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Analysis of Nano Silica Aerogel Based Glazing Effect on the Solar Heat Gain and Cooling Load in a School under Different Climatic Conditions †

Cinzia Buratti [1], Elisa Belloni [1], Francesca Merli [1], Mehrangiz Mastoori [2,*], Seyede Najme Sharifi [3] and Gloria Pignatta [4,*]

[1] Department of Engineering, University of Perugia, 06100 Perugia, Italy; cinzia.buratti@unipg.it (C.B.); belloni.unipg@ciriaf.it (E.B.); merli@crbnet.it (F.M.)
[2] Department of Art and Architecture, Rouzbahan University, Mazandaran 1133701701, Iran
[3] Department of Art and Architecture, Islamic Azad University of Shiraz, Shiraz 7136410041, Iran; s.najmesharifi@gmail.com
[4] School of Built Environment, Faculty of Arts, Design, and Architecture, University of New South Wales (UNSW), Sydney, NSW 2052, Australia
* Correspondence: meh.mastoori@gmail.com (M.M.); gloria.pignatta@unsw.edu.au (G.P.)
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Abstract: Demand for energy-efficient school buildings, which form a major part of public buildings, is growing in Iran. Window insulation is required to reduce the amount of energy wasted through openings. This study investigates the effect of double-glazing with aerogel insulation compared to a 3 mm glazing pane and a double-glazing window in terms of solar gain and cooling load. The case studies are primary schools in Yazd (hot-dry climate), Bushehr (hot-humid climate), and Zanjan (cold climate). Numerical simulations of a two-story school are performed to calculate solar gain and cooling load. The use of the aerogel glazing system in Yazd resulted in a reduction of 73% of the solar gain and about 33% of cooling loads compared to a simple glazing window; if compared to a double-glazing standard window, the reductions are of about 56% and 16%, respectively for solar gains and cooling consumptions. Also, the use of aerogel glazing in Bushehr allows a reduction of about 64% in terms of solar gain and 27% for cooling when compared to simple glazing. By using the aerogel in Zanjan school the solar gain decreased by about 62% and cooling loads of about 22% when compared to a single layer of glazing.

Keywords: solar efficiency; cooling; aerogel double glazing; educational building; hot-dry climate; hot-humid climate; cold climate

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1. Introduction

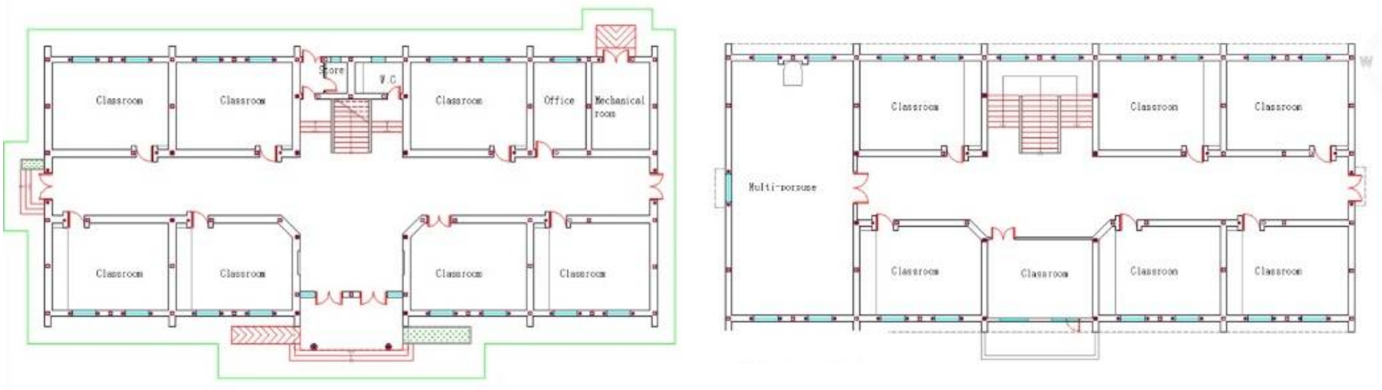
The average energy consumption in school buildings in Iran, as a major category of public buildings, is more than 160 kWh/m^2 [1], which is 2.5 times more than the energy consumed in high-performance schools in developed countries, which is approximately 65 kWh/m^2 [2].

Regarding energy balance, windows can either decrease or increase the energy loads of a building through solar heat gains or conduction heat losses, respectively [3]. To achieve the highest possible thermal resistance, new insulation materials and solutions with low thermal conductivity values are proposed in the present paper [4]. Among insulation materials, aerogel may be a very interesting solution to be used in highly energy-efficient windows. It is a solid material with a conductivity of about 0.015 W/m^2K, very low in comparison with common materials for insulation [5]. It has great potential in the window and glazing industry and its use has increased the thermal resistance of these elements [6–8].

This study aims to investigate the effect of using insulation in comparison with ordinary and double-glazed glass in hot-humid, hot-dry, and cold climates of Iran's schools in terms of solar gain and cooling load.

2. Methodology

In order to compare the performance of aerogel glazing in educational buildings, a two story-story building is selected as a case study (Figure 1). The building has 15.20 m by 35.90 m (area of 545.68 m^2) dimensions; the east-west extension is 545.68 m^2 per floor, height is 3.5 m, the window-to-wall ratio (WWR) is 30%, the occupancy is 20 people/m^2, the target illuminance is 400 lux. The buildings and windows features are given in Tables 1 and 2. The modeled building corresponds to a representative elementary school in almost all cities of Iran. DesignBuilder 6.1.7.007 software, which is based on the computation Energy Analysis Engine Plus 8.9, was used to simulate the energy demand of the building according to the ASHRAE standard [9]. The heating and cooling design temperatures were set at 22 °C and 24 °C, respectively.



(**a**) (**b**)

Figure 1. School building floor plans: (**a**) ground floor, (**b**) first floor.

Table 1. Layers constituting single, double-glazing, and aerogel double-glazing systems and their Solar Heat Gain Coefficient (SHGC) (adimensional and equivalent to g-value) and U-values (W/m^{2}K) according to the EnergyPlus library taken from the ASHRAE standard [9].

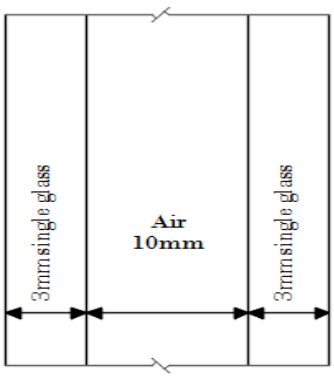
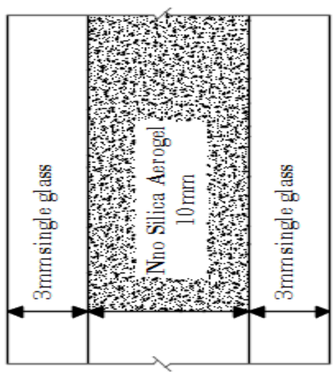
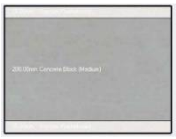
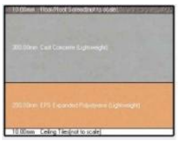
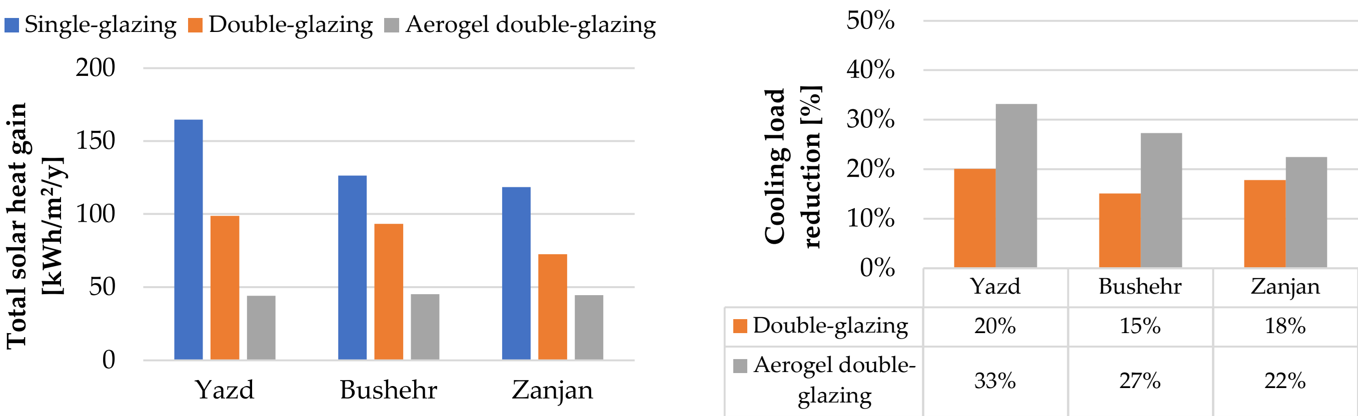
Single-Glazing Pane	Double-Glazing System	Aerogel Glazing System
		
SHGC = 0.74–0.87 *U*-value = 5.829 W/m^{2}K	SHGC = 0.64–0.77 *U*-value = 2.976 W/m^{2}K	SHGC = 0.35 *U*-value = 0.927 W/m^{2}K

Table 2. Specifications of the materials selected to model the building in DesignBuilder software.

	Material	Thickness [mm]	Cross Section	*U*-Value [W/(m²K)]	Rc-Value [(m²K)/W]
External wall	Brickwork Expanded polystyrene Concrete block Gypsum plasterboard	100 80 200 15		0.365	2.741
Internal wall	Gypsum plasterboard Concrete block Gypsum plasterboard	25 200 25		1.716	0.583
Ceiling	Floor screed Cast concrete Expanded polystyrene Ceiling tiles	10 300 200 100		1.4	0.71
Roof	Asphalt Expanded polystyrene Concrete Gypsum plasterboard	5 40 300 15		0.766	1.305

3. Results

The period of the simulation is one year and the office hours of active work in a building were considered. The amount of internal heat load in office spaces and the minimum required level of lighting are stated. These values are the same in all simulation models and the only variable was the transparent solution. After performing the simulations, the solar gain and the cooling load for the studied cities are calculated for one year (Figure 2).



(**a**) (**b**)

Figure 2. Simulated results for school buildings in Yazd, Bushehr, and Zanjan: (**a**) total solar gain for the investigated window configurations; (**b**) cooling load reduction of double-glazing and aerogel configurations compare to the single-glazing pane.

Figure 2a shows the annual solar gains; simple glazing has the highest and aerogel has the lowest solar gain for the three investigated cities. It should be noted that the largest decrease in solar gain is related to Yazd (hot-dry climate). According to Figure 2b, the cooling load of the building with aerogel is less than simple and double-glazed windows. In particular, the use of aerogel has the highest cooling load reduction in Yazd (hot-dry climate), where the solar gain reduction is about 73% and 56% with respect to single and double-glazing, respectively. In Bushehr (hot-humid climate), aerogel shows good performance and decreases the solar gain by around 64% and for cooling loads by about 27%. The use of aerogel in Zanjan (cold climate) produces a reduction of 62% in terms of solar gain, not so different compared to Bushehr. Results are in line with literature data [6,7].

4. Conclusions

In this preliminary study, the effect of aerogel double-glazing system integrated in the envelope of a school building in terms of solar heat gain and building cooling loads is investigated in Yazd (hot-dry climate), Bushehr (hot-humid climate), and Zanjan (cold climate). Simulations are carried out by DesignBuilder and the resulting values of annual solar gain and cooling load of the building with aerogel are compared with those of a single-glazing layer and double-glazing solution. Results shows that aerogel outperforms the single and double-glazing configurations under the three investigated climatic conditions for cooling load reduction. The summary of the results is as follows:

- aerogel double-glazing system could be considered a good solution in terms of annual energy demand reduction with respect to simple glazing, under hot-dry climates (Yazd). The use of aerogel in Yazd has the highest decrease in solar gain (73% and 56% of reduction compared with single and double-glazing systems, respectively) and cooling load (33% and 16% of reduction compared with single and double-glazing systems, respectively) among the three investigated cities;
- in Bushehr, the solar gain is reduced by aerogel and double-glazing of about 64% and 26% respectively, compared to the simple-glazing layer; by reducing the U-value and SHGC the aerogel configuration is able to reduce solar gain and hence cooling load;
- in Zanjan, the solar gain is reduced by aerogel by 62% compared to a single-glazing pane. Also, the difference between aerogel and double-glazing systems in solar gain reduction is 39%. The use of a double-glazing solution reduces the cooling load by 18% with respect to the single-glazing pane, which is about 5% less than the aerogel.

It is important to highlight that the effect of aerogel glazing solutions with respect to standard glazings is not so different in the three simulated climatic conditions because the WWR is low (30%). Therefore, in future developments of this study, the analysis of other school buildings with a higher percentage of glazing surfaces (50-60%) will be performed.

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