International Journal of Architecture and Urban Development
Vol. 10, No.2. P 25-36. Spring 2020

E-ISSN 2345-2331

Case Study Article
DOI: 10.30495/IJAUD.2020.15847

# An Assessment of Indoor Air Quality and Thermal Comfort in Educational Spaces

## (Case Study: Girls' High Schools in Arak, Iran)

*[1]Azin Velashjerdi Farahani, [2*]Mansoureh Tahbaz, [3]Shahram Delfani*

*[1]M.A., Shahid Beheshti University, School of Architecture, Department of Construction, Tehran, Iran.*

*[2*] Associate professor, Shahid Beheshti University, School of Architecture, Department of Construction, Tehran, Iran.*

*[3]Associate professor, Road, Housing and Urban Development Research Center (BHRC), Tehran, Iran.*

Recieved 10.01.2020; Accepted 25.05.2020

**ABSTRACT:** As students spend one-third of their time at school, their health, comfort, and productivity are mostly influenced by thermal condition and indoor air quality of classrooms. Regarding that manual window-opening is a common way for providing fresh air in classes and students aren't allowed to change their uniform, position or control the windows during the lesson hours, providing thermal comfort in winters may cause a lack of fresh air and therefore, dissatisfaction. This article is trying to evaluate the indoor air quality, and thermal condition of the classrooms, in two typical classrooms for 15-16-year-old girls in Arak, Iran. The overall study objective is to compare indoor microclimate measured parameters, with (1) students' subjective judgment, collected through a questionnaire, and (2) standards and to investigate the effects of microclimate on the indoor environmental condition of classrooms. According to the results, the thermal sensation of the students depends on their clothing rate and their understanding of the thermal state. In contrast, their thermal satisfaction is affected by the amount of fresh air provided. In winter, because of closed windows, students are mostly dissatisfied with the air quality and, therefore, thermal comfort, while in spring that the indoor environmental conditions meet the standards; the students feel satisfied with the conditions. The results of this research show that the indoor environment of the classrooms is mainly influenced by internal loads; consequently, its thermal condition is not a defining parameter.

**Keywords:** *Indoor air quality, Thermal comfort, Educational spaces, Natural ventilation.*

## INTRODUCTION

Students spend a large part of their time at school so that their health and comfort and, thus, their educational efficiency is influenced by it. Educational spaces in Iran are mostly ventilated with the manual opening of windows, which is the simplest way of natural ventilation. During the intermediate seasons, windows are opened, and occupants welcome the fresh outdoor airflow into the classrooms. As days become warmer, the risk of overheating increases, and as they become colder, students prefer to close the windows, which causes a lack of fresh air. Therefore, it is essential to study the indoor air quality and thermal condition of these spaces.

In classrooms, because of different conditions compared to home and office spaces, different thermal environment requirements are needed. Furthermore, regarding the high number of students in the classroom, acceptable air quality is assumed to be necessary for achieving a comfortable condition in this kind of space.

This article provides the results of a field study research that has been done in winter and spring of 2018 in some sample classrooms of two girls' high schools in Arak, the Markazi province of Iran. To show the effect of microclimate and local climate of the area on classrooms' indoor condition, one of the schools is located in the central part of the city, while the other one is located on the hillside. The indoor conditions of the classrooms are gathered by data logger instruments, and the students' satisfaction with the thermal condition and air quality of the classrooms is collected by questionnaire. In order to show the novelty of the present research, brief information about the most recent studies is contributed.

### Theoretical Fundamentals and Literature Review

"Thermal Comfort" according to ASHRAE StANDARD, is

*Corresponding Author Email: *m-tahbaz@sbu.ac.ir*

defined as "The condition of mind that expresses satisfaction with the thermal environment," and PMV (Predicted Mean Vote) model based on the heat balance of the human body. (He et al., 2016)(ASHRAE 55, 2010) Generally, there are two groups of factors that affect the thermal comfort ,including human factors and environmental factors, which air temperatures, air velocity, mean radiant temperature, and relative humidity are under the environmental factors (Elshafei et al., 2017).

Acceptable indoor air quality, according to ASHRAE StANDARD is "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction." (ASHRAE 62.1, 2010) Indoor air quality is an issue that is crucially necessary for naturally ventilated buildings that do not have mechanical ventilation to improve the IAQ. (Strøm-Tejsen et al., 2016) CO2 concentration, as a parameter of air quality, is used as an influential one on people's satisfaction and health, which can affect perceived "body odor". In the AStM Standard Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation (AStM D6245), has shown that if the people-related CO2 is maintained at less than about 650 ppm above background levels, body odors in space will not be disturbing to most people entering there.

Many studies have focused on assessing both thermal comfort and Indoor Air Quality in educational buildings, which are naturally or mechanically ventilated by using measurements and surveys. A research in 2019, investigated thermal comfort and air quality in 7 natural ventilated university classrooms under such low outdoor temperature by surveys in China. The results showed that the thermal comfort temperature range was from 19.5 to 21.8 °C and the thermal dissatisfaction rate was lower than 10% when the indoor operative temperature ranges between 18.3 and 23.8 °C. The percentage of dissatisfied occupants for indoor air quality was higher than 20% in some cases, and it was not related to CO2 concentration. The occupant density affected the perceived air quality but had no effect on thermal sensation, and the occupants' acceptability of indoor air quality was mainly affected by thermal sensation. (Liu et al., 2019) Another study in 2018, evaluated the indoor environmental conditions (thermal, visual and acoustic comfort and indoor air quality) in a partially-retrofitted university building in Ireland by physical measurements. The relationship between the performance of the building envelope and occupant comfort is described across retrofitted and non-retrofitted zones of the building. The results suggest that ad-hoc retrofitting of the façade did not make any significant difference to IEQ, and occupants continued to adapt personally to the existing conditions. (Zuhaib et al., 2018) In 2019, a paper aimed to investigate the indoor comfort conditions in a typical classroom of a secondary school in Cyprus. Various ventilation strategies and window opening patterns were examined, especially during wintertime. The measurements indicate values that often exceed the limits defined by standards. (Heracleous & Michael, 2019) A long-term post-occupancy study was conducted on a two-story educational building in France, in 2018. The indoor air quality (IAQ) was assessed by monitoring and analyzing CO2 levels, which were satisfactory for 95% of the occupancy period, and indoor thermal comfort was assessed numerically and by questionnaires, which indicates that growing the indoor temperature by 1 °C can improve the indoor thermal sensation. (Merabtine et al., 2018). In 2014, thermal comfort and indoor air quality in secondary schools' classrooms thermal were evaluated by physical parameters monitoring and survey questionnaires. The measurement campaign consists of measuring the environmental parameters air temperature (Ta), air relative humidity (RH), CO2 concentrations. Outdoor air temperature values were registered hourly at the nearest climatological station. Through this data, along with the actual people's clothing and metabolic rate being known, both Fanger's comfort indices were calculated (predicted mean vote and predicted the percentage of dissatisfied people). The subjective survey investigated the thermal acceptability, the thermal sensation, and the thermal preference. The results show that the students found temperature range beyond the comfort zone acceptable, and it was verified that running on naturally ventilation mode, CO2 concentration limits were highly exceeded. (Dias Pereira et al., 2014)

Another group of studies evaluates thermal comfort in classrooms. In 2019, one of these studies assessed and compared thermal comfort in insulated schools with thermally insulated one in Jordan, using two methods, first through field monitoring and second through thermal simulation. The result indicates that the indoor thermal environment in the new school was more satisfactory than the old one. (Ali & Al-hashlamun, 2019) Another research, in 2017, evaluated thermal comfort in a sample of higher educational buildings located in Egypt and involved a survey of POE questionnaires as an interactive tool for evaluation. The results indicated that only 1/3 of spaces fulfill occupant satisfaction. (El-Darwish & El-Gendy, 2018) In the same year, thermal comfort was investigated through both subjective and objective measurements carried out in 7 classrooms, in Italy. Both 7-value and 13-value scales, were provided to the occupants for the thermal comfort evaluation, and no significant differences in the results were found, (Ricciardi & Buratti, 2017) and in India, thirty classrooms in three university buildings participated in field study and thermal environment variables were recorded according to Class-II protocol of ASHRAE Standard 55 while Students thermal sensations, preferences, and acceptability for prevailing indoor conditions were analyzed statistically. The mean comfort temperature, as predicted by Griffiths' method, was 29.8°C (CI 95% and Std. Dev 2.84). Adaptive models obtained using comfort temperature in the present study show good agreement with the predictions from similar adaptive models. (Singh et al., 2018)

Indoor Air Quality assessment also has been the subject of many studies. In 2018, a study in America aimed to characterize IAQ in elementary school classrooms and estimate average effective fresh air ventilation rates under cold, mild, and warm-season

conditions. Particulate matter, $CO_2$, CO, $NO_2$, total VOCs, and formaldehyde concentrations, as well as relative humidity and temperature, were measured for 24-hour periods in each season in 12 elementary schools. Effective fresh air ventilation rates were estimated using a transient mass balance modeling approach. There was a lack of adequate fresh air ventilation in many cases. (Johnson et al., 2018) Another study in 2016, evaluated the effect of ventilation on indoor air quality in Italian classrooms using a survey. The results revealed that, even in classes characterized by a reduced maintenance state, the permeability of the envelopes was too low to guarantee acceptable air exchange rates. (Oros & Oliveira, 2012)
Regarding this body of literature related to the thermal and air condition of educational spaces, it is shown that the role of microclimate in defining indoor environment conditions has not been investigated. In addition, the difference in orientation of classrooms was not discussed. Therefore, this study attempted to assess the thermal and indoor air conditions in two girls high schools as a representative of educational spaces in Arak, Iran. These schools are located in different contexts with different microclimates, using both objective and subjective methods. These methods are thoroughly discussed in the section, which includes the properties of sample schools and classrooms, the features of measurement tools, the schedule of measurement the questionnaire, and the methods of data analyzing. Then the results of different classroom types are reported in the results and discussion section, which are compared to each other and with ASHRAE standard. Eventually, in the Conclusion section, the final approach is presented.

## MATERIALS AND METHODS

### Process of Study

Since students spend one-third of their time in classrooms, where they can affect their health and productivity, indoor environmental quality assessment is crucially important in these spaces. Regarding the reconstruction and renovation of schools in developing cities, this research follows post-occupancy evaluation in 4 classroom types in Arak, one of the developing cities in Iran, and it is believed that it might be helpful in future constructions. The research progression is presented in Fig.1. As it can be seen, Field measurements and questionnaires were carried inside two north-front and south-front classrooms in each building. The methodology is based on both the objective and subjective survey. The questionnaires were administrated to the students occupying the classrooms understudy while the microclimate parameters were recorded.

### Case Study

The city of Arak is located in the center of Iran. (Fig.2) In reliance on the meteorological data collected from 2005 to 2015 in the synoptic station, located in Arak, Average monthly temperatures are sometimes quite high, over 35 _C in the summer. In winter, the average means temperatures go just under 0 _C. The annual mean temperature is about 14 _C, which shows that this city has a moderate to cold climate. In terms of rainfall, the total yearly value is low, and it occurs mostly in winter. (Iran Meteorological Organization Data Center, 2018) Fig.3 shows the city's climate analysis based on Givoni's bioclimatic chart. (Givoni, 1992) As obvious it is, cold winters and dry and moderate summers are the features.

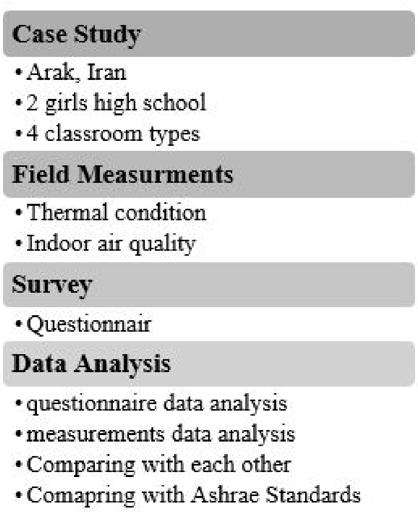



Fig. 1: The process of the research

Fig. 2: The location of Arak in Iran

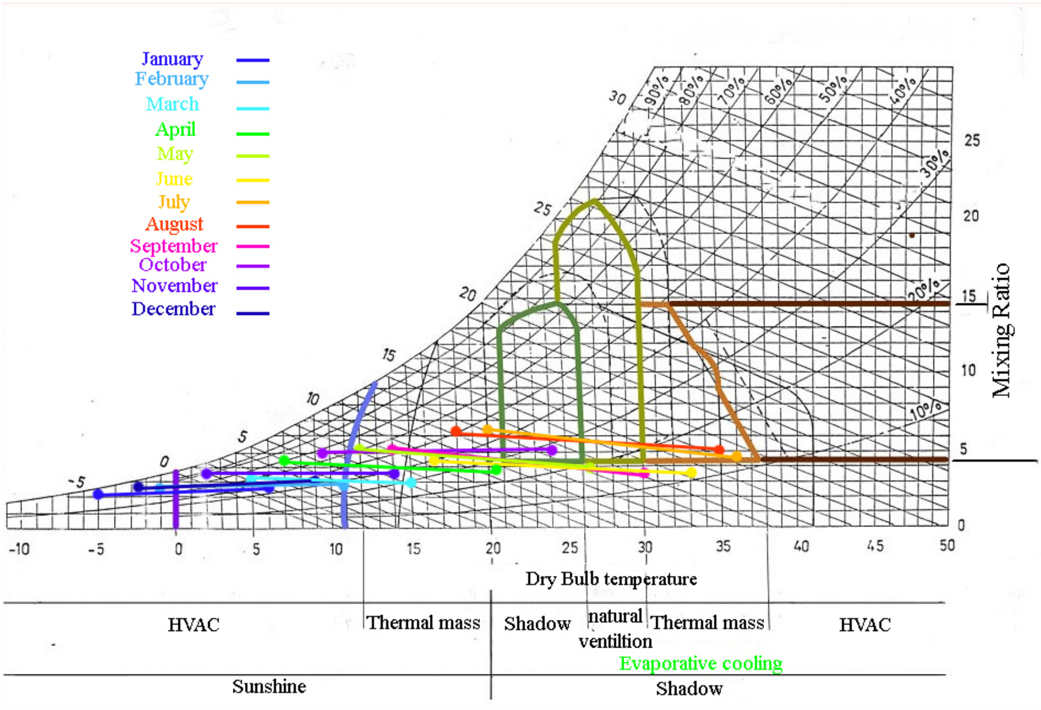



Fig. 3: Arak's climate analysis based on Givoni bioclimatic chart

Since high school students are mature enough to understand the thermal condition of their surrounding spaces and express their opinion about it, this study has focused on classrooms' of high schools. There are two high school buildings, the first one is located in the city center with 12 classes and three floors, and another one is in the countryside with six classes, and two floors are selected. These two are girls' high schools as, in Iran; schools are segregated for boys and girls Fig. 4 shows the features of each building and the selected classrooms, which are defined by red * on the plans. In each school, two classrooms (north-front and south-front) on the upper floor are chosen. Fig. 5 describes these classrooms.

The windows in building type 1 are Aluminum framed with single-pane glazing, and in type two are UPVC framed with double-pane glazing. The walls are made of 15-cm clay block and inside layer of plaster and outside layer of building stone.

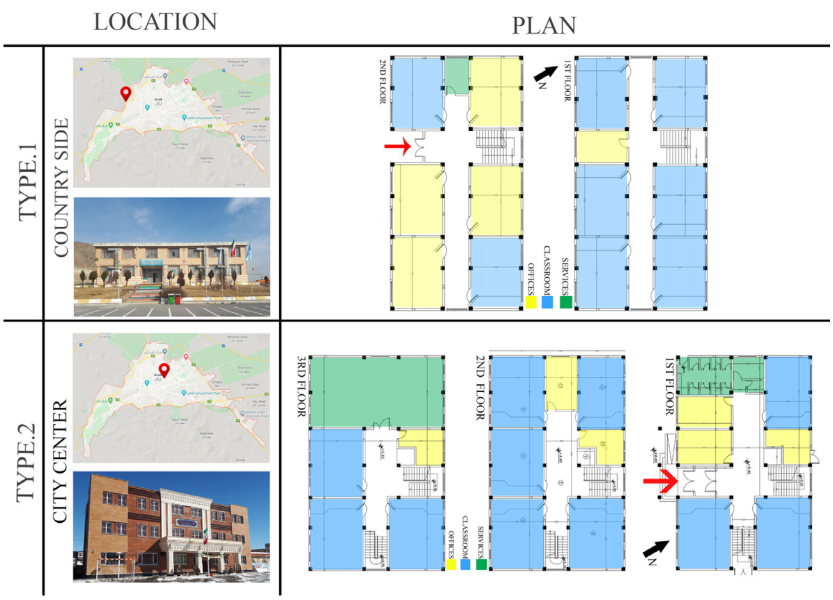



Fig. 4: The contexts and plans of the selected schools

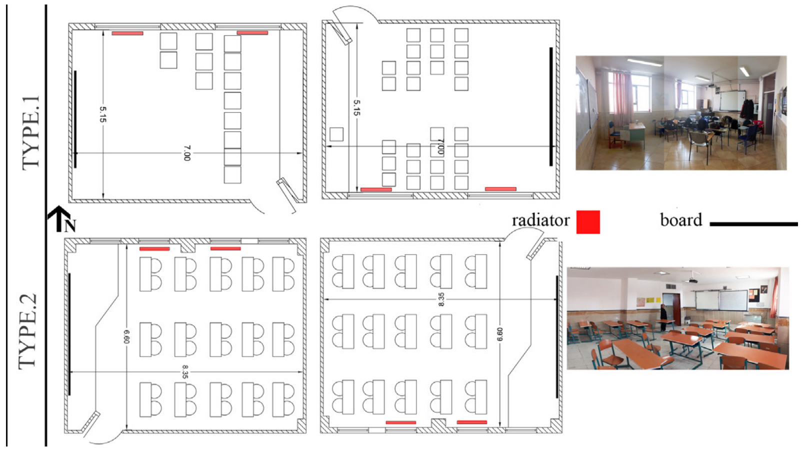



Fig.5: The classrooms' properties

Its total heat transfer coefficient is 1.9 w/m2k.

Each classroom is provided with two active radiators and no mechanical ventilation system. Schools were working on "free-running" conditions in spring and fall and only natural ventilation strategies were used to control the Ta and IAQ. The characteristics of the selected classrooms are presented in Table.1. The students are 15-16 years old. There usually are 13, 27, and 30 students in north-front and south-front classrooms of building type 1 and both classrooms of building type 2, respectively.

**IEQ Data Measurement**

The indoor air quality and thermal comfort factors were analyzed using field measurements of the following parameters, including air temperature (Ta), air relative humidity (RH), Mean radiant temperature (MRT), particulate matter PM2.5, and concentration of carbon dioxide (CO2). The recorded values of these parameters are presented and compared to standard values based on ASHRAE Standard 55 for thermal comfort and ASHRAE Standard 62.1 for air quality (Table 2) in the next section (ASHRAE 55, 2010; Ashrae 62.1., 2010). Air temperature and air relative humidity were measured using a data-logger during one school week in each season (winter and spring) as the representatives of the heating season and transient seasons. As the regular school year period does not include the cooling season (summer), there were no measurements needed in summertime. Data were registered every 10 minutes for the total monitoring period. Mean radiant temperature, PM2.5, and CO2 concentration have been measured two times during the aforementioned weeks. They were recorded each time, every 20 minutes in a one hour, in the middle of one a lesson hour. The measurement timetable is presented in Table.3.

These parameters have been measured using some standard tools which are categorized based on logging or manual recording. Their characteristics and places of installation are shown in Table.4. During the manual measurement, in winter, all the windows and doors were closed, and in spring, the windows were open. The curtains were drawn in both seasons and all types.

**Micro-Climate Data Measurement**

Since two selected buildings have different contexts, the microclimate of each would be different and can affect the indoor environmental conditions. In this study, the micro-climate has been recorded, measuring air temperature, wind direction and speed, relative humidity. These parameters were simultaneously measured in both buildings during the measuring week in each season (27-31 Jan and 21-25 Apr 2018), using two 4500 kestrel trackers that were installed on stands of the roof. This data was registered every 30 minutes for the total monitoring period.

On the other hand, METARs data produced in Arak's synoptic station in the same weeks were compared to the registered data. In this way, the effect of micro-climate can be observed.

**Questionnaire**

As the objective of this study is to compare the results of the measurements with standards and students' votes for satisfaction, surveying to understand their thermal condition and status about air quality seems to be necessary. Thus, a questionnaire has been prepared based on ASHRAE Standards (ASHRAE 55, 2010). It has five different parts: 1) The amount of cloth that students have worn that comes in a list, 2) Thermal sensation in 7-value scale question, 3) Thermal satisfaction in 7- value scale question and the reasons of dissatisfaction, 4) Thermal preference in 7-value scale, 5) Satisfaction of air quality and the frequency of body syndromes such as headache. The total number of 383 questionnaires has been filled during the monitoring period (at the same time with the manual measurements). Microsoft Office Excel and Spearman Rank Correlation coefficient (ρ) are used for data analysis because the data collected from the questionnaire is ordinal. (Zar, 1974)

Table.1: The Physical Characteristics of the classrooms

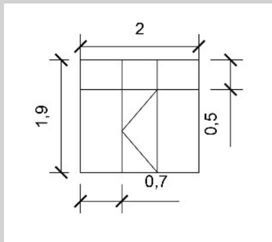
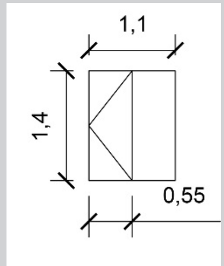
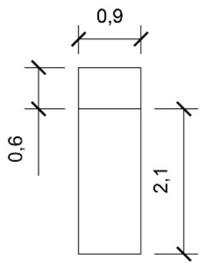
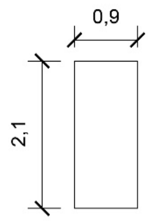
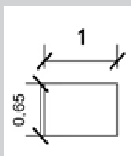
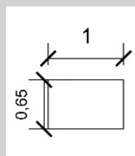
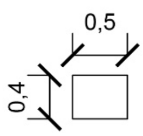
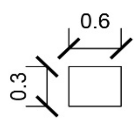
| | Type 1 | Type 2 |
|---|---|---|
| **Area ($m^2$)** | 35 | 55 |
| **Window** |   |   |
| **Door** |   |   |
| **Heating unit (radiator)** | 20 blades   | 24 blades   |
| **Cooling unit (evaporative)** |   |   |
| **Height (m)** | 2.9 | 2.7 |

Table.2: Standard used in analysis

| | | |
|---|---|---|
| **Ashrae 62.1** | PM2.5: 35 µg/$m^3$ | CO2: 1000 ppm |
| **Ashrae 55** | PMV: ±0.5 | Adaptive approach: 0.31To+17.8 |

Table.3: IEQ measurement time table

| | | Data logger | Manual measurements |
|---|---|---|---|
| Parameters | | Ta, RH | Ta, RH, TMRT, CO2, PM2.5 |
| Date and time | Winter (2018) | 27-31 Jan<br>24 hours a day<br>every 10 minutes | 27,30 Jan in type 1<br>28,31 Jan in type 2<br>10_11 am, every 20 minutes |
| | Spring (2018) | 21-25 April<br>24 hours a day<br>every 10 minutes | 23,24 April<br>10_11 am, every 20 minutes |

Table.4: The characteristics of measuring tools

| Tool | Model | Accuracy | Installation |
|---|---|---|---|
| Kistok data logger | Kimo KH50 | 0.1 C, 0.1% | On the whiteboards |
| Thermo Anemometer | TES RS1341 | 0.1 C, 0.1% | On the stand, in the middle of the classrooms |
| WBGT meter | Heat Index 8778 | 0.1 C | |
| CO2 detector | B Asden AZ77535 | 1 ppm | |
| Air quality monitor | TES 5322 | 1 μg/m³ | |

## RESULTS AND DISCUSSION

### Micro-Climate Analysis

What stands out from Fig.6, the wind roses of the monitoring weeks based on the rooftop tools measurements and Arak synoptic stations reports in both seasons. Generally, wind speed in schools was less than 2 m/s while it was more than 5 m/s in the station. The school type 1 experienced a calmer weather situation in both seasons in comparison with school type 2 because of the context difference.

The outside temperature, which was measured on the rooftop of the schools in winter and spring as the representative of the local climate, is compared with the recorded temperature collected in Arak synoptic station as the representative of the city climate at the same time. (Tahbaz, 2013) Fig.7 shows the outside air temperature fluctuation on January 28th and April 22nd, 2018, as a sample day of measurement weeks. As it was

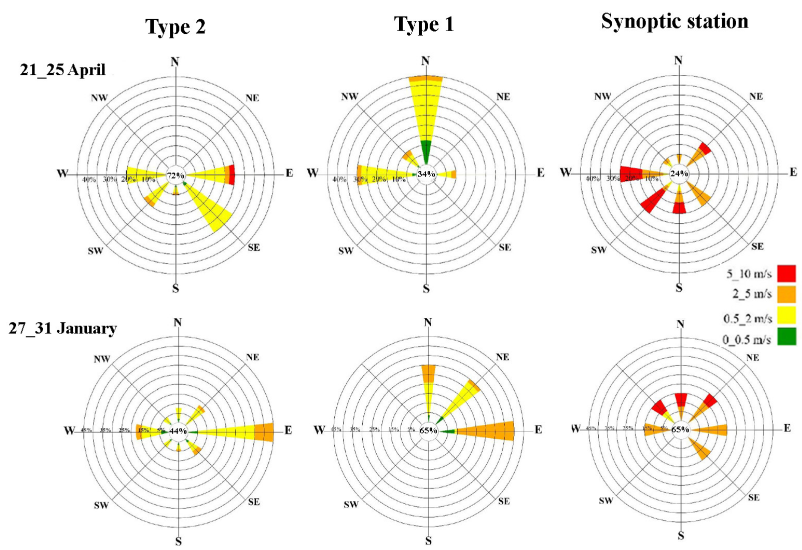



Fig. 6: Wind roses of data monitoring weeks

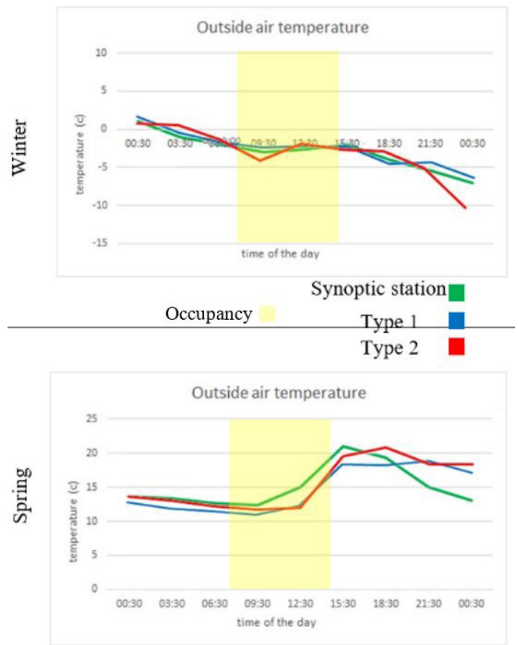



Fig.7: Comparison of outside air temperature during the data monitoring in two seasons

predictable, in school type 1, it is lower than school type 2, most of the time in both seasons. In winter, because of snowy weather, the midday wasn't the warmest time of the day.

## IEQ Analysis

### Measurement Results

Data-loggers have recorded air temperature and relative humidity during the measurement weeks every 10 minutes. These data are used to analyze the effect of students' presence on the temperature of the classrooms. Fig.8 illustrates the air temperature fluctuation on January 28th and April 23rd in the south-front class of type 1, as the sample of all types and measurement days in winter and spring, respectively. The yellow squares on the charts show the break time between the class periods when students leave the class and open the doors. This action has made the classroom about 1 C cooler. When it comes to 14, leaving for home, the air temperature goes down clearly.

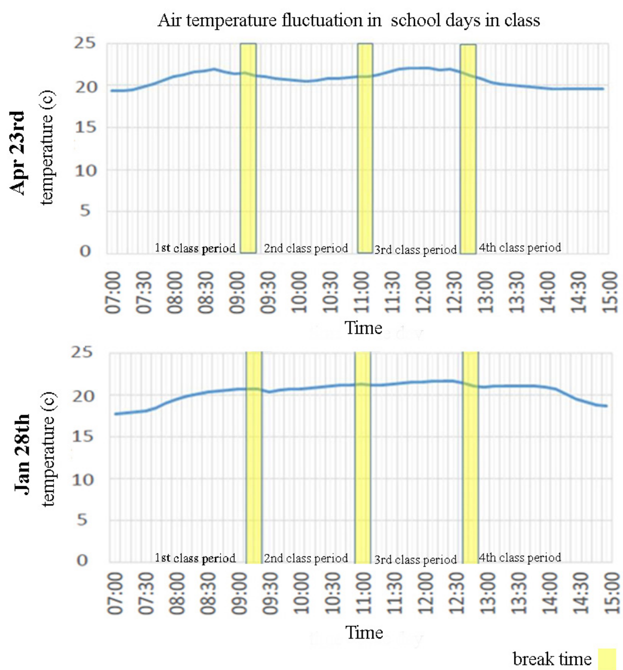



Fig. 8: The effect of students' presence on classrooms' air temperature

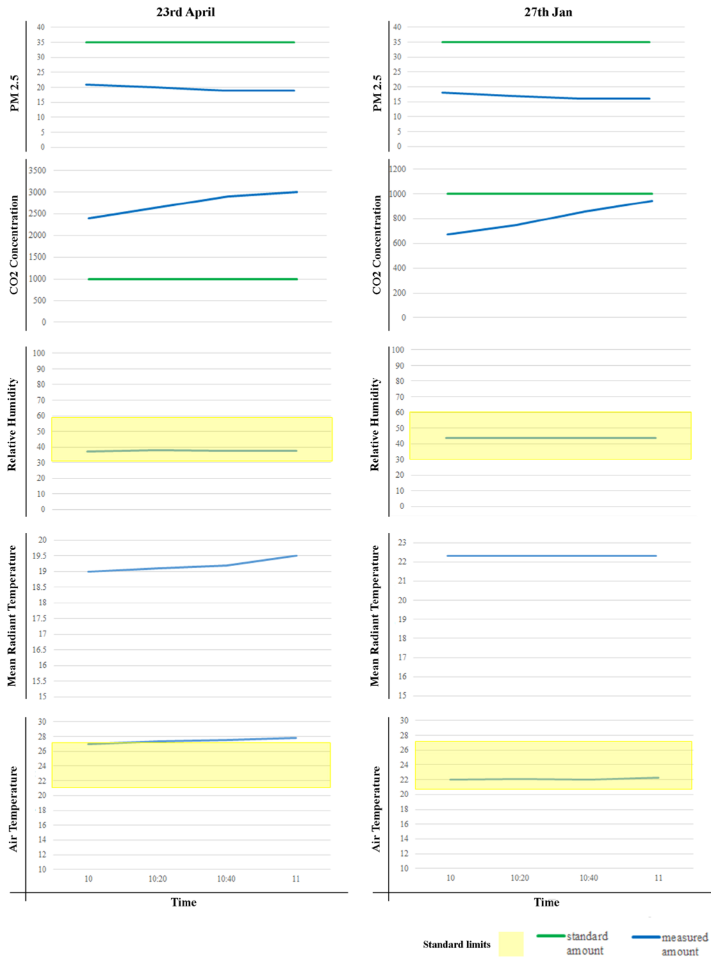



Fig. 9: the measured parameters in south-front type 1 classroom

The amount of thermal and air condition parameters in the south-front classroom is presented in charts in Fig.9, where the standard amount is also shown. Based on the adaptive Approach in ASHRAE 55, when the outside temperature is 13 C, the comfort temperature limit is between 18.3 and 25.3 C, which is used for spring. In winter, the air temperature was slightly above 27 C, and CO2 concentration was excessively more than 1000 ppm, while in spring all the parameters' amounts meet the standards.

**Questionnaire Results**

In the previous session, the results show that the amount of CO2 concentration was above the standard rate in winter. In addition to the ASHRAE standard, the air was slightly warmer than the comfort zone. For evaluating the thermal and air condition of the classrooms, it is essential to understand the students' votes about it. In winter, the data of the clothing rate collected from the questionnaires and manually measured parameters are used for PMV calculation in the CBE comfort tool. (CBE Thermal Comfort Tool, 2018).The results in all classroom types are mostly the same, so that the result of the south-front classroom of type 1 is presented here.

**Clothing Rate**

The absolute frequency of clothing rate is calculated in each class in comparison with 0.7 Clo, which seems to be suitable for spring and 1 Clo, which is suitable for winter. This data is presented in Fig.10 for the south-front classroom of type 1 as a sample of all types. These pie charts show that most of the students wore more than the regular cloth rate needed for each season. The reason may be the low outdoor temperature that they have experienced during the break time. As there was no place and time to change the cloth, they sat in the class with a high cloth rate.

**PMV Calculation**

As radiators were active during the winter, the PMV model is calculated for winter based on the measurements and clothing rate. As the chart shows in Fig.11, PMV is mostly in standard limits, and only for 30% of students, it is in the warm zone.

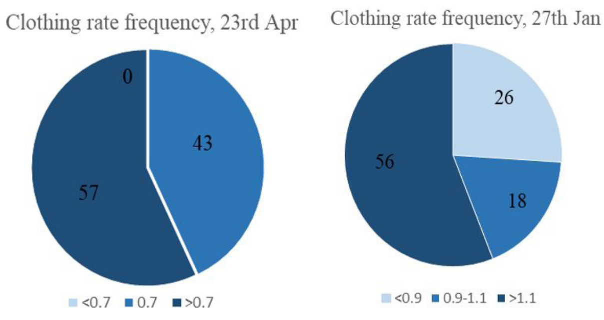



Fig.10: Clothing rate frequency in south-front classroom of type 1

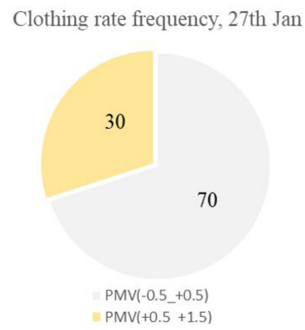



Fig.11: PMV frequency in south-front classroom of type 1

**Thermal Sensation, Preference, and Satisfaction**

In winter, while only 41% of the students have felt neutral, about 70% of them were satisfied with the classroom's thermal condition. Investigating the spearman correlation (ρ) between thermal sensation and cloth rate, thermal satisfaction, and preference shows that students with less cloth rate felt cooler and preferred a warmer space. Nevertheless, cooler thermal sensation made students more satisfied (Fig.12). In spring, despite the high thermal sensation, 92% of students were satisfied with the condition, although they preferred a cooler space. (Fig.13)

In the questionnaire, there was a question asking about the reasons for dissatisfaction with four options, including 1) cold or hot surfaces around, 2) wind-chill from windows, 3) solar radiation, and 4) low ventilation rate. Collected data shows that the most frequent reasons were low ventilation rate and cold or hot surfaces around that may happen because of the positions of radiators.

**Air Quality**

In the questionnaire, students have been asked to evaluate the indoor air quality in a 3-value scale question and declare whether they see any problem in it or not. Fig.14 shows the results. In winter, a growing number of students said the air quality was poor, and all of them have seen problems in the air. While in spring, more than 90% of students evaluated it as neutral and good; only 15% of them have seen problems in the air condition of the classroom. (The most mentioned problems were body odor and lack of oxygen.)

On the other hand, in winter, the most frequent syndrome that

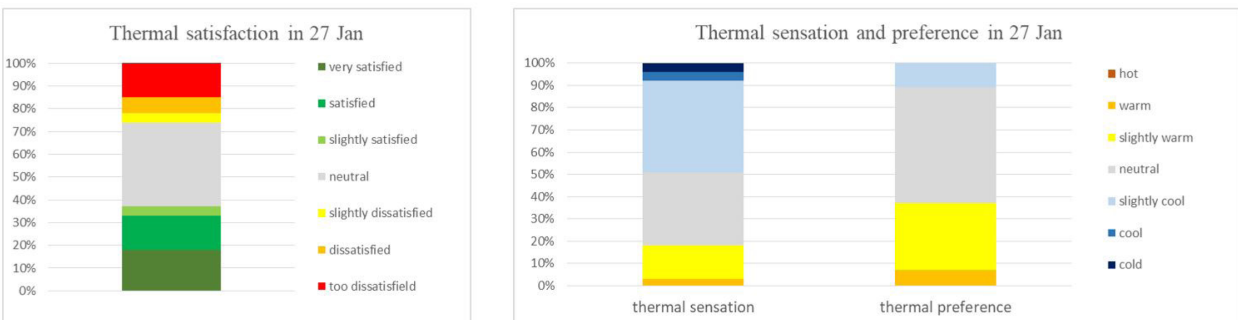



Fig.12: Students' thermal understanding, 27th January

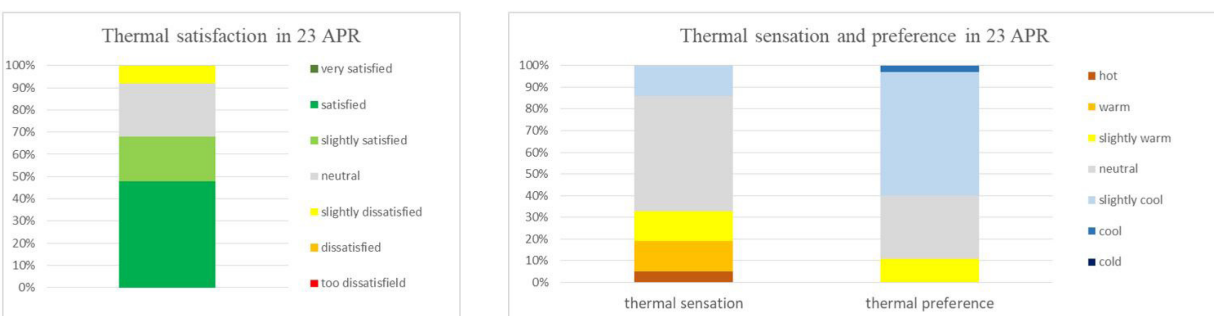



Fig.13: Students' thermal understanding, 23th April


Fig.14: Air quality evaluation

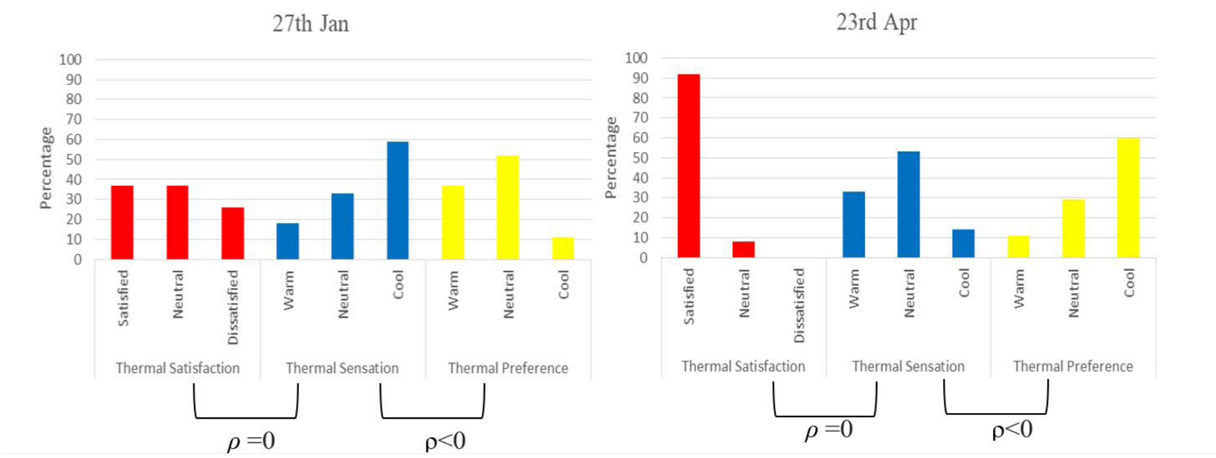



Fig.15: The correlation between thermal sensation, satisfaction and preference

happened for students was tiredness and sleepiness, with more than 70% of the votes , which reason is the high amount of CO2 concentration. The next frequent ones were headache and shortness of breath, with 41% and 30 %, respectively. These two are mainly caused by the lack of oxygen. According to the votes collected in spring, the most frequent syndrome was tiredness, but with 45% of the votes and headache with 26% was the second frequent one. Burning and watering eyes, which are caused by particle pollution, were considered as the rare syndrome in both winter and spring.

**Discussion**

The measured thermal comfort parameters have met the standards in both seasons. More cloth rate, which was the result of cold outdoor temperature, made students feel warmer in spring and prefer a colder space, although more than 90% of them were satisfied with the thermal condition. Students, who wore less than 1 Clo in winter, recognized cool as their thermal sensation and preferred a warmer space. 74% of students were satisfied with the condition in winter.

The calculated Spearman correlation (ρ) shows that there is no correlation between thermal sensation and thermal satisfaction in spring and winter, while there is a negative correlation between thermal sensation and thermal preference. (Fig.15)

The measurement and Questionnaire results of indoor air quality part, in winter, illustrate that the air condition did not comply with the standards and students' satisfaction. However, in spring, the air quality has been considered reasonable based on standards and students' votes.

According to the same results collected in different types, the indoor condition is mainly influenced by the number of students (internal loads), not outdoor micro-climate, and students' comfort depends on cloth rate and air quality.

It seems the problem is not the thermal condition but the air quality. As the thermal state in both seasons was conforming to the standard and thermal dissatisfaction was the result of asymmetric temperature distribution and low ventilation rate.

So that, strategies such as using some vents in external and internal walls to provide standard minimum fresh air with natural ventilation, utilizing linear radiators to decrease temperature difference in the classroom width, seems to be beneficial.

## CONCLUSION

In this work, the results of a field study investigations on thermal comfort and IAQ in Iranian girls' high school classrooms located in Arak, center of Iran, are shown. The survey was carried out during the mid-season in free-running conditions and winter with an active heating system.

The environmental parameters influencing Thermal comfort and IAQ were measured, while parallel subjective assessments of the occupants were collected. The study allows a comparison between TC indices predictions (calculated with the monitored data) and a subjective perspective observed from the questionnaires.

Based on these results, it was found that the problem is not the thermal condition, but the air quality as the thermal condition in both seasons was conforming to the standards and the students' satisfaction. Moreover, thermal dissatisfaction was the result of asymmetric temperature distribution and low ventilation rate. Thus, designing several vents on external walls and several ones on the corridor's wall, which can provide cross ventilation due to the pressure difference, sounds to be necessary. Using a linear radiator is another suggestion that can provide better temperature distribution.

This study had some limitations that should be considered for future works. First, this data has been collected through short-term monitoring, the places that measurement tools were installed, have depended on the students' seats and boards, the schools' rules, and situation, and the facilities the researcher had so they weren't the best spots for the most accurate data. The process of questionnaire survey has been observed and monitored carefully, but about 2% of the answers were not reliable enough to use.

## ACKNOWLEDGMENT

This paper is entirely based on a master thesis entitled "Evaluation of Thermal Comfort and Indoor Air Quality in Educational Spaces with Natural Ventilation, Case Study: High schools in Arak" done by Azin Velashjerdi Farahani under supervision of Dr. M. Tahbaz and Dr. Sh. Delfani at Shahid Beheshti University, in February 2019.

We have to express out our appreciation to the students and the teachers (Farzanegan and Ghamare Bani Hashem high schools) for their company and patience during the field study.

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