Trends in Life Sciences
An International Peer-reviewed Journal
ISSN: 2319–4731 (p); 2319–5037 (e)

THE IMPACT OF DOUBLE-SKIN FACADE AS A SOLAR PASSIVE SYSTEM ON DECREASING OF COOLING LOAD OF BUILDINGS

Seyyed Mohammad Ghaffari Khalaf Mohammadi, Hajar Bahri, Ahmadreza Karamian Boldaji
Department of Architecture /Shahr-e-Kord Islamic Azad University-Science & Research Branch; (Iran)
Sghafari@gmail.com, h.bahri1607@gmail.com, ahmadreza.karamian@yahoo.com

ABSTRACT
In architecture plans, easy-to-apply and aesthetically pleasing approaches are of high priority so that energy consumption can be saved and environment protected. The façade of a building, as an interface between the interior and exterior, plays a major role in the amount of energy supposed to be consumed. In this regard, double skin facades are capable to save energy consumption, to use air conditioners more economically and, at the same time, to care aesthetic concerns. Not only do double skin facades serve as decorative elements but, as efficient architectural modules, they decrease energy consumption efficiently. Depending on different climatic considerations, however, different approaches should be adopted to apply them. In order to cool the interior more economically, especially in hot climates, it is imperative to use systems to minimize the penetration of solar energy and to provide natural ventilation. Recent double facades are equipped with technologies to meet enough shading, ventilation and fire protection. The present study aimed to study double facades and other related shades capable to save energy needed to cool the interior especially in hot regions. The methodology of the study is descriptive-analytical and data were gathered mainly from library sources.

KEYWORDS: Decreasing cooling load, double façade, shading.

INTRODUCTION

The issue of being *multi-skinned* has a long history in traditional and climate-based architecture, especially in Persian architecture. The aim has been improving the living conditions; the concept of the whole issue, contrary to popular belief, is not a modern one. In fact, the thermal problems in modern buildings appeared with the advent of thin glass facades which had low thermal resistance. One of the solutions proposed was changing the kind of glass used as well as making use of devices to control sunlight. In connection with this, double skin facades, mainly made of glass, came to the fore. The facades are composed of outer and inner layers with *ventilable* space in between. Providing of thermal and acoustic insulation and saving energy consumption are among the salient benefits of such facades. Double facades also allow users to open and shut the openings depending on different conditions in terms of air pollution, direct sunlight, strong winds, etc. Of the other advantages is that several shades can be installed onto the facades to prevent the direct sunlight during the hot seasons of the year so that cooling load of the buildings could be reduced efficiently. On the other hand, during the cold seasons, the double skin facades serve as thermal convectors through collecting and then guiding the sunlight in. As a result, the difference in temperature between the interior and the exterior would be optimized. The space between the outer and inner layers of double skin façade can be ventilated either naturally or mechanically. The kind of openings used, air pressure difference, wind velocity and direction are among the factors affecting ventilation efficiency. In sum, the benefits of using double skin façade can be summarized as follow: ventilation during summer nights, saving energy consumption and respecting environmental issues, sound and thermal insulation, decreasing wind pressure as well as transparency in design. It's worth mentioning that high cost of applying such facades will be compensated in a rather short time after completion of the building.

MATERIALS AND METHODS

The structure of double-skin facades

A double-skin façade consists of the following parts:

1- Outer skin which is made of glass
2- Inner skin which is often made of two-layered glass (transparent or absorbing). The inner skin may or may not be made of full glass; usually high thermal density materials are used so that they can save thermal energy during the day. In inner skins several openings can be installed as natural ventilators.

ISSN: 2319–4731 (p); 2319–5037 (e)

3- The middle space which is a space filled with air designed with various widths. The efficacy of the double-skin façade and its maintenance depends on the very width. The middle space can be ventilated naturally or mechanically.
4- Other pieces of equipment: Since the sunlight enters the middle space directly, its temperature increases considerably. Therefore, making use of natural ventilation is very important in order to decrease the cooling load of the building. Of the best solutions is installation of shades in the middle space. Available in various kinds, the shades-as passive cooling systems-attract or reflect the solar energy.

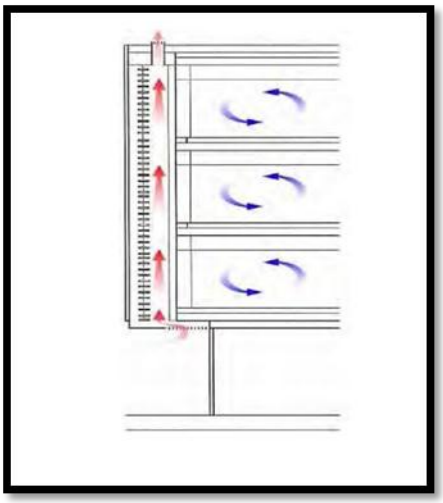
The heat absorbed by the shades will be emitted out through convective currents resulting in saving energy due to reduced cooling load of air conditioners or other cooling systems.

The intended goals of applying double skin facades
Applying double skin-facades meet the following goals:

1- Decreasing thermal load of the building.
2- Taking optimal advantage of natural sunlight rather than artificial light.
3- Providing an acoustic environment which creates, in turn, a tranquil space free from environmental pollution.
4- Taking advantage of a full glass view with its ideal characteristics.
5- Controlling the air current (through opening/shutting openings) in buildings exposed to strong winds
6- Making use of shadings optionally in adverse weather conditions(including heavy rain and wind).

Kinds of double-skin facades
Double-skin facades can be mainly grouped as follows:
1- Protective or partition facades.
2- Twin facades.
3- Ventilator facades.
4- Hybrid facades.

Protective or partition facades
Such facades are composed of two glass surfaces with a 250-750 millimeter-distance in between. This in-between space is quite airtight.



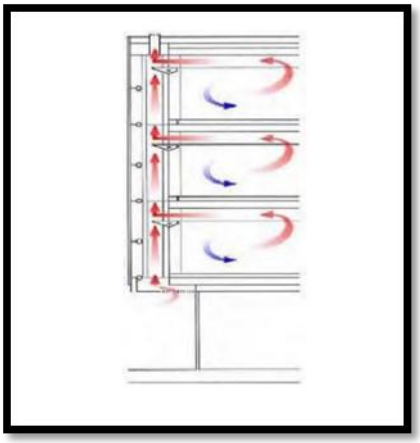
Schematic view of a Protective or partition facade

Twin facades

Twin facades include inner and outer skins. The function of the outer skin is mainly protecting the air-filled space between the two skins (shading system) against environmental factors. The openings onto the outer skin are arranged in an alternate pattern or basically are installed far from the inner view windows so that acoustic control can be managed easily.

Ventilator facades

Ventilators facades consist of two glass insulated surfaces and a secondary plastic layer between the two surfaces. The stagnant air between the layers is blown out through mechanical fans. Consequently, the inner glass surface becomes cold, whereas the outer glass layer keeps the loss of thermal transition at a minimum. This system is mainly used when the natural ventilation is not possible (where there is much sound, odor or wind).

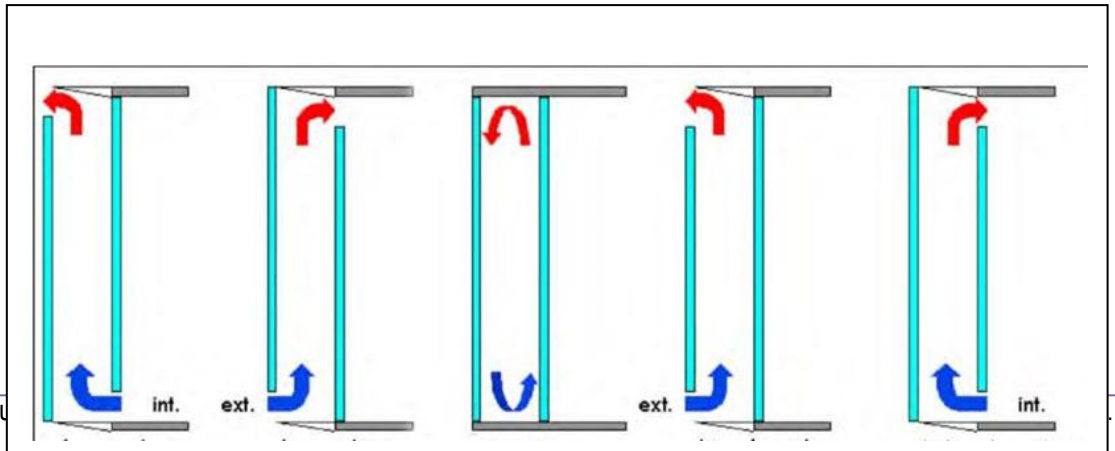


Natural ventilation

The main aim of natural ventilation is exchanging the stagnant air of the interior with fresh air. The purpose may be met by mechanical ventilation as well. In double-skin facades the air behavior depends on material(s) used in middle layers. Similarly, the quality of wind dictates whether shades are used.

Ventilation in double-skin facades may be done through one of the following ways:

1- The current of the wind- in and out of the space- is from the exterior.
2- The air enters the space from the interior and again returns to the interior.
3- The air enters from the exterior towards the interior.
4- The air enters the space from the interior and is blown out the building
5- The space between the two skins is not ventilated.



Air evacuation Air building Resistant zone Exterior air current Interior air current

Trends in Life Sciences
An International Peer-reviewed Journal
ISSN: 2319–4731 (p); 2319–5037 (e)

Solar shades

Double skin-facades decrease the thermal load of the building considerably. In this regard, the temperature of the middle space (between the two skins) plays an important role. In fact, it is the very *middle space* that protects the building against cold. However, it increases the cooling load of the building because the transition of direct sunlight to the interior results in temperature rise and, in accordingly, in cooling load surge. Therefore, solutions must be adopted to reverse the trend. One of these solutions is using solar shades. The shades may be installed uniformly within the space between the two skins. Reaching the optimum temperature within the space mainly depends on wise selection of shade. Regardless of form and kind of the shades and the place of their installation, they must prevent causing green-house conditions through curbing excessive direct sunlight.

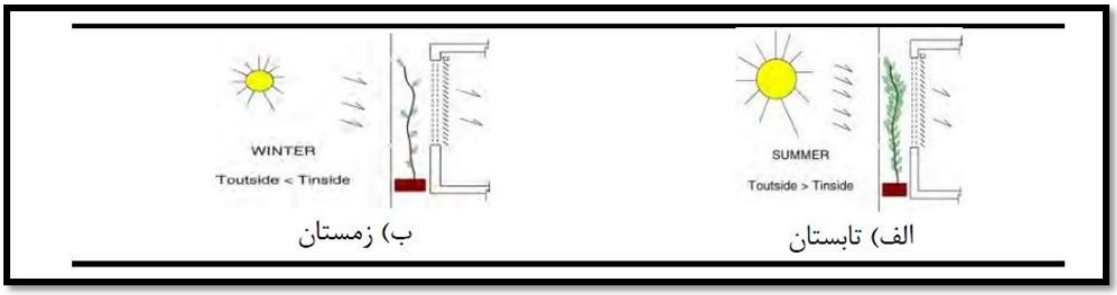
Factors to improve the function of shades

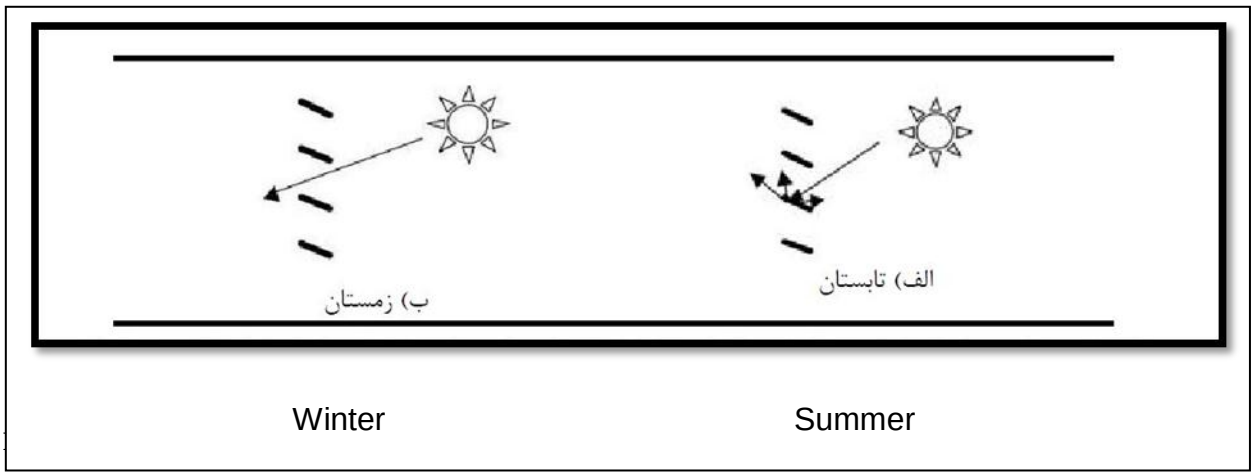
1- Installation place of shades' equipment
2- Color of shadings
3- The kind of shadings (Poirazis, 2004).

KINDS OF SHADES

Plants

Plants are able to decrease the intensity of solar radiation to a great amount. Compared with aluminum blind shades, plants transfer their latent heat more readily, and, as a result, they are cooler. During summer, plants creating shades decrease the cooling load of the building. Conversely, they let the sunlight come through the middle space during winter creating a passive solar source. The temperature of plants does not exceed 35°C; whereas, it may exceed 55 °C for blind shades. Plants within the middle space not only reduce air pollution, through absorbing dust particles and chemical gases, but also they improve the atmosphere of the interior.





Blind shades

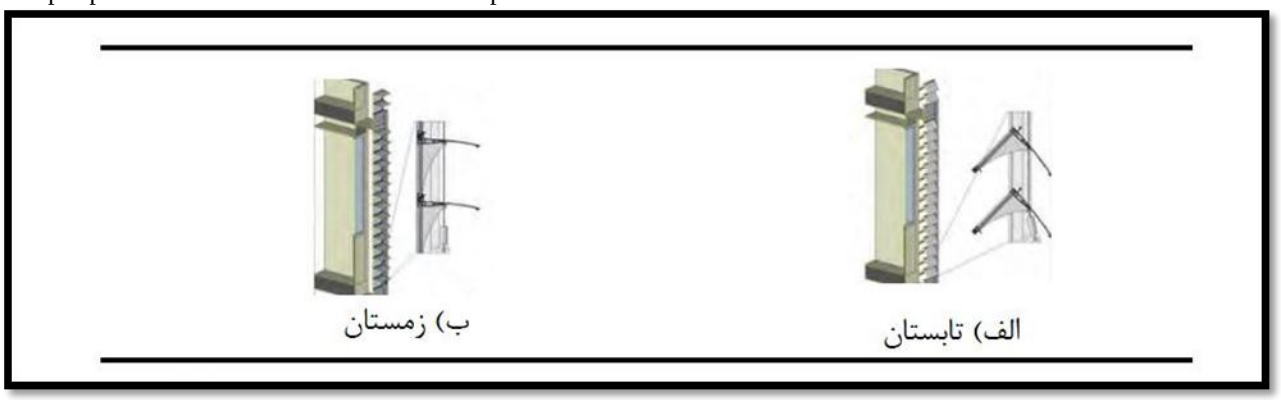
Blind shades are, in fact, modules made from wood, aluminum, plastic or other materials with low thermal density. The modules are placed at equally distant intervals. The size and angle between the modules are determined by climate as

well as geographical location of the building. During cold months of the year, the angle between blades must be set in a way that maximum attraction of sunlight can be possible; the case must be reversed during hot months so that maximum reflection of the sunlight takes place. Color and material of the shades also play a major role in intensity of sunlight reflection or attraction. Blind shades are of horizontal or vertical kinds.

Dented shades are composed of a set of blades separated from each other by certain prefabricated surfaces. The surfaces are completely transparent with high conductivity and very low thermal density. In such shades, each point is defined by two blades (surfaces) forming the front and rear views. The surfaces can be attached to each other in a way that thermal loss is kept at a minimum. Blades and surfaces can also be interwoven in such a way that penetrating the direct sunlight into the interior would be possible. Basically, by such a system it is feasible to distribute the sunlight as desired so that the knots of interior and exterior air currents could be determined (defined) separately. The major function of most shades, notwithstanding, is to prevent direct sunlight. The angle between the blades and transparent surfaces must be set in a way that the maximum attraction and reflection of the sunlight can happen during winter and summer months respectively (M.Rasouli and Y.Shahbazi 2012).

Moving shades

Moving shades, with their movable openings made of polyvinyl, are installed near the outer skin of the system. The shades are set horizontally during winter months to let in the maximum sunlight. During summer months the outer skin is kept open so that the air within the middle space can be ventilated.



Winter Summer

Where to install equipment of the shades

The equipment may be installed at different points: if installed in front of the view, they are directly exposed to wind and environmental pollutants of the exterior but, at the same time, they serve as the ideal protection against sunlight; excessive radiation has been already repelled before reaching the middle space. Therefore, the coming solar radiation and, consequently, the cooling load of the building would be both decreased extensively. If the shades are installed within the middle space, they are safe from wind and environmental pollutants but, at the same time, they increase the cooling load of the building because they attract thermal radiation during summer. This problem can be overcome by considering several openings at top and bottom points so that the hot air can be blown out in a chimney-like manner. The place of the shades within the middle space is very important. In short, shades may be installed at different positions: in front of the inner skin; within the middle space and at the one third of the middle space near the outer skin. Generally speaking, the optimum place to install the shades is the last mentioned choice; by doing so, the solar radiation can be controlled to a large extent and the cooling load of the building can be decreased as a result.

The color of the shades

Applying bright colors for the shades, compared with darker ones, creates a slighter green-house effect reducing the temperature within the middle space as much as 2.5 °C. When the bright colors are applied, the air current moves slower. Also, bright colors attract less amount of solar radiation compared with other colors.

Trends in Life Sciences
An International Peer-reviewed Journal
ISSN: 2319–4731 (p); 2319–5037 (e)

Table – The impact of color on the efficacy of shades given the location of them

Color of shades / Location	Grey-color shades	Bright-color shades
On the inner skin	The shade temperature will increase considerably. The cooling load, however, will decrease as much as 17.5 %	Compared with grey color, the temperature of the double-skin façade will decrease as much 2.5 °C. Also, the amount of solar energy attraction will decrease considerably.
On the outer skin	While the temperature of the middle space is more than the former state, the temperature of the inner skin is much less than that of the former state. Also, the cooling load of the building is less than that of the former state.	The attracted sunlight is directly reflected outside and, compared with grey color, the temperature of the double façade will decrease considerably (about 14°C). In addition, the shade temperature will be as much as 18 °C less than that of the grey color.
In the middle space	The temperature of the inner view will be certainly less than that of two former states. Accordingly, the cooling load will decrease considerably as well.	Compared with grey color, the shade temperature will decrease as much as 8.5 °C. Accordingly, the cooling load will decrease as much as 4.2%.

Application of double skin-facades in hot and humid climates

Studies show that double-skin facades have best performance in cold climates; in order to be used in hot climates, certain modifications must be made. Naturally, the main challenges in hot and humid climates are direct sunlight and green-house effect. The former is generally removed by using highly reflexive glass and the latter by identifying the optimum depth of the middle space.

Defensive parameters of double-skin facades against green-house effect

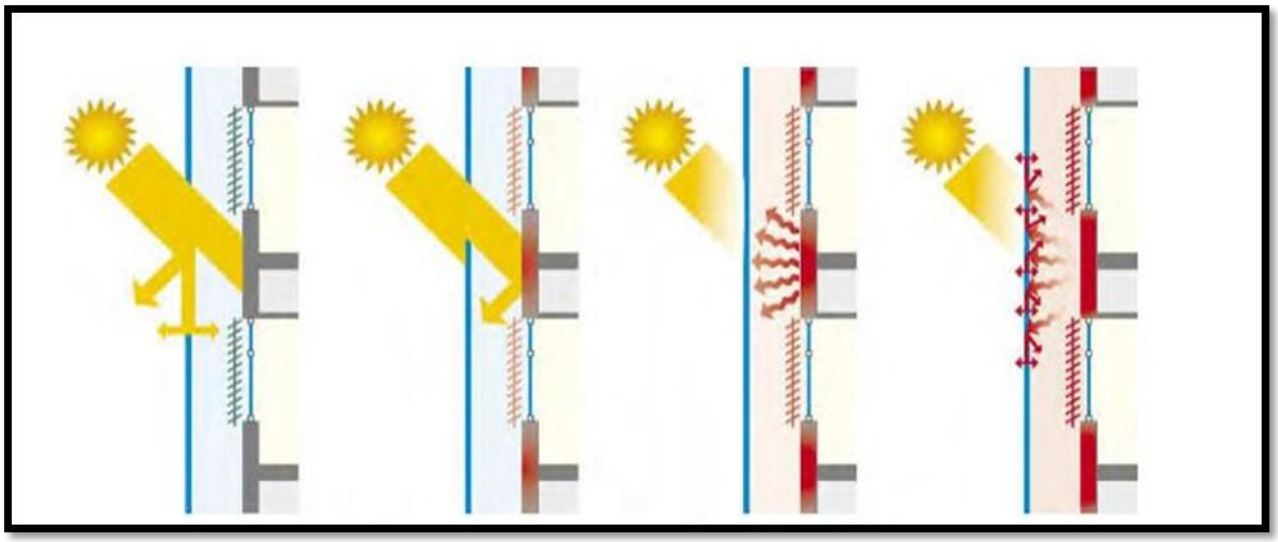
Intensity of solar radiation

The most important factor which intensifies the green-house effect is solar radiation penetrating into the middle space. In other words, the green-house effect is directly related to solar radiation intensity. When the sky is clear, the amount of attraction of solar radiation by the outer skin and temperature of the middle space vary during different seasons of the year; despite that the duration of solar radiation in winter is shorter, the radiation angle is rather perpendicular to the outer skin resulting in more attraction of solar radiation. This, in turn, may cause a temperature difference as much as 36 °C between the temperature of the two skins and that of the surrounding environment. Conversely, despite that the duration of solar radiation in summer is longer (about 16 hours), the sun radiates to the outer skin obliquely. As a result, the amount of sunlight attraction decreases considerably and the temperature rise of the middle space would be less than that of winter. The highest temperature rise in the middle space takes place in the fall equinox; the temperature of the middle space may become 43 °C more than that of the outer environment. It should be mentioned that, as a general rule, in cloudy conditions the maximum increased temperature compared with that of the outer environment would be about a few centigrade degrees.

The depth of the middle space

Generally, the depth of the middle space does not play a major role in the amount of solar energy attraction; a middle space as wide as .3m is, all things being equal, only 5.8 °C warmer than a 2.4meter-wide middle space. The highest difference in temperature takes place in summer southward.

Trends in Life Sciences
An International Peer-reviewed Journal
ISSN: 2319–4731 (p); 2319–5037 (e)



The impact of greenhouse effect in double-skin façade

Strategies to control the double-skin façade in hot climates

Researchers recommend the following strategies to design double-skin façades:

1- Applying appropriate materials such as smooth glasses based on computer simulation in order to decrease the thermal load of the building.
2- Correct installation in correct direction; despite applying appropriate materials, the green- house effect may take place in middle space in case of incorrect installation.
3- Applying appropriate skins; hybrid system with correct settings consistent with inlets and outlets must be applied.
4- Controlling the she shades appropriately.
5- Controlling the air movement and natural ventilation in the middle space is appropriate for temperate climates. For hot and humid climates, however, reaching ideally comfortable conditions would be very difficult without using active systems. In such conditions, ventilator-aided middle spaces are recommended.
6- The kind of applied glass in façade has a great effect on the annual cooling load.

RESULTS AND DISCUSSION

A double-skin facade is both a thermal insulation and a passive solar system in order to attract solar energy during winter. In summer, however, the cooling load of the building increases considerably due to high temperature rise of the middle space. In fact, the heat transition by direct sunlight which, in turn, reaches the inner skin, results in intense temperature rise of the interior. This will increase the cooling load of the building much more than the thermal load. Therefore, the application of shades is a natural solution to decrease the cooling load of the building. Shades are capable to considerably save energy needed to cool, heat and illuminate the building annually. The efficacy of such systems, given the climatic conditions, can be effectively improved through well-calculated setting of involved parameters. By doing so, reaching a sustainable architecture would be easier.

REFERENCES

Allan D. (2006). Modeling double skin façade. A thesis submitted for the Degree of MSc Energy Systems and Environment, Department of Mechanical Engineering University of Strathclyde, Glasgow UK.

Basiri H. and Noori N. (2012). Double-skin glass facades: A new approach to architecture. The first national forum on new approaches and technologies in architecture.

Ebrahimi E. Pesarak L. and Ragimi Etati. S.(2011). The impact of double-skin facades on reducing energy consumption in high-rise buildings. National forum on civil engineering, archyeture, urbanism and energy consumption. Ardestan.

Gorji M. and Abdi Rad H. (2011). Sustainable Solar Energy. Imam Khomeini International University Publications.

ISSN: 2319–4731 (p); 2319–5037 (e)

Mahmoodi A. and Haghighat F. (2013). Double-skin systems: A sustainable policy in buildings' views (an approach in hot and humid climates). International conference on architecture. Tabriz,

Poirazis H. (2004). Double Skin Façades for Office Buildings. Literature Review "Department of Construction and Architecture, Division of Energy and Building Design, Lund Institute of Technology.

Rasooli M. and Shahbazi Y. (2012). The impact of shades on improving the efficacy of double-skin facades to decrease cooling load of buildings. The first national conference on monuments. Mashad.

Rasooli M., Shahbazi Y. and Zare Sharif M. (2014). The Impact of horizontal shades in double-skin facades in order to reduce annual energy consumption. The first international conference and exhibition of solar energy.

Seyyedian S. A. and Esfandiari Kenari M. (2012). Double-skin façade: A step to sustainable architecture (Examination of double-skin façades' efficacy in hot and humid climates).

