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Energy efficient cooling through natural ventilation in Kosovo

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Abstract: The buildings consume nearly 55% of global electricity. As people are forced to spend more time indoors after pandemic COVID 19, energy efficient, well ventilated, adequate indoor air quality became critical for their health. The household energy consumption is mostly for heating but also for cooling in Kosovo. Aiming to improve energy efficiency, a passive cooling strategy can be applied by using a natural ventilation as the most essential method. However, that requires an analysis of different factors such as positions and the sizes of the openings within one area, the specific period used for ventilation, and the external temperatures and conditions. In this work, the computer application Optivent 2 was used to analyze a generic airflow strategy and evaluate the decisions regarding the feasibility of cooling with natural ventilation for a single house in Kosovo during the warmest month of the year (i.e. August). The results prove that the natural ventilation during the day at the houses, which the areas have only one-sided openings, is effective only for fresh air flow but not sufficient for cooling purposes. When the openings are designed on the opposite walls of the rooms or areas, the conditions will enable that through cross ventilation, the area will be cooled at the same time, by achieving up to 90% of the accessibility limits of comfort, both during the day and nights, at different scenarios on the warmest summer months in Kosovo. These findings will help the architects of Kosovo to identify the proper and most effective passive designs strategy, when it comes to buildings cooling during the summer, in order to achieve the maximal benefit of their designs and the operation of their designed building.

Keywords: *Cooling, Efficiency, Kosovo, Passive, Ventilation*

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1. INTRODUCTION

The last situation created by pandemic COVID 19, created a major impact on the construction sector where a lot of jobs were lost and it was general drop in construction market values, comparing to 2019. Despite COVID 19 impact in construction industry, the affordable and healthy buildings turned to be of essential importance to respond to pandemic and for users' overall health. The energy consumption of buildings mainly is realized by the building systems used for heating, cooling and domestic hot water. From 50 largest megacities in the world, 27 are situated under hot climates wherein the interior cooling is much needed to create a thermal comfort for the inhabitants [1]. For temperate climate, such as the Kosovo's climate, solar radiation and temperatures fluctuate considerably throughout the year, therefore additional consume of energy is required for heating purposes as well as for cooling. Researchers have revealed that at the buildings that are designed by including passive strategies, taking advantage of the local climatic conditions and building features, the energy consumption can be reduced, as well as its carbon footprint. One of the effective passive strategies, which is tested within this paper, is passive cooing effectiveness toward the building features. The passive cooling is a design of technological feature formed for providing cooling to the buildings with or without using a minimum of energy [2]. The energy, economics and environmental potential of passive designs strategies is different depending on the building features and climatic conditions [3]. The effectiveness in reducing energy demand is proven to be effective when the buildings are well designed. The inputs affecting passive cooling strategies and the decisions and approaches on the building designs are airflow patterns on the surrounding areas, building internal heat gain, heat transfer through the building envelope, and outdoor and indoor air temperatures. As there are different passive cooling strategies, this case study on the cooling through natural ventilation is tested for different building's openings characteristics for the residential building in Kosovo. These findings will help the architects of Kosovo, to identify the proper and most effective passive designs strategy, when it comes to buildings cooling during the summer, in order to achieve the maximal benefit of their designs and the operation of their designed building. Through cooling with natural ventilation, the additional benefit is achieved in creating internal comfort, saving the energy and in indoor air quality, as it removes indoor air pollutants which are emitted from different sources inside the building.

2. MATERIALS AND METHOD

The aim of this study is to analyze the passive cooling through the ventilation using natural conditions in a context of energy efficiency and achieving acceptable indoor air quality in residential building. The knowledge and expertise of various experts is also analyzed and encapsulated for this purpose throughout this paper. A natural ventilation steady-state calculation tool for an early design state of the building, Optivent 2.0 is used to assess a feasibility of natural ventilation for a single cell, for the weather conditions in Kosovo. The given inputs for the calculation are buildings layout, aperture areas, stack height and the outputs are airflow rates, which indicate if the fresh air and cooling requirements are achieved. The number of occupants is used to calculate the minimal requirement for ventilation and supply of fresh air. The heat gains are calculated based on solar gains, number of occupants, equipment's and lighting gains. The calculation method process output airflow rates driven by buoyancy and driven buoyancy and wind. The analysis is made for the warmest month of the year in Kosovo, which is the month of August, based on the data taken for the climate in Kosovo. In order to compare the possibilities, there are also analyzed the differences of the temperature during the periods of night and days, during August.

3. HEALTHY HOUSING AND THERMAL COMFORT

According to ANSI/ASHRAE Standard 55-2010, the thermal comfort definition is "condition of mind that expressing satisfaction with the thermal environment". However, as the satisfaction related to thermal environment varies from person to person, physiologically and psychologically, it is difficult to say "a thermal condition that would satisfy everyone in a space". Thermal discomfort is not just a lack of satisfaction with the surrounding ambient temperature but it also reflects a situation where might be a potential threat to human health – e.g., when the temperature falls below 18 ^{o}C or rises above 24 ^{o}C for a certain period of time [4]. Housing, among other functions, provides also a protection from a related illnesses and deaths that might come from the fast and risky fluctuations of temperatures. As energy used and consumed by housing, that contributes to global climate change. The improvements in energy efficiency have shown that it has two potential benefits:

(a) by avoiding the direct exposure to extremes of temperature, thus protecting the health of the occupiers;
(b) by reducing energy use and consume, it reduces the contribution to climate change from the housing sector [5]. A "healthy housing" expression was usually used to describe a feeling that people have in sense of "belonging, security and privacy" [6].

In addition, by being structurally bound the houses provide a shelter by enabling the internal thermal, hygienic and visual comfort. In the developed countries, 70% of the people spends time inside their home [7]. Apart from this, the most endangered groups are children, elder people and people with disabilities, as they spend more time at home. By the year 2050, the number of aged people, who spend a most of their time at home, will double [8]. After the Covid 19 Pandemic, the population all over the world faced a new form of organizing their lives and jobs, by working from home. Many surveys showed that up to 25% of the workforces in advanced economies could work from home between three and five days a week. Comparing to the pre-pandemic situation, that is five times more remote work. The humans have a right to adequate housing and this is recognized in the Universal Declaration of Human Rights (adopted in 1948) and the International Covenant on Economic, Social and Cultural Rights (adopted in 1966). Houses are required to fulfill seven criteria to qualify as adequate: security of tenure; availability of services, materials, facilities and infrastructure; affordability; habitability; accessibility; location; and cultural adequacy [9].

The temperature of the human body ranges between 36.1 C and 37.2 C. Lower and upper temperatures can harm human health. When the temperatures on the outdoor are high, human body responses by trying to cool itself through its natural cooling mechanisms with perspiration, evaporation through the skin. The exposure to heat waves is much riskier for the people living in a temperate climate. Having not enough time to adapt the body to the temperature changes increases the risk for mortality [10]. A World Health and World Meteorological Organization have highlighted the importance of human acclimatization, thereby adapting to excessive heat exposure. But the acclimatization to the unfamiliar thermal conditions make human body get adapted much longer. If the temperatures are constantly high but are usual, people may adapt much easier, comparing to the temperatures that are variable and thus changing over a short period, not giving enough time for body to get used to it.

To summarize, the new developments with pandemic and similar global risks will more and more create requirements for people to spend most of their time indoors. Being more exposed to internal thermal discomfort due to high outdoor temperatures, the mitigation measures will include indoor cooling as key characteristic of healthy housing. Using air-condition would consume energy and can also exacerbate urban noise and heat. Therefore, passive mitigation measures such as passive cooling will be more often preferable.

3.1. Hygienic Comfort and Natural Ventilation

Starting from the attempt to extract from the shelters, the smoke from heating and cooking, and the need for having appropriate air quality indoors began very early in a human history [110]. The desire to control smoke from indoor fires, lead to the development of natural draft methods [12] in most European Countries, from simpler roof opening to chimney terminal devices and smoke dumper devices placed in it. While the people who lived in warmer climates searched for natural ventilation methods and cooling therefore from site planning and building configuration to wind driven and buoyancy driven airflow strategies. Except for the cooling, the ventilation is needed for indoor air quality purposes. ASHRAE related to air quality control defines "air where there are no contaminants at harmful concentrations and with which a substantial majority of the people exposed do not express dissatisfaction". The newest guidance issued by ASHRAE Epidemic Task Force [13], in regards to reducing Airborne Infectious Aerosol Exposure, after COVID 19 pandemic are based on the new concept. According to the recommendations, all building systems for indoor air cleaning be deployed flexibly to achieve exposure reduction goals.

In dependence to the nature of environmental pollutants, the quantity of ventilation is defined. Poor internal building ventilation is associated with unhealthy buildings [14] for example, highlights the association of increasing bacteriological concentration with decreasing ventilation rates, while Billington [15] has produced an historical review of the role of ventilation in improving health and reducing the spread of illness. One of the essential roles of ventilation is improving the indoor air quality as well as thermal comfort. However, the ventilation must be considered as just one of the required tools within the process of the building design.

3.2. Pollutants and Pollutant Sources

The pollutants of the indoor ambience usually come from indoor and outdoor sources. When we tend to secure acceptable health and comfort conditions, each of the sources has different requirements.

Sick Building Syndrome: It's a definition of a condition when building occupant experience a number of symptoms while present in the building, if the building has a large level of pollutants indoor. Typical symptoms that humans gain from being for a long period inside the buildings classified with Sick Building Syndrome include lethargy, headaches, lack of concentration, runny nose, dry throat and eye and skin irritation. When the occupants go out of the building, the symptoms usually disappear. However, if the period of exposure is longer than these can become a serious health condition for people.

Outdoor air pollution: Some outdoor pollutants such as discharge of ozone depleting chemicals (CFC's) into upper atmosphere, which also increase the concentrations of CO_2, are global problems requiring the effort of international authorities in order to control it. Other outdoor pollutants are more linked to local industry, traffic, natural pollutants such as gas emissions from volcanic activity, pollen and fungi spores, etc. The typical outdoor pollutants are presented below.

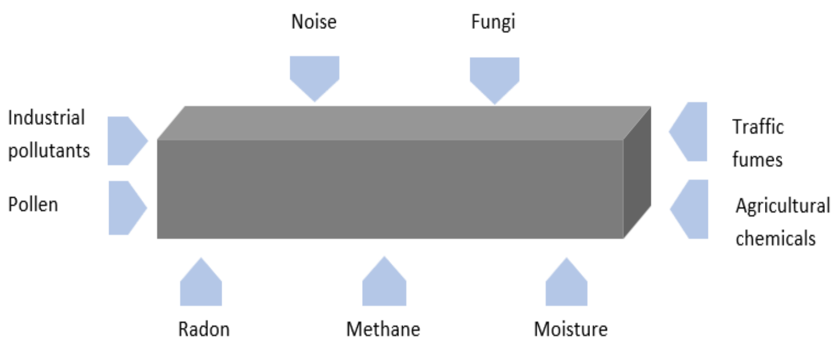

Figure 1. Typical sources of outdoor pollutant.

Indoor Pollutants – The sources of pollutants emitted inside buildings are usually the metabolism, the activities of occupants, emissions from materials used in construction and furnishing. Major indoor pollutants Carbon dioxide which is a product of metabolism and combustion found in cooking areas and heating appliances; A products of incomplete combustion, highly toxic and odorless such as Carbon monoxide; fiber boards and foam insulations that contain Formaldehyde; Occupant's activities such as cooking, washing, clothes drying etc. that creates a moisture; Odor, which is generated as part of metabolism and is emitted from furnishings and fabrics; Ozone - a pollutants released from photocopiers, laser printers and other office equipment; particles including dust, organic fragments, fibers, and smoke particles; tobacco smoke - a major source of indoor pollution and can be the dominant source of pollutant in rooms or buildings where smoking takes place. The most common indoor pollutants are presented on the graphic below.

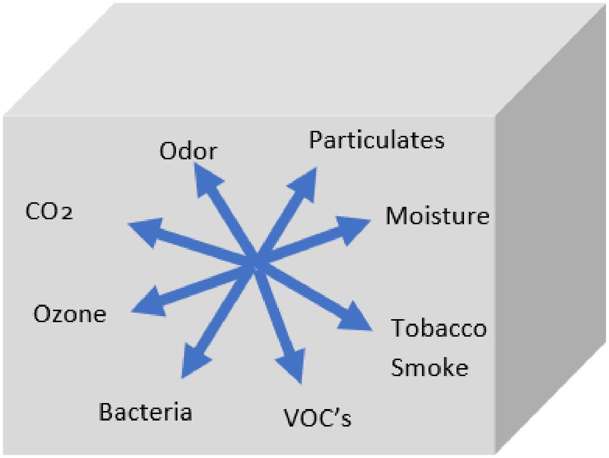

Figure 2. Typical sources of indoor pollutant.

The cooling of the building becomes essential because the heat itself plays a role of a dominant pollutant. In a large building, the heat gains come from occupants, solar radiation, high outdoor temperatures, electrical devices, computers, etc. Therefore, there are two options, either to introduce the active cooling system using the electricity or introducing the ventilation cooling which contributes to reduce power consumption. For the countries such as Kosovo, with temperate climate that have the fluctuation of temperatures during the year, an effective building design and passive strategies can significantly reduce the need for refrigerate cooling.

3.3. Passive Cooling

Passive cooling is known as a design or technological strategy for providing cooling to the buildings with or without using a minimum amount of energy [16]. This strategy is a strategy used for improving the effectiveness of energy usage in the buildings [17]. Whenever power consumption occurs, passive cooling methods are small set alongside the consumed cooling compared to active methods of cooling [18]. An effective passive cooling strategy can be achieved, based on the calculations of the internal heat gains and from outdoors temperatures. However, this requires a knowledge of many factors such as airflow patterns around the building, the effects of other buildings around, the orientation and building thermal characteristics etc. In order to induce a ventilative cooling, it is required a specific microclimatic condition to be suitable. The need for mechanical cooling will be reduced by natural ventilation, as it directly removes warm air from buildings internal spaces to outdoors. The incoming air, which is cooler, will reduce perceived temperature due to the effect of an air motion. When the outdoor temperature is 30°C, the average preferred temperature in naturally ventilated indoor areas of the building is 27°C, compared to 25°C in mechanically ventilated buildings [19]. Natural ventilation is induced through the differences in air pressure, arising from inside – outside temperature. There are required adequate number and specific positions of openings, in order to create airflow. Architectural elements, that create thermal driving forces and/or utilize wind effects, include courtyards, atria, wind towers, solar chimneys and operable windows [20]. In climates with a difference from 5°C to 7°C of temperatures between night and day, natural night time ventilation combined with thermal mass can be very effective. Many studies [21] have demonstrated that such comfortable indoor environments can be provided for outdoor air temperatures of up to 29ºC (and even 34ºC) if air velocity reaches 2-3 m/s.

3.4. Kosovo Climatic Data and Cooling Requirements

Kosovo has a continental climate in most of the parts with hot summers and cold winters with Mediterranean and Mountain impacts. The average temperature is between +30ºC and -10 ºC. The months of December and January are considered as the coldest months, while June and August are the warmest months. The plane between Mitrovica and Kaçaniku city belongs to the driest zone in Kosovo. The opposite is evaluated for the Dukagjini plane between Peja and Prizreni city, with the largest quantity of rainfalls between November and March. Kosovo can be divided into three climatic main zones:

1. *Climatic zone of Kosovo Plane: That includes the Ibri Walley and it's under the impact of Mediterranean air masses.*
2. *Climatic zone of Dukagjini Plane: That includes the watershed backbone of Drini i Bardhe, under the impact of warm air masses coming from the Adriatic Sea. During the winter the average temperatures goes from 0.5 ºC to 22.8 ºC.*
3. *Climatic zone of mountains and forests: With short summers and long winters.*

For the temperate climate in Kosova, the energy is used mostly for hot sanitary water and for heating purposes in residential buildings. However, during the summer months, as the temperature varies from 30-38 ºC during the day, energy is also used for cooling and ventilation. The differences between the temperatures during night and day can create appropriate conditions for cooling and ventilation to be easily done by passive strategies. Ventilation can be comfortably provided by windows and openings for almost all the year round, with only the outdoor air temperatures during the winter, which can restrict natural ventilation. For this purpose, however, a number of different factors must be considered in order to explore the different possibilities available, especially during the design phase.

The present paper analyzes the different scenarios for households located in Prishtina city, which is the capital of Kosovo and as a location is influenced by Kosovo Plane climatic zone. As we are focused on cooling strategies through natural ventilation, the aim is to identify the warmest months and the possibilities to use the natural ventilation strategy for the purpose of cooling. The data from the table below shows that June, July and August have the highest air temperatures during the year from 24 ºC to 28 ºC (Fig. 3). The highest air temperatures during the day, recoded for these months are up to 38 ºC (Fig. 3), while the differences of the temperatures during the night goes sometimes to 15 ºC (Fig. 4).

Table 1. The annual highest air temperature records for Prishtina [22].

Month	J	F	M	A	M	J	J	A	S	O	N	D
Record High ºC	12	18	23	30	31	37	38	38	35	30	22	14
Average High ºC	3.28	6.1	10.8	16.4	20.5	25.4	28.5	29.6	24.0	17.4	11.1	5.04
Daily mean ºC	0.12	2.7	7.4	12.8	16.9	21.8	24.5	25.1	19.7	13.5	7.95	2.1
Average low ºC	-4.1	-2	1.5	5.3	8.4	12.3	14.4	15.1	11.6	7.4	3.75	-1.5
Record low ºC	-27	-25	-18	-4	1	5	8	7	2	-2	-7	-16

Table 2. The annual averaged day/night temperatures in Prishtina.

Month	Day	Night	Raining days	Month	Day	Night	Raining days
January	3ºC	-4 ºC	14	July	29 ºC	15 ºC	15
February	6 ºC	-2 ºC	13	August	30 ºC	15 ºC	11
March	10 ºC	1 ºC	16	September	24 ºC	12 ºC	13
April	16 ºC	5 ºC	18	October	17 ºC	7 ºC	12
May	21 ºC	9 ºC	21	November	11 ºC	4 ºC	11
June	25 ºC	12 ºC	20	December	5 ºC	-1 ºC	13

4. STUDIED SCENARIOS - QUANTITATIVE ASSESSMENT

In this section, two scenarios are examined by using the natural ventilation steady - state calculation tool OptiVent 2.0, to analyze a generic airflow strategy and evaluate the decisions regarding the feasibility of cooling with natural ventilation for a single house, in Kosovo during the warmest month of the year, August. The first scenario presents the calculation for the natural ventilation during the day, in to different sub-scenarios: Natural ventilation in the cell, with single opening and natural ventilation, by using a cross ventilation strategy. The second scenario presents the calculation of night ventilation for the same different sub-scenarios.

For both scenarios, the input parameter used are the same, thereby, solar Transmittance Factor for the glazing and shading proportion are 0.6 and 20, respectively. The parameters for the walls are: Surface Absorptance 0.6, U-Value (W/m^{2}K) is 0.3, External Surface Transmittance 4.0 (W/m^{2}K). The conditions to calculate the internal gains are applied for four people at rest, the internal gains from equipment are 15 W/m^2 and from lighting 10W/m^2. The cell dimensions are assumed to be 6 x 6 m and 3 m high. The average outdoor temperature is taken for the day time and night time ventilation in order to obtain the required results. The calculation process outputs airflow rates driven by buoyancy and driven by the buoyancy with wind.

5. FINDINGS

5.1. Day Single-Sided Ventilation

For the first study scenario, the day ventilation at single sided opening cell is analyzed. Based on ASHRAE 55-2010 is taken the prevailing mean outdoor temperature. The inlet axis high is adapted 1.5 m above the ground level and the outlet stack height with axes of 1 m above the inlet axis. Between internal and external environment, the air temperature difference is ΔT = 4°C. The buoyancy driven ventilation depends from this rate.

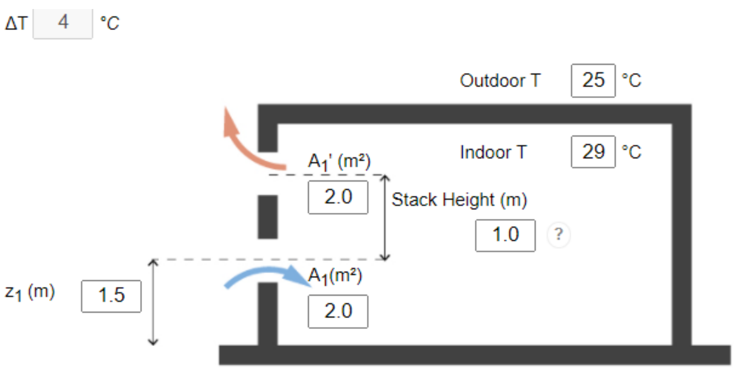

Figure 3. Airflow data input for single sided day natural ventilation.

Buoyancy+wind driven: With the parameters given for the location and the cell, with single sided ventilation, the air flow rate required for fresh air is 0.08 m^3/s, while required for cooling is 0.69 m^3/s. The air flow achieved is 0.24 m^3/s as shown in Fig. 4. Therefore, it can be concluded that within these conditions, only the air flow required for fresh air, can be achieved. However, this will not be sufficient for cooling purposes of the indoor air. The status of adaptive comfort band, complies 80% of acceptability limits according to ASHRAE Standard 55–2013. The percentage of acceptability levels limits, as shown in Fig. 5 presents the comfort zone with the temperatures between 4-5 °C on either side of the line. This percentage presents the lower temperature parameters and that the comfort zone is around the neutrality line. Therefore, when the comfort zone is not created on the internal spaces, the human body will not react normally. The prolonged periods of similar discomfort for inhabitants, might lead to poor physical health expressed in many forms of diseases.

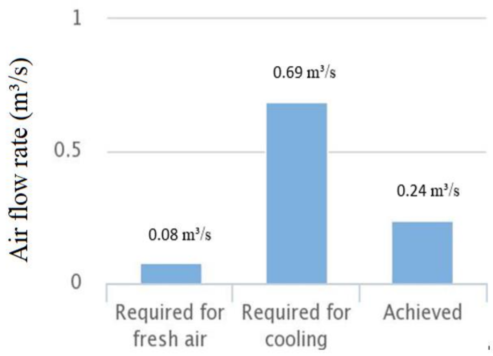

Figure 4. Air flow rate (m³/s) for day single sided ventilation, buoyancy + wind driven.

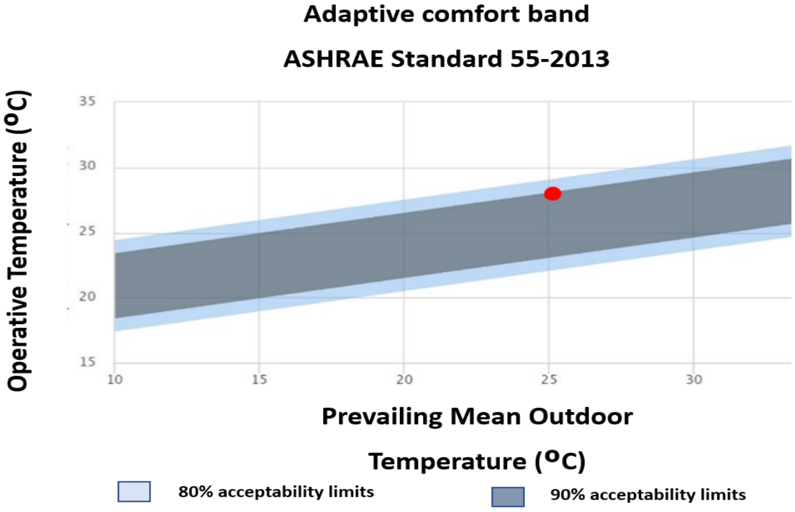

Figure 5. Acceptability limits for day single sided ventilation, buoyancy + wind driven.

Buoyancy-driven: For the buoyancy-driven scenario, the air flow rate required for fresh air is 0.08 m³/s, while required for cooling is 0.69 m³/s. The air flow achieved is 0.22 m³/s shown in Fig. 6. The findings show that we achieved the same effect as on the above previous case, therefore the airflow will enable only the supply with fresh air but not for cooling purposes. The status of adaptive comfort band, complies 80% of acceptability limits according to ASHRAE Standard 55-2013. Similar to the above presented strategy, where the airflow is induced by buoyancy effect and wind driven, the percentage of acceptability levels limits is the same. Fig. 7 presents the comfort zone with the temperatures between 4-5 °C on either side of the line. This percentage again shows that the lower temperature parameters and comfort zone is around the neutrality line.

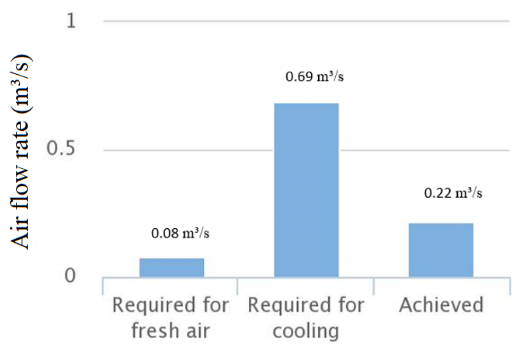

Figure 6. Air flow rate (m³/s) for day single sided ventilation, buoyancy driven.

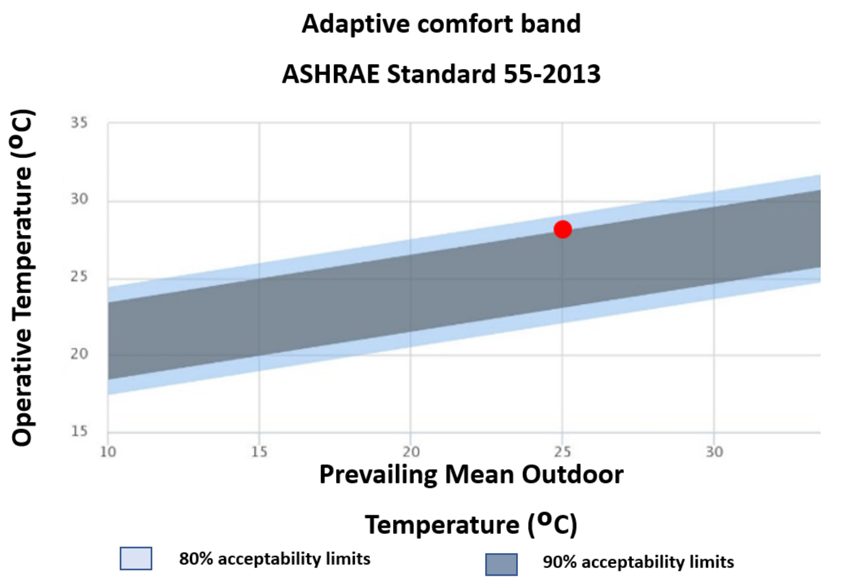

Figure 7. Acceptability limits for day single sided ventilation, buoyancy driven

5.2. Day-Cross Ventilation

For the scenario of day ventilation, it was also analyzed the strategy of cross ventilation. The prevailing mean outdoor temperature is taken based on ASHRAE 55-2010. The inlet axis high is adapted 1.5 m above the ground level and the outlet stack height with axes of 1 m above the inlet axis. Between internal and external air temperature the difference is $\Delta T = 4^{\circ}$C. The buoyancy-driven ventilation depends from this rate.

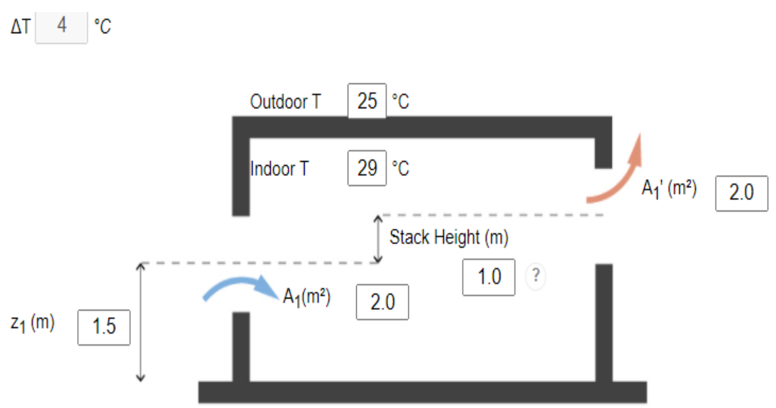

Figure 8. Airflow data input for day natural cross ventilation.

Buoyancy+wind driven: With the parameters given below for the given location and the space area, with the cross-ventilation strategy, the air flow rate required for fresh air is 0.08 m³/s, while, it is required 0.61 m³/s for cooling. The air flow achieved is 0.28 m³/s as shown in Fig. 9. The results do not differ much from the previous tested cases, therefore the amount of air flow will be sufficient only for supply with fresh air but not for cooling purposes. The status of adaptive comfort band complies 90% of acceptability limits, according to ASHRAE Standard 55–2013 as shown in Fig. 10. The higher percentage of acceptability limits shows that there is present a good indoor thermal comfort, therefore this has directly a positive effect on the health of inhabitants, wellbeing and productivity.

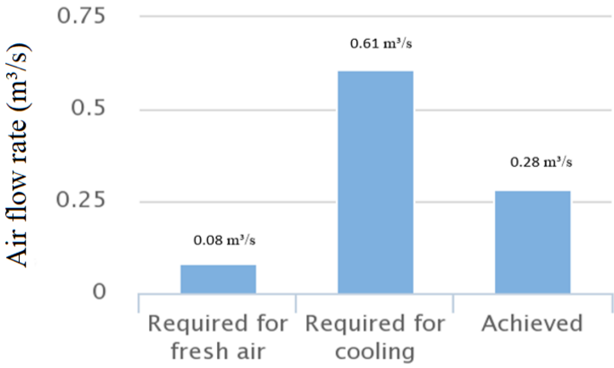

Figure 9. Air flow rate (m³/s) for day cross ventilation, buoyancy+wind driven.

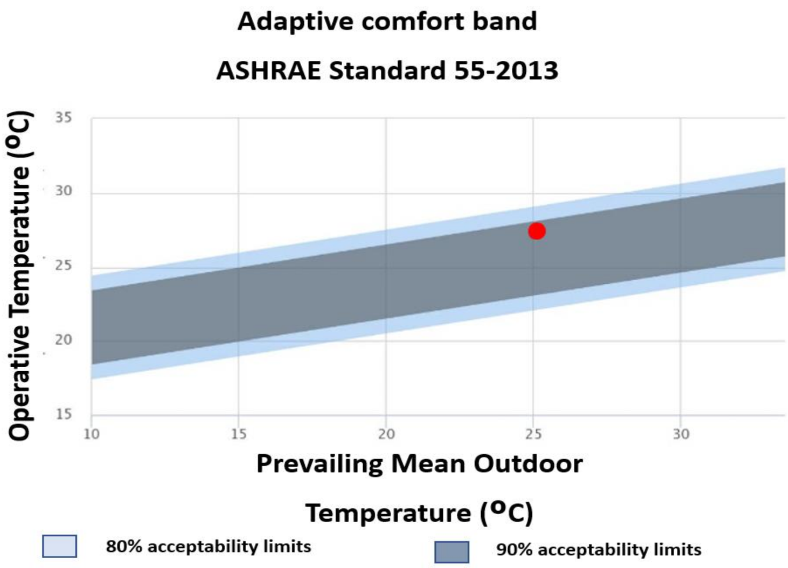

Figure 10. Acceptability limits for day cross ventilation, buoyancy+wind driven.

Buoyancy driven: For the buoyancy-driven scenario, the air flow rate required for the fresh air is 0.08 m³/s, while required for cooling is 0.69 m³/s. The air flow achieved is 0.22 m³/s as shown in Fig. 11, thereby, it will be sufficient only for the supply with fresh air. The status of adaptive comfort band, complies 80% of acceptability limits according to ASHRAE Standard 55-2013 as shown in Fig. 12. Unlike the buoyancy and wind driven combined strategy, this form of inducing air circulation does not show that the required effect can be achieved, consequently the comfort line is yet close to neutral.

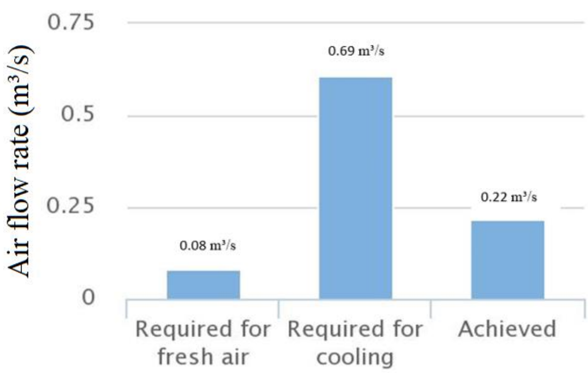

Figure 11. Air flow rate (m³/s) for day cross ventilation, buoyancy-driven.

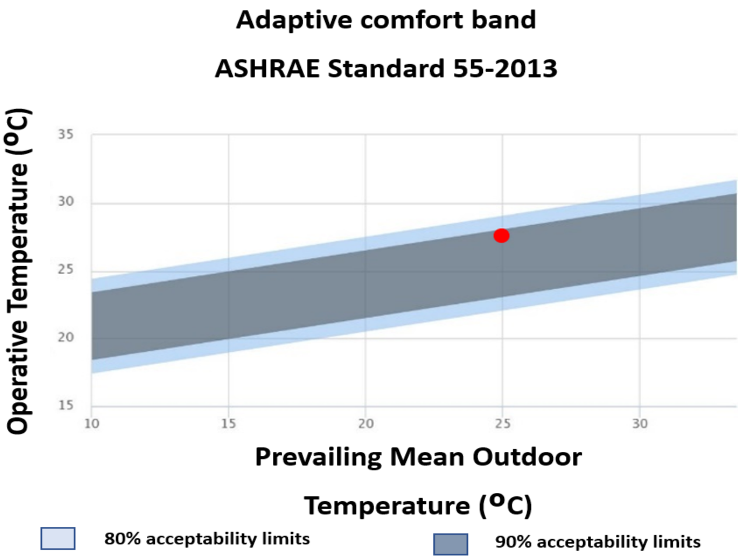

Figure 12. Acceptability limits for day cross ventilation, buoyancy-driven.

5.3. Night Ventilation-Single Sided

For the second case study, the scenario of ventilation during the night, at the single sided opening, is analyzed. The prevailing mean outdoor temperature is taken based on ASHRAE 55-2010. Between internal and external air temperature the difference is ΔT = 7 °C. The buoyancy driven ventilation depends on this rate. The axis of the inlet opening is 1.5 m above the ground and the outlet opening is 1 m higher than the axis of the opening.

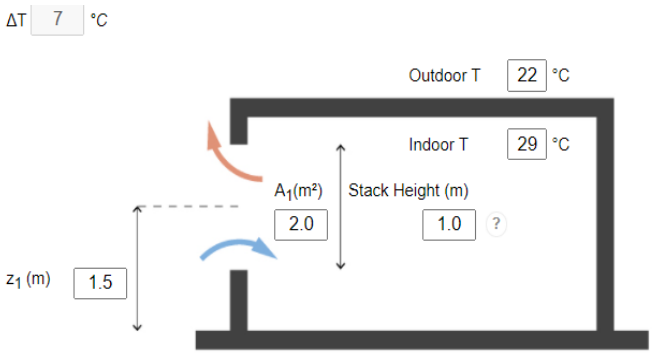

Figure 13. Airflow data input for single sided night natural ventilation.

Buoyancy+wind driven: With the parameters given for the location and the space area, with single sided ventilation, the air flow rate required for fresh air is 0.08 m³/s, while required for cooling is 0.10 m³/s. Fig. 14 shows that this strategy will enable the sufficient amount of air flow sufficient not only for the supply with fresh air but for cooling of indoor environment also. The air flow achieved is 0.31 m³/s. The status of adaptive comfort band, complies 90% of acceptability limits according to ASHRAE Standard 55–2013. This percentage of acceptability limits shows that the conditions contribute to a good indoor thermal comfort, therefore this has directly a positive effect on the health of inhabitants, wellbeing and productivity.

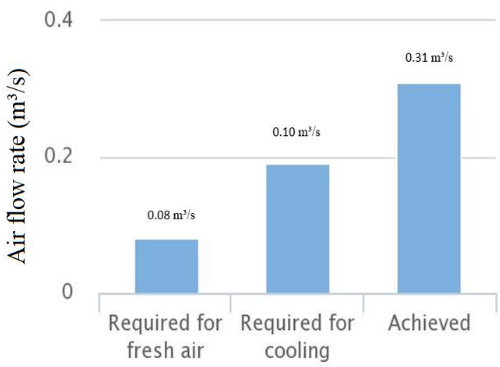

Figure 14. Air flow rate (m³/s) for night single sided ventilation, buoyancy + wind driven.

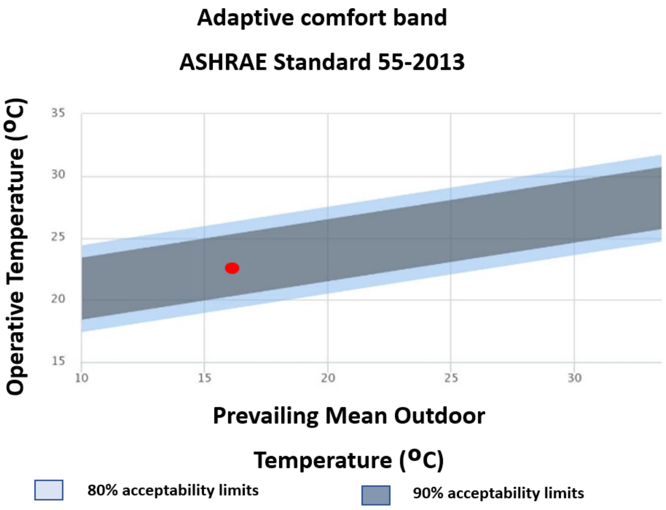

Figure 15. Acceptability limits for night single sided ventilation, buoyancy+wind driven.

Buoyancy-driven: For the buoyancy driven scenario, the air flow rate required for fresh air is 0.08 m³/s, while required for cooling is 0.19 m³/s. The air flow achieved is 0.29 m³/s. Fig. 16 shows that this strategy will enable the sufficient amount of air flow not only to create the supply with fresh air but also for cooling of indoor environment. The status of adaptive comfort band, complies 90% of acceptability limits according to ASHRAE Standard 55-2013. As shown in Fig. 17, this percentage of acceptability limits shows that this strategy, it can be achieved a good indoor thermal comfort which directly has a positive effect on the health of inhabitants, wellbeing and productivity.

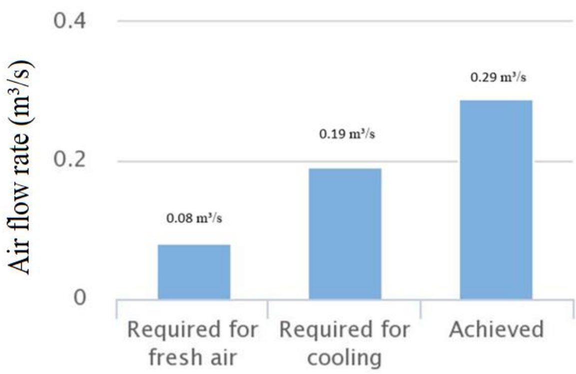

Figure 16. Air flow rate (m³/s) for night single sided ventilation, buoyancy-driven.

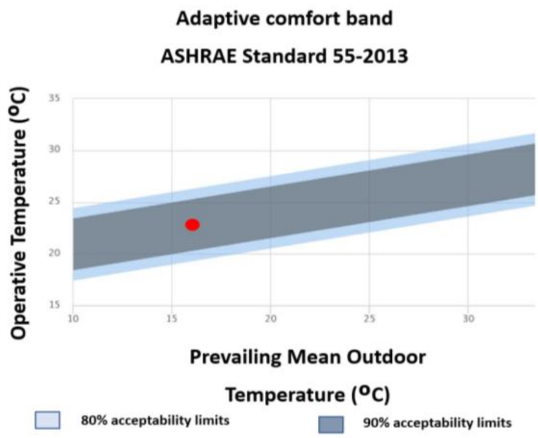

Figure 17. Acceptability limits for night single sided ventilation, buoyancy-driven.

5.4. Night Cross Ventilation

For the sub-scenario of ventilation during the night, the cross ventilation is also analyzed. The prevailing mean outdoor temperature is taken based on ASHRAE 55-2010. The inlet axis height is adapted 1.5 m above the ground level and the outlet stack height with axes of 1 m above the inlet axis. The difference between internal and external air temperature is ΔT = 7 °C from which depends buoyancy-driven ventilation rate.

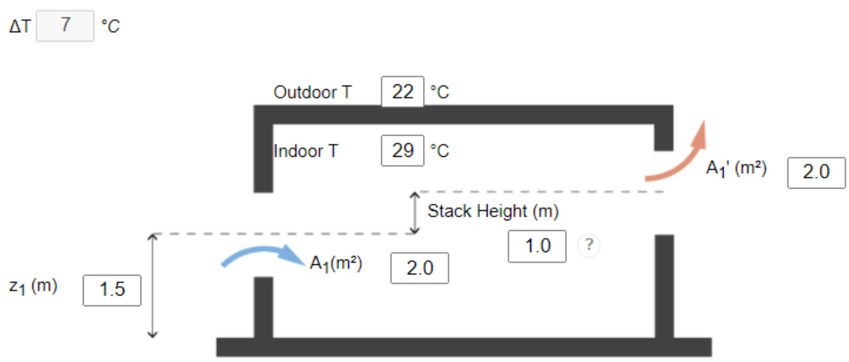

Figure 18. Airflow data input for cross night natural ventilation.

Buoyancy+wind driven: With the parameters given below for the location and the space area, with cross ventilation, the air flow rate required for fresh air is 0.08 m³/s, while required for cooling is 0.19 m³/s. The air flow achieved is 0.34 m³/s The Fig. 19 shows that this strategy will enable the sufficient amount of air flow not only to supply with fresh air but also for the cooling of indoor environment. The status of adaptive comfort band, complies 90% of acceptability limits according to ASHRAE Standard 55–2013 as shown in Fig. 20.

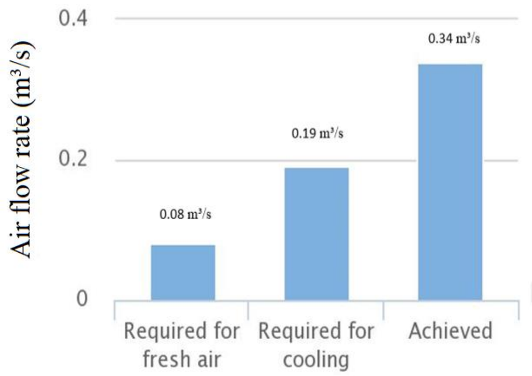

Figure 19. Air flow rate (m³/s) for night cross ventilation, buoyancy+wind driven

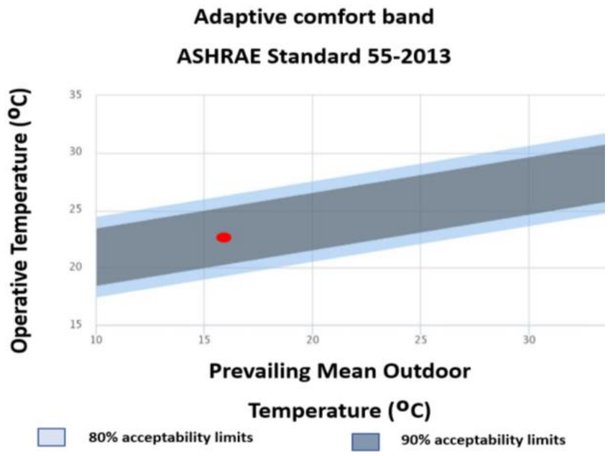

Figure 20. Acceptability limits for night cross ventilation, buoyancy + wind driven.

Buoyancy-driven: For the buoyancy-driven scenario, the air flow rate required for fresh air is 0.08 m³/s, while required for cooling is 0.19 m³/s. The air flow achieved is 0.29 m³/s. The Fig. 21 shows the that this strategy will enable the sufficient amount of air flow to create not only the supply with fresh air but for cooling of indoor environment also. The status of adaptive comfort band, complies 90% of acceptability limit according to ASHRAE Standard 55-2013 as shown in Fig. 22.

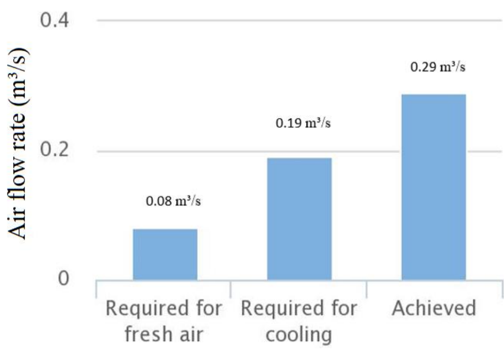

Figure 21. Air flow rate (m³/s) for night cross ventilation, buoyancy driven.

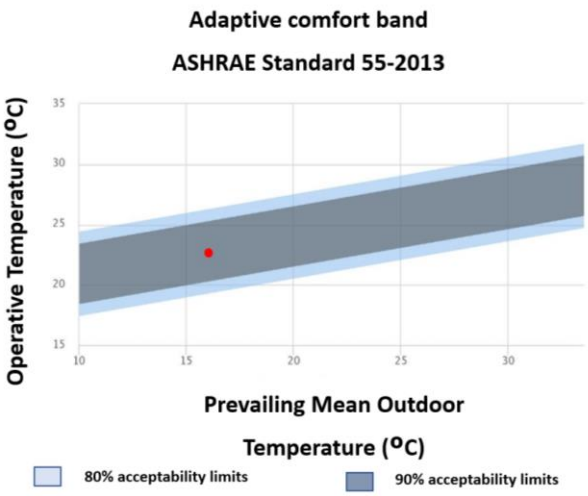

Figure 22. Acceptability limits for night cross ventilation, buoyancy driven

Based on the results above for both scenarios these can be inferred: Single-sided and cross ventilation applied during the nighttime, and by both sub-strategies can successfully be used to induce air flow within the indoor environment of the building. The achieved results show that this way, it will be created a good indoor thermal comfort. As elaborated above, this strategy ensures that with minimal energy consume, the maximal thermal comfort is achievable for the inhabitants.

6. CONCLUSIONS

The key issue in effectiveness of passive strategies, in this case cooling, is climate parameters. There were different tools and means proposed and developed by engineers and scientists, which are very useful when deciding for the passive strategies to be applied and incorporated into the early building design. In the present paper, a single cell case study is presented to help determine the feasibility of passive cooling strategy for the temperate climate such as in Kosovo. When a drift of high temperature from daytime to nighttime is achievable, the potential for night ventilation might be very interesting especially for the locations with harsh condition. The presented cases study showed that for the similar climate as in Kosovo, and with adequate position of the building elements such as openings, night cooling can successfully be applied and has its benefits in creating thermal comfort for inhabitants and reduction of energy needs for cooling.

The results prove that the natural ventilation during the day, at the houses which the rooms have only one-sided openings, is effective only for fresh air flow but not sufficient for the cooling purposes. When the openings are designed on the opposite walls of the rooms or areas, the conditions will enable that the area will be cooled at the same time through the cross ventilation by achieving up to 90% of the accessibility limits of comfort both during the day and nights at different scenarios in the warmest summer months in Kosovo. On the other hand, the case studies prove that the natural ventilation during daytime can still be interesting as the air flow rate enables the fresh air supply on the house. Planning of the trees and shades around the building would contribute a lot in creating difference in temperatures even during the day, therefore including these factors, the cooling through natural ventilation could be achieved even during the day. Furthermore, climatic conditions at a specific location are not only determined by weather data, but also affected by topography and urban areas. The wind patterns are modified based on the building shape and the surroundings, as well as the access of the solar radiation to the building. In addition, the real conditions under which operates a building are often affected also by urban heat island. In these cases, a comprehensive analyze would be required, as well as indoor comfort requirements and characteristics. In addition, the future developments will be studying the usage of the home automation in controlling window openings during the day and night period, based on the surrounding temperature conditions.

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