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Energy Performance of Double Skin Façade – Mosul City as Case Study

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ABSTRACT

The Double Skin Façade is one of the key strategys for passive solar systems since it helps to lower building energy demand, which in turn reduces the need for fossil fuels and reduces greenhouse gas emissions. This research focuses on this strategy because it also offers protection from wind and noise while providing natural light and ventilation. This project aims to explore an environmental solution for the Mechatronics Engineering Department building at Mosul University, which was built in 1963 and renovated and reopened in 2013. The "Double Wall" strategy will be applied to a virtual building with the same design to evaluate its effectiveness in improving the building's efficiency, the computer simulation program (Autodesk Ecotect Analysis 2010) is used in the study provided by experimental data for the climatic conditions of the city of Mosul in Iraq in two cases—the first with a single skin, and the second with a Double Skin Façade of the corridor type and for eight directions. Due to their effectiveness in lowering the energy loads spent on cooling in the summer and in all directions, research has demonstrated the effectiveness of applying façades with the corridor. Additionally, Thus, the efficiency of the corridors façades with have demonstrated their effectiveness in lowering cooling system's electrical energy consumption for all directions.

1. INTRODUCTION

Passive solar systems are among the most significant methods for saving energy in buildings. The importance of façade design, including the Double Skin Façade, one of the cutting-edge systems in managing the interaction between interior and exterior spaces [1]. This strategy helps reduce energy use, the associated carbon emissions, and the environmental impact without abandoning aesthetics such as transparency, views, and comfort [2] and it is a passive and effective strategy at the same time [3]. Although the idea of Double Skin Façades is not new, it was first used in a German factory at the beginning of the twentieth century for its first instance, and it then developed in Russia at the end of the previous century. After that, an increasing trend among architects and engineers to use it in the aesthetic desire to increase transparency and the need to improve the internal environment, improve sound in buildings exposed to noise pollution, and reduce energy use during the building's occupancy phase led to the development of this European architectural trend in the 1990s [4, 5]. This is because the air conditioning system in the building is the consumer. Since the majority (more than 40%) of the building's electricity is consumed by the air conditioning system [6].

The Double Skin Façade, the Active Façade, in which the air cavity is typically mechanically ventilated, the Passive Façade, in which the air cavity is naturally ventilated, or simply the Double Façade are some of the names given to it or the Second Environmental Skin [4].

It is defined as “the façade of a building covered with an additional layer of glass for one or several floors, forming an air gap that is ventilated naturally or mechanically and with a width ranging from 200 mm to 2 m”. In contrast to the inner layer, which is not entirely made of glass but can be, the outer layer is made entirely of glass and a double layer of glass. It has benefits for improving building insulation and is constructed of double glazing, which lowers heat loss in the winter. In contrast, heat is absorbed by the air moving inside the cavity, which lowers the building's cooling needs [7].

Another defined for it is “a multi-layer skin made up of an inner layer, a middle space, and an outer layer”. The middle area typically has adjustable sun shading devices installed for thermal control, and the outer and inner layers are constructed of glazed safety or float glass panels. Configurations with double skin are usually classified under the following groups: Box Window façade, Shaft-Box façade, Corridor façade, and Multi-story façade” [8, 9].

Figures 1 and 2, respectively, show the classifications of double walls based on geometric configurations (box-window, shift box, corridor, multi-story) and air passage.

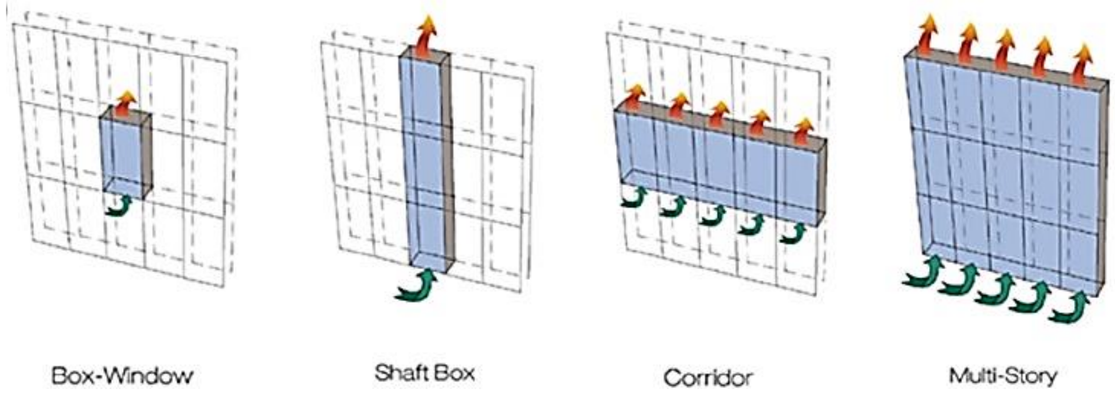


Figure 1. According to geometric configurations, double walls are classified (box-window, shift box, corridor, multi-story) [10]

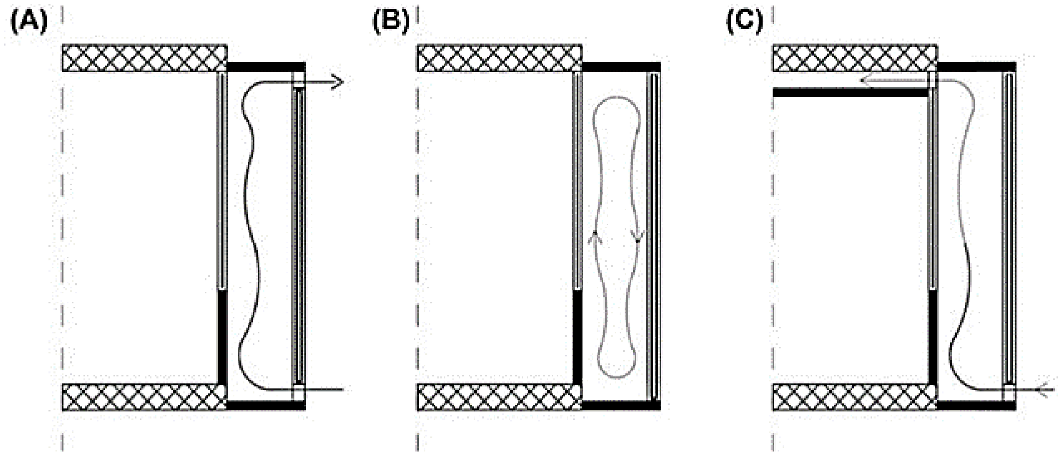


Figure 2. Double wall classifications according to air passage [11]

The types of ventilation used in the façade are: Naturally ventilated façades, mechanically ventilated façades and Hybrid or mixed-mode ventilation, which the third type combines both natural and mechanical ventilation, and it is suitable for countries with hot climates [12].

Many studies on the Double Skin Façade have been conducted in different climatic regions to see the extent of improving the internal environment of buildings.

A study found that the double wall was used to increase the demand for administrative buildings that achieve a healthy and stimulating work environment when they are exposed to external noise and wind loads [13]. The description of energy modeling for double-skinned façades. Using computer simulations of a five-story, two-façade office building in Belgium, thermal behaviors were examined and compared with the presence and absence of the double skin for eight types of days.

Previous study used computer simulations to assess the energy performance in reducing electrical loads of a typical double-skin office air-conditioning system in subtropical conditions in Hong Kong [6]. These configurations included glass type and location and glass layering.

A study was conducted [14] on the efficiency of Double Skin Façade systems on a completely transparent façade, by conducting field measurements and simulations of the effect of different façade systems on energy demand in Iran's hot and dry climate.

Previous study contributed to presenting an innovative façade to increase thermal comfort with different façade systems by changing the shading elements and adding the glass skin element in Vienna [15]. Four measuring rooms were used to study their façades to study the effect of multi-skin façades on energy demand.

Previous study presented a study of the use of the double façade of an administrative building that is highly glazed as one of the methods for controlling the solar radiation gain of the western façade in the tropical regions of Malaysia by conducting field measurements, thus reducing energy consumption while maintaining the aesthetic aspects, using a combination of Types of glass and shading tools [16].

The study considered the Double Skin Façade to be one of the smart façades in achieving thermal performance by rationalizing energy consumption on an eight-story administrative building, by applying the (multi-story) façade system and for the climate of Mosul, Iraq [17].

Application of Double Skin Façade (Corridor type) for administrative building in Baghdad, Iraq and demonstrating their effectiveness in achieving energy efficiency in the building [18].

When comparing earlier studies, we discover that they focused on the idea of the Double Skin Façade's impact on improving the thermal behavior of the building and, consequently, on energy conservation in accordance with the climates that suit the study area, which, of course, do not suit the climate of Iraq, particularly the climate of the city of Mosul, where the study area is for the present research, or the studies did not address the air passage pattern (Corridor) as one of the double wall patterns, specifically in Mosul climate.

2. PRACTICAL STUDY

For the purpose of achieving the research goal to explore an environmental solution for the Mechatronics Engineering Department building at Mosul University, which was built in 1963 and renovated and reopened in 2013, in Figure 3, the "Double Wall" strategy will be applied to a virtual building with the same type design to evaluate its effectiveness in improving the building's efficiency the computer program for environmental performance (Autodesk Ecotect Analysis 2010) and the climate of the city of Mosul were relied upon, hot dry summer and cold rainy winter [19] based on the outputs of METEONORM'S Data 5.1. A [20] proposed administrative model as a virtual model in the Mosul City.

Figure 3. The mechatronics engineering department building at Mosul University

2.1 Building with a two-type design

The first proposed building (Building 1) will measure the energy loads expended for heating and cooling purposes within the spaces of the virtual single-skin building from eight in the morning until three in the afternoon, as in Figure 4, and in eight directions (South, East, North, West, Southeast, Northeast, Northwest, Southwest).

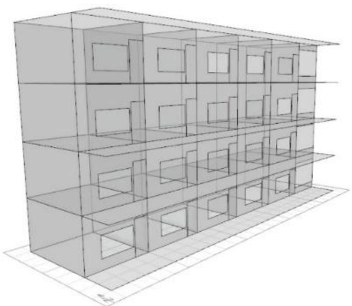


Figure 4. The virtual single skin façade

The second proposed building (Building 2) will measure the energy loads expended for heating and cooling purposes within the spaces of the virtual building and in the cover of one of its façades with a double skin (by replacing one of the façades of the building envelope with a double façade of the corridor type (classified according to its geometry) from eight in the morning until at 3 pm, in Figure 5, in eight directions (South, East, North, West, Southeast, Northeast, Northwest, Southwest).

The (Autodesk Ecotect Analysis 2010) calculations' results will be compared in order to demonstrate the efficiency variation in the heating and cooling energy loads for each building and each façade separately.

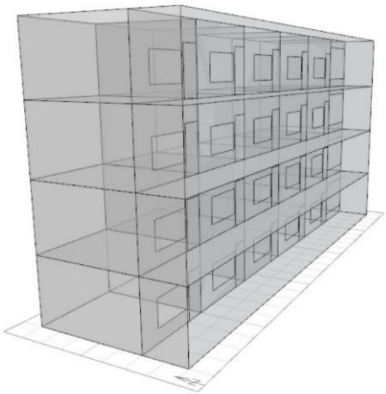


Figure 5. The virtual double skin, building of the corridor type

2.2 The proposed building's a virtual model

The virtual building that is being proposed for an administrative building in Mosul City has four floors, dimensions (7 × 23 m) as in Figure 6 and a height of (12 m), and is made of (concrete block render) for the walls, (suspended concrete ceiling) for the roofs, and glass for the single skin façade, these features are similar to those in Figure 7.

A Double Skin Façade of the corridors, with an air cavity width of 2 m, was installed in place of one of the building's façades for the first model. The glazing is located in the double outer shell as shown in Figure 8. The interior spaces have a mixed-mode system for the air conditioning system. While the type of air conditioning in the air cavity is set (Natural Ventilation), when the air temperature in the cavity is greater than 24℃, which ensures that the air cavity does not heat up.

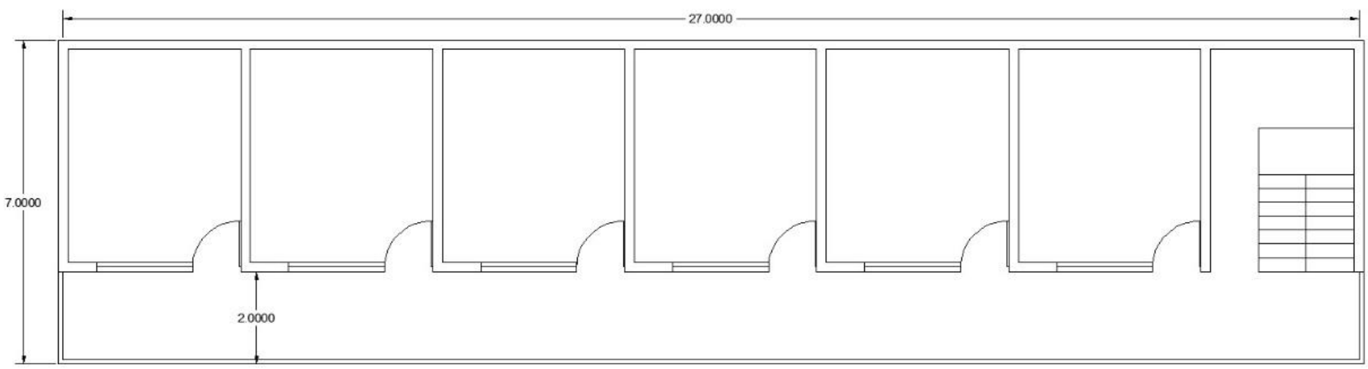


Figure 6. The horizontal plan of the building

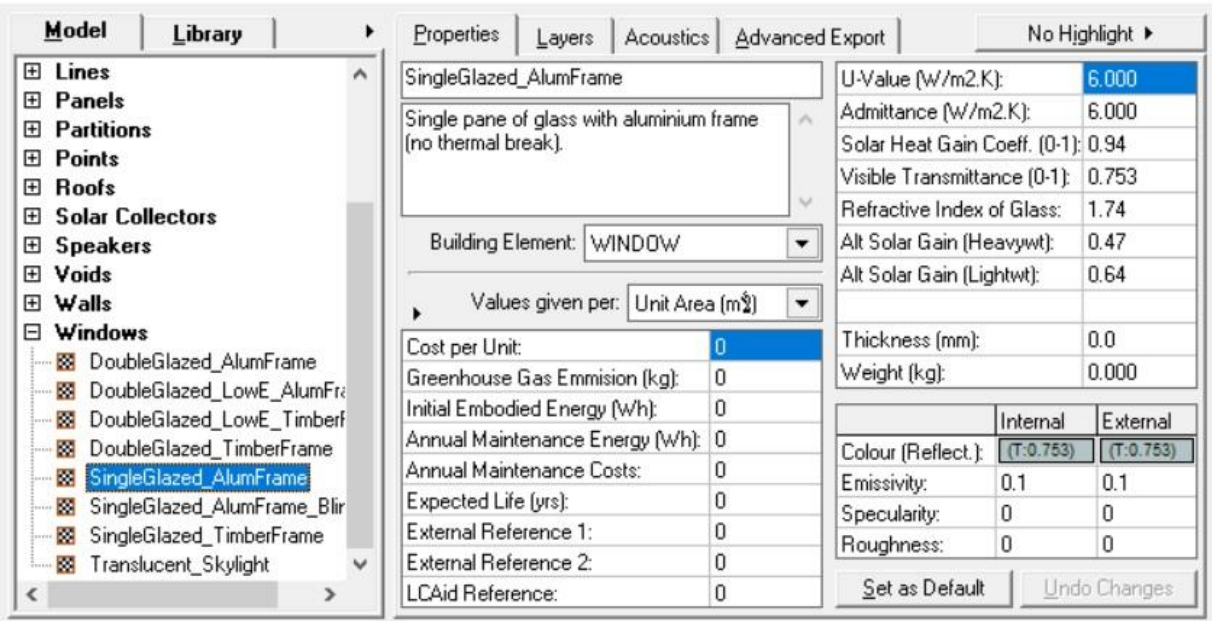


Figure 7. The type of glass used in the first building's with a single skin (single Glazed_AlumFrame)

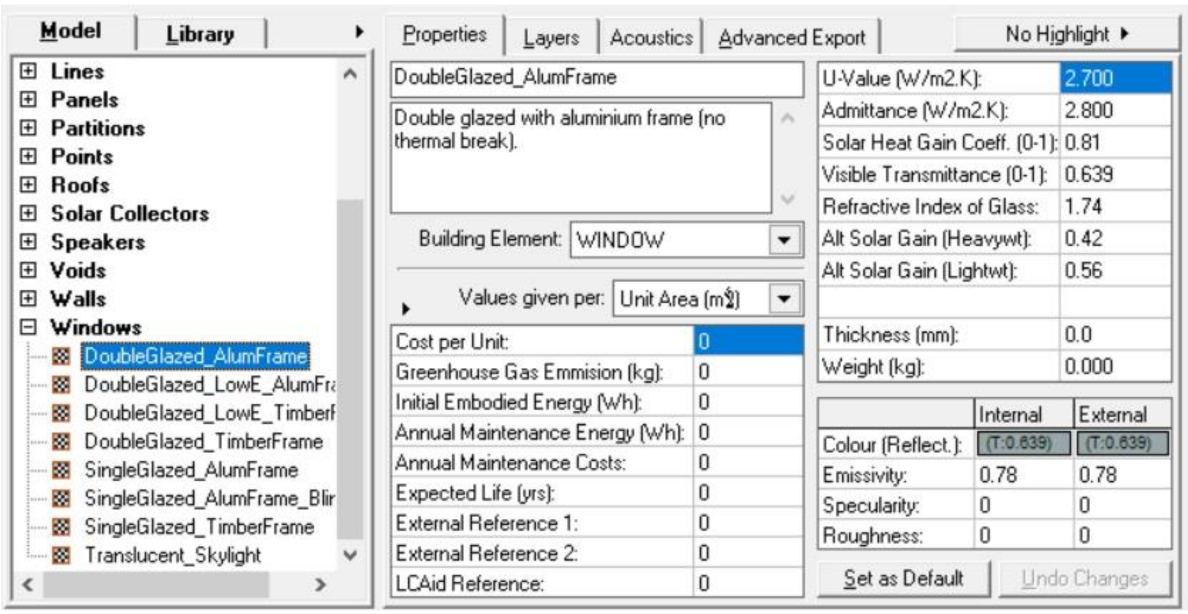


Figure 8. The type of glass used in the second building's double skin, which includes a corridor (Double Glazed_AlumFrame)

3. RESULTS AND DISCUSSION

The first building with a single skin had its heating and cooling energy loads measured in eight directions, namely (South/ East/ North/ West/ Southeast/ Northeast/ Northwest/ Southwest). The measurement results for the Southern façade are shown in Figure 8 and Table 1, respectively. This displays the eight directions.

Then the calculations were repeated again (for the second building) with a double skin and in eight directions, which are (South/ East/ North/ West/ Southeast/ Northeast/ Northwest/ Southwest). The measurement results were as in Figure 9 for the southern façade and Table 1 explains this for the eight directions.

After comparisons between the energy loads used for heating and cooling the entire building with a single-skinned façade and the energy loads used for heating and cooling the entire building with the façade with the corridor, it was discovered that:

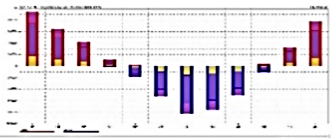
The Southern façade: The energy loads used for cooling for the entire building with a single skin façade amounting to (29065972 Wh) as in Figure 8 and Table 1, and comparing them with the total cooling loads used for the entire building with the façade with a corridor, amounting to (24281024 Wh). As shown in Figure 9 and Table 1, the efficiency of the façade with the corridor in reducing cooling loads in summer has been proven.

As for the energy loads used for heating for the entire building with a single skin façade, which amount to (33008798 Wh), as in Figure 8 and Table 1, and compare them with the total heating loads used for the entire building with a corridor, which amount to (39173088 Wh), as in Figure 9 and Table 1, it has been proven that the corridor façade is inefficient in reducing heating loads in winter.

MONTHLY HEATING/COOLING LOADS

All Visible Thermal Zones
Comfort: Zonal Bands

Max Heating: 64550 W at 09:00 on 16th January
Max Cooling: 44275 W at 12:00 on 24th July



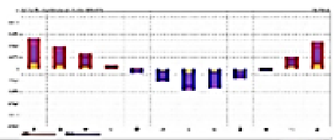
MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	9441168	0	9441168
Feb	6417004	0	6417004
Mar	4251310	0	4251310
Apr	1209617	69900	1279518
May	266798	1802518	2069316
Jun	0	5254988	5254988
Jul	0	8218818	8218818
Aug	0	7596712	7596712
Sep	0	5041279	5041279
Oct	409352	1081756	1491108
Nov	3226265	0	3226265
Dec	7787282	0	7787282
TOTAL	33008798	29065972	62074768

Figure 9. The results of the calculations for the heating, cooling, and total energy load for the first building with a single skin and toward the south

MONTHLY HEATING/COOLING LOADS

All Visible Thermal Zones
Comfort: Zonal Bands

Max Heating: 63977 W at 09:00 on 16th January
Max Cooling: 43254 W at 12:00 on 24th July



MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	10614746	0	10614746
Feb	7768226	0	7768226
Mar	5148267	0	5148267
Apr	1356708	26228	1382936
May	266983	1415089	1682072
Jun	0	4590558	4590558
Jul	0	7523738	7523738
Aug	0	6690951	6690951
Sep	0	3509422	3509422
Oct	484101	525038	1009139
Nov	4208824	0	4208824
Dec	9325231	0	9325231
TOTAL	39173088	24281024	63454112

Figure 10. The results of the calculations for the heating, cooling, and total energy load for the second building with a corridor and toward the south

Table 1. A comparison of the results of the heating and cooling energy loads for the first and second buildings and in the eight directions

State	Direction	Heating (Wh)	Cooling (Wh)	Total (Wh)
First State	South: single skin	33008798	29065972	62074768
First State	South: corridor	39173088	24281024	63454112
Second State	East: single skin	36225240	30797396	67022636
Second State	East: corridor	38629904	25545172	64175076
Third State	North: single skin	37486496	27519586	65006080
Third State	North: corridor	37507728	25574248	63081976
Fourth State	West: single skin	37066668	32353702	69420368
Fourth State	West: corridor	38998372	26519056	65517428
Fifth State	South-East: single skin	33890180	30529162	64419344
Fifth State	South-East: corridor	38907808	25031006	63938816
Sixth State	North-East: single skin	37852028	28873362	66725392
Sixth State	North-East: corridor	38219948	25532024	63751972
Seventh State	North-West: single skin	37703384	30222430	67925816
Seventh State	North-West: corridor	37991904	26505600	64497504
Eighth State	South-West: single skin	35332320	31272868	66605188
Eighth State	South-West: corridor	39742936	25378224	65121160

As for the total energy loads used for heating and cooling for the entire building with a single skin façade, amounting to (62074768 Wh), as in Figure 8 and Table 1, and comparing them with the total heating and cooling loads used for the entire building with corridor, amounting to (63454112 Wh), as in Figure 9 and 10 and in Table 1, it was proven that the façade with corridor is inefficient in reducing the total heating and cooling loads.

Figure 11. The results of the calculations of the heating, cooling and total energy for both building types facing south

Figure 12. The results of the calculations of the heating, cooling and total energy loads for both building types facing east

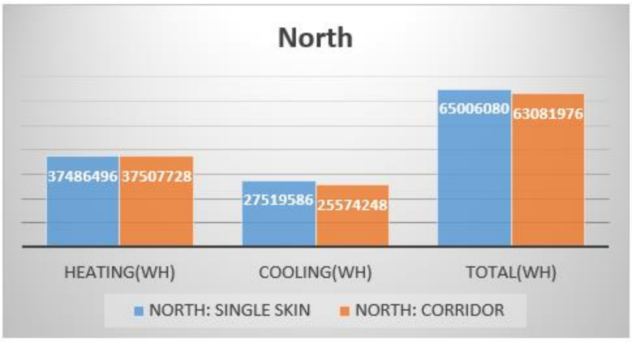


Figure 13. The results of the calculations of the heating, cooling and total energy loads for both building types facing north

Figure 14. The results of the calculations of the heating, cooling and total energy loads for both building types facing west

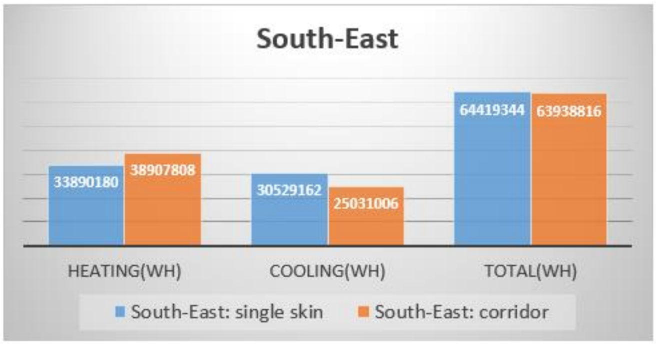


Figure 15. The results of the calculations of the heating, cooling and total energy loads for both building types facing the southeast

Figure 16. The results of the calculations of the heating, cooling and total energy loads for both building types facing the southwest

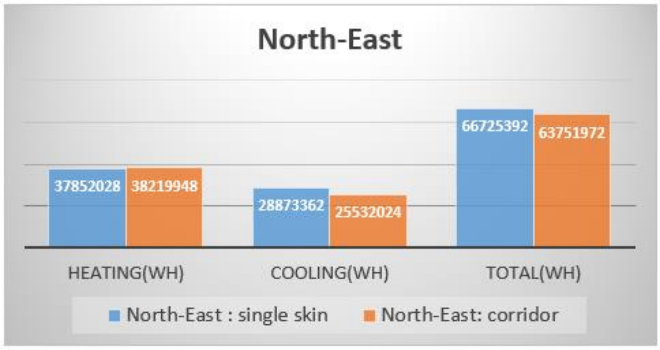


Figure 17. The results of the calculations of the heating, cooling and total energy loads for both building types facing the northeast

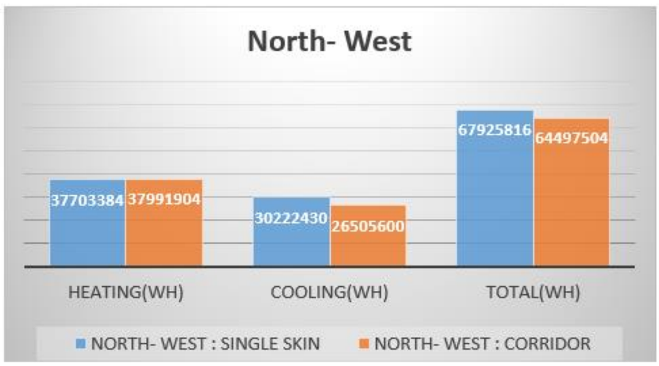


Figure 18. The results of the calculations of the heating, cooling and total energy loads for both building types facing the northwest

The remaining seven façades (Eastern façade / Northern façade / Western façade / Southeastern façade / Northeastern façade / Northwestern façade / Southwestern façade) were as follows:

Comparing the total cooling loads for the entire building with the façade with a corridor, as in Table 1, with the energy loads used for cooling for the entire building with a single skin façade. It has been proved that a façade with a corridor effectively lowers summer cooling loads.

It has been proved that the façade with a corridor is ineffective at reducing heating loads in the winter based on the energy loads used for heating the entire building with a single skin façade, as shown in Table 1, and the total heating loads used for the entire building with a corridor, as shown in Table 1.

As for the energy loads used for heating and cooling for the entire building with a single skin façade, as in Table 1, and comparing them with the total heating and cooling loads expended for the entire building with a corridor, as in Table 1, it has been proven that the façade with a corridor is effectively in reducing heating and cooling loads, as shown in Figures 11-18.

4. CONCLUSIONS

- Adoption of a Double Skin Façade in buildings has the potential to decrease the cooling system's electrical energy consumption for all directions.

- The corridor façades have demonstrated their effectiveness in lowering the energy loads required for cooling during the summer and in all directions, as follows: Southern façade by 16.46; Eastern façade by 17.05; Northern façade by 2.75; Western façade by 18.03; Southeastern façade by 18.00; The Northeastern façade are 11.57, 3.02 in the northwestern direction, and 3.12 in the southwest direction.

- Accordingly, the efficiency of the double wall varies depending on the direction in which it is used to reduce the energy loads required for cooling during the summer. The most efficient façade is the Western one, which is followed by the Southeastern, Eastern, Southern, Northeastern, Southwestern, Northwest, and lastly the Northern.

- The corridors façades with have demonstrated their effectiveness in lowering the overall energy loads used for heating and cooling, with the exception of the Southern façade, where it increases by 2.17. In the other directions, the energy loads decrease as follows: 4.24 in the Eastern façade, 6.50 in the Northern façade, 6.94 in the Western façade, 0.75 in the Southeast façade, 6.67 in the Northeast façade, 6.79 in the Northwest façade, and 2.22 in the South west façade.

- The efficiency of the double wall is in reducing the total energy loads expended for heating and cooling, according to the directions, the Western façade will have the highest efficiency, followed by the Northwestern façade, then the Northeastern façade, then the Northern façade, then the Eastern façade, then the Southwestern façade, and finally the Southeastern façade. As for the Southern façade, it has proven inefficient.

- The double skin movable façade strategy can be applied in the winter (the strategy is cancelled) to benefit from it in reducing electrical energy consumption also for the heating system and in all directions.

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