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Investigating the Thermal Behavior of Wind Catcher Room of Rasoulian House in Yazd and Proposing Some Methods for its Improvement

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ABSTRACT: Yazd traditional houses are valuable and precious inheritance from our ancestors; therefore, some actions such as changing their application must be taken in order to protect and maintain them. Changing the application of these buildings to some others such as educational, cultural and entertainment centers leads to consumption of nonrenewable energies to prepare thermal comfort for their users. However, the consumption of nonrenewable energies can be minimized using potentialities of these houses. This investigation tries to study thermal behavior of the wind catcher room of Rasoulian house in Yazd which nowadays has been changed into a classroom, for architecture students. In addition to thermal behavior at the traditional status, climatic methods which were implemented at this space are also introduced and analyzed; this study also reviews some other researches in order to find some solutions for improving thermal behavior and minimizing nonrenewable energy consumption. Therefore, some methods are explained to use the potentialities of this building with making minimum changes in the body of the building to prepare thermal comfort for its users.

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INTRODUCTION

Rasoulian house in Yazd is one of the valuable traditional houses inherited from our ancestors. This house and some other buildings such as Laary house, Kermani house and Kasmaei house together make the Art and Architecture Faculty of Yazd University. There are several reasons for changing the application of this building which among the most important ones is maintaining its historic and valuable texture.

Rasoulian house in Yazd, like other traditional buildings in this region, has been built in kiblah direction (northeast – southwest) which makes it convenient for both hot seasons and cold seasons. Regarding the fact that this building must be used all around the year after changing its application, it needs a lot of nonrenewable energies to provide thermal comfort for its users. Also, using many of climatic elements such as wind catcher has been abandoned; this occurs because of the current conditions of the building and desired condition of new generation. Despite their current condition, these elements can be used again and the consumption of nonrenewable energies can be reduced.

This investigation tries to study and compare thermal behavior of Rasoulian house as a summer-stay building at its traditional status, the current implemented status and the proposed methods for its improvement. It should be mentioned that at its traditional status, wind catcher transferred cool and fresh air into the room at day time and It has been discharging air from room and replacing cool and fresh air from central courtyard at night by means of the chimney effect. In the implemented status though, wind catcher has been changed into the vent-hole and it transfers cool and humid air by fans from the shallow which is placed just under this space. In the proposed solution, wind catcher must be changed into vent-hole and must use intensive suction; this way, the air is sucked from inside this space and the cool and humid air is transferred into the space; his occurs without any fans. In the forthcoming sections, each of these items will be explained completely. In this study, the potential uses of this building with making minimum changes in its body is explained in order to provide thermal comfort for its users.

The wind catcher room of Rasoulian house in Yazd

Yazd has placed between 29°,48′ to 33°,30′ of northern latitude and 59°,45′ to 56° ,30′ eastern longitude from meridian, near the central desert of Iran. It is hot and dry with very hot summers and very cold winters. The yearly temperature change in Yazd is about 58°c Its maximum temperature is 45°c with relative humidity of 12% in summer and its minimum temperature is -13°c with relative humidity of 73% in winter.

Rasoulian house, together some buildings such as Laary house, Ghazi Nasab and Kasmaei house, has made the Faculty of Art and Architecture of Yazd University. This building is placed in Mosallaa-Atigh neighborhood. This is one of the oldest neighborhoods in Yazd. Mosalla is a part of Goudul-e-Mosalla Quarter (Figures 1and 2). Currently, Mosalla neighborhood is in the center of Yazd, between Emam and Qiam streets. This was one of

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the most important parts of Yazd because it was placed near bazaar.

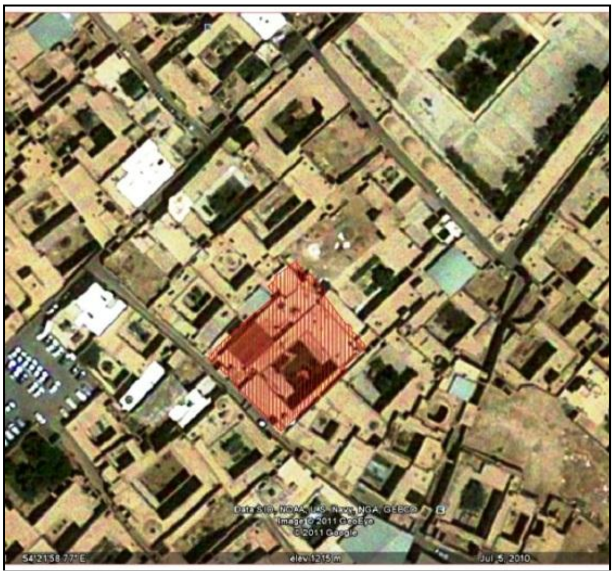

Figure 1. Arial photo of Rasoulian house

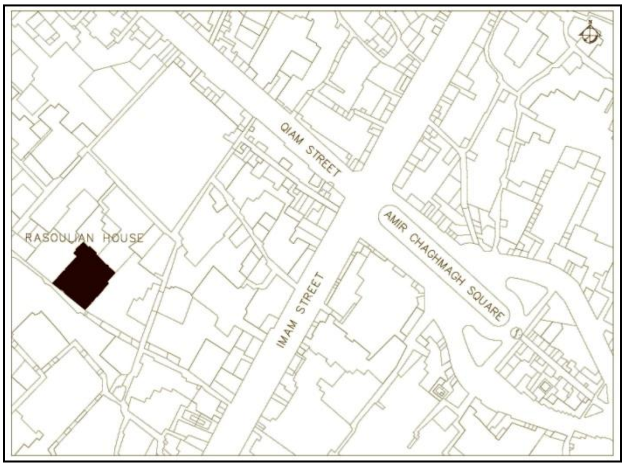

Figure 2. The position of the Rasoulian house in Yazd urban context

Rasoulian house in Yazd, like the other traditional buildings in Yazd, has been built in kiblah direction (northeast-southwest) which makes a convenient place for both hot and cold seasons. This summer-stay place includes cellar shallow, underground spaces in the southwest and northeast forehead, wind catcher room and hall in the southwest forehead. Winter-stay place of it includes a room with three doors, another room with five doors and a room with seven doors in the northwest and northeast.

Wind catcher room is in southwest which was used in hot seasons by family. Due to the changing in its application, this room is now a classroom for architecture master students (Figure 3). Climatic solutions are to be considered for preparing thermal comfort which will be explained in the following sections.

The first solution is its direction to the northeast southwest line. This results in placing some spaces places toward sunlight and some behind it. Some spaces such as wind catcher room is receiving direct sunlight only at the first and last hours of the day; during the other hours it enjoys shade. In addition, “because of the great height of the wind catcher room, which reduces temperature by itself, and the position of the sun behind the space, it makes a shading region against the central courtyard." (Figures 4 and 6)(Kazemi et al., 2012)

Using proper materials such as brick on floors, walls and ceiling for summer-stay parts Yazdis another solution against intense and onerous heat in the summer Yazd Because of their high heat capacity, the materials store the heat during the day and this way "the inside surfaces of the building take to their maximum temperature much more later than the outside surfaces" (Kasmaie, 2006)

In addition to what was mentioned above which is common for all summer-stay buildings, the natural ventilation also plays an important role in the wind catcher room of Rasoulian house. The wind catcher and pergola in this space make an air flow resulting in thermal comfort. This will be explained in the forthcoming sections.

A B C

Figure 3. A) View of outside the wind catcher room of the Rasoulian house in Yazd; B) View of inside the wind catcher room of Rasoulian house in Yazd; C) Floor plan of the Rasoulian house in Yazd

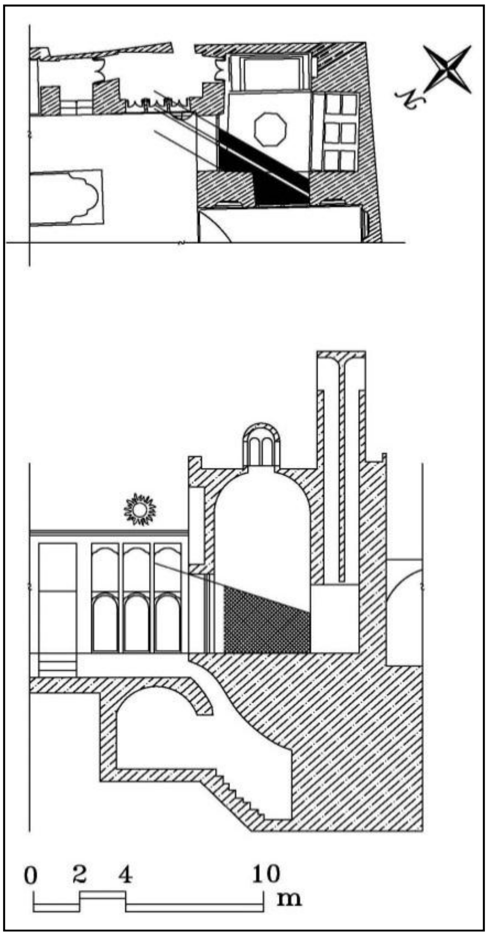

Figure 4. Sun position in Jun 22 (morning)

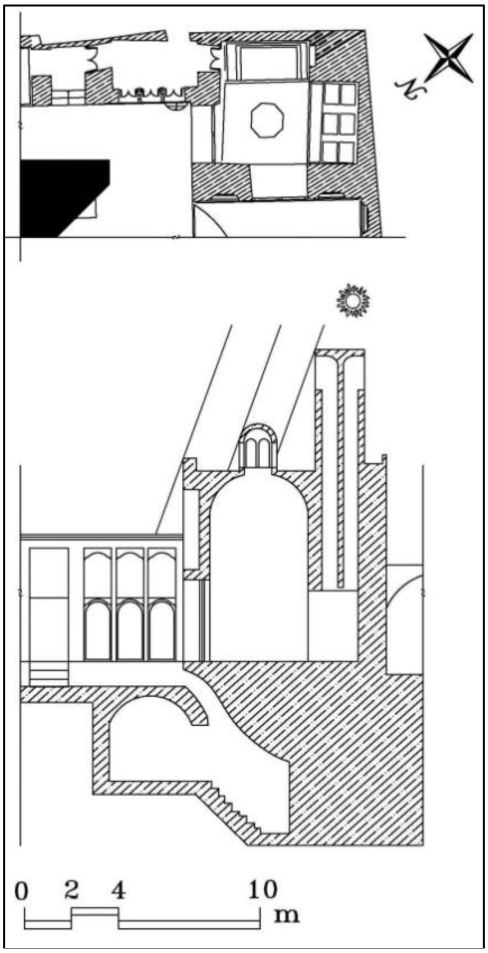

Figure 5. Sun position in Jun 22 (Afternoon)

The thermal behavior of wind catcher room in Rasoulian house at its traditional status:

The wind catcher room of the Rasoulian house has several elements and features for thermal comfort at its traditional status. Some elements such as wind catcher and pergola, the connection between sash doors and the space of hall and central courtyard and great height of this space provide continuous air flow resulting in temperature reduction. Overall, the thermal behavior of wind catcher room can be studied during the day and night which is to be mentioned in the coming sections.

1. The thermal behavior of wind catcher room in Rasoulian house during the day: During summer days and specially during the mid-day hours, sash windows were closed and wind catcher and pergola together caused air flow and natural ventilation. Thus, channels of wind catcher located toward the wind received the fresh and cool air during the windy days and the other channels which were placed against wind, according to Bernoulli effect, played the role of vent-hole and transferred the hot air out of the room (Mahmoudi et al., 2008). On the other hand, pergola and the air flowing within it, based Bernoulli effect, was another factor for sucking hot air. According to what was mentioned above, it can be concluded that cool and fresh air was transferred into the room in such a way that it lost its hot temperature; the suction of the other channels of wind catcher and pergola caused natural ventilation (Figure 6).

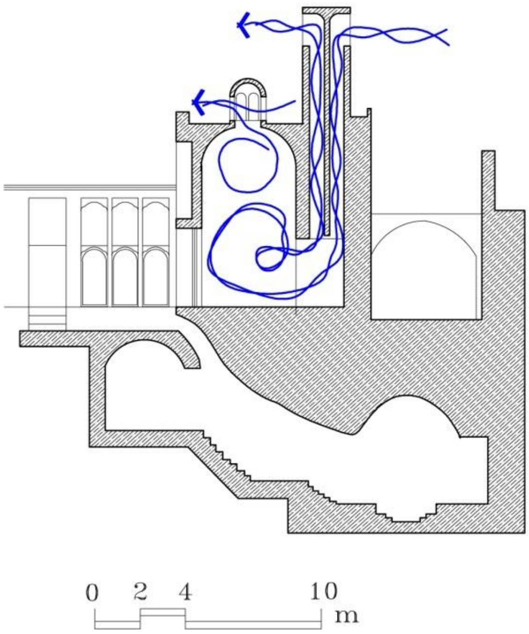

Figure 6. The natural ventilation of the wind catcher room at traditional status during the day

2. Thermal behavior of wind catcher room in Rasoulian house during the night:

At the end hours of the day and during the summer nights, sash windows were opened toward the hall and the central courtyard. Wind catcher which was warmed during the day, operated as a solar chimney. It should be mentioned that pergola caused sucking the air out of the room during night, too. Thus, the air in the central courtyard which was cool and humid because of water pool and trees, was transferred to the room (Figure 7).

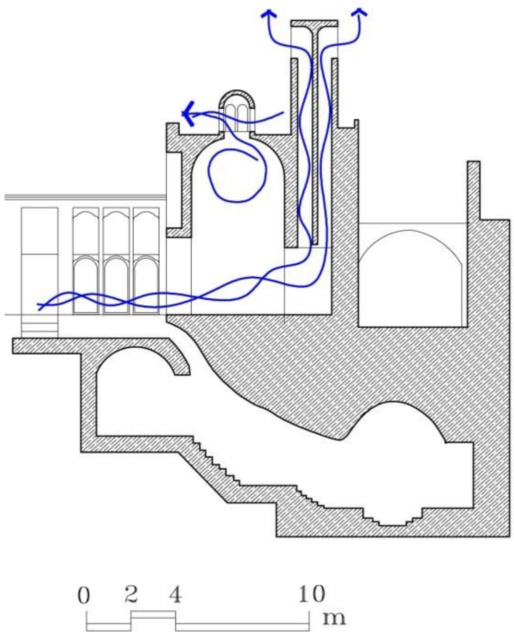

Figure 7. The natural ventilation of wind catcher room at traditional status during the night

The thermal behavior of the wind catcher room in Rasoulian house at implemented status:

Due to the intense and onerous heat in Yazd and its current air pollution, the use of wind catcher's suction capability rather than its donation was taken into consideration in the reviving plan of building of Art and Architecture Faculty of Yazd University. On the other hand, the temperature in shallow locating under the ground below this place, "is constantly 19.7°c in most times of the year" (Pourahmadi et al., 2011). Thus, the connection between these two sections by digging a channel was discussed to transfer the cool and humid air into the room by means of the wind catcher capability. To achieve only suction behavior of wind catcher, the designing team decided to close the trap door (shutter) in the lower part of wind catcher instead of placing a trap-door at its stem (Figures 8 & 9) (Ayatollahi, 2002)

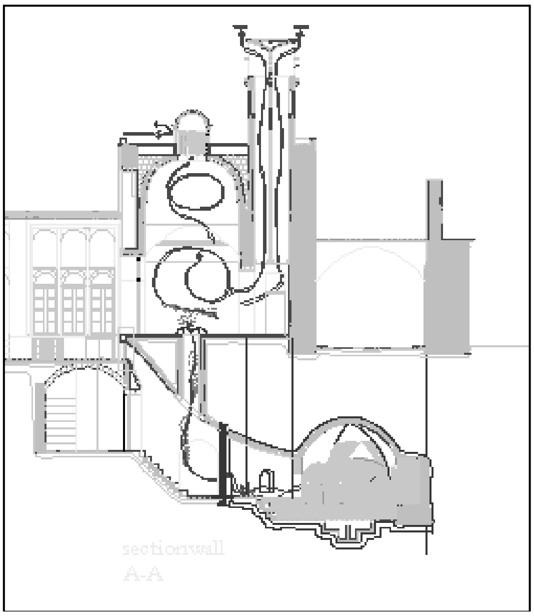

Figure 8: method of ventilation based on the designer team expectation in the implemented design

Figure 9: installed trap-door on the stem of the wind catcher and closing the lower trap-doors.

After implementation of the mentioned idea, it was not able to meet designer team's expectation. Therefore, there wasn't a considerable difference in reducing the temperature of the room. This system had several deficiency including improper operation of wind catcher suction and insufficient air flow from shallow into the room. Then, the designer team decided to use an electrical fan for supplying sufficient air flow. Using the electrical fan wasn't a good idea either, because in addition to electrical energy consumption, this was far from the targets of the green architecture and noiseless structure. On the other hand, with flowing considerable air per unit of time, cool and humid air (19.7°c) is replaced by relative warm air and expected coolness and humidity decreases gradually.

Thermal behavior of the wind catcher room in Rasoulian house at proposed status:

Since implemented experience in the wind catcher room of Rasoulian house wasn't successful practically, this paper tries to examine its weaknesses and disadvantages by the use of the new methods of the green architecture in order to improve the thermal behavior of wind catcher room.

The most important weakness of the implemented status was failing to supply proper natural ventilation from shallow to wind catcher room. In fact, without using electrical fan and forced air flow, there isn't any air ventilation. One of the most important reasons for this failure is the improper suction behavior of the wind catcher; this is because trap–door on the stem of wind catcher can't provide the necessary suction. Suction channel is small and can't provide the expected air flow for reducing the room temperature. It is necessary to increase the speed of the suction; this is impossible by passive process. It is clear that more suction of air flow from shallow to the room is necessary for increasing cool air flow without active methods. Thus, the target is attainable if we remove the failures of the implemented status; this way, the target is met by increasing the suction of the wind catcher and inlet air flow.

1- Increasing the rate and surface of the wind catcher suction:

It is clear that increasing the surface of the air suction and its speed at the same time is necessary to increase the power of the wind catcher suction. According to the considerable average rate of ventilation by solar chimney in hot and dry climate (for July 22, it is estimated to be about 0.269 m^3s^{-1}" (Saghafi et al., 2012). It seems that using solar chimney is the best method to increase the wind catcher suction. Using glass for the front part of the wind catcher toward sunlight (for head in it toward southwest), it can be changed into solar chimney and consequently the wind catcher will increase its operation.

If southwest forehead of the wind catcher which is in front of sunlight is covered by glass, the inside of wind catcher is changed into a solar chimney and by considerable increase in the temperature of inside this surface, the speed of suction increases since suction surface is in this forehead and by this change, all the channel takes a suction status; also, the trap-doors in the lower part of the wind catcher can be opened in order to significantly increase air suction area. As the speed of the air suction increases, the air flow ventilation also increases. On the other hand, the storage mass for heat time is delayed since the heat inside the solar chimney during the night is necessary for solar chimney efficiency during the day and night. Since wind catcher is built by brick and it has a proper volume, its storage mass is good and the use of glass for all its surfaces can build a solar chimney.

2-Increasing the rate and quality of the inlet air:

Another failure for implemented status of Rasoulian house is the low rate of air flow from shallow to room. Increasing the channel diameter is the most proper method for increasing the rate of the inlet air from dug channel; therefore, the volume of the inlet air flow is increased without the speed of the suction. Another problem that may occur by this method is the loss of the coolness and humidity quality of the air inside the shallow with increasing the rate of the transitioned air flow into the room, while water pool in shallow was full of the water for solving this problem. Thus, using water jet and increasing evaporation rate can result in decreasing the replaced air rapidly and increasing its humidity. Moreover, in order to make one opportunity for air humidification and reduce its temperature by making a non real ceiling between movement path and connection path with wind catcher room, suction air from the outside of the space is transferred as a forced air flow to the lowest part of shallow and water pool and is then transferred into the wind catcher room. It seems that the use of proposed principal and policy significantly increases system efficiency.

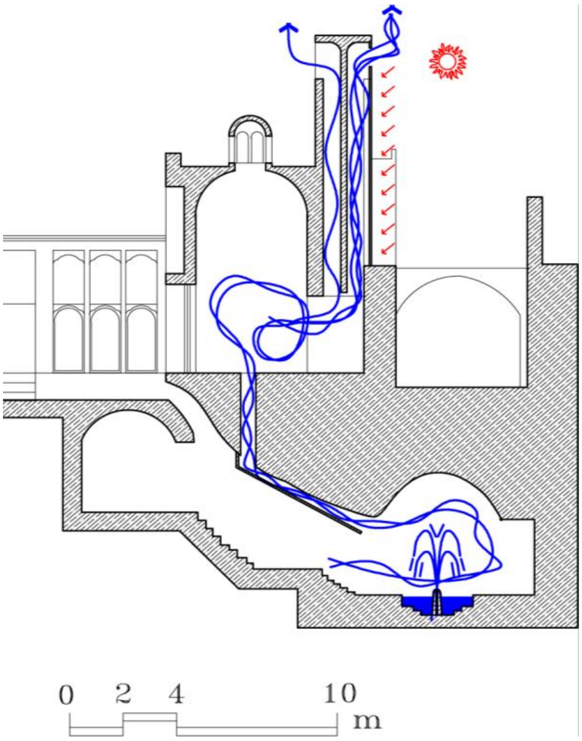

Figure 10: proposed status to improvement the thermal behavior of the wind catcher room

Figure 11: the path to direction air flow to the lowest part to shallow

CONCLUSION

Yazd traditional houses are the valuable and precious inheritance from our ancestors; therefore, some actions must be taken for their protection and maintenance. Since the new generation uses these spaces during the whole year, nonrenewable energies are significantly needed. On the other hand, some climatic elements of these building such as wind catcher aren't used anymore and they actually lost their role.

The nonrenewable energies consumption of the wind catcher room in Rasoulian house can be minimized by the use of the potentialities of this building and this, to a great extent, has been considered by students of master of science studying architecture. In the traditional status, the cool and fresh air was transferred into the room by the wind catcher and hot air was vented by holes in the suction state of wind catcher and pergola.

In the implemented status, wind catcher has been changed into vent – hole for transferring cool and humid air into the room. This method isn't operated naturally and a fan has been used in this case with its undesirable noise.

In the proposed status, wind catcher makes a solar vent-hole and transfers cool and fresh air into the room as a result of changing the setting of the transition air flow. Thus, by making some few changes on the body of wind catcher room in Rasoulian house, a lot of nonrenewable energies can be saved or even can be decreased to zero.

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