Fundamental Journals
International Journal of Fundamental Physical Sciences (IJFPS)

Original Research Papers
Open Access Journals
**ISSN: 2231-8186**

IJFPS, Vol 14, No 1, pp 1-6, March, 2024
https://doi.org/10.14331/ijfps.2024.330162



# Simulation-Driven Strategies for Improving Natural Ventilation in Educational Spaces: A Case Study of An Educational Building in Sari

**Sina Tabibi**

Iran Construction Engineering Organization (IRCEO), Iran

Tabibi.sina@gmail.com

*Received Nov 2023*
*Received in revised: Feb 2024*
*Published: March 2024*

## ABSTRACT

Any architectural space, especially the architecture of an educational complex, should provide comfort for human beings in the face of geographical and climatic characteristics. Climatic factors have always profoundly affected the formation of the physical environment of buildings. Energy demand has always been one of society's most critical issues. Saving resources is one of the architectural design goals to achieve a suitable environment-friendly architecture. This architectural approach, which comes from the concepts of sustainable development, is one of the basic human needs in the current world due to its compatibility with the environment. The goal is to build constructions that can improve the climate, prevent the waste of energy consumption, and avoid the adverse effects of construction on the environment. In traditional Iranian architecture, there are numerous passive methods; natural ventilation is an essential part of Iranian conventional building design, which is being ignored today. Since humid and moderate climates have high relative humidity on most days of the year, one important goal is to move the stagnant moisture inside to establish a suitable thermal environment for occupants. The research method of the present study is descriptive-analytical, which has been experimented with according to library studies in addition to climate and meteorological data. Then, analysis of the data is provided by an energy simulator. It is concluded that the best orientation of the educational building is south, which can provide proper natural ventilation and solar heat gain. In other words, optimal interior air quality is achieved in this orientation.

**Keywords:** Simulation-Driven; Natural Ventilation; Educational Spaces; Case Study



## INTRODUCTION

Climatic characteristics firmly have definitive and multidimensional effects on buildings. Architectural design must provide optimal conditions for human comfort concerning local climatic conditions. One of the crucial features of the weather that architects have a challenge with is the high humidity of the environment, which leads to an increase in the cooling energy consumption of the building during hot seasons. (Baderia & Design, 2014).
Educational complexes are critical public spaces among different buildings because indoor environmental conditions

significantly influence occupants' health, productivity, and performance. There is some research in the area.
For instance, Bayraktar et al. review the relationship between thermal comfort and the performance of students in a school. They concluded that the productivity of students in schools is improved by increasing thermal comfort (Bayraktar, 2013).
Other research conducted by Alwetaishi et al. revealed that classrooms with proper air conditioning could improve occupants' health (Ragheb, El-Shimy, Ragheb, & Sciences, 2016).
It is imperative to ensure that indoor conditions are suitable for students' productivity and health since students spend more than half a day in it (Tucker & Izadpanahi, 2017).
On the other hand, one of the outstanding issues in sustainable building design is decreasing the energy consumed in school buildings. Energy-efficient buildings perform heating, cooling, and lighting by considering optimal climatic, visual, acoustic, and thermal comfort. Based on these contexts, using passive strategies to obtain energy-efficient and comfortable buildings has become more of an issue (Ahmed, Khan, Maung Than Oo, Rasul, & Engineering, 2014).
Natural ventilation is a very effective passive cooling strategy in providing energy efficiency and acceptable interior air quality. Natural ventilation in school classrooms can provide the energy needed for cooling and thermal comfort without the need for active systems (Perez & Capeluto, 2009).
Another strategy for effective passive heating in the cold season is increasing the amount of radiation that can pass through windows, called heat transmittance. This strategy allows buildings to be heated without consuming additional energy sources, such as natural gas. It is a practical approach and can improve the internal environment and air quality due to reduced emissions of greenhouse gases like carbon dioxide. Solar Heat Gain refers to the portion of the total energy that can enter a building via windows, and it can be used as the standard to determine window ability (Alwetaishi & Gadi, 2018).
Orientation of the building is an essential factor that can affect the natural ventilation rate and Solar Heat Gain. In climatic conditions, determining the best orientation by considering the wind speed and direction and the angle of solar radiation is crucial to designing a sustainable building, especially an educational complex with the ideal interior condition (Al-Tamimi, Fadzil, & Harun, 2011).
Within this framework, the present study works on a typical school in Sari City in Iran. It evaluates natural ventilation and solar radiation absorption through windows concerning different orientations of buildings. The result of this study could effectively be applied for designing educational complexes in moderate and humid clime regions.

## LITERATURE REVIEW

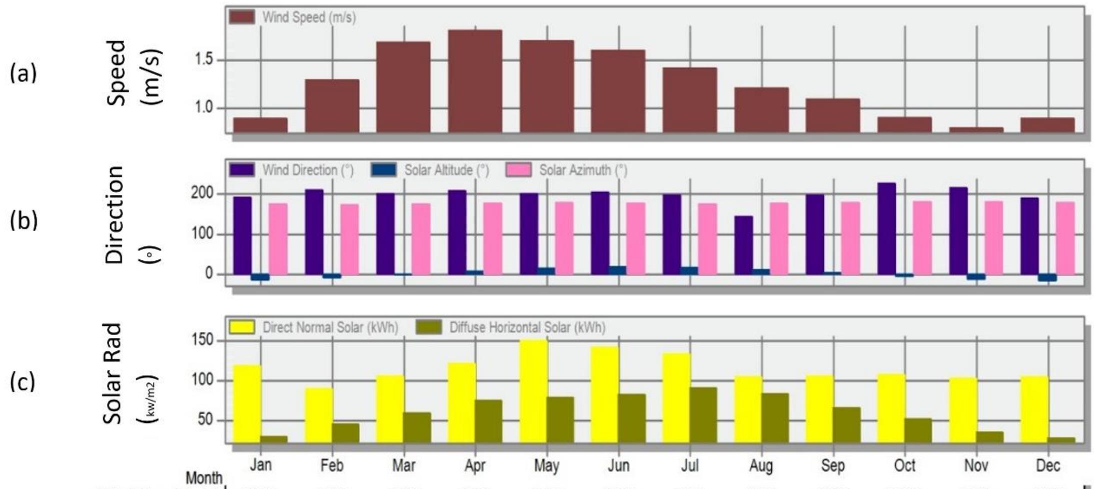
Abasnejad et al. studied building orientations to optimize energy consumption in Gorgan city with similar weather conditions to Sari. They assessed climatic diagrams and concluded that the south direction and 150 – 160 degrees south are the best orientation for the construction of buildings in the area. Within these orientations and putting suitable openings in the building, it can be received enough solar radiation energy and wind, so it is the ideal direction for domestic air conditioning (Ansarimanesh, Nasrollahi, Mahdavinejad, & Development, 2019).
Kouhirostami et al. evaluate the impacts of influential climatic factors on designing school buildings in Mazandaran province. This study analyzed the efficiency and performance of systems and design for a sustainable school and its classrooms. Based on local architecture knowledge of Mazandaran and climatic design principles, systems, and efficient design principles are classified. They successfully design sustainable schools that have reduced energy consumption and use renewable energy sources effectively (Kouhirostami, 2020).
Baghaie Daemaie et al. simulated the natural ventilation in a residential apartment in Rasht City as an example of a temperate and humid region. Their simulation consists of bilateral and one-way ventilation in buildings. They concluded that natural ventilation helps to better air conditioning, and by using wind as a clean energy resource, energy consumption in the building can be decreased. This approach handles the high humidity content of air, and better interior air quality is achieved (Daemei, Limaki, & Safari, 2016).
Opropeze Perez's research result based on an airflow simulation demonstrates that by using natural ventilation, thermal comfort was estimated to be more than 90% (Oropeza-Perez, 2015). With simulation modeling, Zhou, Wang, et al. proved that natural ventilation could reduce energy consumption. (Zhou et al., 2014)

## METHODOLOGY

The present study aims to evaluate the most proper school building orientation considering natural ventilation and solar radiation to minimize energy consumption. The school building was simulated and analyzed using Design Builder software v.4.5. The following directions were selected and evaluated in the simulation of the school building: 45 degrees southeast, 17.5 degrees south to southeast, 15 degrees south to southwest, 20 degrees south to the southeast (approximate building angle).
Furthermore, the climatic and geographical information about Sari was collected using library studies. The influence of window sunshades on solar radiation absorption was assessed. The case study selected was the thirteen-Aban high school located on Ferdowsi Street, Sari City, Iran. That is a four-story building with a gable roof. The total area of the building is 1200 square meters.
The building is oriented in such a way that openings have mainly exposure to the east and west directions. The school is used continuously from 7 am to 1 pm from September to June. In summer, the school building is occupied three days a week.

## RESULTS CLIMATIC PARAMETERS

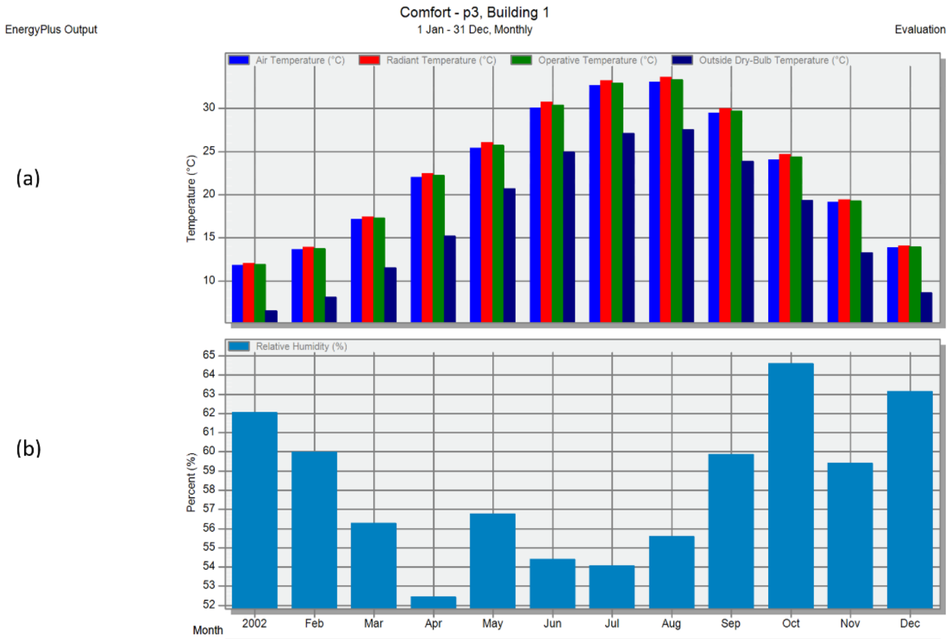
The climatic parameters in Sari are shown in the following figures. The wind speed, direction, and amount of solar radiation in the Sari climate are shown in Fig (1) a, b, c, d. Over the past few years, the coldest temperature in this city has been in the winter at -12°C (winter of 2007) and in the summer at +40° C (summer of 2004). maximum and minimum wind speeds are in April and November.
The wind direction in this city is more south-southwest, and the maximum radiation is in May (mid-May-mid-June) and minimum radiation in February (mid-February-mid-March). Wind speed in April (mid-April-mid-May) is more intense than in the other months of the year and in November (mid-November-mid-December) has a minimum value.Fig (1) b




| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wind Speed (m/s) | 0.90 | 1.30 | 1.69 | 1.81 | 1.70 | 1.60 | 1.41 | 1.21 | 1.09 | 0.90 | 0.80 | 0.89 |
| Wind Direction (°) | 190.84 | 210.63 | 200.57 | 208.67 | 201.15 | 204.81 | 197.08 | 144.24 | 196.29 | 226.47 | 215.17 | 189.37 |
| Solar Altitude (°) | -15.49 | -9.77 | -1.52 | 7.23 | 13.98 | 17.08 | 15.80 | 10.40 | 2.34 | -6.45 | -13.62 | -17.05 |
| Solar Azimuth (°) | 174.80 | 173.68 | 174.77 | 176.76 | 177.70 | 176.79 | 175.51 | 175.86 | 178.02 | 180.31 | 180.56 | 178.02 |
| Atmospheric Pressure (Pa)x10^3 | 100.05 | 100.07 | 100.08 | 100.08 | 100.11 | 100.13 | 100.14 | 100.15 | 100.13 | 100.11 | 100.07 | 100.06 |
| Direct Normal Solar (kWh) | 118.51 | 89.70 | 105.65 | 121.64 | 150.10 | 142.07 | 133.67 | 104.73 | 105.93 | 107.79 | 102.79 | 104.80 |
| Diffuse Horizontal Solar (kWh) | 29.65 | 44.64 | 59.10 | 74.47 | 78.16 | 82.48 | 90.41 | 83.03 | 65.79 | 52.00 | 35.18 | 27.46 |

**Fig 1**. General climatic information of Sari

Fig (2) a, b, c. presents temperature and relative humidity diagrams of Sari. These diagrams illustrate the maximum and minimum average temperature and relative humidity in different months of the year .In the summer, the weather of Sari is warm and humid, and in winter, it is relatively cold and humid. The southern mountainous region of this city has frigid winters.




| Month | 2002 | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Temperature (°C) | 11.77 | 13.57 | 17.09 | 21.97 | 25.36 | 30.01 | 32.60 | 33.01 | 29.43 | 24.04 | 19.11 | 13.81 |
| Radiant Temperature (°C) | 12.02 | 13.86 | 17.42 | 22.42 | 26.01 | 30.68 | 33.17 | 33.57 | 29.96 | 24.63 | 19.39 | 14.04 |
| Operative Temperature (°C) | 11.89 | 13.72 | 17.26 | 22.19 | 25.69 | 30.34 | 32.88 | 33.29 | 29.69 | 24.34 | 19.25 | 13.93 |
| Outside Dry-Bulb Temperature (°C) | 6.54 | 8.09 | 11.51 | 15.19 | 20.65 | 24.91 | 27.07 | 27.53 | 23.87 | 19.33 | 13.25 | 8.60 |
| Relative Humidity (%) | 62.05 | 59.98 | 56.28 | 52.44 | 56.76 | 54.39 | 54.06 | 55.59 | 59.86 | 64.58 | 59.41 | 63.13 |

**Fig 2**. Temperature and relative humidity diagrams of Sari

## ANALYSIS OF NATURAL VENTILATION AND SOLAR RADIATION

This study analyzed natural ventilation Fig (3) a. and solar radiation based on the different orientations of the building. Four directions were selected: 45 degrees southeast, 17.5 degrees south to southeast, 15 degrees south to southwest, and 20 degrees south to the southeast (approximate building angle) Fig (3) b. The actual orientation of the school building is presented in Fig (3) a, b, c.

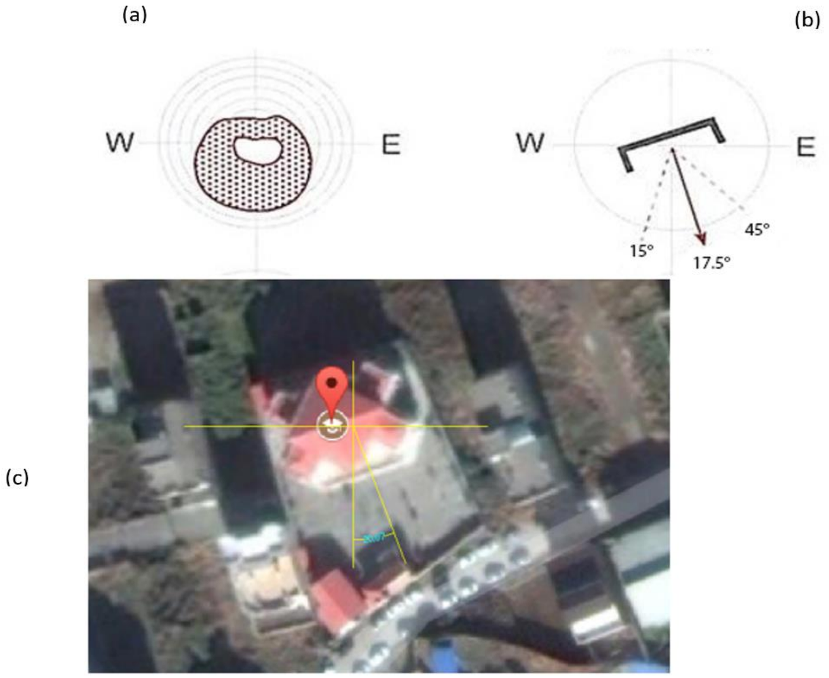



**Fig 2**. The orientation of the educational building

**Table 1**. Climatic comfort table (Nadim et al.)

| Station | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 18.46 | 18.91 | 17.22 | 13.91 | 9.81 | 5.62 | 0.99 | -0.10 | 2.68 | 6.54 | 12.74 | 15.56 |

| Hot | Warm | Moderate | Cold |
|---|---|---|---|

Design Builder Software needs a schedule for openings to determine the appropriate orientation. The school is used continuously from 7 am to 1 pm in May to June and is used in summer three days a week with fewer people. According to the climatic comfort (table 1), in Sari, the months that require natural ventilation are from May (mid-May to mid-June) to October. The rest of the months, from November to early April, will require radiation energy to minimize the consumption of the heating system. As the school building is less used in summer, it requires less natural ventilation. This study considers energy absorption of radiation by buildings and openings a priority.

Fig 4 presents a natural ventilation diagram and proposed angles of the building. According to the schedule, for two months of the year (May to June) and the end of September and October, natural ventilation is used for cooling the school building. The south direction can make increase ventilation for the building. Of course, it should be noted that the amount of air conditioning is close to each other in the four suggested directions (15 ° west, south, 17.5 ° south-south-east, 45 ° southeast) and the construction direction (20 ° south-south-east). However, it is more suitable for the south than for other directions. Natural ventilation is also higher in May and June (May-June -early July) than in other months.

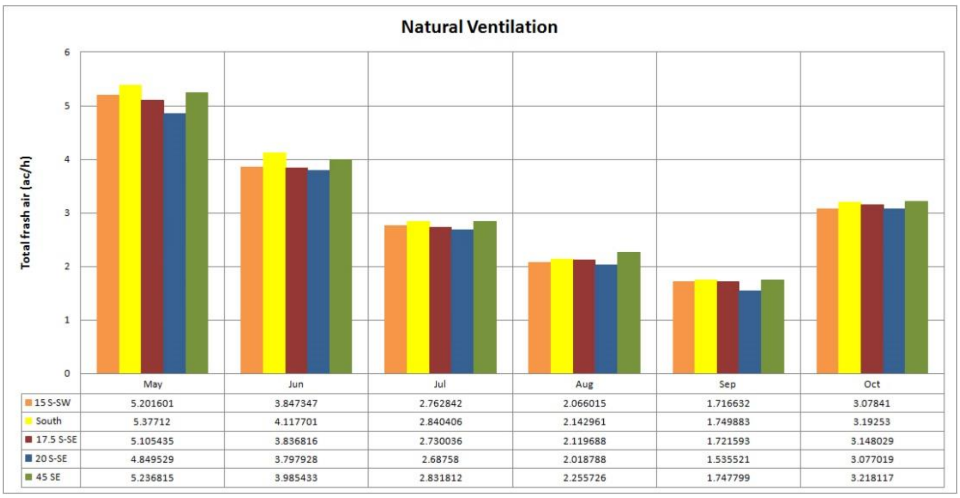



**Fig 4**. Natural ventilation diagram -proposed angles

In the natural ventilation diagram (fig 5), south orientation (proposed orientation) and school building orientations (20 degrees south-southwest) are shown. The research concludes that the south was the best orientation for better interior comfort conditions because this direction facilitates natural ventilation of the building.

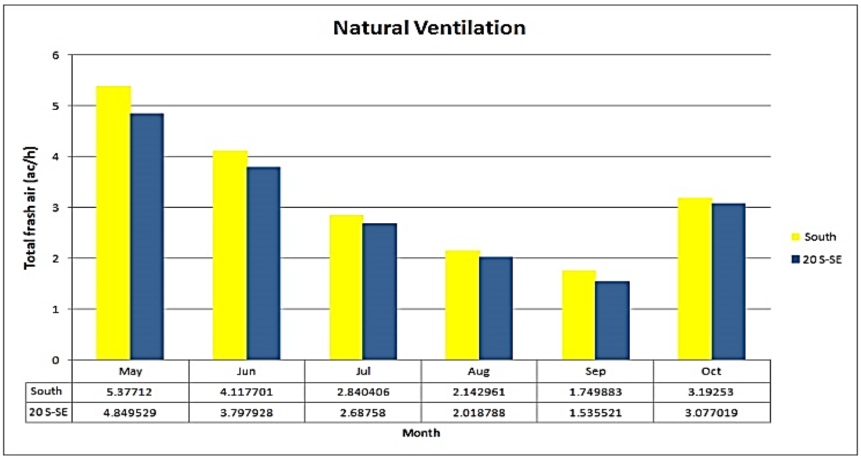



**Fig 5**. Natural ventilation diagram south orientation (proposed orientation) and school building orientation (20 degrees south-southwest)

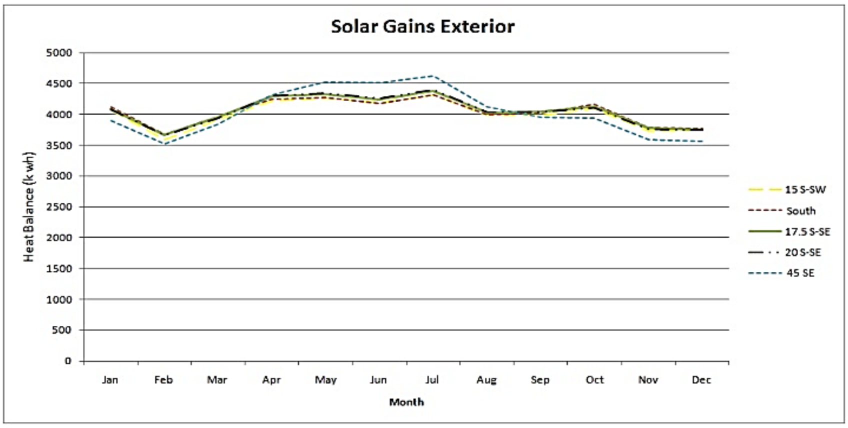
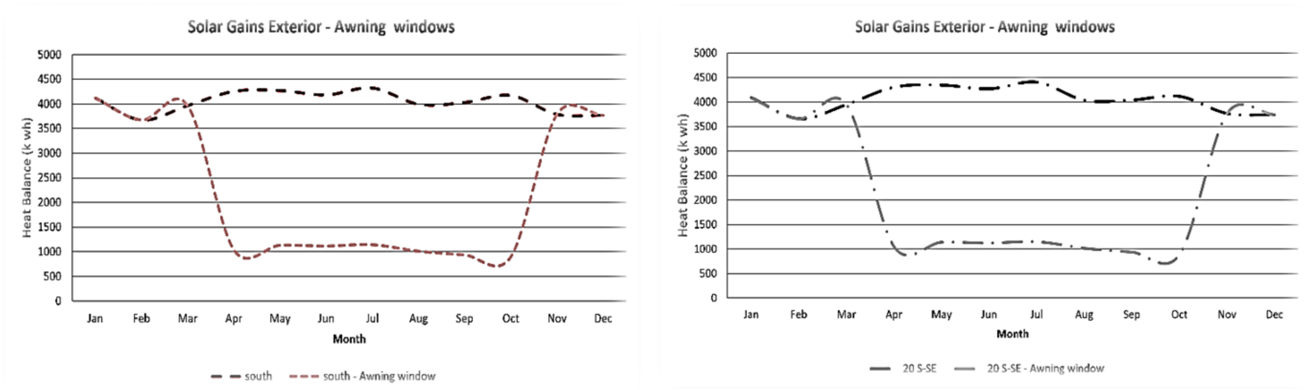



**Fig 6**. Solar radiation absorption diagram

The solar radiation absorption diagram is shown in Fig 6. The chart presents the amounts of absorbed heat by building in the proposed orientation in different months. 45-degree east is an inappropriate orientation for solar gains; maximum radiation absorption occurred in summer while minimum solar gain occurred in winter. 20-degree south to southwest and 15-degree southeast orientations have the same solar gains, but the south orientation of the building is ideal due to maximum absorption in summer.




**a** **b**

**Fig 7**. Solar radiation absorption by building with and without sunshade windows in ***a)*** south direction, ***b)*** existence orientation of school building

Based on the analysis and according to Sari's moderate and humid climate, the south orientation is the best orientation for constructing the building. The solar radiation absorption diagram of the structure with and without sunshade windows

at the south (Proposed orientation) and the southeast (building actual orientation) is present in fig7 a and fig7 b.
Solar radiation absorption is reduced using windows sunshade during the hot season (Fig 8). The sunshade should be closed and do not prevent the absorption of sunlight in winter.

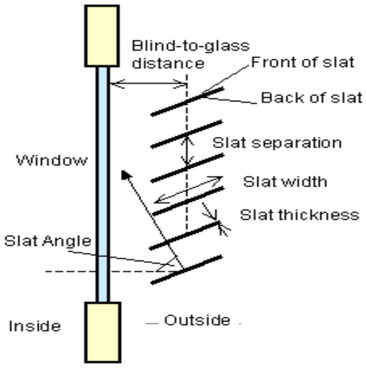



Fig 3. The proposed canopy

## CONCLUSION

In the present study, an educational complex in Sari with a moderate and humid climate was analyzed with the design-builder software energy simulator and assessed the effects of solar radiation heat gain and natural ventilation on different building orientations. In addition, the building's canopy was analyzed regarding the solar heat gain.
It is concluded that the south was the best orientation for better interior conditions due to increased solar radiation absorption in the coldest months of the year and optimization of natural ventilation in the hot season.
Based on the results of this work, the following suggestion in Sari and the temperate and humid climate present:
1) The length of the building should be along the east-west.
2) The North-South direction works better in regards to maximizing the airflow and radiation
3) The space between the buildings ought to be wide and open so that the airflow can be provided
4) The height of the building from the ground's surface determines the wind and natural ventilation usage in buildings.
5) The dimensions of the windows and apertures should be located in the north and south walls and at the height of the human body
6) The dimensions of the windows, apertures, and lighters should be 25 to 40% of the wall area
7) Light walls with thermal insulation must be used in buildings. The ceiling should also be lightweight with thermal insulation because when the daily temperature fluctuation is low, thermal storage does not matter.

## REFERENCES

Ahmed, A.-S. F., Khan, K.-M. M. K., Maung Than Oo, A.-A., Rasul, R.-M. G. J. I. J. o. M., & Engineering, M. (2014). Selection of suitable passive cooling strategy for a subtropical climate. *9*, 1-11. doi:https://doi.org/10.1186/s40712-014-0014-7

Al-Tamimi, N. A. M., Fadzil, S. F. S., & Harun, W. M. W. J. J. o. S. d. (2011). The effects of orientation, ventilation, and varied WWR on the thermal performance of residential rooms in the tropics. *4*(2), 142. doi:http://dx.doi.org/10.5539/jsd.v4n2p142

Alwetaishi, M., & Gadi, M. J. C. E. (2018). Toward sustainable school building design: A case study in hot and humid climate. *5*(1), 1452665. doi:https://doi.org/10.1080/23311916.2018.1452665

Ansarimanesh, M., Nasrollahi, N., Mahdavinejad, M. J. J. A. A., & Development, U. (2019). Determination of the optimal orientation in the cold climate administrative buildings; case study: Kermanshah. *12*(27), 1-9. doi:https://doi:10.22034/aaud.2019.92428

Baderia, N., & Design, M. A. E. (2014). *The role of thermal mass in humid subtropical climate: thermal performance and energy demand of CSET building, Ningbo.* Paper presented at the 30th International PLEA Conference.

Bayraktar, N. (2013). *Evaluation of natural ventilation efficiency in school buildings in the context of thermal comfort and interior air quality.* Paper presented at the International Conference" Standardization and related activities-the means of International and Collaboration the Balkans, Technical University-Sofia Science.

Daemei, A. B., Limaki, A. K., & Safari, H. J. E. P. (2016). Opening performance simulation in natural ventilation using design builder (case study: a residential home in Rasht). *100*, 412-422. doi:https://doi.org/10.1016/j.egypro.2016.10.196

Kouhirostami, M. (2020). Designing sustainable schools in moderate and humid region (case study: Babolsar). doi:https://doi.org/10.6084/m9.figshare.12733058.v1

Oropeza-Perez, I. J. E. P. (2015). Assessment of natural ventilation within buildings located on hot-temperate and mild-temperate regions. *78*, 1513-1518. doi:https://doi.org/10.1016/j.egypro.2015.11.180

Perez, Y. V., & Capeluto, I. G. J. A. E. (2009). Climatic considerations in school building design in the hot–humid climate for reducing energy consumption. *86*(3), 340-348. doi:https://doi.org/10.1016/j.apenergy.2008.05.007

Ragheb, A., El-Shimy, H., Ragheb, G. J. P.-S., & Sciences, B. (2016). Green architecture: A concept of sustainability. *216*, 778-787. doi:https://doi.org/10.1016/j.sbspro.2015.12.075

Tucker, R., & Izadpanahi, P. J. J. o. e. p. (2017). Live green, think green: Sustainable school architecture and children's environmental attitudes and behaviors. *51*, 209-216. doi:https://doi.org/10.1016/j.jenvp.2017.04.003

Zhou, C., Wang, Z., Chen, Q., Jiang, Y., Pei, J. J. E., & Buildings. (2014). Design optimization and field demonstration of natural ventilation for high-rise residential buildings. *82*, 457-465. doi:https://doi.org/10.1016/j.enbuild.2014.06.036