{m}/_{Sec.}$ Other climatic data such as the wind velocity and temperature of the city is also shown per Table 2.

Table1. Specifications of the Implemented Glasses (Tabatabaeipour, 2013; Hosseinpour and Kashani asl, 2010)

	The Inner Glass	The Outer Glass
Thickness (mm)	150 (The Double Glass Windows Gap)	5
Coefficient of Thermal Conductivity (W/m^2.K)	2.9	5.9
Specific Heat Capacity (j/Kg. K)	2500	

Table 2. Climatic Data (Kasmai, 2008)

	Winter daytime
Outside Average Temperature (○ C)	15
Inside Temperature (○ C)	23
Average Wind Velocity (m/s)	4

RESULTS AND DISCUSSION

The Temperature Changes

The outside temperature is intended to be 15°C and the inflow air temperature of the exterior windows is 12°C. The interior openings and openings on the top and bottom of air gap are to be closed and three exterior openings are to be opened in order to enter and exit air.

In the model, the interior windows are closed and as a result, the flowing air of the air-gap allows the temperature in the first floor to reach 15°C, the second floor to 13°C, and the third floor to reach 14°C. It produces 2°C reduction with respect to outside temperature. It also shows an 8°C to 10°C reduction with respect to 25°C comfort temperature.

The experiment model in brief shows that if the interior air inflow windows to the building are to be closed and the exterior air inflow windows to the building are to be opened, the air flow in the air-gap will have an insignificant adverse effect on the internal temperature of the building.

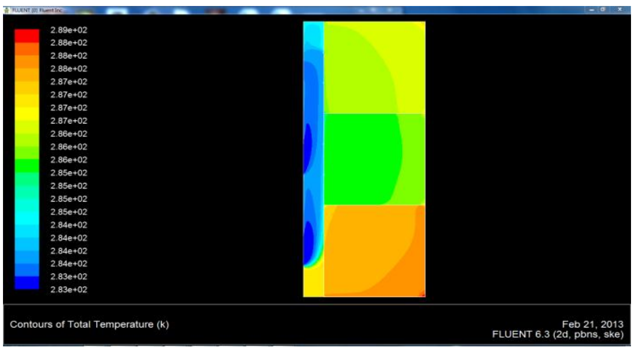

Figure 2. Temperature changes in winters, day time, the interior windows and the upper opener are closed, but the exterior windows are to be left open

The Velocity Changes

The inflow air to the model is intended to be $4^{M/Sec}$ and with regards to the fact that the inflow windows to the building are closed, the wind velocity has no effect on the in-building air current.

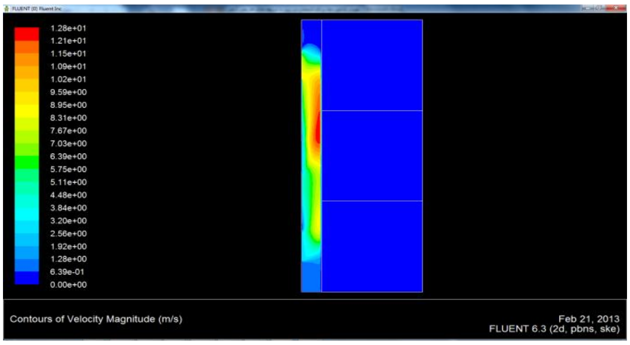

Figure 3. Velocity changes in winters, day time, the inner windows and the upper opener are closed, but the exterior windows are to be left open

The Temperature Changes

The outside temperature is intended to be 15°C and the inflow air temperature of the bottom opening of air gap is 14°C. In the model the interior and exterior windows of inner and outer façade are closed and openings on the top and bottom of air gap are to be opened in order to enter and exit air.

The interior and exterior windows are closed and as a result, the flowing air of the air-gap allows the temperature in the first floor to reach 16°C, the second floor to 15°C, and the third floor to reach 16°C. It produces 1°C increase with respect to outside temperature.

This means that the ventilation method in this model will approximate the outer temperature 1°C to inner temperature and leads to less heat transfer between the inside and outside. The experiment model in brief shows that if the interior and exterior air inflow windows to the building are to be closed, the ventilation of air-gap in tunnel shape corridor have a Favorable effect on the internal temperature of the building.

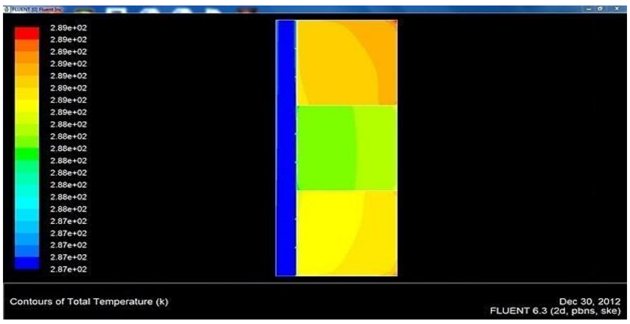

Figure 4. Temperature changes in winters, day time, the interior and exterior windows are closed, but the upper and bottom opener are to be left open.

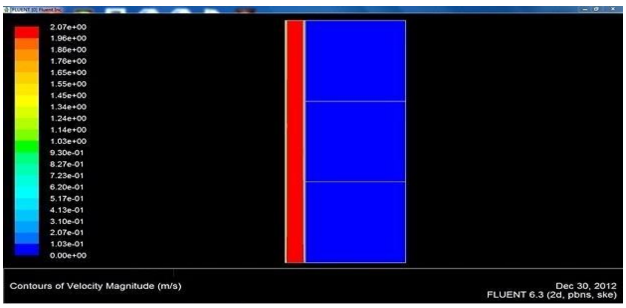

Figure 5. Velocity changes in winters, day time, the interior and exterior windows are closed, but the upper and bottom opener are to be left open.

CONCLUSION

With reference to the studies done on the charts, the following results are established:

Graph 1 analysis: In this model according to closed interior windows with ventilations in the air-gap in a way that the air enters through two windows located at the bottom of the external skin to the first and the second floor. The passing air exits through the upper window located on the external skin near the third floor of the building. The air flow in the air-gap will have an insignificant adverse effect on the internal temperature of the building. Considering the temperature outside is 15°C and the comfort temperature is 23°C, it produces 2°C reduction with respect to outside temperature. It also shows an 8°C to 10°C reduction with respect to 25°C comfort temperature.

Therefore, the ventilation method in this model reaches negative results in the change of the indoor temperature so that this model is not suitable for winter.

Graph 3 analysis: The dimensions of the windows are 1 meter, when ventilating the air-gap in tunnel shape corridor (the air enters from the lower opener to the air-gap, and exits from the opener located on top of the air-gap), when the inflow and outflow windows of both inner skin and the outer ones of the building are closed, they could produce some positive results. It is reasonable to conclude when the outside temperature is considered to be 15°C, and the inside comfort temperature at 23°C, the model has shown a 1°C increase with respect to outside temperature, and still needs a 7°C to reach the comfort temperature inside the building. One of the effective parameter in balancing the inside temperature in winters is the radiating effect, but since the issue is much too complicated and it is also falls outside of the research scope; therefore, it is skipped. Without considering the influence of radiations that improves the model's result; therefore, the model of choice recommended the best for winters.

So comparing the two models above were numerically analysis shows that the second model with tunnel shape corridor ventilation in air gap will approximate us to appropriate results. This model as the optimal model in this comparison will reduce the use of air conditioners and energy consumption in winter.

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