International Journal of Architecture and Urban Development
Vol.7, No.3 Summer 2017

An Efficient Double Skin Façade for an Office Building in Shiraz City

[1]*Ramin Movahedpour, [2]Maria Kordjamshidi, [3]Mohammad Javad Mahdavi Nejhad
[1]M.A., Yasuj Branch, Islamic Azad University.
[2] Assidtant Professor, Faculty of Art and Architecture, University of Mazandaran, Babolsar, Iran.
[3] Associate Professor, Department of Architecture, Faculty of Art and Architecture, Tarbiat Modares University, Tehran, Iran.

Recieved 30.12.2015; Accepted 12.09.2016

ABSTRACT: Energy efficiency in office buildings has been the center of attention for many researches. This special attention is due to highly energy consumption in this building type. Refinement of facade and building's envelop is a good approach to reduce buildings energy requirements. Double skin facade concepts are commonly used to achieve that object. Although the concept is not new, there is a growing tendency from the architects to put it into practice. However inappropriate selection of technical parameters in this kind of façade, such as its interior/ exterior openings, layers, materials and shading device would lead to reverse expected results. The objective of this study is to improve and optimize the thermal performance of an office building in hot and dry climate. For this purpose a suitable double skin façade concept is designed to reduce the building's annual energy requirements. This concept is optimized by integrating with a windcatcher. The optimization is performed based on simulating a designed office building by Energy Plus software. The results revealed that double skin façade integrated with wind catcher can significantly reduce annual energy requirement by 26.65%. The proposed solution can be considered as an effective platform for sustainable architecture and reduction of energy consumption.

Keywords: *Double skin façade, Windcatcher, Optimal design, Office buildings.*

INTRODUCTION

It is expected that building technology beside other technologies adapt to new conditions before employing it, in order to provide optimize condition in building industry. This matter is important for buildings with passive systems to exploit energy installation by architects. Double skin façade are examples of these passive systems which optimize energy consumption based on climatic parameters such as orientation and intensity of wind along with orientation of building.

Although there are numerous studies related to double skin façade, few of them have tried to localize the mentioned technology aimed at optimizing energy consumption. There are multiple studies conducted on the same topic aimed at finding characteristics such as material and color of layers (Blanco et al., 2014; de Gracia et al., 2012; Chan et al., 2009; Joe et al., 2014; Coma et al., 2014; Diarce et al., 2014; Gratia & De Herde, 2007), proper depth of the two layers (Joe et al., 2014), optimized orientation of double skin façade (Wong et al., 2008) and dimensions of layers of double skin façade (Gratia & De Herde, 2007; Wong et al., 2008; Ding et al., 2005). Beside these parameters, focus should be upon usage of climatic element in buildings which are matched to the climatic conditions and have been meeting needs of habitats.

There are a few studies conducted on localization of double-shell faces. Wenting Ding et al. (2005) investigated the usage of an atrium integrated with double skin façade in order to have natural ventilation. Double skin façade is surrounded by a solar chimney from the south and by an atrium from the north. Results of the mentioned research led to an appropriate ventilation of the building.

One of the approaches used to reduce energy consumption for cooling in local architecture of hot and dry climate is to use windcatcher (Khalili & Amindeldar, 2014; Bahadori & Yaghobi, 2006) which is a conventional architectural masterpiece in vernacular architecture of Iran. It is a traditional Persian architectural element to create natural ventilation in buildings. It can be considered in the concept of sustainable architecture to use renewable energy (A'zami, 2005). Windcatchers have been used in hot and dry regions of Iran and countries around Persian Gulf to provide natural ventilation and to cool the environment (Moghaddam et al., 2011). Components of windcatcher include chimney, tunnel, cord and chain and shelf. Due to fluidity of air, windcatchers provide natural ventilation inside the building (Montazeri et

*Corresponding Author Email: *ramin.movahed68@gmail.com*

al., 2010). In fact, temperature is different between the inner and outer part of the building and also it is different between the various parts of windcatcher. This result in pressure divergence and consequently air flow (Campton. 2001). As a matter of fact, when there is no or little wind, temperature gradient leads to natural ventilation (Afshin et al., 2016). During the day, when sun rays hit the southern section of windcatcher, air trapped in the mentioned section absorbs the heat and goes up, air escapes from the upper window, relative vacuum is formed inside the porch and cold air moves down through the north window (Fig. 1& Fig. 2).

Fig.1: Windcatcher in vernacular Iranian architecture

Sheds are among architectural elements used in traditional architecture of Iran. In traditional architecture of Iran, Sheds are formed by porch or Shanashyr. (VakiliNejhad et al., 2013) (Fig. 3 & Fig.4).

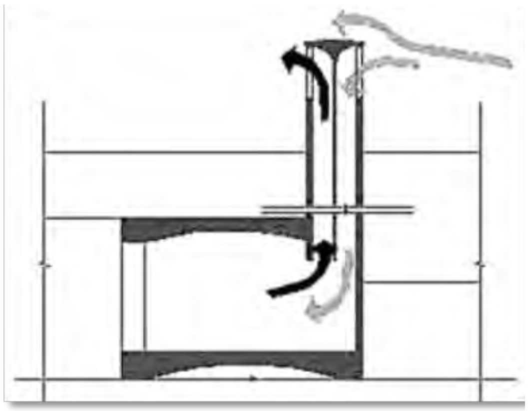

Fig.2 : Windcature performance diagrams for building ventilation (Source: Moghaddam. 2011)

There are studies conducted on the relationship between canopies and double skin façade. Gertia & Herd (2007) conducted a study on the optimized location of canopies between two layers and found out that the best location for canopy is the midpoint of interface of the two layers. Blanco et al. (2014) conducted another study to investigate a new type of double skin façade which have porous metal plate as the canopy on the outer layer. It prevents inside space from getting hot. Color of canopy was evaluated in another study by Gartia & Herd (2007). Results showed the trivial effect of color.

The current study is aimed at designing and modeling double skin façade for Shiraz official buildings based on Shiraz local architectural patterns. To this end, different usages of double skin façade are analyzed and the ecological effects of canopies and windcatchers on building energy consumption are investigated.

Fi g. 3: Porch as a shed in vernacular Iranian architecture (Source: Wong et al. 2008)

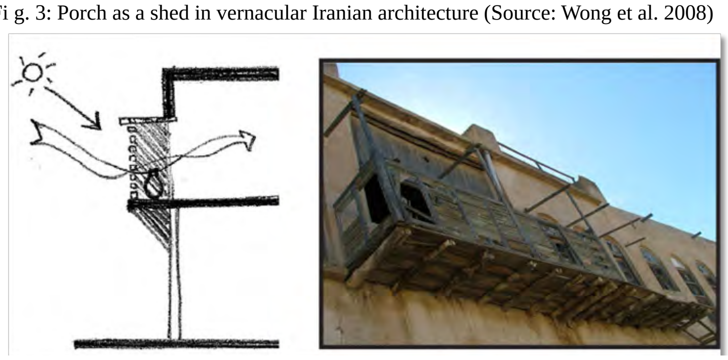

Fig. 4: Shanashyr in vernacular Iranian architecture for shading (Source: Wong et al. 2008)

MATERIALS AND METHODS

To provide integrated approaches of conventional architecture and modern technology in the current study, double skin façade in different forms are evaluated. Also, local methods of meeting heat requirement in conventional architecture are investigated in order to achieve a suitable architecture model. The mentioned model is analyzed and optimized using simulation software, Energy Plus 8.2.

Mateus et al. (2014) evaluated the effectiveness of the Energy Plus in order to investigate the heating capacity of double skin façade. Results have indicated the agreement between the results of simulation and experiments although there were trivial errors which were ignorable. Therefore, the software Enrgy Plus is proved to be a useful tool to simulate double skin façade in order to investigate energy optimization in official buildings.

Research Process

An office building of the same dimensions and physical characteristics as the existing official buildings is modeled to investigate the heating capacity. Then, the amount of energy consumed to heat or cool the building is calculated. In the next step, double skin façade is added to northern, southern and northern-southern sections to investigate heating capacity. The next step is aimed at evaluating the idea of adding windcatcher to the northern and southern sections and also to the double skin façade. In the next step, the effect of canopy is evaluated. Next step is aimed at locating canopy between the two layers of DSF. The last step is to investigate the integration of the two external canopies. To conclude, the energy consumption of each step is calculated. Additionally, performance of different forms of DSF installed in northern and southern sections affected by external environment in different seasons is investigated to optimize the building energy consumption.

In cold seasons, DSF are closed and only small openings of the area of 1.2 m2 are embedded in internal shell to let the DSF exchange energy with residence in order to reduce energy consumption (Fig. 5).

In mild seasons, weather is not disturbing and DSF with the openings of the area of 7.2 m2 per floor let the air enter the building. In this case, double-shell face is quite different from DSF including windcatcher and bonnet. Parallel to openings embedded in internal shell, there are openings with the same area embedded in external shell in order to let air enter the residence. In the case of DSF including windcatcher, openings are embedded on the top point. On the other sections, openings are blocked in order to trap the wind. Then, wind enters the internal space with high pressure through the internal shell (Fig 6).

In the hot seasons, temperature is over 400C. Openings of internal shell are closed to prevent the hot air from entering the space. Openings of the area of 12 m2embedded in the highest and lowest points of double-shell face are opened to optimize ventilation. Double-skin facade including windcatcher is not different. There are openings embedded in the lowest point to optimize ventilation using bonnet. (Fig.7)

The Case Model

An 8-storey office building with open plan having DSF is considered in this study (Fig. 8). On the top section of the mentioned building, a heat storage called solar chimney is embedded (Fig. 9). Double-skin facade connects to solar chimney. Depth of DSF in northern and southern section is 80 cm. area of the interface connected to DSF is 9.3 by 26 m2. In one case, DSF is integrated to conventional architectural windcatcher which is 80 cm in depth. Its height is the same as DSF. Materials and thickness of different layers of DSF embedded in northern and southern sections from outside to inside are as the following: 8 mmclr، loe spec selclr 6mm، loe spec selclr 6mm.

To optimize ventilation and meet thermal comfort requirements, various openings are embedded in DSF and windcatcher.

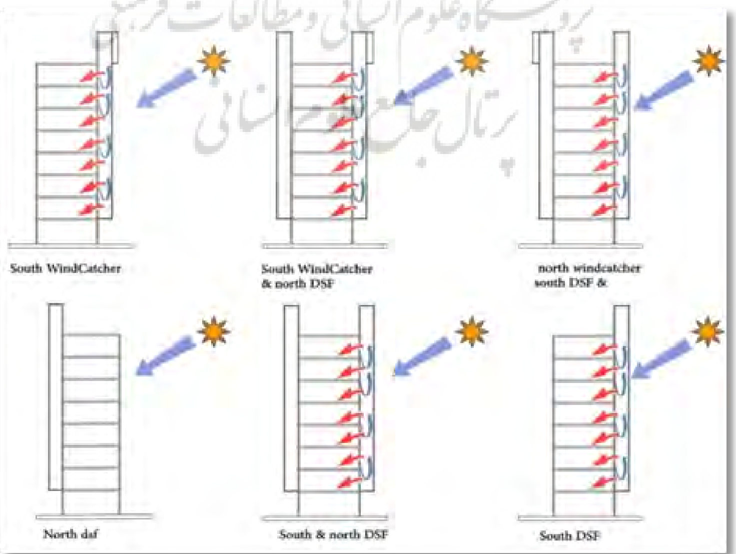

Fig. 5: Opening and closing procedures in the cold time

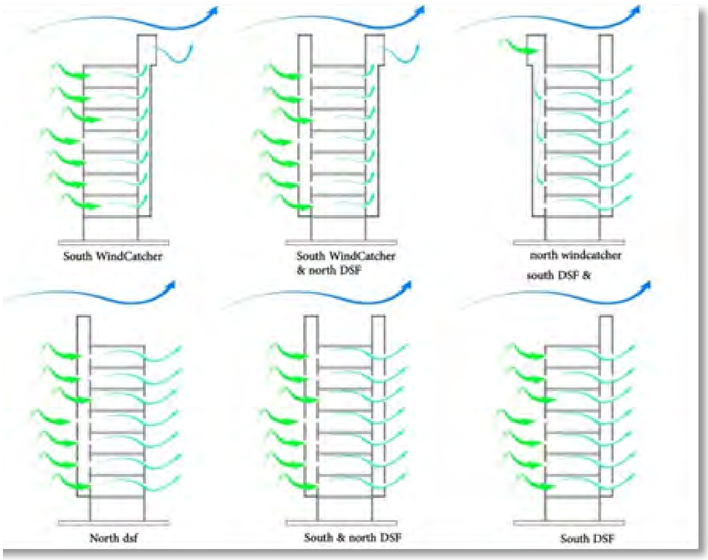

Fig. 6: Opening and closing procedures in mild time

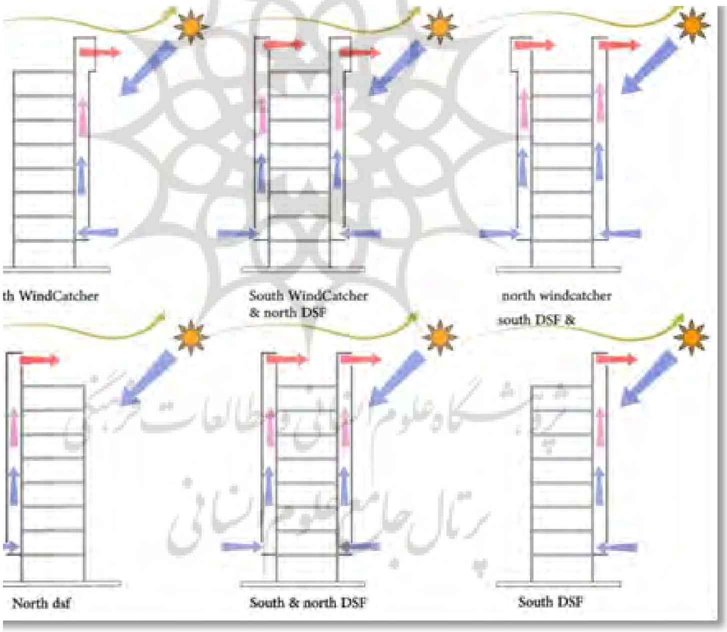

Fig. 7: Opening and closing procedures in hot days of the year

Researchers have confirmed that even small openings embedded in DSF positively affects on energy consumption (Gratia & De Herde, 2007) . Consequently, openings are closed and opened alternatively based on seasons. In cold seasons including November, December, January, February and March (Behzadianmehr, 2013) openings embedded in DSF are closed although there are some openings embedded in southern internal shell opened to let heat of sun rays enter inside. In mild seasons including April, May and October, weather is not disturbing. Consequently openings of the both shells are opened. But in the hot seasons including June, July, August and September weather is so hot and openings of internal shell have to be closed to prevent hot air from entering inside. Openings of external shell are opened to keep temperature of interface low. In this way, ventilation is optimized. In the following, certain characteristics of openings and schedule of opening and closing them are given:

During cold months, double skin façade is closed. Only small interior openings with the dimension of 1.2 m2 are mounted in each floor to reduce thermal loading of building. Weather is not distributing in mild months. Consequently, interior/exterior openings of 7.2m2 let the air enter the building. But,

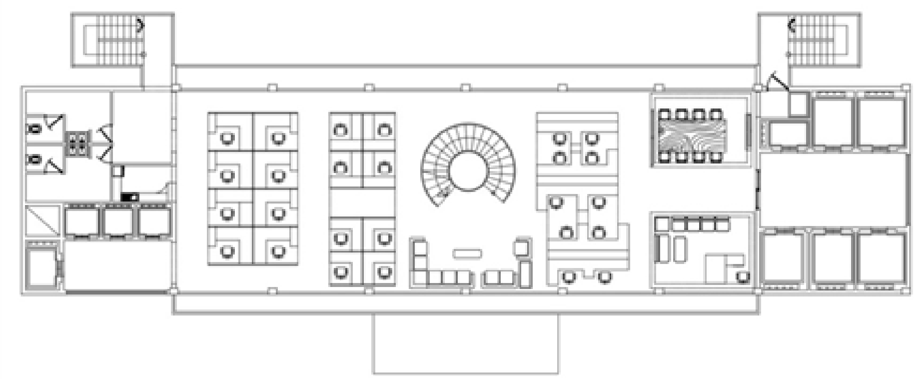

Fig. 8: The plan Sample of office building

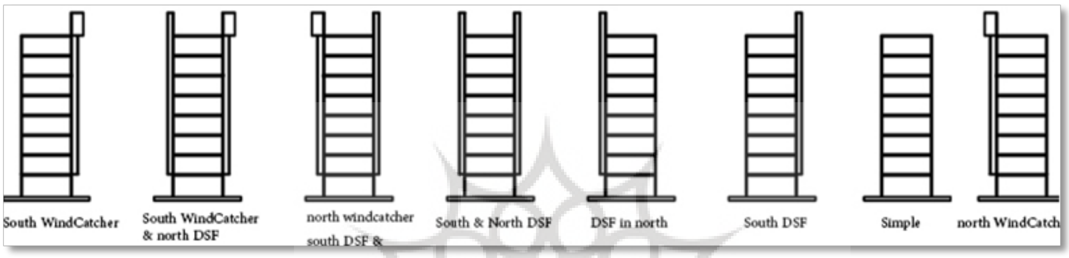

Fig. 9: Models evaluated by simulations

it is over 400c in hot months and hot air has to be prevented from entering the interior space of building. But, temperature is rising inside the double skin façade due to the greenhouse effect. The mentioned problem would be resolved by mounting interior/exterior openings of 12 m2 in order to exert pressure difference to let hot air exit.

Two types of shading device are used in this study. Shading device mounted between two layers of double skin façade and exterior shading devices. Shading devices are located 40cm away from interior and exterior layers. It means that they are mounted in depth of double skin façade. Exterior shading device is of 80 cm area based on Iran building regulations. Length of an optimized shading device is calculated about 120 cm based on latitude and incident angle during the hot seasons.

Climatic Data

Shiraz is located at longitude of 52.25 and latitude of 29.27 with the height of 1491 m above sea-level (Management and Planning Organization, 1996). The city is oriented 30 degrees toward west. Based on climatic evaluations, optimized orientation is considered as west-east with deviation of 17 or 18 degrees toward east (Kasmaee, 1993). Dominant winds come from west and north (Shaterian, 2009). Shiraz is too cold to tolerate in November, December, January, February and March. But, it is mild in April, May and October.

The current study is aimed at evaluation the positive points of double skin façade in cold and mild seasons. But, greenhouse effect of double skin façade has to be neglected for some seasons because in the given seasons, it is really hot. It is concluded that performance of double skin façade is strongly interwoven with temperature.

RESULTS AND DISSCUSION

To perfectly compare samples, modeling is done through four stages. In the first stage, there is no shading device. In this stage, simple models and models of integrated windcatcher and double skin façade are investigated. AT the second stage exterior shading device is added to southern façade of the models mentioned in the first stage. The third stage is aimed at adding window shade to southern façade and between the two layers of façade. The last stage is aimed at investigating the combination of exterior shading device and window shade. In the following, results are deliberately described (Fig.10).

Assessment of models without Sheds

Results of thermal evaluation of an office building without double skin façade located in Shiraz reveal that to 202552 kw/hr of energy is consumed for cooling and heating. It means that 173291 and 29261kw/hr of energy is consumed for cooling and heating, respectively. The next stage is followed by adding double skin façade in different ways. As mentioned, openings are opened and closed based on a pre-defined schedule. Evaluation of different forms of double skin façade and windcatcher indicate that to reduce energy requirement, windcatcher mounted in southern façade is of the optimized performance. In this way, energy consumption is about 16336kw/hr which means that compared to the initial stage; energy consumption is reduced by 20%. The undesirable

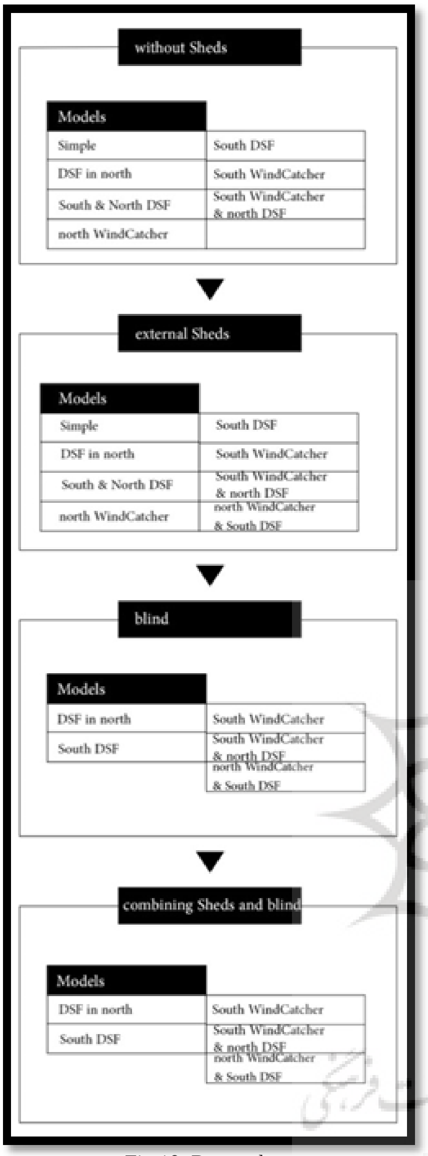

Fig.10: Research process

case is related to a windcatcher located at north façade. In the mentioned case, annual energy consumption is 221782kw/hr. compared to the buildings with no double skin façade, increase of 9% in energy consumption is proved (Fig.11).

Assessment result adding external sheds

The next stages of modeling are aimed at investigating exterior shading device. The mentioned shading devices force some changes in order to optimize energy requirement. In this case, reduction of energy consumption is clear. The optimized model is a building with a windcatcher located at southern façade. In this case, annual energy consumption is 157469kw/hr, addition of shading device to this model leads to optimization of 2%. The least percentage of optimization is related to northern double skin façade which has the energy consumption value of 196867kw/hr (Fig. 12).

Assessment result adding blind in the space between Double glazed

In this stage, there are models with southern double skin façade. Results show that window shades are absolutely more effective than exterior shading devices. In this way, energy consumption reduces. The results point to the superiority of window shades to exterior shading devices. The optimized results are related to a model with southern windcatcher with annual energy consumption of 143441kw/hr (Fig. 13).

The results of the samples by combining external Sheds and blind

The last stage of modeling process is related to evaluation of combination of window shade and exterior shading device. In this case, energy consumption reduces compared with initial models and models with exterior shading device. But, it is not as effective as window shade. The optimized case is a model with southern windcatcher with annual energy consumption value of 146947kw/hr (Fig.14). Compared to the initial case, it has increased by 27%. The greatest energy consumption is related to a building with southern –northern double skin façade. It consumes 160900kw/hr.

CONCLUSION

Simulation results have shown windcatcher and double skin façade hvea significant effects on reducing building energy requirements. Comparing different models indicates the weakness and strength points of initial ideas related to usage of traditional architectural elements in double skin façade.

Application windcatcher and its ventilation principles in double skin facades

In this case, usage of windcatcher and openings opened and closed based on a predefined schedule leads to positive changes in energy consumption. In all models, southern windcatcher outperforms.

The Use of External Sheds

Exterior shading device is not as effective as window shade due to the size of exterior shading device and preventing the space between two layers from getting hot. In this model, temperature gradient is enough to lead to pressure gradient. Consequently, air flow decelerates and ventilation deteriorates. Window shade mounted between two layers gets hot under the solar rays. Therefore, the air trapped in window shade gets hot. Due to openings mounted on the lowest section of double skin façade, cold air flow at bottom and hot air flow up due to low density. Temperature gradient and pressure gradient lead to an air flow really greater than that caused by exterior shading device.

Integrated exterior shading device and window shade is not as effective as window shade alone. But, this combination outperforms exterior shading device alone. So, window shade increases the temperature gradient and improves ventilation.

Finally, after evaluation and analysis of effectiveness of combination of double skin façade and windcatcher, the proposed pattern for energy consumption reduction in Shiraz official buildings is summarized in the following figure (Fig.15).

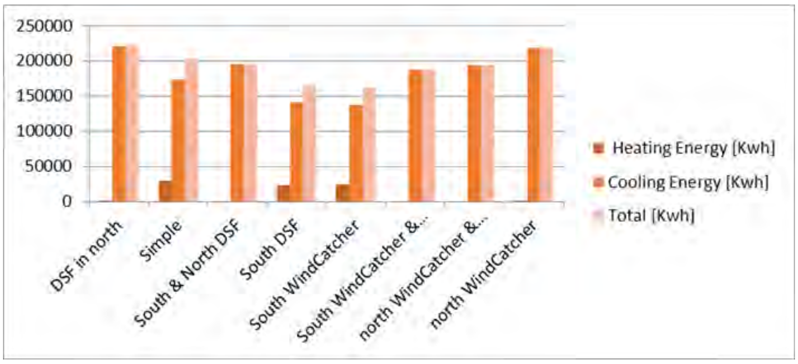

Fig.11 : A comparison between energy requirements in primary models

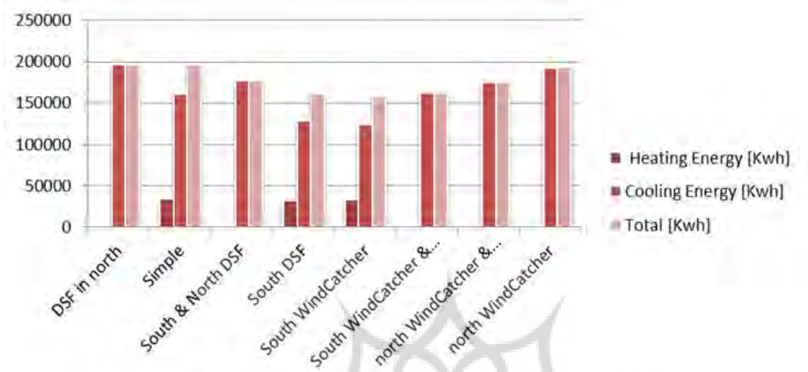

Fig.12**:** A comparison between models performances after adding external sheds

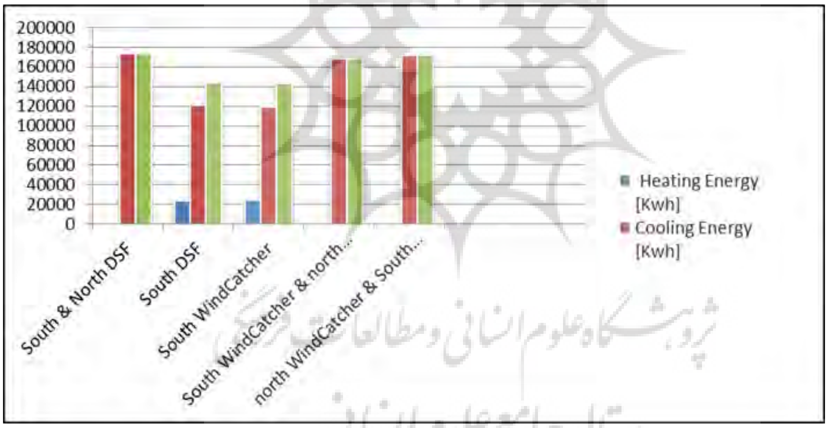

Fig.13 : A comparison between thermal performances of models after inserting blinds

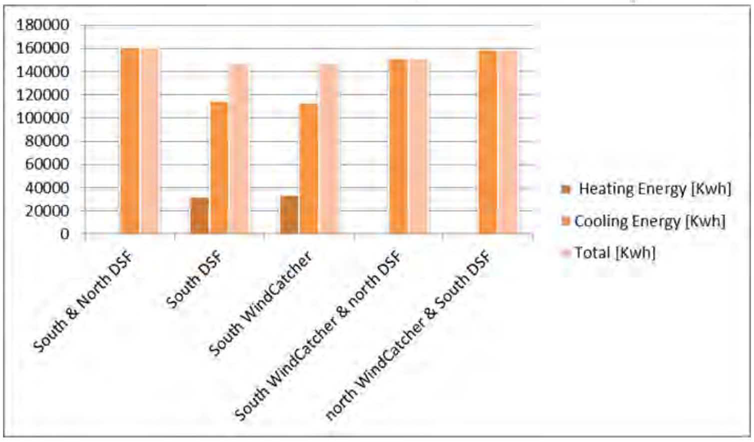

Fig.14: A comparison between thermal performance of models after adding blind and Sheds in external wall

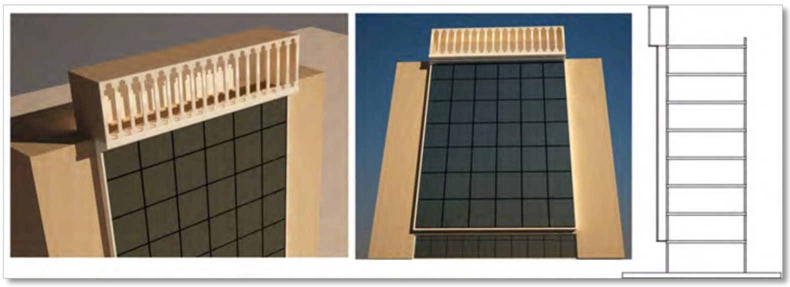

Fig. 15: Proposed model for the localization of the double skin façade

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