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Studying the Thermal and Cryogenic Performance of Shevadun in Native (Local) Buildings of Dezful Based on Modeling and Environmental Measuring

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Abstract In the native buildings of Dezful, spaces called (Shevadun) that were constructed under the ground, were used, which used the thermal mass property of the earth to be protected from cold and warm weather conditions. In the old buildings of Dezful, these spaces that are constructed under the ground are called ((Shevadun)) in native language. In this research, first,the temperature and humidity in one Shevadun sample of the Dezful native buildings were measured using Data Logger units in 5 days (during August). Then, using the Design builder software which is a reliable software in modeling the energy and CFD calculations, the available sample is simulated in order to study the thermal and cryogenic performance. The results of the research show that the temperature of Shevaduns in summer is less than the average maximum temperature and the average minimum temperature of outdoor, and the thermal condition of the Shevadun space during the measurement is lower than the thermal comfort limit which is specified in the ashrae standard. In other words, the Shevadun space is colder than the summer comfort limit of ashrae. The effect of the cold weather of Shevadun on summer places above it which are connected with a trap door, was studied, and the results show that if the summer habit is connected with shevadun, the average temperature is 4 degrees centigrade lower than when the connection trap door is closed, and when the trap door is open, the relative humidity of the summer place will be 2 to 3 percent's higher, which shows the high potential of the shevaduns in using the passive cooling of spaces. The other part of the paper studies how the cool air inside the shevadun is transferred to the summer place by the trap doors. The results show that in the day, because the door of the shevadun is closed to prevent from entering the warm air of outside to inside the shevadun, the air movement in shevadun and trap door which is the connecting canal between the shevadun and summer place, is very slight, and it is the result of the temperature difference between the vertical layers of the air inside the shevadun , trap door and space, so that , this air movement is not felt, and the cool air of the shevadun has less effect than during the night that the door of shevadun is opened for ventilating its air.

Keywords: *sustainable development, thermal comfort, thermal mass of the earth, shevadun, modeling*

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1. Introduction

Passive coolers are defined as the heat removers from the building and environment using the natural processes of evaporation, radiation, convection and conduction [1]. In the past architecture of Iran, different methods are used for achieving the thermal comfort, In the north part of Khuzestan plain , particularly in Dezful region which has a ground made of hard conglomerate , for achieving the Thermal comfort and being protected from the intolerable heat of outdoors, they constructed a space under the ground called Shevadun and they used the thermal mass of the earth. Certainly, using the cryogenic property of the earth in the past was not only restricted to Dezful. Using different static cooling systems was one of the most important strategies of the human for being protected from the excessive heat of the environment in the past. Several researches have been conducted to study the performance of these systems and the strategies for improving them and even new ideas for using static cooling systems are given. One of the sources which has high potential for generating the coldness required for the thermal comfort of the human is the direct and indirect use of the underground spaces. In this regard, B.Barker, Michael (1986) performed an extensive research on the energy consumption of four important underground buildings of the USA, that in all of the buildings, the energy consumption in the winter and summer was considerably lower than the other buildings that hadn't used the underground spaces [1]. Ojima.Toshio and Gideon (1996) divided the use of underground spaces into five groups, which were used in ten different ways [2]. In this research, the effect of using the underground spaces on the natural environment and mental comfort of the humans is studied, and according to it, using the underground spaces has desirable effect on the both of them. Mohsen Bita (2008), in a field research, studied the thermal condition of the Dezful shevaduns and it was determined that the temperature of shevadun in summer is cooler than both the maximum temperature and the minimum temperature of the outdoors; the daily temperature fluctuation of the shevadun is less than a half degrees. S.M Jafarian et al. (2009) analyzed the performance of the passive cooling system using the underground canals in the ancient building of the city of Bam, and they concluded that the warm air, by passing the underground canal, become so cold and its humidity increases [3]. Also, Vikas Bansal et al. (2011) analyzed the performance of the underground canals and their combination with water coolers in order to create coldness in hot and dry regions, and it was determined, if we first pass the air into the underground canals and after generating a precooling, pass the air to the water cooler, the output of the water coolers will increase significantly [4]. All of the conducted researches show the high potential of the underground spaces and the thermal mass of the soil for achieving thermal comfort and reducing the energy consumption. But the point that distinguishes this research, studying the performance of one of the most traditional methods of using the thermal mass of the soil by field sampling and numeral simulations, and in the next step, studying the thermal comfort condition of its users, so that we can dicuss the potentials of using this method that was used in the traditional houses of Dezful for today’s architecture.

2. The Research Method

The method which is selected for this research is using the field sampling and simulating the sample by the Design builder software. By using the simultaneous recorders of the temperature and humidity, the shevadun spaces and the outdoor air and the air of the summer habit connected to the trap door of the shevadun (3th to 7th of august) in the standard condition defined for the recorder units, was sampled (taken), the thermal comfort in these spaces was studied. Then, the sample was simulated using the Design builder software which is reliable software for modeling energy and performing numeral calculations. and the results of the temperature and humidity from modeling the spaces in this software is compared with the results of the environmental sampling, and after being confident about the low error coefficient of the modeling results, it was studied how to use the coldness of the shevaduns by using the CFD calculations performed by the Design builder software, and the potentials of these spaces for using the passive cooling system in today’s architecture have been studied.

3. Definition

Shevaduns are spaces that were constructed under the ground in order to be protected from the warm weather in the traditional buildings in Dezful. And considering the hard and stable ground of this region, the depth of this space is sometimes more than 10 meters. The conducted researches show that the air temperature in shevaduns in the hottest days of the year is about 25 degrees centigrade, and also the temperature of the surrounding streets reaches 54 degrees centigrade. In the Figure 1 and Figure2 spatial the section of one of the traditional houses in Dezful and the shevadun plan of this house with its spaces, are shown respectively.

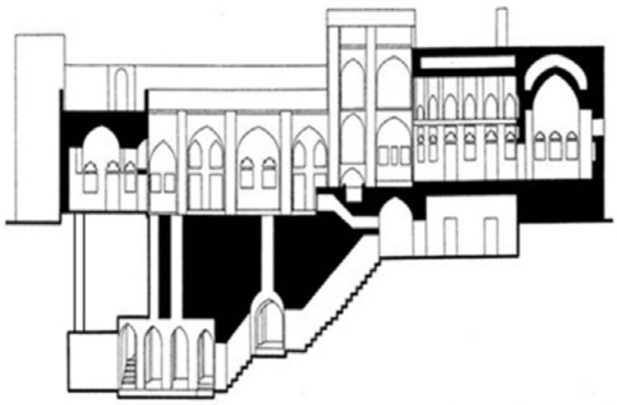

Figure 1. the section of one of the shevaduns traditional plan and its spaces in Dezful

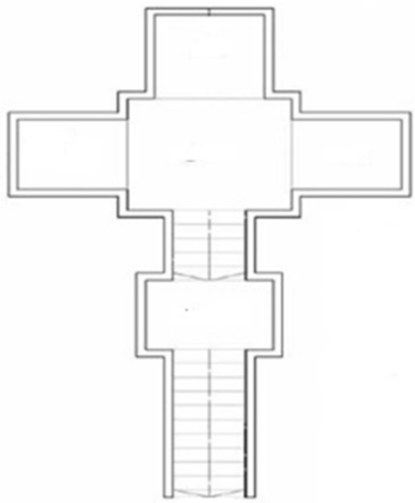

Figure 2. samples from the houses of Dezful

4. Data Analysis

4.1. The Results of the Environmental Measurement of the Air Condition in Shevadun

The field samplings in this research by the temperature and humidity recorders of Gemini data loggers are done separately in the interval of per 1 hour in 5 days from 13th to 17th of Ausust 2012 in standard condition. It is evident that the recording time is the hotest month of the year in Dezful. The results of the environmental measurements and monitoring in the diagram 1 show that, in general, when the temperature in shevadun is in its highest value, the relative humidity of the shevadun spaces is minimum and vice versa, and these two states occur in the two intervals of 16 to 20 and 4 to 8. Also, based on the results of diagram 1, the average minimum of the relative humidity in 5 days is 71.2 percent's and occurs about 21 P.M. The average maximum of the relative humidity in shevadun in this interval is 76.3 percent and occurs at 8 A.M. The average maximum of the relative humidity of the outdoors is 55 percent and occurs in the interval of 3 to 4 A.M, and in this interval, the average relative humidity in shevadun is 76.2 percent, and as it is evident, the relative humidity in the shevadun space is so high, because the walls of shevadun are humid and they are subjected to the shevadun space without any cover. The minimum relative humidity of the outdoor air occurs in the interval of 15 to 16 P.M, and its average is 18 percent, and in this interval, we see that the average relative humidity of shevadun is 75.1 percent. As it is evident, the air humidity fluctuations of the shevadun is lower than the outdoor air, because it should be protected from the thermal changes of outdoor and should have connections with the humid walls of the space. As it is evident from the diagram 1, the maximum temperature of shevadun is 24.9 degrees centigrade and it occurred at 18 P.M, and the minimum temperature of shevadun in these 5 days is 23 degrees centigrade and it occurred at 8 A.M. The temperature in shevadun has little fluctuations; we can say that the temperature of shevadun in the summer of Dezful is equivalent to the temperature of winter in this city, because the high thermal mass of the soil reaches the depth of the ground and shevadun with some months delay. The average maximum temperature of the outdoor air is in the interval of 15 to 16 P.M , and it is 48 degrees centigrade, and in the same interval, the average temperature of shevadun is 24.1 degrees centigrade, the significant temperature difference in the hottest hours of day in summer between the temperature inside the shevadun and the temperature of the outdoors, shows the high potential of this space for using its coldness in the buildings spaces and even using it for the times of the day. The average minimum temperature of the outdoors occurs in the interval of 3 A.M to 4 A.M and its value is 28 degrees centigrade, and the average temperature of shevadun in this interval is 23.2 degrees centigrade, which shows that the average minimum temperature in Dezful is higher than the average temperature in that interval in shevadun.

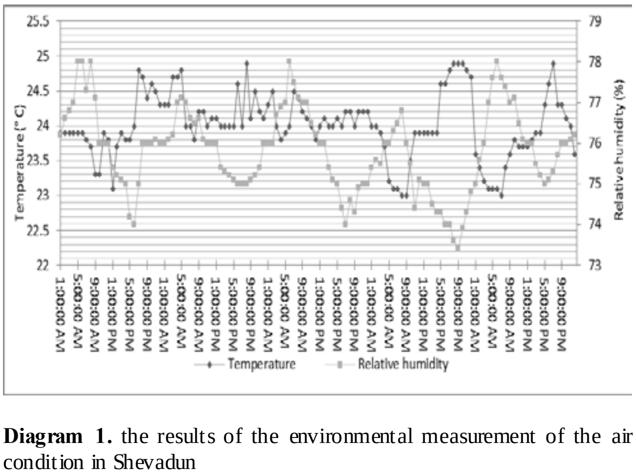

Diagram 1. the results of the environmental measurement of the air condition in Shevadun

The important problem in the environmental measurement of the summer place, is studying the effect of the cool air of the shevadun on the value of the temperature and relative humidity of summer place. So, we divide the summer place in two parts which have the same characteristics in terms of dimensions and the number of openings as well as the thickness of the walls that are the most important factors affecting the temperature and humidity of the old buildings. One of these parts is connected to the trap door and the other part is isolated to break off its connection to the trap door which is connected to the shevadun. As it can be seen from the Diagram 2, in general, we can say from the summer place space connected to shevadun, when the temperature in the summer place is maximum, the humidity will be in its minimum value and vice versa, and these two states occur in intervals of 14 to 18 P.M and 3 to 7 A.M. According to the diagram 2, the average minimum relative humidity in these 5 days in the summer place connected to shevadun is 23.8 percent and has occurred in 18 P.M, and the other part of the summer place that doesn't have connection with the trap door, the average minimum temperature is 20.2 and has occurred in the same interval, and this is evident from the diagram 3. The average maximum value of the relative humidity of the other part of the summer place occurs in the same interval but its value is 48.2. As it can be seen from the obtained numbers, the average minimum and the average maximum relative humidity of the summer place connected to shevadun is higher, and this shows the effect of the shevadun air on increasing the relative humidity of the summer place connected to it. The average maximum temperature of the summer place connected to shevadun is 38.1 degrees centigrade and occurs at 17 P.M, and it can be concluded from the data in diagram 3, this value for the other part of the summer place at the same time is 42.3 degrees centigrade, and on the other hand, the average minimum temperature of the summer place connected to shevadun is 32.2 degrees centigrade and occurs at 6 A.M. The average minimum temperature of the other part of the summer place is 36.6 degrees centigrade and occurs at the same time (hour). It is evident that the average minimum temperature of the summer place connected to shevadun is 4.4 degrees centigrade lower, and the average maximum temperature of the summer place connected to shevadun is 4.2 degrees centigrade lower, that shows the high potential of using the cool air in the underground even without using any mechanical devices for the air expulsion.

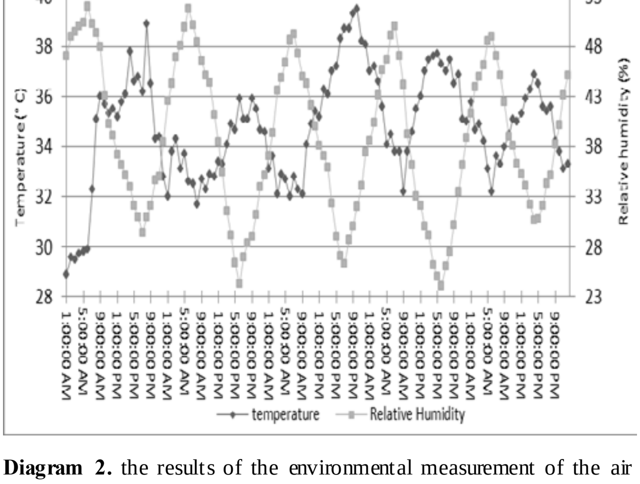

Diagram 2. the results of the environmental measurement of the air condition inside the summer place connected to shevadun

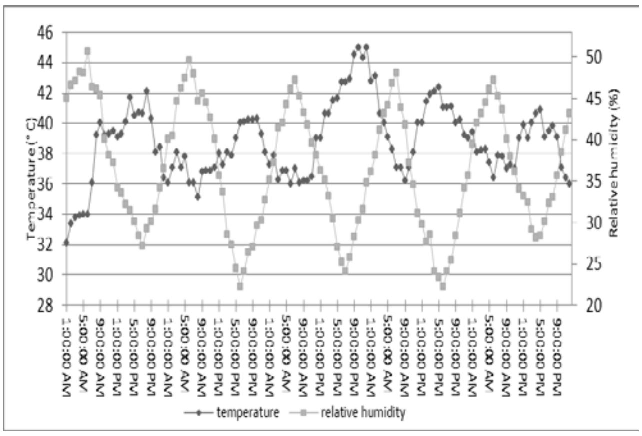

Diagram 3. the results of the environmental measurement of the air condition inside the summer place that is not connected to shevadun

4.2 Studying the Psychometric Diagram in the Shevadun Space

As it can be seen from diagram 4, all of the measurements are in the left part of the summer limit of ashrae standard 2010. These results show that the thermal condition of shevadun during the measurement is lower than the thermal comfort limit specified. In other words, the space inside shevadun is colder than the summer comfort limit of ashrae.

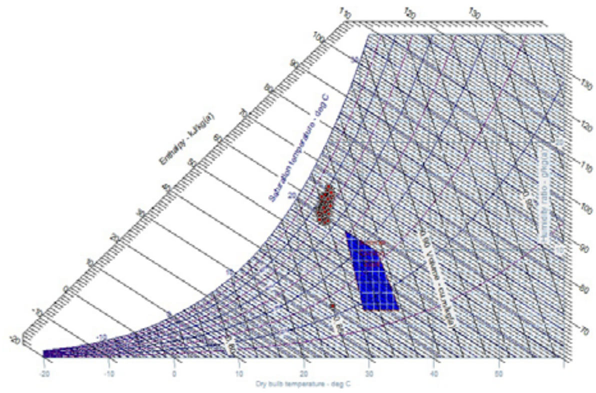

Diagram 4. studying the psychometric diagram in the shevadun space

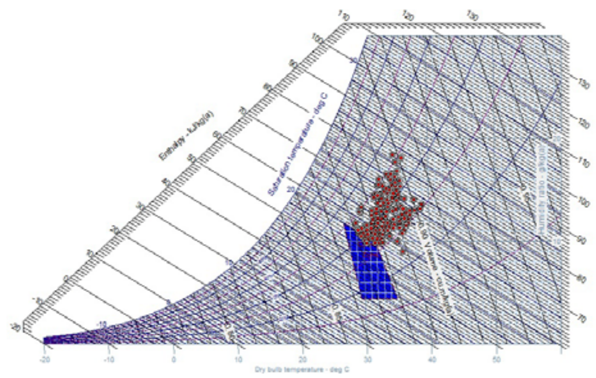

Diagram 5. studying the psychometric diagram in the summer place space

4.3. The Results of the Simulation by Design Builder Software

The design builder software is used in different parts of the building such as the physics of the building (building materials), the building architecture, cooling and heating systems, lighting systems, etc. so this software can model all the aspects of the building. This modeling software which is the most advanced software in the world for modeling the building, can dynamically model different energy consumptions of the building such as heating energy consumption, cooling energy consumption, lighting, furniture's, the warm water consumption, etc.. This software can model CFD, model the mechanical and natural ventilation, calculate the thermal comfort inside the building space, calculate the energy dissipation and the energy received from different elements of the building. The results the modeling's of all the building, one story of the building and the single spaces of the building is extractable. This software can extract the modeling results in the form of diagram and excel files that can be used for dimensional analysis. This modeling software is taught in the most important universities of the world such as Harvard University. The modeling motor of this software is Energy Plus that is developed by the American energy department in 2011, and is one of the most important energy modeling software's in the world [7]. Before giving the modeling results of the performance and the cryogenic use of shevaduns in the local houses of Dezful by the Design builder software in this section, for validating the modeling results, the results of the environmental measurements of shevadun and the model of shevadun that is built by the Design builder software in the temperature and humidity simulation of the spaces, are compared. The diagram 6 shows that the range of the temperature difference of shevadun between the existing condition and computer modeling is 0.1 to 0.7. This shows that the differences are insignificant.

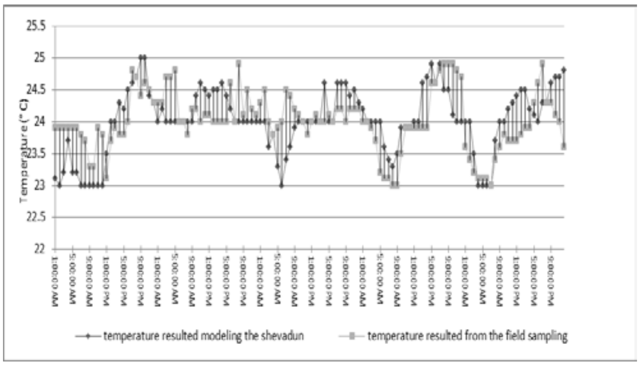

Diagram 6. the comparison of the temperature resulted from the field sampling and modeling the shevadun

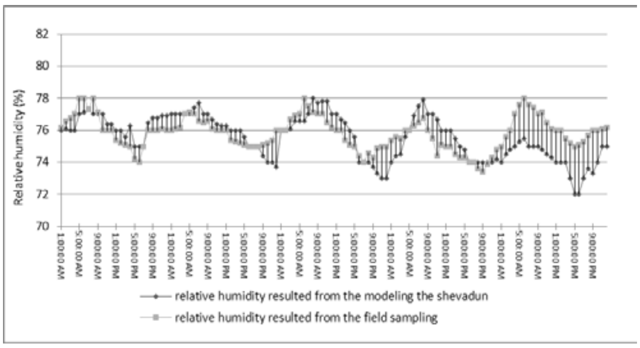

Diagram 7. the comparison of the relative humidity resulted from the modeling the shevadun

5. Modeling the Performance and the Cryogenic Use of Shevaduns in the Local Houses of Dezful

In this section, we model the studied house in order to examine the thermodynamic performance of the cool air inside the shevadun at night and day and we study the effect of the cool air of shevadun on the summer place connected to it, to determine its potentials for cooling the spaces of today's buildings.

5.1. The Characteristics of the Built Model in the Design Builder Software to Perform the CFD Calculations

First, by the Design builder software, the spaces of the studied building was drawn according to the drawings of the cultural heritage organization of Dezful, the neighboring buildings are considered as the controlled blocks in the model. This building has a shevadun at the depth of 7 meters and the area of 37 square meters, and in order to transfer the cool air of shevadun to the summer place of the building and to ventilate the air of shevadun, is connected to the summer place room by a trap door that has a cross section of 0.35 square meters . In modeling for making grids according to the geometry, the organized grids were used. It is noteworthy that after making grids inside the Design builder software, for improving the results in sensitive points specially the places where the intensive gradient is a physical variable such as pressure-velocity and temperature, the density of the grid in these points has been increased. As the physics governing the flow requires a steady flow, the analysis of the flow is conducted as a steady flow, and has considered the flow as a incompressible flow, the air density is considered in an incompressible condition. According to these constraints, the discrete method is used in the software for solving the equations. The governing equations are the continuity-momentum and energy equations. Also, considering the behavior of the flow, it is suitable to use turbulent model of k-$\in$. So, the two other equations (k and $\in$) are analyzed. According to the fluid type of air and water, the chemical equations for the volumetric fraction of $H2O$ and $O2$ are added to the governing equations. Also, in the built model, the internal and external boundaries are considered sufficiently far away from the building to maintain the uniformity of the flow. And the turbulent condition is used based on the intensity of the turbulence and the turbulent viscosity ratio. The temperature of the walls of the model is assumed equal to the ambient temperature and the error range for solving the equation is 2e-06, and according to the equations, they are converged after 5000 to 7000 repeats. In the Figure 3, the characteristics of the built model in the Design builder software to perform the CFD calculations.

6. Alyzing the Coldness of Shevaduns and Studying the Results of CFD Calculations by the Design Builder Software

The performance of shevaduns depends on two factors: 1- the underground temperature in depth 2- the ventilation of the air inside shevaduns. In this section, we study the cryogenic performance of the thermal mass of the earth and the effect of air layers movement on the performance of shevaduns and the numerical study and the performance of the shevaduns for creating the required cooling for the inhabitants in the warm seasons of the year.

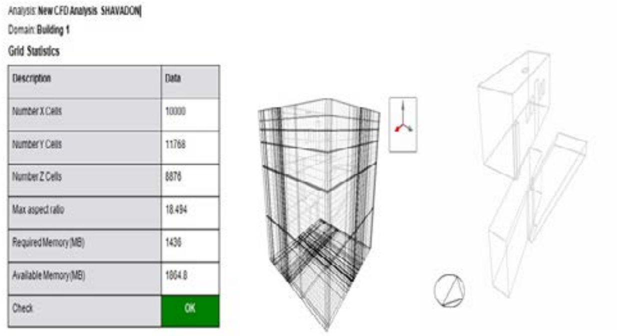

Figure 3. the characteristics of the built model in the Design builder software to perform the CFD calculations

6.1. The Cryogenic Performance of the Thermal Mass of the Earth

The temperature of the earth crust at the down parts is about 800 degrees centigrade, and for each 100 meters increase of the height, the temperature decreases 3 degrees centigrade [5]. And this temperature decrease continues until the temperature of the earth outer crust reaches the ambient temperature, this part of the crust is the part that we live on. The down surface of this crust that the underground stores of the building are built inside it, is less affected from the ambient temperature, so that the daily temperature change which is 17 degrees centigrade only affects one degrees on the temperature of 1 meters underground and at the depth of 5.6 meters, the temperature change doesn't affect the earth crust [5]. So, we can store the coldness of the winter and the warmness of the summer for 6 months, and because of the high thermal capacity of the soil, the coldness of the winter reaches the earth with a 6-month delay which is the summer season and that is when the inhabitants need this coldness for providing the thermal comfort [6]. The walls of the underground spaces that shevaduns are one of them, have the temperature equal to the average annual temperature, and according to the statistics of the meteorology organization, this average is 25 degrees centigrade for Dezful.

6.2. The Effect of the Air Layers Movement on the Performance of Shevadums

In addition to the earth temperature that makes the shevaduns cold in summer, the ventilation of the shevaduns air is very important in increasing the coldness of the air. If we ventilate the air of the shevaduns with a colder and warmer air relative to its natural air, the temperature will change and its walls will lose its heat. So, to decrease the temperature of shevaduns, some holes are placed for entering and exiting air to decrease the temperature of the shevadun walls. Since the warm weather of Dezful doesn't have this characteristic, so the cold weather of the sky dome should be used, and this cold air supply is used by two methods: 1- the transfer by displacing air 2- the transfer of coldness by the radiation to sky.

6.3. The Numerical Study of the Performance of Shevadums for Creating the Required Cooling of Inhabitants in the Warm Seasons

6.3.1 The Numerical Study of the Performance of Shevaduns for Creating the Cooling at Night

At night, which is with a mild wind from south west, the doors of the shevadun and its holes are opened to use the cool air of the sky dome and the air flow that includes the horizontal and vertical movements of the air layers and the expulsion of the cold air of shevadun by trap doors to the upper space of shevaduns. For modeling the performance of shevaduns for creating cooling at night in the traditional buildings of Dezful, first, according to the data received from the meteorology organization of Dezful and the climate information file of Dezful that was provided from the building research center and was studied by the Ecotect software, the average wind speed, average temperature, average relative humidity and the direction of the winds at 3 A.M in August at Defzul was studied. On the basis of this study, the average wind speed in August at Dezful at 3 A.M was 1.8 m/s and it was from the south west direction. Also, the average temperature and the average relative humidity at 3 A.M are 29.5 degrees centigrade and 56.3 percent, respectively. These data as the initial data for solving the equations were given to the software. Figure 7 shows the distribution of the wind around the building. It is evident that the wind at some meters upper in the building has the uniform velocity, but around the building, according to the type and the form of neighborhoods, the wind speed in different point is different from each other.

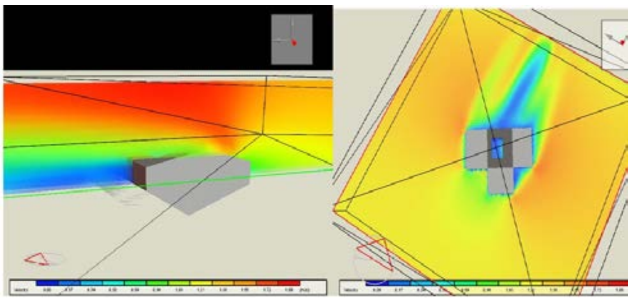

Figure 4. the distribution of the wind speed at 3 A.M in August around the building

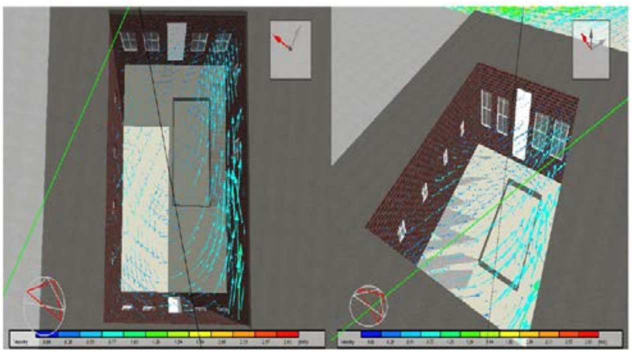

Figure 5. the distribution of the wind speed vectors at 3 A.M in August at the central yard

This speed difference in points that have central yards become more meaningful, so that the central yard creates a microclimate for the building, and it affects the wind speed around the entrance door to the shevadun. As it can be seen from Figure 8, the existence of central yard and its structure reduces the wind speed around the entrance door to shevadun, so that it can reduce the wind speed in outdoors from 1.8 to 0.7m/s.

But besides this negative effect of the central yard on the transfer and ventilation of the cold air of shevadun, it should be considered that because of the less turbulence of the air flow in the central yard especially at the vertical directions of the air layers , the transfer of the cool air of the sky dome by displacing is more stable, and on the other hand, by considering the spatial structure of the central yard, it is in the shade in more hours of the day, so it has a cooler air in comparison with the environment and the wind, and it has a cooler air when there is not a central yard. The door and the holes of the shevaduns are opened at night for ventilation and using the outdoor air flow to expulse the cool air of shevadun by the trap door to the summer place room. From Figure 9, at 3 A.M when the average air speed of the outdoor is 1.8 m/s, the wind speed in the entrance stairway to shevadun not only depends on the wind in the region, but also depends on the vertical flows of the air, geometry and the central yard proportions and the place of the windbreak.

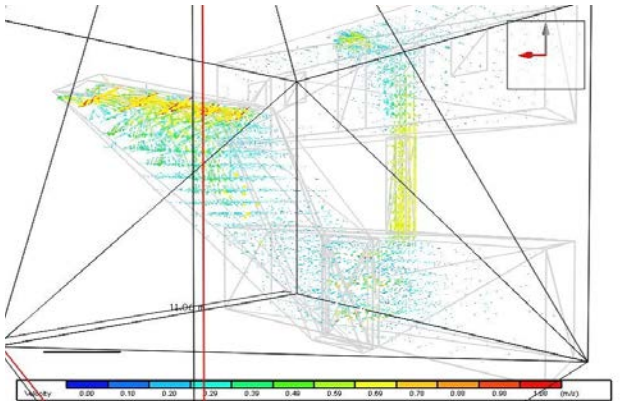

Figure 6. the distribution of the air flow velocity at 3 A.m. in August in the studied model

In the traditional houses of Dezful, usually a trap door with the dimension of 0.12 square meters is built for ventilation, during the wind blow, this trap door which is on the roof, is subjected to negative pressure (suction) and on the other hand, the stairway entrance to shevadun and the entrance doors of shevadun is subjected to the positive pressure, and this causes the air flowing the stairway entrance directs to the entrance door of shevadun, but because of the contact of the air flow to the stairs walls, its velocity (speed) decreases, and enters the shevadun space with the velocity of 0.3m/s. The air entering the shevadun has two roles. 1- If the temperature of the entered air is lower than the available air in the shevadun, the walls of shevadun will lose their heat and they store the coldness of the entered air because of their high thermal capacity, so that the inhabitants can use it at daytime. As it is evident from Figure 10, the temperature of the air entering the shevadun is higher than the shevadun itself. 2-as it was stated, the stairway entrance and the shevadun door is in negative pressure and trap doors that are on the roof of the summer place is in negative pressure, on the other hand, the shevadun and the summer place above it are connected by a canal called trap door. After the entrance of the air into shevadun, because of the suction that the trap door generates at inside the summer place, the air that is entrapped in shevadun during the day moves upward, because of the reduced cross section relative to the shevadun space, the velocity of the air flow increases, and as it is evident from Figure 9, it reaches to 0.7m/s, because of the suction that exists in the summer place, the air in the trap door moves upward, and enters this space from the upper entrance. As soon as entering the summer place space, because the fluid enters a bigger space, its velocity decreases, and creates an air flow with the speed of 0.3 m/s in the summer place space, this air movement inside the summer space is because of the trap door on the roof, and because this trapdoor is in suction condition, an air flow in vertical direction inside the summer place is created, and as it is evident from Figure 11, it exits the room with the speed of 0.5m/s.

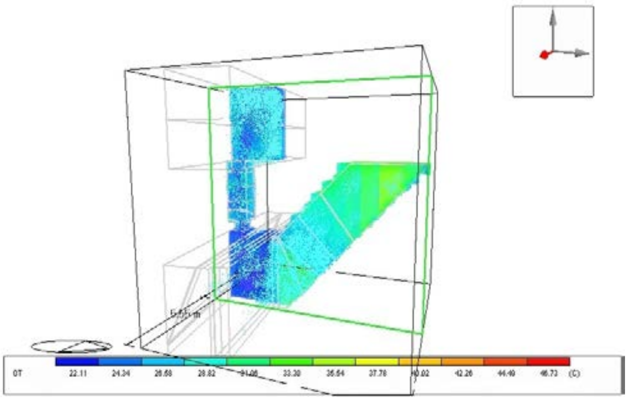

Figure 7. the distribution of the temperature in the studied model at 3 A.M in August

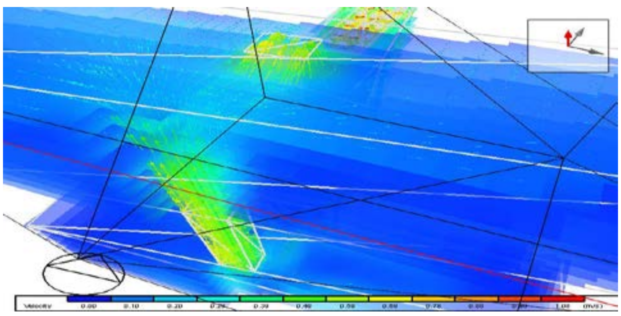

Figure 8. the distribution of velocity in the trapdoor on the roof at 3 A.M in August

As it was stated, and it is evident from Figure 10, the created air flow increases the temperature inside the shevadun because it has higher temperature in comparison with shevadun, but on the other hand, because of the pressure difference that exists between the trapdoor on the roof and the stairway entrance leading to shevadun, the ventilation is done and exits (expulses) the humid and sultry air that causes the thermal uncomforted for the inhabitants, and the fresh air is stored for the next day of the inhabitants, and on the other hand, the shevadun air is cooler than the summer place air. So, as it is evident from Figure 10, the studied air flow transfers the cool air of shevadun to the summer place space by the trapdoor and decreases the temperature of the summer place at night. The direction of the air, the air speed and the ventilation of the shevadun space and summer place is shown in Figure 12.

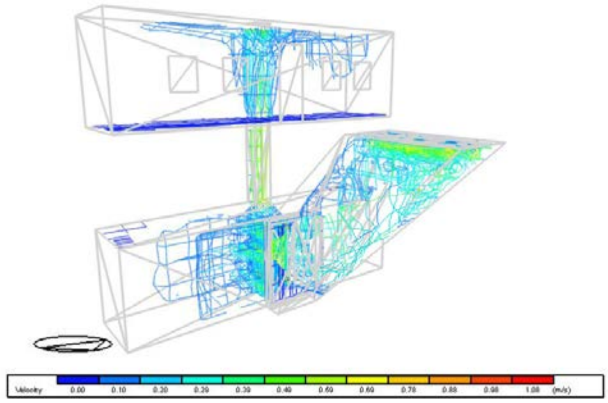

Figure 9. the is velocity and the direction of air flow in the studied model at 3 A.M in August

6.3.2 The Numerical Study of the Performance of Shevaduns for Cooling During the Day

During the day, because of the hot weather condition of the region, they usually closed the doors and holes of shevadun, so that the inhabitants can use the cool air in shevadun, even if the doors are opened, because the warm air movement is upward, no ventilation takes place. For modeling the performance of shevaduns for cooling during the day in the traditional buildings of Dezful, according to the received data from the meteorology organization of Dezful and also the climate information file of Dezful which is provided but the building research center and was studied by the ecotcet, the average wind speed, average temperature, average relative humidity of the air and the direction of the wind at 3 P.M in Mordad in Dezful, was studied. On this basis, the average wind speed in Mordad in Dezful at 3 P.M is 2.7m/s in the direction of south west, also, the average temperature, the average temperature and the average relative humidity of the air at 3 P.M is 45 degrees centigrade and 16.3 percent. These data are given to the software as the initial data for solving the equations. Figure 13 shows the distribution of the wind speed around the building.

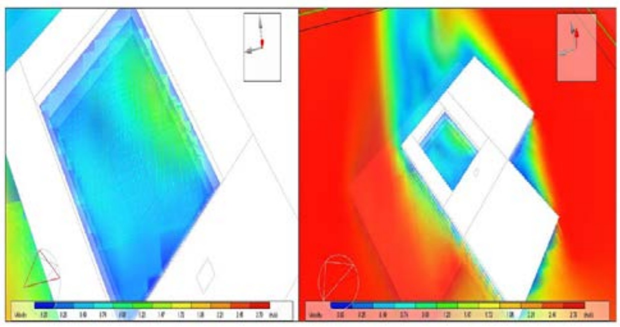

Figure 10. the distribution of the wind velocity at 3 P.M in August around the building and the central yard

As it was noted in the previous section, the existence of central yard decreases the effect of the wind speed of the region on the building spaces, so that when the wind speed in the outside of the building is 2.7m/s, it is decreased to

1m/s in the central yard . Because of the high temperature of this wind, it is better not to subject the entrance holes and spaces of air to this wind, so that the cool air which has been stored in the spaces last night doesn't discharge. As it is evident from figure 14, in this case, the door of the stairway leading to the shevadun is open. So, it is subjected to the positive pressure, and the trapdoor which is on the roof of the summer place is under the negative pressure, but the door is closed to prevent from entering the hot air of outdoors and discharging the stored cool and fresh air in shevadun, the air movement in shevadun and trapdoor that is the connecting canal between the shevadun and summer place is insignificant and it is the result of the temperature difference between the vertical layers of the air inside the shevadun, trapdoor and space, so that, this air movement is not felt. Only because of the suction that takes place in the trapdoor on the roof, some of the air inside the room near the trapdoor is discharged, and this requires the entrance of the outdoors warm air by the chink of the openings. So, closing this trapdoor will be better for creating the thermal comfort condition for the inhabitants, but because of the difficult access of inhabitants to it, this trapdoor is usually opened in the summer.

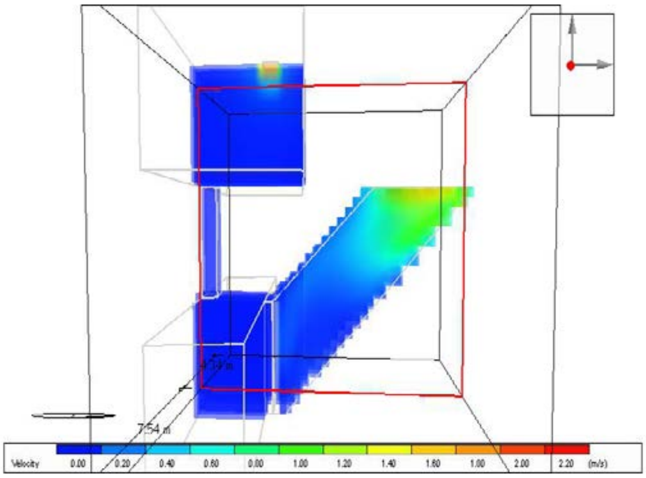

Figure 11. the airflow velocity distribution at 3 P.M in August in the studied model

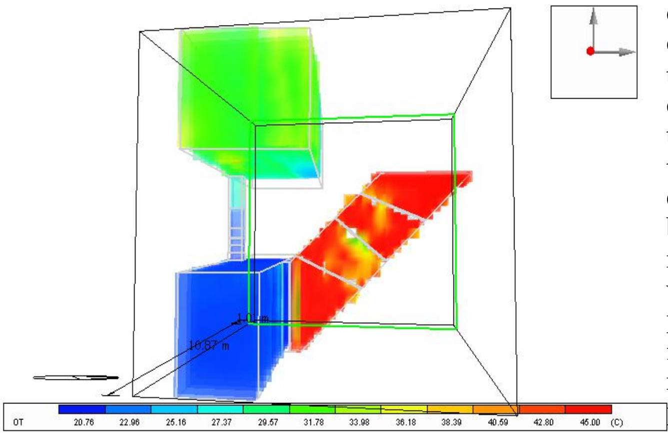

Figure 12. the distribution of the air temperature in the studied model at 3 P.M in August

In Figure 15, we can see the distribution of temperature in stairway, shevadun and the summer place space at 3 P.M in Mordad. It is evident that, the warm air of the outdoors doesn't affect the cool air inside the shevadun, and the temperature of shevadun during the day in the temperature range of 22 to 23 degrees centigrade is constant. The summer place space has received the cool air from the shevadun, and because of the high thermal capacity of its walls, keeps this coldness during the day in itself, but after sometime, its temperature is affected by the warm air of outdoors, so that its 29 degrees temperature at 3 A.M reaches the temperature of about 34 to 35 degrees centigrade at 3 P.M.

7. Conclusion

The research results show that the temperature of the shevaduns in summer is less than the average maximum and the average minimum temperature of the outdoors, and it has the fluctuations about 0.9 degrees centigrade which is negligible, and its thermal condition at the time of measurement is lower than the thermal comfort limit specified in ashrae standard, in other words, because of the high thermal capacity of the soil, the shevadun space is colder than the summer comfort limit in ashrae. On the other hand, the average relative humidity of the air inside shevadun is 73 percent, which is not desirable for the thermal comfort of the human, so, it causes the air of the shevadun to be out of the thermal comfort range (limit) in ashrae standard, because the walls of the shevadun are humid and they are connected to shevadun without any cover. The effect of the cool air in shevadun on the summer place above it which are connected to each other by a trapdoor, is very important, and the field data show that if the summer place is connected to the shevadun, the its average temperature is about 4 degrees centigrade lower than when the connecting trapdoor is closed. And when the trapdoor is open, the relative humidity of the summer place will be about 2 to 3 percent higher. Which shows the high potential of shevaduns in using the passive cooling of spaces? In the other part of the paper, the way of transferring the cool air inside the shevadun to summer place by trapdoor is studied. The results show that in days, the doors are closed to prevent from entering the warm air of outdoors inside the shevadun, the air movement in shevadoon and trapdoor is insignificant and it is the result of the temperature difference between the vertical layers of the air inside the shevadun, trapdoor and the space. So that, this air movement is not felt, and in the best condition, the velocity of the air movement of shevadun towards the summer place by the trapdoors is 0.1m/s, and the cool air of shevadun has less effect in comparison with during the night when the shevaduns doors are opened because of the ventilation and the velocity of the air movement in the trapdoor reaches 0.6m/s. In this research, we sought the performance, effect and identifying the potentials of one of the native spaces of the Dezful houses for the passive cooling, and according to the conducted researches, the high potential of using this space for the passive cooling and the reduction of energy consumption in the contemporary architecture is evident, but we give some strategies for the preserve and the scientific development of this type of spaces:

- It is suggested that the existing shevadoons be preserved and by enacting persuasive regulations, prevent from their filling.

- The shevaduns of the existing buildings be optimized. We should find solutions for the problems of water penetration and the humidity of its walls.
- By the right design, it is possible that, in addition to the stored cold air at night at the shevadun spaces, we can direct the excess cold air of the cooling devices such as coolers which are wasted from the chinks of the windows, to inside the shevadun, in order to use it after storage.
- By considering the low velocity of the air movement inside the trapdoors that is the result of the suction and pressure of the trapdoors, there is a potential that by using the mechanical devices such as fans, we can use the cool air of shevaduns in the upper rooms more efficiently.
- Today, most of the residential spaces have several stores, according to the high potential of the underground for the passive cooling of the spaces, the effective study and design for using the cool air underground in multi-story buildings for reducing the energy consumption in these types of buildings is very important.

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