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A state of art for using Double skin façade in hot climate

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Abstract. One of the most remarkable methods of building, especially in hot climates, helping in having pleasurable life, is designing double skin façades. Specifically about the climate properties, it is one of the sustainable building design and construction techniques, from climate properties point of view. Undoubtedly, to have a sustainable design, it is necessary for the architect/ designer of the buildings, to be cognizant about the construction environment's characteristics, to employ the sustainable strategies properly. In this regard, one of the suitable design method double skin façade, in which the building is design in a two layered (two skins) form, with flowing air between the layers, providing an energy efficient and sustainable system. Therefore this study has gone through the advantages and disadvantages of these systems in hot climates in the literatures, in addition to studying the screening devices and ventilation systems in these climates.
It is found that this strategy is suitable in hot climates, where gaining heat is reduced dominantly. What is aimed in this study is to provide an investigation about building the double skin façades in hot climate areas, in terms of energy efficiency, the previously published researches, ideas of authors, suggesting the best-resulting analysis about using this approach.

Keywords: double skin façade, hot climate, energy efficiency, energy saving

1. Introduction

Buildings, as aimed to serve the occupants from environmental phenomena, including cold, heat, rain and etc., should be designed to provide pleasant indoor climates [1]. Having this aim, by considering the concerns about environmental issues and energy resources, it is necessary to change some strategies, especially in designing stage of buildings. In this regard, one of the interesting approaches is to reduce the energy consumption of the buildings, resulting in new techniques of passive solar systems and sustainable designs, between which double-skin facades (DSF) are tremendously attractive, proposing systems of buildings, with two skins and flowing air in the intermediate cavity, between them.

Ventilation of the air layer can be done by different mechanisms such as mechanical, natural or fan-supported tools. At all cases, the beginning and ending destination of air can be different, depending on occupational hours of building and HVAC strategy, the location, use and climatic conditions of the building [17]. The glassy skins can be both single and double layers, apart from each other with the distance varying from 20 centimeters to 2 meters. In order to have protection and better heat extraction while cooling, specific devices for solar protection are provided inside the cavity space [10].

This technology which is specially becoming popular for commercial buildings is also facing challenges to keep balance between its performance, aesthetic qualities, acoustic insulations and visual benefits [18].

Energy consumption of these buildings (DSFs) are strongly dependent on their thermal behavior, especially thermal heat transfer and solar energy gain, which varies in different seasons and locations with different latitudes. According to the published literatures, this technology is so far mostly employed in cold to moderate climates, and in fact, very limited researches have been done on the performance of DSFs in regions with hot climate. Bearing in mind that specially in hot climates huge costs are spent for providing comfortable conditions and maintenance, which are arising when the designs are inappropriate, in this paper,

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the major available methods of thermal behavior and performance of these buildings and the possibility of using these techniques mainly in hot climates are studies [8] and Zain et al. [21].

Inappropriate designs, which can result in excessive heat loss in winter time and heat gain in summer time, due to buildings envelopes, roofs and walls, can be avoided by employing proper techniques such as heat gain reduction in over heated and under heated times [9]. Buildings should be designed to decrease the heat gain and to reach this aim; analyses must be performed on different components [15].

2. Literature Review

Overall characteristics of DSF buildings contain an inner skin of glazing, a cavity (with air flowingin it) and an outer skin. Each of these skins can be made of single or double layer glazing. Usually, the exterior glazing is a hardened single layer, and interior is insulator and double layered [12]. This structure can be accompanied by shading devices, like blinds, to decrease the solar energy gain, resulting in reduction of building's cooling demand. In DSF buildings, during hot seasons, as the result of extra solar gains and thermal conduction of the outer layer, heat is trapped in the cavity layer between the two skins [14]. In these design systems, the extra skin layers offers better insulation systems, resulting in reduction of heating and cooling demands in winter and summer respectively. When solar shading protections are associated in the building, extra protection is achieved from excessive sunlight [7].

Four types of double skin façade systems are known, which are: Box windows, Shaft-box, Multi-storey and Corridor façades.

To explain them briefly, Box window structures are the oldest system of these buildings, including a structure with openings towards the inner space [16]. A particular form of window box window system is called the shaft box, which is formed according to the concept of twin-façade, including a system of box window, with unbroken continuous shafts in vertical direction; broaden over some stories until a change happens in box windows and segments of vertical shafts [5]. Another form of these systems is corridor façades, in which the intermediate space is closed at the story levels. Finally the multi-story façades consist of their intermediate space to be broadened horizontally and vertically by some rooms [6].

Advantage and disadvantages of DSF systems are summarized in the following table, according to the researches carried out on this topic.

Table 1: Advantage and disadvantages of DSF

Advantages of the DSF	Disadvantages of the DSF
Lower construction cost	Higher construction costs compared to conventional façade
Acoustic insulation due to an exterior wall	Additional maintenance and operational costs
Thermal insulation during the winter due to exterior wall	Increased air flow speed
ventilation	Increased weight of the structure
Energy savings and reduced environmental	
shading or lighting devices	
Reduction of the wind pressure effects	
Transparency-Architectural design	
Thermal comfort temperatures	

3. Result and Discussion

In this section, some proposed ideas in previously investigated researches on double skin façades in hot climates is discussed and the best idea is chosen as the result of this paper.

One of the researches has studied a glassy DSF, associated with flexible shading devices, utilized in three modeling levels of fluid dynamics of DSF, building energy balance and optics of materials, in hot climates, preventing hotness, causing discomfort. The open external skin provides gap for the air to escape from and consequently provide from excessive hot weather, which is a common issue in typical DSFs. The shading devices are provided with high slops comparatively, preventing the penetration of solar radiations [2]. As shown in fig (1), the external skin is circumscribed by stratified glass, combined shading devices of anodized aluminum, producing an alloy with good mechanical properties, along with comparatively low density and superior properties against environmental and atmospheric agents.

The mobile shading system remains horizontal (open) in winter time, to provide the building with the maximum possible solar radiation, which penetrate through the fa çade of the building, specifically due to lower height of sun at this time of the year. This system becomes more efficient as it is associated with multiple reflection of opaque surface of shading system

Fig. 1: Prototype of the double skin fa çade proposed in an open configuration

Another investigation done about double skin fa çade in hot regions declares that the outer layer may decrease the building room's gain of the direct solar heat, however the trapped heat in the intermediate space between layers can help in reducing the hot weather away from the inner layer of the building. In this investigation, to convey the general intuitions about the performances of these buildings specifically in hot areas, in the methodology, an analytical method is adopted, by means of dynamic simulation software (IESVE). The outcomes of this investigation research show the better performance of reflective double skin buildings compared to a reflective single skin one, in terms of energy saving. As an agreement between the intuitions and the buildings performance, is in the angling the buildings, in hot dry weather conditions, due to the direct solar light intensities. In these regions, west and east directions are tried to be avoided, whilst north and south directions reduces the cooling demands. The demand reduces more and in fact gets minimized, when transparent layers, reflective glasses are employed in these building systems [11].

In another investigation done by Wong a new kind of DSF characteristics are suggested, specifically for hot and humid weather conditions, as CFD, in order to provide better thermal comfort conditions, in indoor spaces, mainly through natural ventilation, in high rise buildings. The specific goal of this research was to investigate the natural ventilation potentials of an 18-story building, located in hot humid climates, with DSF system. The building is in fact a DSF system, with its 1st floor stating at 2.8m, rising up to the 17th story, and a parapet at 1-m above the roof level. Being an office building, the spaces are divided into small offices, tenanted to different users [19].

The investigation declares that the system of DSF gives the best results in North and South direction, with the air gap of 300 mm between the layers, in that particular situation, with natural ventilation.

In another investigation, the influences of DSF system buildings have been compared with single skin fa çades, again in hot arid area of Tehran Iran. The investigation is performed on the case studies, revealing that in the winter time the difference between the temperatures of inner skin, the outer one and the space between them can contribute to a significant energy saving. On the other hand, to obtain a pleasant weather during summer additional techniques are required including night ventilation, and shading devices, which can reduce the cooling load and the temperature significantly. As for the orientation of buildings, through studying the case studies, it is found that North-west and South-West façades each the highest temperatures [10].

Dynamic thermal simulations have been the main tool of an investigation in 2010, in which a new building's preliminary thermal analysis was tries to be found. The building is a DSF building, located in central Abu Dhabi, with a curved fully glazed form. It was found from the analysis that as the building orientation is in south and west south directions, higher temperatures are expected inside the double skin systems [18].

Yellamraju investigated the hot climates performance of DSF systems, concluding that in these climates, the effectiveness of these systems can only pronounced when they are associated with proper materials, orientation and transparency [20].

In another interesting investigation, natural ventilation was studied through adding DSF systems to historical buildings, by means of a full-scale fluid dynamics model and another model with the scale of 1/25. Outcomes of the study indicate that employment of these systems can annually save nearly 12% of the ventilation energy [3].

For the buildings to be naturally ventilated, in the north hemi- sphere the most influential façade, for seizing the solar energy and facilitate natural ventilation in DSF buildings, is the one facing the southern direction with a rotation of 45 °[4].

In an investigation in 2010, factor of wind direction was also considered in the study, suggesting that the orientations of North and South can be beneficial for ventilation systems of DSF [16].

Three different buildings as case studies were investigated in climate conditions of Belgium, in 2005, resulted in finding that controlling the factors of airflow rate and air returning, from multiple skin façades, demands of heating and cooling of the buildings can be meaningfully improved [17].

During separate investigations, Gratia and Herde have studied DSF systems from various points of view. Energy consumption of these systems has been focused on in one investigation, revealing the fact that there are many factors, affecting the efficiency of DSF buildings [22]-[27]. The factors are; building's function (its type and use), orientation of the building, the inner skin's proportion of opaque surfaces and the glazed ones, building's insulation level, double skin system's operation mode, and the type and position of shading devices [26].

Concentrating on the greenhouse effect of these systems in another investigation, the researchers found that depending on the buildings' facades orientations, greenhouse effect of these buildings are in moderate level [23].

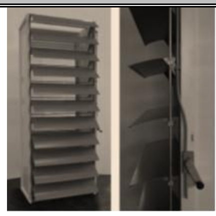
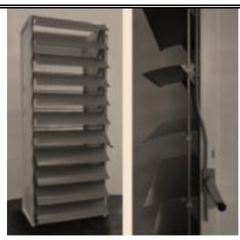
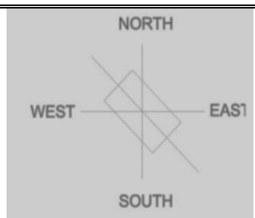
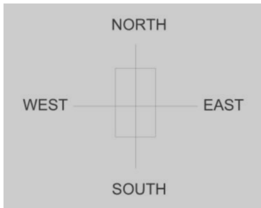
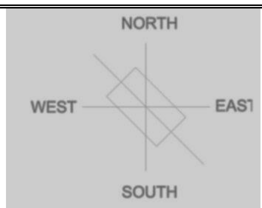
In another investigation, the same researchers have gone over the evaluation of double skin systems performance and energy consumption, based on the orientation and insulation level of them [25]. The research compares the energy consumption of heating and cooling demand, in single and double skin buildings, with or without natural techniques of heating and cooling [24].

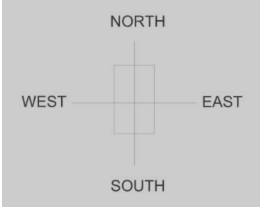
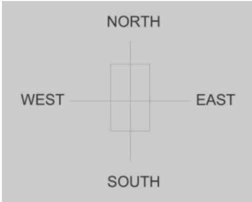
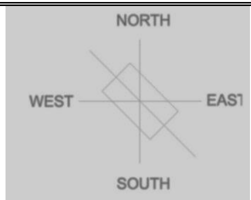
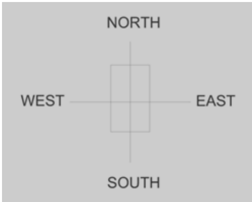
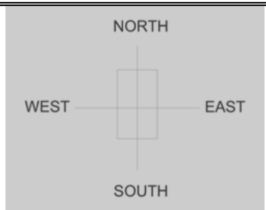
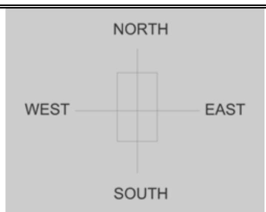
Other investigations in this field consist of the research done by Commission of the European Council, under supervision of Blomsterberg, in which some techniques have been summarized for the employment of DSF systems [19].

At last, the DSF systems positive points were investigated in a research, revealing that these systems are mostly beneficial during winter, for providing the thermal comfort. Other than that, excessive heating is generated as the result of employing them. Specifically, during summer, on the southern opening, wind overcomes the effects of buoyancy, when blowing from north, resulting in limited effects of these systems. TAS simulation program was employed in the study, and the analysis showed a good agreement with the program's results, which led the researchers to employ it further, in order to test the parameters as many as possible, within a suitable time. The outcomes of the research showed that the most perfect states of the system is when the windows are opened automatically, and the cavity (intermediate space) is 30cm wide[12].

The following table shows the summary of researches and their proposals on DSF systems.

Table 2: summary of researches and their proposals on DSF systems

Authors	Proposal	Sketch	Result
Alibaba And Ozdeniz (2011)	►Windows are set to open automatically and horizontal shading ►Cavity width of 30 cm provides slightly better results.		►thermal comfort during the winter
Baldinelli (2009)	►Using North and South orientations. ► constituting the shading system with horizontal form.		►shading devices ►ventilation
Ballestini Et Al. (2005)	► shading systems with horizontal form.		natural ventilation
Barbosa And Ip (2014)	►south facing façade orientation (A rotation 45 °)		►Shading devices ► natural ventilation
Hamza (2008)	►Using North and South orientations. ►using transparent double skin facades ► selective reflective glass		►Better energy savings ►least cooling loads
Hashemi Et Al (2010)	►North-west and South-West orientations.		►To reduce the cooling loads ►night ventilation ►shading devices
Authors	**Proposal**	**Sketch**	**Result**

Shamir Et Al. (2010)	►North and South orientation		►Ventilation
Wong Et At (2008)	►North and South orientations ►air gap size of 300 mm		►particular conditions in a naturally ventilated space North and south orientations
Yagoub Et Al (2010)	►Southern and west southern orientations.		►Ventilation ►highest air temperature inside
Yellamraju (2004)	► orientation and transparency		►effective only if used in combination with other materials
Gratia and Herde (2007)	►“ Orientation, the level of insulation, the proportion of opaque and glazed surfaces of the inside skin, the operating mode of the double skin, and the type and position of shading devices” Gratia and Herde (2007)		►Saving energy ►shading devices
Shamir et al. (2010)	►North and South orientation		►Saving energy ►shading devices ►Ventilation

Based on this research, and what have been summarized in the previous table, to employ DSF systems in hot climates, shading devices are suggested for better results in terms of natural ventilation, and north and south orientation of buildings are suggested regarding energy saving and minimizing the cooling demand. Secondly, North-west and South-West orientations, with horizontal shading device systems, and at last, choosing carefully manufactured reflective glass, are the performing better in hot climates. The following Diagram is showing the results of analysis.

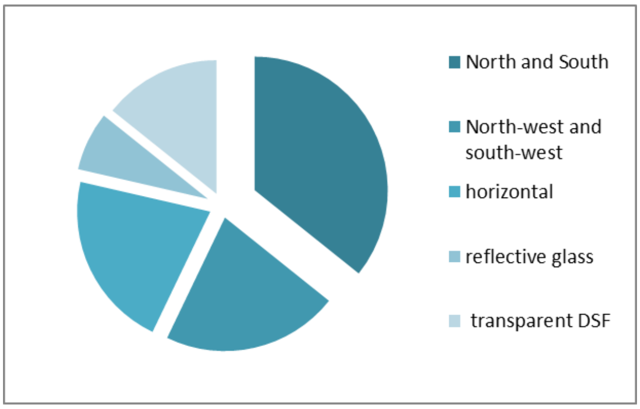


Fig. 2: Result of proposal for using DFS in the hot climate

4. Conclusion

According to the explained literature survey and analysis, in hot climatic regions, buildings will face extra heat and will be thermally discomfort if not effective strategies are implemented in their systems. Knowing the problem, it is important to minimize the extra heat through optimized methods of energy consumption. Regarding this, air conditioning is not a desirable method, due to its high consumption and cost, leading us to methods of better controlling the heat, through more effective methods, by knowing solar radiation behaviors and characteristics of building envelope. Unlike energy that is conceivable, comfort cannot be compromised, which leads the societies towards new technologies like DSF systems employment, otherwise comfort will not be achieved through natural ventilations. According to the mentioned researches, in hot climates except from a few cases showing weaknesses, advantages of these systems are more pronounced, motivating people to employ shading DSF systems associated with natural ventilation, with high inclination angle against excessive solar radiation. This system can also help in saving energy in winter time. As for the summer time, it is essential to integrate shading devices for the intermediate space. According to the literature and simulation software, the experiences of DSF systems in hot area are best resulting when the orientation of buildings are towards north and south, with horizontal shading systems and automatically opening windows, along with the width of cavity space equal to 30cm, which provides better results in terms of shading system, natural ventilation, sustainability and energy efficiency.

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