Keywords:

Office design, thermal comfort, relative humidity, natural lighting, glazing

Article Information

Received:
16 March 2018
Received in revised form:
10 July 2018
Accepted:
11 July 2018
Available online:
14 July 2018

Impact of Glazing on Thermal Comfort, Relative Humidity, and Lighting Level in Office Spaces

H. Nur ÖZKAN ÖZTÜRK*

Abstract

Providing a working environment that has certain level of comfort is one of the most prominent requirement of an office space. Clearly, relevant space parameters are necessary to perform minimum space quality. In this regard, building components that have an impact on indoor environmental quality (IEQ) are so critical that can change the quality of the place in a critical extent. Even if the buildings are typical and orientation is the same, comfort conditions could be different. Furthermore, facade configuration of a building has an impact on space comfort. Glazing of an office space can affect the comfort conditions in terms of temperature, relative humidity and light intensity. For this purpose, three typical office spaces in Mustafa Kemal neighborhood in Ankara are studied as a case and examined in terms of environmental conditions of interior.

* Çankaya University, Faculty Architecture, Department of Architecture, Ankara, Turkey
nurozkan@cankaya.edu.tr

Anahtar kelimeler:

Ofis tasarımı, ısıl konfor, bağıl nem, doğal ışıklandırma, cam

Makale Bilgileri

Alındı:
16 Mart 2018
Düzeltilmiş olarak alındı:
10 Temmuz 2018
Kabul edildi:
11 Temmuz 2018
Çevrimiçi erişilebilir:
14 Temmuz 2018

Ofis Mekanlarında Cam Tipinin Isıl Konfor, Bağıl Nem ve Işık Seviyesine Etkisi

H. Nur ÖZKAN ÖZTÜRK*

Öz

Belirli bir seviyeye sahip bir konfor düzeyi içeren bir çalışma ortamı sağlamak bir ofis mekanının en temel gerekliliklerinden birisidir. Açıktır ki minimum düzeyde bir mekan kalitesi elde etmek için ilişkili mekan parametrelerini sağlayabiliyor olmak gereklidir. Bu açıdan bina bileşenlerinin iç mekan ve hava kalitesine etkisi kritik düzeylere çıkabilir. Bina formu, ve yönelimi aynı olsa bile konfor koşulları değişken olabilmektedir. Bunun yanı sıra, cephe düzeni de mekan konforu üzerinde bir etkiye sahip olmakla birlikte, ısı, nem ve ışık yoğunluğu gibi parametreleri yakından etkileyebilir. Bu sebeple, Ankara'nın Mustafa Kemal mahallesindeki üç farklı ofis mekanı vaka olarak çalışılmış ve iç mekan çevresel koşulları incelenmiştir.

* Çankaya Üniversitesi Mimarlık Fakültesi, Mimarlık Bölümü, Ankara, Türkiye
nurozkan@cankaya.edu.tr

1. Introduction

In many fields of study, workspace arrangement embraces the necessity of individual and/or group working areas, especially with the last century. It is a critical point to be aware of necessary characteristics for a better organized and more productive working environment (Loftness, et al., 2006). Fulfillment and performance are closely related to architectural space planning, whether it is having an open plan or cellular office, furniture, public space arrangement and other facilities considering the employee. Becker and Kelly (2004) emphasized the importance of this topic to comprehend that effective arrangement of workspace helps not only the worker but also the owner in terms of financial concern.

According to Laing et al. (1998) information technology has gained importance with the 90s. Work hours of Information Technology' (IT) have become more irregular and intermittent comparing with the routine 9 to 5 job. As a result, necessities and requests of office inhabitants were transformed. Work patterns have not kept same and evolved into more flexible forms. "Buildings should be a multi-sensory experience." said Clements (2006); in that sense, the role of environmental properties and comfort is undeniable. Especially in workspaces comfort and space design are an inseparable whole and should be handled together. Choi et al. (2011) emphasized the importance of technology infrastructure with the combination of and its flexibility in office spaces, besides paper-based tasks. The authors continue with the lack of recognition of modern office variables in present standards.

Space comfort can be handled in several elements, such as climatic elements, namely thermal characteristics; humidity; lighting level, regarding natural or artificial; or design-dependent elements, namely building form, orientation of the building, thermal mass, façade organization, etc. (Çakır, 2006). Undoubtedly that each of these parameters has a certain effect in satisfaction and relatedly productivity levels of employees in office spaces; however, thermal and lighting aspects are the main parameters of this study, depending on quantitative measurability in space.

As it is emphasized in Panchyk (1984), the impact of environmental conditions' on the capability level of each human being is undeniable and crucial. Furthermore, individual values of each environmental characteristic might not mean something significant. In the earlier standards of American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) defined a term called "effective temperature", links the interior optimum temperature with relative humidity and air flow rate. In 22.5 °C, which can be considered as an effective temperature, relative humidity should be within the limits of 25% and 65% and air movement rate should be 4.6 - 7.6 meters per minute (Panchyk, 1984). It should also be mentioned that there is not an exact value for interior thermal comfort, but rather an interval that provides reference values. There are several reasons behind this, the effect of cultural differences might be one of them. For example, the perception of “cold” environment might be way more different in Oslo, comparing with Cape Town regarding “comfort” level of thermal characteristics. Fanger (1970) mentioned that it is impossible to fulfill a group of people’s expectations of living in the same room, depending on their physical variance. In this way, thermal comfort level of highest percentage of the group could be taken into consideration. ASHRAE generally defines the effective temperature interval of approximately between 22.5 and 25.3 °C (ASHRAE, 1982). Additionally, changing working patterns is also subjected in later versions of ASHRAE. In Standard 55 (ASHRAE, 2010), the critical outcome of this transition in working habits is outlined, the decrease in the paper-based tasks also lead a decrease in the physical activity rate, and correspondingly, the metabolic rate of employees decreased.

In general sense, light is necessary to fulfill various needs of human being, Illuminating Engineering Society of North America (IESNA) defined the human needs that served by the lighting as visibility, task performance, mood and atmosphere, visual comfort and aesthetic judgement (IEASNA, 2000). Lighting standards in office spaces is a critical factor that affects the comfort of employees and their work performance in office spaces. Most of the tasks in a regular office space require certain visual comfort level to perform necessities, and in this sense, the comfort level of the eye is crucial. There are very many factors that affect the comfort level of the eye, and some of them are illumination level of the room depending on both natural and artificial lighting, selection and positioning of luminaires to avoid possible disturbances for occupants, selection of indoor finish material to avoid the problem of glare. National Optical Astronomy Observatory (NOAO) in States recommended a guideline for reference values of illumination levels depending on activity type, and office functions should provide 250 to 500 lux (NOAO, n.d.). On the other hand, IESNA (2004) recommended 500 lux illumination for paper-based tasks and 300 lux for computer-based tasks.

Nowadays, most of the working environment depends on computer-based performance and the monitors emit a particular amount of lighting, and it is technically possible for employees to work in an environment that has neither natural, nor artificial lighting, regardless of acquired comfort level. However, there is a certain necessity of light for the comfort of the eye, and also the performance of other types of tasks. Veitch (2005) mentioned in her research that the access of an office occupant to a window brings fulfillment regarding lighting level of environment comparing with an occupant who does not have an access to a window.

A research conducted by Choi et al. (2011) in American federal offices measured the relationship between existing indoor environmental quality parameters and the satisfaction level of employees. It is reflected that temperature is the most concerned environmental parameter by employees regarding all indoor environmental quality related parameters; such as air quality, acoustics, relative humidity, etc.

Stegou-Sagia et al. (2007) conducted a similar research on the impact of glazing on indoor comfort and energy consumption in office and housing units. Three glazing-related parameters were questioned in this research, clear glazing, grey tinted glazing, and reduced are of glazing (half percent) in Greece. The results of the study showed that spaces with tinted glass have less solar gains than spaces with clear glass, and thus, they have higher energy consumption rates in heating periods but lower consumption rates in cooling periods.

Perez and Capeluto (2009) conducted a comparative research design variables that have an effect on energy consumption. In this study, glazing type is also included as a parameter, and the analysis is done with computer simulation in hot-humid climatic zones. The results showed that glazing is the third variable after light control and infiltration that affect energy consumption in school buildings. Furthermore, low emissivity (low-e) or double green double-glazing in glazing has a considerable effect on cooling loads since the study subjects hot-humid climate. Regarding the heating loads, low-e glazing performs slightly better than double-clear glazing at north faced facades.

2. Material and Methodology

There are some parameters that affect environmental comfort level and productivity in office spaces. This paper examines these parameters that could affect employees' productivity, the relation between these parameters and effect of façade organization on this situation. In other words, the aim of this research is making a comparison between some of the critical parameters in an office environment such as room temperature, relative humidity, and light intensity values depending on level-floor and relationship of them with the organization of the facade. That is why three typical office building in small-scale was selected as a case and a qualitative comparative method was practiced on these buildings.

The research is conducted in "Barış Sitesi", in which the term "site" stands for the housing estate developments in the Turkish language. It is located in Mustafa Kemal neighborhood of Ankara, Turkey. Climate of Ankara is continental, in which climatic conditions of winter times are more challenging than summers. The construction date of this settlement cannot be identified exactly; however, it should have 20 years past at least. It first planned to serve residential functions of the neighborhood that also has service functions of its own, such as marketplace, post office, or community clinic. In time, not only the settlement but also the entire Mustafa Kemal district has been started to transform into office and mixed-use especially at the Eskişehir Road periphery, which can be considered as one of the main axis' of Ankara currently. That is why housing settlement in "Barış Sitesi" has also been used for office function quite commonly today.

The main reason behind the selection of “Barış Sitesi” is having a rich set of alternatives that are same or similar in layout. Additionally, some alternatives have gone under renovation in time to perform office function in a better way. This provides a variety in the set of samples. The site contains nearly 540 individual house or offices, apart from the five high rise apartment blocks located at the center. As it can be partially identified in Figure 1, attached layout between individual units is the usual settlement type in “Barış Sitesi”, while there is a small group of detached building type at eastern part. In the selection of the samples in the study, the main concern is to make a comparison between aluminum curtain wall and timber joinery. Since the original joinery type is timber at the construction, two of them with same orientation is selected. There is also another sample that has curtain wall façade indeed, but the building typology is slightly different than common, therefore it is not included in this study. All measurement spots in three buildings are oriented to the north-western facade.

All data loggers placed to 100-150 centimeters from the façade (regarding the inner wall finish), and 150 centimeters higher from floor finish level of the corresponding slab. The variety at the depth of spots depends on the obstacles that prevent the placement of devices, such as a painting, a decoration, or a shelf. In the placement of loggers, direct exposition to sunlight is avoided to get more accurate results. That is why, the height of the positions of loggers are same, but the depth could slightly differ.

Three separate units were evaluated in this region. There is attached typology was adopted in all dwelling units in this settlement. All of the buildings were constructed in exact same type at the beginning; however, they have undergone some modifications in time. One of them has aluminum curtain wall glazing while others have traditional timber frame joinery. The effect of curtain wall on data variables is major concern of this research. The locations of studied buildings are indicated in Figure 1.

This research depends on observational inputs; interior conditions of 3 sample buildings were examined and compared. Type of data collected was quantitative data. The data was collected with HOBO data loggers that calculate temperature (°C), relative humidity (%), and lighting level (lux) and Tinytag loggers that calculate temperature (°C), relative humidity (%). The devices do not need any detailed calibration, except the attachment to the measured spot. After the loggers launched, they started to keep the record of mentioned parameters in every 15 minutes in 3 days measurement period. Additionally, observations on furniture layout and building organization were noted, and Excel software was utilized for the visualization and interpretation of the collected data. Measured data is presented in line charts in following part. The measurement was started in 28th of April, at 10:00 and ended on 30th of April, at 17:00, in 2015. Temperature data of Ankara is obtained from Turkish Meteorological state and added as a reference value to temperature measurement tables.

Figure 1 Site plan of Barış Sitesi, representing the locations of sample buildings.

Source: Google Earth (8th of March, 2018).

2.1. The Analyses of the Buildings

In this part, a brief analyses of three different buildings that are located at Barış Sitesi, Ankara, is given as a primary research sample. Existing features about the placements of the loggers, materials of the facades and glazing types, furniture layout of the sample buildings were listed below.

2.1.1. Building 1

Building 1 is shared by three different companies that are architecture, software and consultancy companies. Loggers were placed 3 different floors in place, and all of the rooms where loggers placed are located on southwest facade. General outlook of the facade is indicated in Figure 2. There are no apparent sun-blocker (tree, signboard, etc.) near the building, except a canopy above the second floor.

The building has an aluminum curtain wall at attributed façade where measurements are taken. Glazing type is reflective glass.

Figure 2 At left Building 1 exterior picture that examinations were mainly went on. Photo was shot at 21st April, 2015. At right, an interior image of Building 1 showing the exterior walls adjacent to the curtain wall. The photo was shot at 27th April, 2015.

Source: Authors Archive

The measurement was done between 28th and 30th April, 2015. Loggers were placed approximately 100-150 cm deeper (in horizontal axis) from exterior wall /facade, and 150 cm higher from the finish level of the ground. The placement of them and furniture layout of related rooms are indicated in Figure 3.

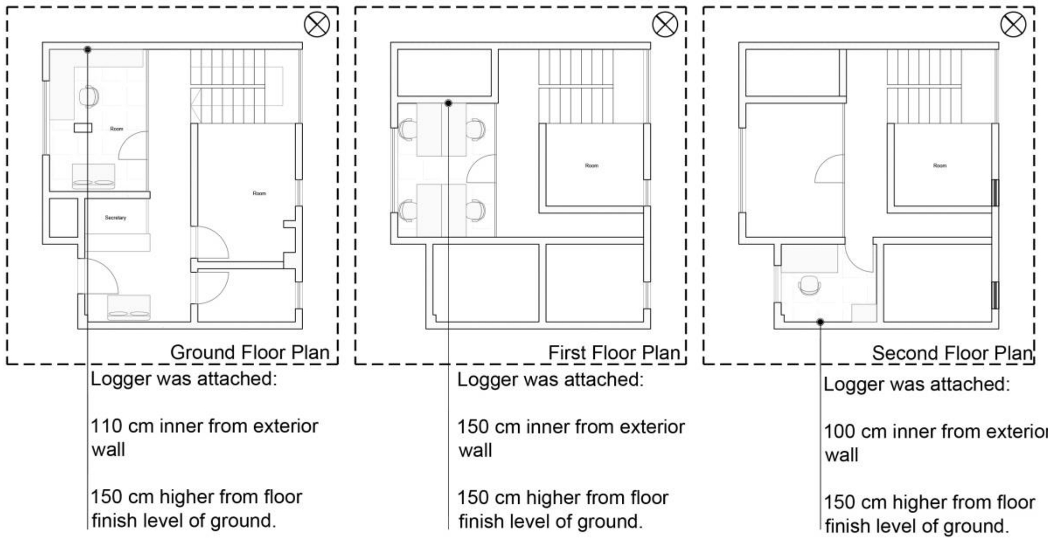


Figure 3 Location of data loggers and furniture layout of related rooms in building 1. The facades that measurements were taken are highlighted.

Heating system of the building is regular combi boiler. However, it was turned off during measurement. Although the facade is curtain wall glazing from outside, interior part has also the exterior walls adjacent to curtain wall, which can be seen in an interior picture given in Figure 2.

Figure 3 represents the furniture layout of the related rooms in the building 1. Most of the rooms used for working areas, especially the ones that the measurements are taken. The other rooms have also architectural functions, but they are not given in plan layout because of privacy concerns. Additionally, stair core of the building is not separated by doors or any kind of partitions. The building went under a reconstruction in time, their additional openings were added of size of the openings were widened.

2.1.2. Building 2

Building 2 is used by an architecture company. Loggers were placed 3 different levels in place, and all of the rooms where loggers placed are located on southwest facade. Glazing system is timber frame joinery. General outlook of the facade is indicated in Figure 4. Measurements were taken from the southwest facade. There are several possible sun-blockers (trees and shrubs) at the close surrounding of the building.

Measurement was done between 28th and 30th April, 2015. Loggers were placed approximately 100-150 cm deeper (in horizontal axis) from exterior wall /facade, and 150 cm higher from the finish level of the ground. Positions of them are indicated in Figure 7. As indicated in floor plan, 1st and 2nd floors have no furniture and users during measurements. Heating system of the building is regular combi boiler. It was opened during measurements only at ground floor level.

Figure 5 represents the furniture layout of the related rooms in the building 2. Only ground floor was used as office during the measurements, and it should be noted that 1st and 2nd floors have no furniture. Additionally, stair core of the building is not separated by doors or any kind of partitions. The building did not go under a serious reconstruction in time, except for regular maintenance.

Figure 4 (Left) An exterior picture of Building 2. Photo was shot at 21st April, 2015. (Right) Building 02 exterior picture (examinations were done in the rooms on this facade). Projection of 1st floor can be identified. Photo was shot at 21st April, 2015.

Source: Authors Archive

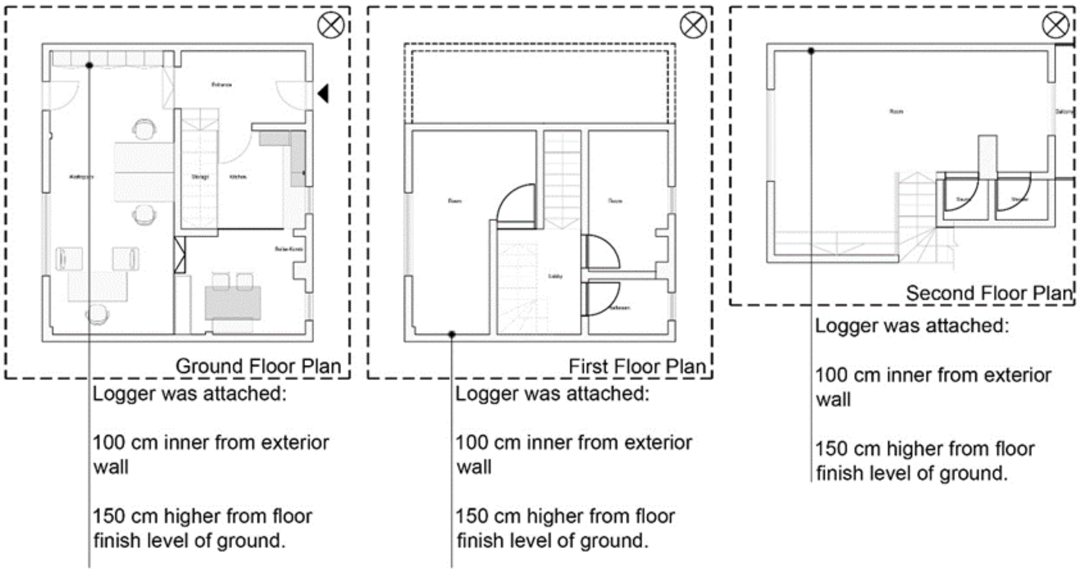


Figure 5 Location of data loggers and furniture layout of related rooms in building 2. The facades that measurements were taken are highlighted.

2.1.3. Building 3

Building 3 is used as an office of a law company. Loggers were placed 3 different levels in place, and all of the rooms where loggers placed are located on southwest facade. Glazing system is timber frame casework. General outlook of the northeast facade is indicated in Figure 6. Measurements were related with the opposite face.

Measurement was done 28th April, 2015, as an 8-hour-work between 10 am-6 pm. Loggers were placed approximately 100-150 cm deeper (in horizontal axis) from exterior wall /facade, and 150 cm higher from the finish level of the ground. Positions of them are indicated in Figure 7. 2nd floors used as storage have no furniture and users during measurements.

Heating system of the building is regular combi boiler. It was opened during measurements only at ground floor level.

Figure 7 represents furniture layout and plan organization of the related rooms in the building. At ground and first floor, the devices are located in offices areas, and at second floor, the room was used as a storage space/attic. Additionally, stair core of the building is not separated by doors or any kind of partitions.

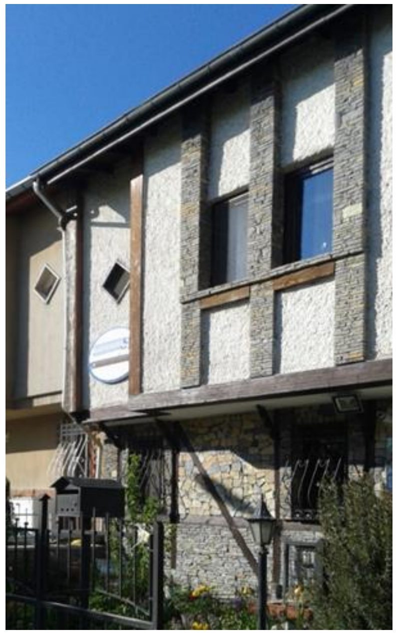


Figure 6 Building 3 exterior picture representing northeast façade. Examinations were done in the rooms on opposite façade. Projection of 1st floor can be identified. Photo was shot at April 21, 2015, at 8:30 am.

Source: Authors Archive

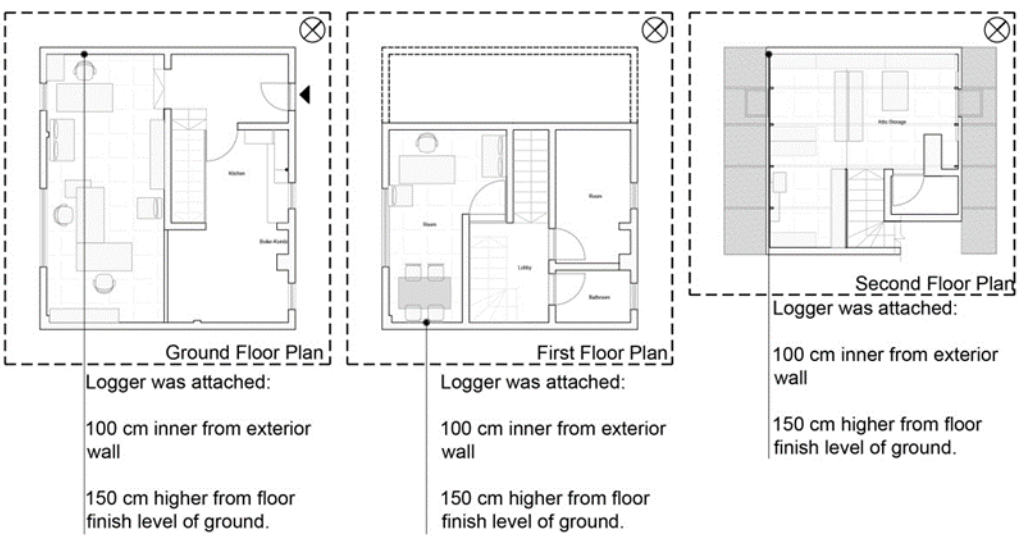


Figure 7 Location of data loggers and furniture layout of related rooms in building 3. The facades that measurements were taken are highlighted.

2.2. The Measurement Data of the Buildings

2.2.1. Building 1

Table 1 represents the temperature measurement of Building 01 in 28th, 29th and 30th of April, 2015. According to the results, the temperature of the ground level is the lowest, and second floor has the highest in general term. In other words, as the level of the room rises, amount of temperature that penetrates inside is increases. Mean values for each floor are 19.27, 21.31, and 21.83°C respectively. The rise of values from ground floor to first floor is greater than first floor to second floor. The reason behind this might be the position of the logger in 2nd floor. The facade of the room where logger put does not have curtain wall façade that is indicated in Figure 1. Highest and lowest values in this building are 24.476°C at second floor and 17.796°C at ground floor. The reference values of ASHRAE (1982) for effective temperature interval office environments is between 22.5 and 25.3 °C.

There are two major peaks at Table 1, between 4-7 pm at first and second measurement day. It is quite likely this movement is related to the orientation (southwest) of the facade. The heating system was closed during measurement, that's why there is no observable effect of it on the curves.

First floor temperature line has a couple of several more minor peaks comparing with other two temperature lines. This can be explained by the user activity. As it is seen in Figure 02, room capacity is for 4 people while others are private rooms. The number of inhabitants plays a role in this regard.

Table 1 Temperature (°C) graphic of building 1 depending on level / height.

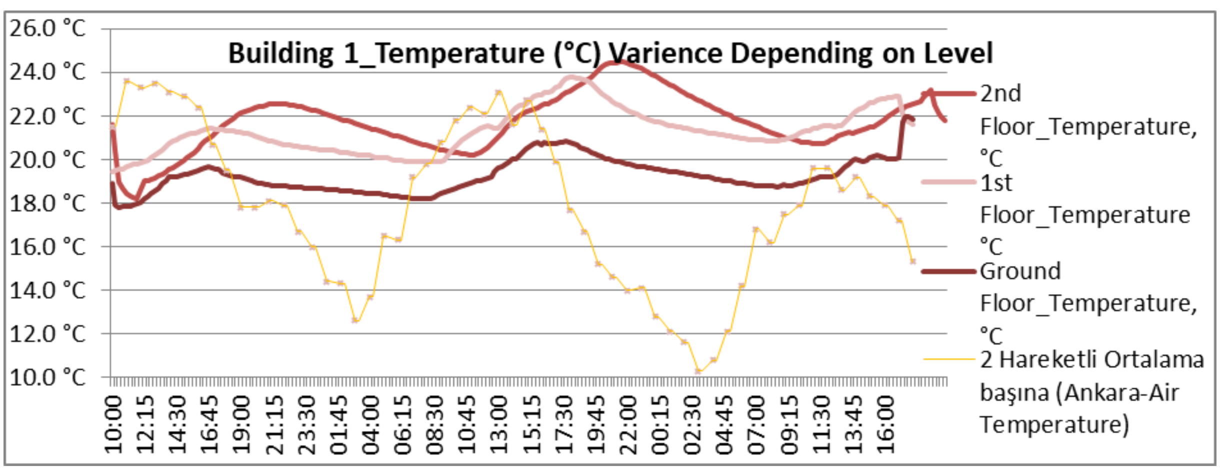


Table 2 depicts relative humidity measurement of Building 1 for three days. Overall progresses of three curves are similar. Effect of the elevation of the measurement spot quite clear in Table 1. By the level rising, RH value gradually decreases. Mean values for each floor are 49.05%, 43.39%, and 38.49% respectively. Highest and lowest values in this building are 29.4% at second floor and 55.72% at ground floor.

Table 2 Relative humidity (%) graphic of building 1 depending on level / height.

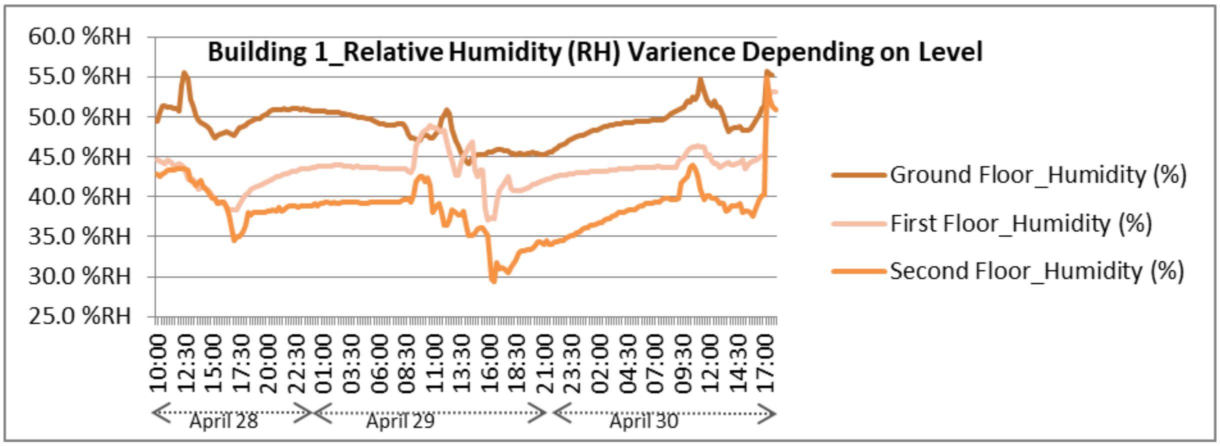
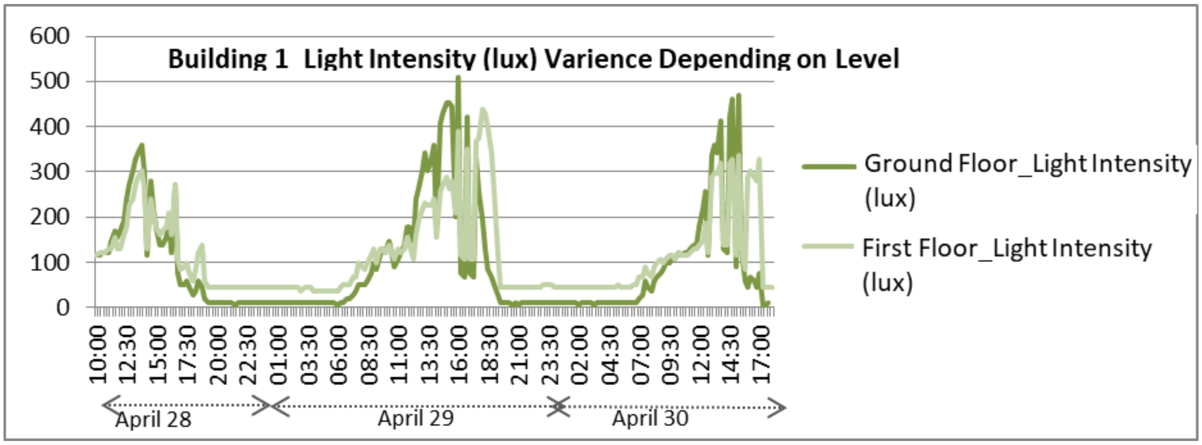


Table 3 shows the light intensity value. HOBO data loggers calculate the light intensity that falls on it rather than average light intensity in the room. The table represents the level of light intensity level in first floor is slightly greater than ground floor as might be expected. Mean values 99.02 and 118.04 lux respectively. The reference values of National Optical Astronomy Observatory (n.d.) in the United States are located between 250-500 lux for various office types, while IESNA recommended 300 lux for computer tasks and the measured mean light intensity level located below this interval. There are several peak points in each floors light intensity curve. There might be several reasons behind this, one of them could be switching on the artificial lighting during the cloudy hours can cause these differences. All three days that measurements took place are weekdays, Tuesday, Wednesday, and Thursday respectively.

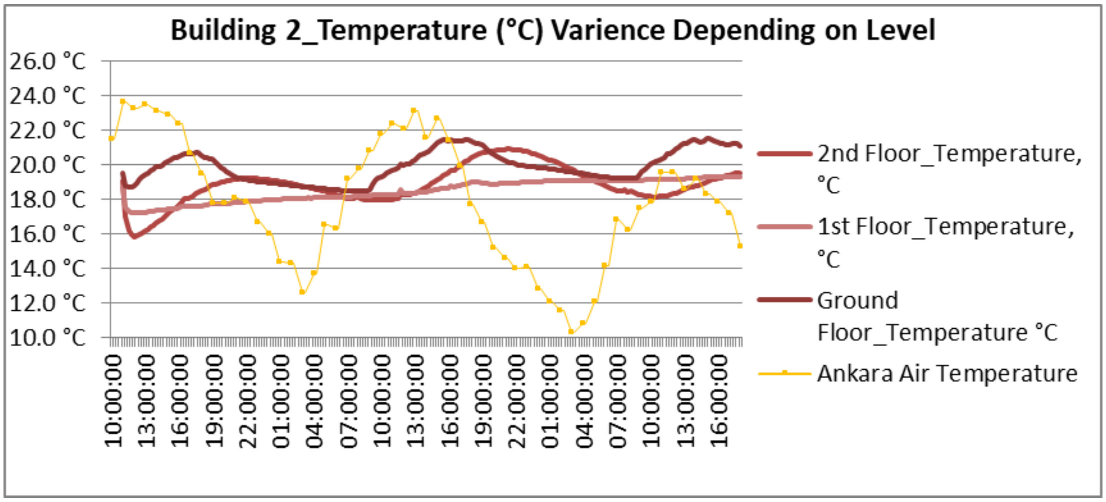
Table 3 Light intensity (lux) graphic of building 1 depending on level / height.



2.2.2. Building 2

Table 4 represents the temperature measurement of building 2 for three days. According to the values, ground level temperature is the highest, first floor is the lowest in general term. Effect of height might not be obvious in this table. There might be several reasons behind it. First of them is heating system was open only in ground floor level. It is the only floor in use in the building, first and second floors have no furniture. Second reason is related with the temperature values of first floor. The door of the room, where the measurements have done, left closed during these 3 days. In this way, the room is able to maintain its thermal mass better, there is no visible fluctuation in the graphic. The temperature graphic of second floor is also fluctuating. The reason for this is there is no considerable door or any partition regarding the stair cove of the building. That's why temperature values are not similar with first floors. Furthermore, higher peak values of the roof are similar with ground floor that has heating during measurements, while lower peak values are seemingly lower than ground floor values.

Table 4 Temperature (°C) graphic of building 2 depending on level / height.



Mean values for each floor are 19.9, 18.49, and 19.04 °C respectively. Highest and lowest values in this building are 21.43°C at ground floor, 17.35 °C on first floor, and 16.65°C at second floor. Indoor thermal performance of building 2 remains under the optimum conditions of ASHRAE (1982). Additionally, orientation of the façade that measurements were taken is southwest; this explains the apparent peak in the hours between 4:00 – 7:00 pm.

Table 5 represents the relative humidity measurement of building 2 for three days. Similar reasons with temperature curves could be influential. Mean values for each floor are 50.47, 46.28 and 53% respectively. Highest and lowest values in this building are 29.4% at second floor and 55.72% at ground floor.

Table 5 Relative Humidity (%) graphic of building 2 depending on level / height.

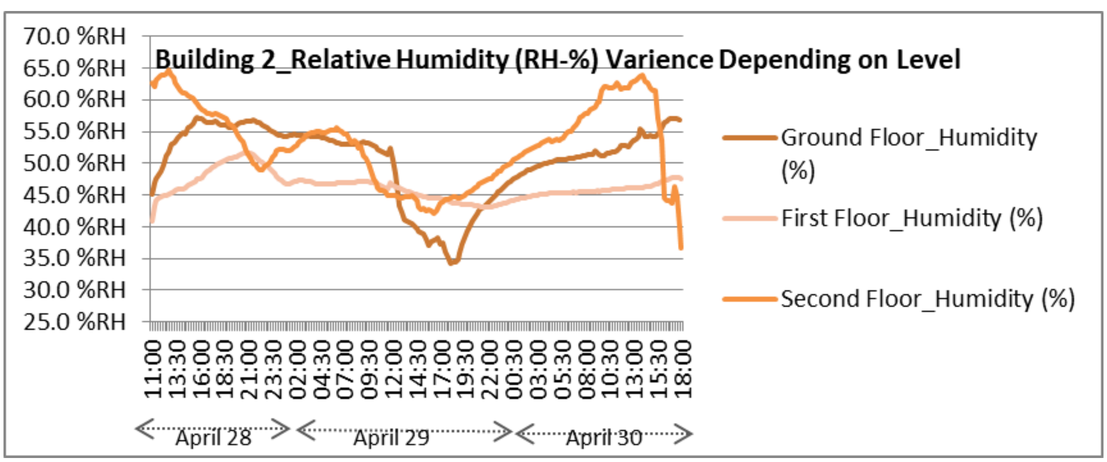
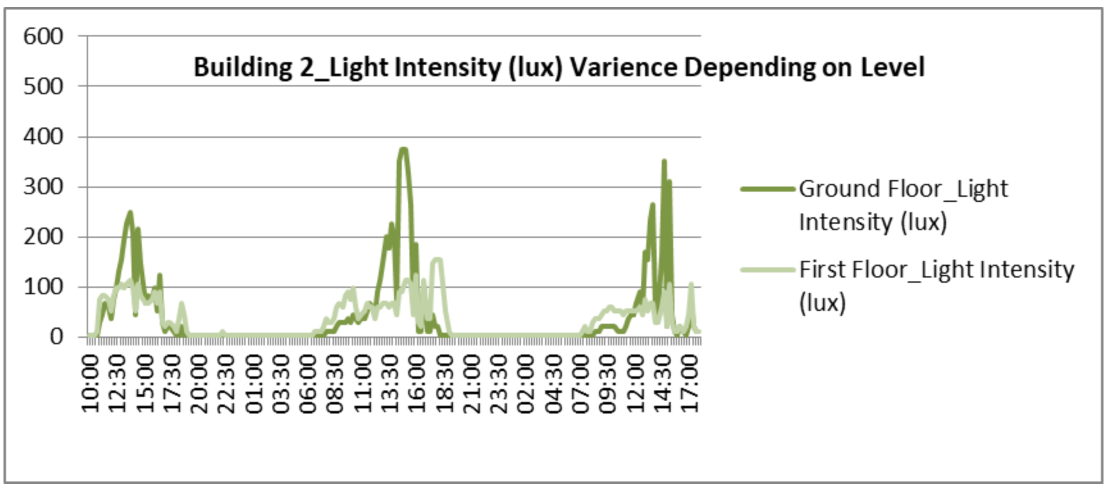


Table 6 shows the light intensity graphic of building 2. The table represents ground floor light intensity level is a little bit greater than first floors. Mean values 42.68 and 34.64 lux respectively. It is an uncommon condition that light intensity level is getting lower by the level is getting higher. The reason for this might be the 10-20 year-old trees in the backyard, the height of them reaches the first floor and this could be blocking the sunlight. There are several peak points in each floors light intensity curve. Switching on the artificial lighting during the cloudy hours can cause these differences, regarding lack of space utilization in first floor. The reference values of National Optical Astronomy Observatory (n.d.) in the United States are located between 250-500 lux for various office types and the measured mean light intensity level located dramatically below this interval in building 2.

Table 6 Light Intensity (lx) graphic of building 2 depending on level / height.



2.2.3. Building 3

The measurements of building 3 for done as an 8-hour-calculation due to permission shortage depending on privacy concerns. Table 7 represents the temperature measurement of building 3 in April 28. According to the values, first floor temperature is the highest and second floor is the lowest in general term. Mean values for each floor are 20.9, 25.12, and 20.11°C respectively. The shapes of ground and second floor demonstrate that there was no considerable change at temperature level during measurements. The reason of this might be having quite small openings at roof level (depending on pitched roof structure) and several trees and scrubs at backyard. These factors can prevent sun penetration into the building. First floor temperature climbing steadily till 3 pm and it remains constant till 6 pm. Highest and lowest values in this building are 27.23°C at first floor and 18.6°C at second floor.

Table 7 Temperature (°C) graphic of building 3 depending on level / height.

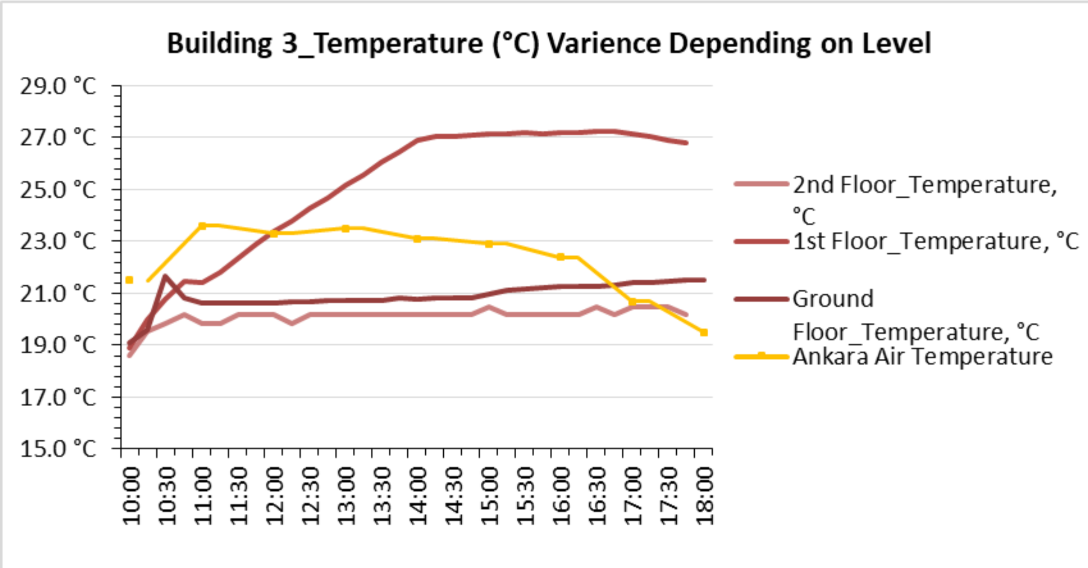
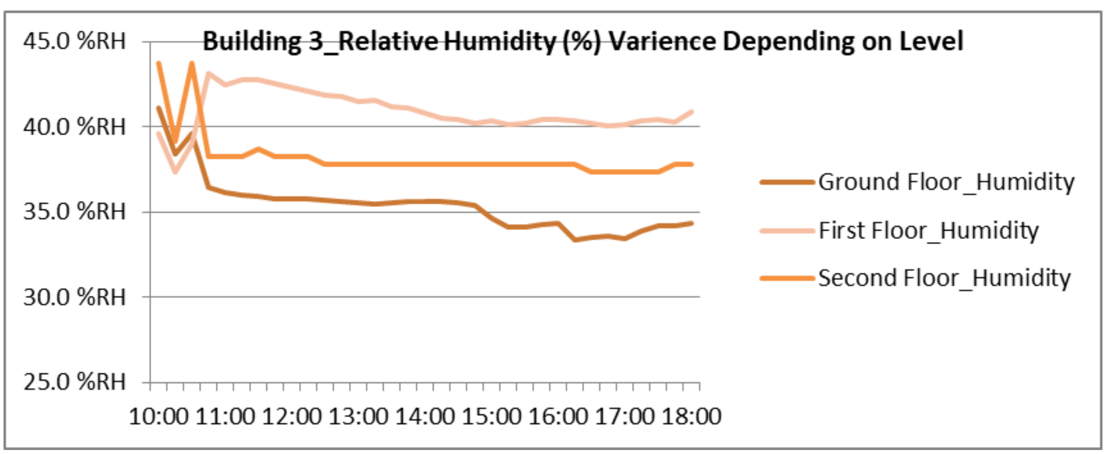


Table 8 depicts the relative humidity measurement of building 3 in April 27. The overall progression of graph shows there is a fluctuation between 10-11 am. Afterward the values of all three floors remain constant. Similar reasons with temperature curves could have influence on. Mean values for each floor are 35.4, 40.87 and 38.22% respectively. Highest and lowest values in this building are 43.7% at first floor and 33.36% at ground floor.

Table 8 Relative humidity (%) graphic of building 3 depending on level / height.



2.3. Comparison Between Buildings

The data collection of 3 different buildings and 3 different variables were done between 28th and 30th of April. Comparison of these three was done regarding 8-hour period in 28th of April.

2.3.1. Temperature

Table 9, 10 and 11 represent the daytime temperature measurement of related subjects.

According to Table 9 and 10; Building 3 performs better regarding temperature at both ground and first floor levels. Mean values of related charts are 18.85, 19.93, and 20.9 °C at ground floor; 20.56, 17.9, and 25.1 °C at first floor respectively. These values and the graphs represent heating performance of building 3 is better. At ground floor level, Building 2 comes second (considering the heating system's being turned on) and building 1 has lowest performance. When the interior temperatures of buildings and temperature value of Ankara are compared, it is seen that thermal mass of building 1 and 2 is usually preserved in night time.

Table 9 Temperature (°C) values of Building 1, 2 and 3 depending on ground floor level.

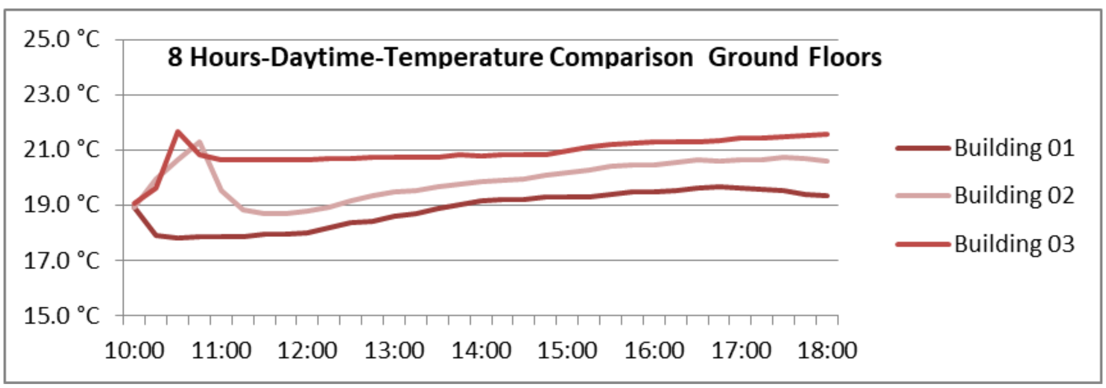


Table 10 Temperature (°C) values of Building 1, 2 and 3 depending on first floor level.

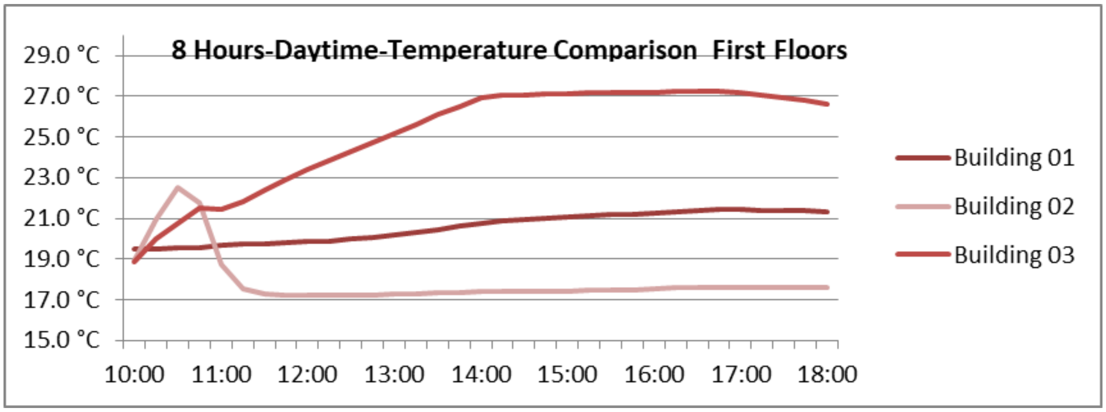
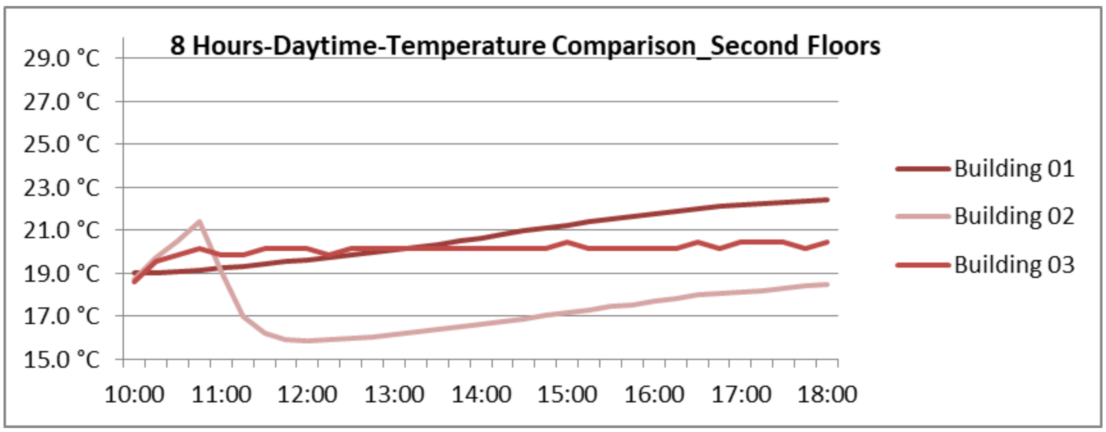


Table 11 Temperature (°C) values of Building 1, 2 and 3 depending on first floor level.



Building 1 has slightly highest values regarding temperature measurements taken from second floor that is the highest floor level. Mean values for Table 11 are 20.69, 17.9, and 20.11 °C respectively. These values and progression of graph demonstrate Building 1 temperature has greater than others. It should be taken into account that the room of third floor of Building 1 has no curtain wall glazing.

Considering the orientation of the buildings was the same, it can be interpreted as this type of curtain wall has no significant effect on heating as a result of this study. Besides the mean values of three buildings are appeared similar in short-term measurements, there is also no significant fluctuation in day time, from 10:00 to 18:00. Secondly, building 3 is the only building that roof used as an attic, and configured as a pitched roof. This type of variation has no considerable effect on temperature values of the building. Lastly, the height has clear positive effect on heat gain.

2.3.2. Relative Humidity

Table 12, 13 and 14 represent the daytime temperature measurement of related subjects on April 28. The overall progression of these three graph shows that RH values of building 02 are greater than other two while Building 03 has the lowest values in general. Considering the ranking, similar reasons with temperature of curves could be influential. Mean values of the ground floor are 49.87, 52.32, and 35.4% respectively while first floors are 41.43, 45.84, and 38.22 and second floors are 40.47, 58.67, 40.87.

According to ASHRAE standards (1999), relative humidity percentage of a space should be in between 30-60%. Values greater than 70% can cause fungal contamination (i.e. mold, mildew, etc.). Highest value among all is belonging to Building 2 second floor (see Table 05), 64.7%. This slightly exceeds the limits of ASHRAE. The reason behind this might be misinterpretation in insulation layers of roof. Lowest value belongs to Building 1 second floor (see Table 02), 29.4%. This is slightly lower than mentioned standard values.

At overall, it can be seen in three of the buildings that RH has inverse proportion although it is a proved information. That is why, most of the peaks (lowest or highest points) in relative humidity corresponds with the inverse peaks of temperature.

Table 12 Relative Humidity (%) values of Building 1, 2 and 3 depending on ground floor level.

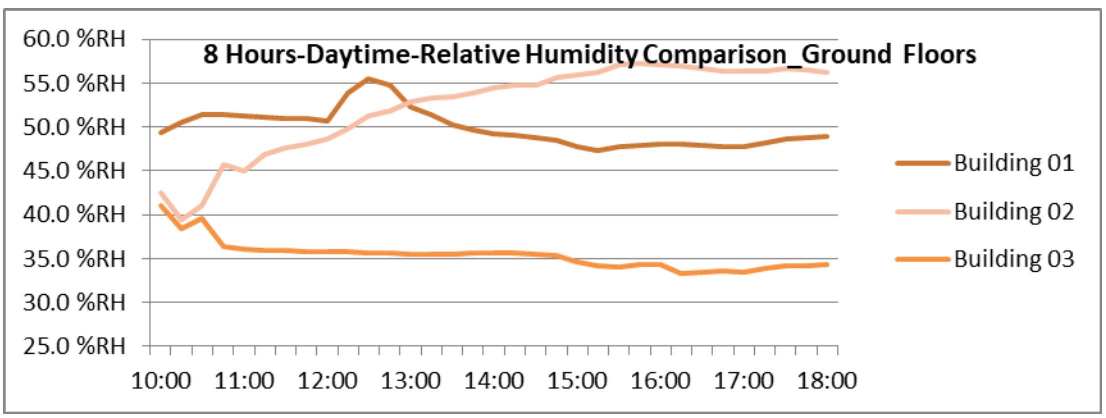


Table 13 Relative Humidity (%) values of Building 1, 2 and 3 depending on first floor level.

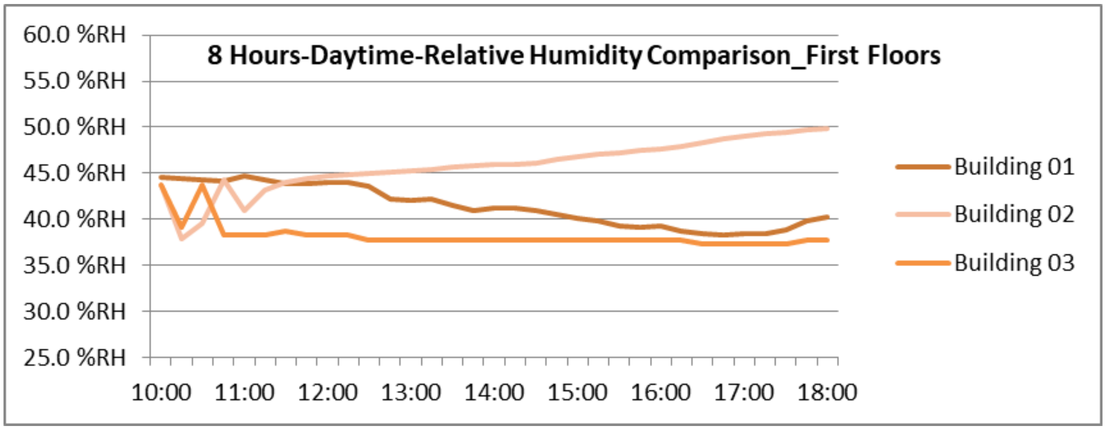
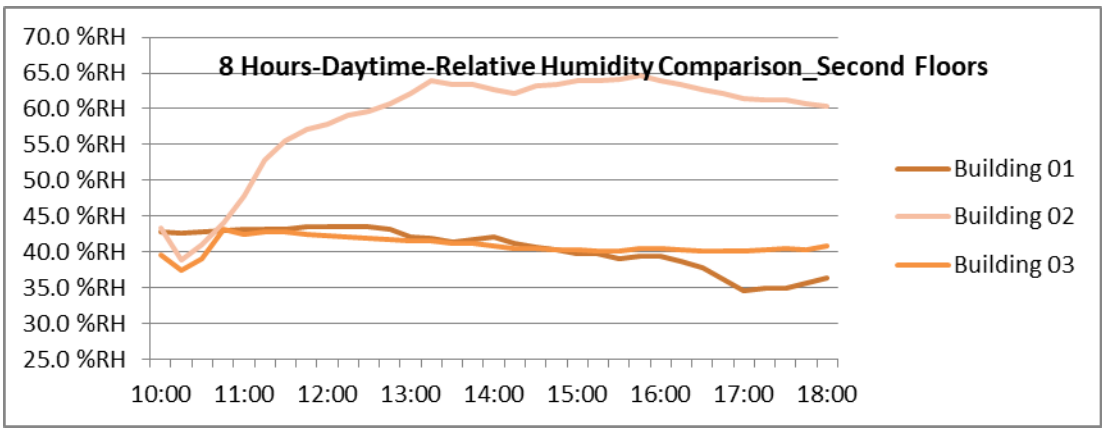


Table 14 Relative Humidity (%) values of Building 1, 2 and 3 depending on second floor level.



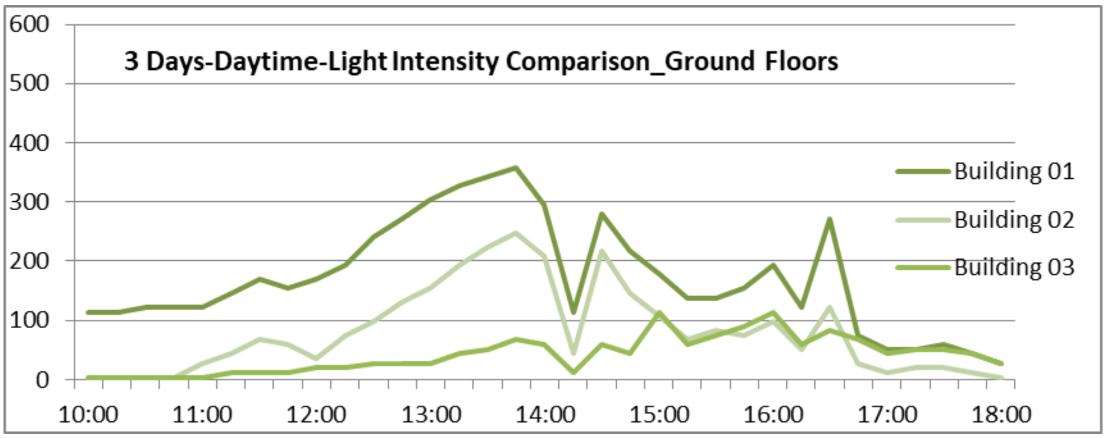
2.3.3. Light Intensity

Comparative chart of light intensity at ground floor level is indicated below. Table 15 demonstrates the daytime temperature measurement of related subjects on April 28. Mean values of Table 15 for each floor are 172.12, 81.33, and 42.15 lux, respectively. Considering the graph and mean values, indoor light level is highest in building 1. Curtain wall glazing type and lack of small vegetation's at ground floor level affect light intensity level of the at building 1 positively. Wooden framework, which is used for decorative purposes, may cause the scarcity in light intensity level of building 3.

During 3-day measurements, occasional lighting level peaks are observed at some points. The reason behind this might be the sudden changes in weather conditions. Especially in 29th and

30th of April, this can be observed more frequently. This means natural lighting and façade articulation is not sufficient for a working environment so that occupants need artificial lighting. The reference values of IESNA (2004) for computer-related tasks is 300 lux, and according to Table 15, natural lighting performance of all three building is low.

Table 15 Light Intensity (Lux) values of Building 1, 2 and 3 depending on second floor level.



3. Conclusion

There are many factors that affect comfort level in space to a certain extent. This study investigates some of the basic parameters that are important in providing a particular comfort level in office spaces, which are mainly temperature, relative humidity, and lighting level. In this sense, articulations in façade configuration might also have an effect. In order to measure this effect, 3 different building types selected and studied as a case, first of which has aluminum curtain wall, second and third of them has traditional timber joinery.

The main aim of this study is making a comparison between the effect of timber joinery and curtain wall, in combination with clear and reflective glazing on indoor environmental parameters of temperature, relative humidity, and lighting. The results of this study showed that curtain wall and reflective glazing does not contribute to heat gain in a significant way comparing with clear glazing and timber joinery, as it was studied in Perez and Capeluto (2009). Considering the rooms that measurements were taken, the size of the opening is approximately the same in all of the three buildings. Accordingly, light intensity level of building 1 was affected positively by curtain wall and reflective glazing. Last parameter of this study is relative humidity, and it also has not been affected by type of joinery.

This study depends on a quantitative methodology that thermal, humidity and lighting data of three office spaces were measured and interpreted. Correspondingly, there are several limitations related with methodology, material, or content of this study. One of the limitations is that some inconsistencies between case buildings cannot be interfered during measurements. Heating system was opened during measurements in building 2, while other two sample were not opened. Despite this, temperature data of building one was lower than other two samples, but the temperature of the indoor environment that was not heated cannot be identified. Secondly, lighting level could be changed while artificial lighting system was turned on or off because it was an office space that employees were working in. It cannot be determined that lighting systems' being on or off, it could only be estimated depending on graphical data. Thirdly, there are two types of data loggers were available for this study, first type measures temperature, relative humidity, and lighting data, while second type measures only temperature and relative humidity. That is why lighting level cannot be measured in each floor of each building.

In further studies, the deficiencies that are mentioned above will be eliminated within the scope of this study, and several aspects will be regarded. Firstly, the amount of data loggers that placed in each building should be increased indeed, and sample size can be widened and the amount of data loggers can be regarding other office spaces in Barış Sitesi to see the effect of other glazing and joinery types in façade articulation. Considering the sample size and variety in this settlement, it is possible and convenient for this study. Secondly, this study should be repeated seasonally to obtain a better conclusion for the subject, and the duration of measurement should be longer. Thirdly, measurement of surface temperature, relative humidity, and lighting will provide more accurate information rather than the measurement of a point.

Acknowledgement

This study is prepared within the scope of a graduate course named as "BS 504 - Research Methods in Building Science" given at the Middle East Technical University, Ankara. Data loggers of Building Science laboratory is used for the study, thus the author would like to thank Prof. Dr. Soofia Tahira Elias Özkan who conducted the course and is in charge of Building Science laboratory. Additionally, the author expresses her gratitude to Selvi Law Office, KZ Architecture, İhale Software, Akdan, and BO Architecture for the permission to the measurement of data in each building.

REFERENCES

ASHRAE. (1982). American society of heating, refrigerating and air-conditioning engineers, handbook of fundamentals. Atlanta: ASHRAE.

ASHRAE. (1999). Ventilation for acceptable indoor air quality. Atlanta: ASHRAE.

ASHRAE. (2010). Standard 55: Thermal environmental conditions for human occupancy. Atlanta: ASHRAE.

Becker, F. & Kelley, T. (2004). Offices at work- uncommon workplace strategies that add value and ımprove performance. San Francisco: Jossey Bass Business and Management Series.

Choi, J. H., Loftness, V., & Aziz, A. (2012). Post-occupancy evaluation of 20 office buildings as basis for future IEQ standards and guidelines. *Energy and buildings*, 46, 167-175.

Clements, D. (2006). Creating the productive workplace. Oxon: Taylor & Francis.

Çakır, Ç. (2006). Assessing thermal comfort conditions: a case study on the METU Faculty of Architecture building (Master's thesis). Retrieved from Middle East Technical University Library thesis database. (Accession No. 1050387741).

Fanger, P.O. (1970). Thermal comfort: analysis and applications in environmental engineering. Copenhagen: Danish Technical Press.

Google earth. (March 8, 2018). Barış Sitesi Ankara Turkey. TerraMetrics 2018, DigitalGlobe 2018. http://www.earth.google.com [March 8, 2018].

Loftness, V., Hartkopf, V., Poh, L. K., Choi, J., & Snyder, M. (2006). Sustainability health are integrated goals for the built environment. *Proceedings of Healthy Buildings*, 1, pp. 1-17. Lisbon, Portugal.

National Optical Astronomy Observatory (n.d.). Recommended light levels (illuminance) for outdoor and indoor venues. Retrieved in 8th of March, 2018, from https://www.noao.edu/education/QLTkit/ACTIVITY_Documents/Safety/LightLevels_outdoor+indoor.pdf.

IESNA (2000). The IESNA Lighting Handbook. New York: IES.

IESNA (2004). American National Standard Practice for Office Lighting (ANSI/IESNA RP-1-04). New York: IES.

Stegou-Sagia, A., Antonopoulos, K., Angelopoulou, C., & Kotsiovelos, G. (2007). The impact of glazing on energy consumption and comfort. *Energy Conversion and Management*, 48 (11), 2844-2852.

Panchyk, K. (1984). Solar interiors: energy-efficient spaces designed for comfort. USA: Nostrand Reinhold Company Inc.

Perez, Y. V., & Capeluto, I. G. (2009). Climatic considerations in school building design in the hot–humid climate for reducing energy consumption. *Applied Energy*, 86(3), 340-348.

Veitch, J. A. (2005). Creating high-quality workplaces using lighting. In D. Clements-Croome (Ed.), *Creating the productive workplace* (pp. 206-222). London: E and FN Spon

Biography of Author

Nur ÖZKAN ÖZTÜRK is a research assistant at Çankaya University, Department of Architecture, in Ankara. Obtained her Bachelor degree in Architecture, and her Master of Science degree from Building Science program of from Middle East Technical University. Master thesis subjects smart and sustainable cities and assessment systems in the urban domain. Currently, continues her doctoral studies in Architecture program of METU, and continues to working on sustainability in urban environments.

Yazarın Biyografisi

Nur ÖZKAN ÖZTÜRK Çankaya Üniversitesi Mimarlık bölümünde araştırma görevlisi olarak çalışmaktadır. Lisans derecesini Orta Doğu Teknik Üniversitesi Mimarlık bölümünden, yüksek lisans derecesini aynı üniversitenin Yapı Bilimleri programından elde etmiştir. Master tezi akıllı ve sürdürülebilir kentler ve bunların kentsel bağlamdaki değerlendirilme sistemleri ile ilgilidir. Doktora çalışmasını Orta Doğu Teknik Üniversitesi Mimarlık programında halen sürdürmektedir.