The Role of Cellars in Reducing Energy Consumption in the Residential Architecture of Iran

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Received: 28/ 2/ 2014; Accepted: 16/ 11/ 2014

Abstract

According to research, between 15 to 20 percent of the total energy consumption of every country is used for residential spaces. This amount is explanatory of the high cost and will follow the destruction of natural resources and environmental demolition. The aim of this research is to recognize earth thermal ability and its usage in public buildings and especially in private buildings in order to reduce energy consumption which can lead to huge savings in natural resources. It is intended to pay attention to the role of cellars as underground spaces in reducing energy consumption in residential spaces in this research. Cellars which are one of the climatic elements were very useful in residential spaces in the past and underground spaces in cities and public spaces are using in the contemporary era. Native Iranian architecture has exclusive features in residential spaces. One of the reducing energy consumption techniques is using ground depth and underground spaces in private and public buildings. Pit gardens, *Shovadan*, aqueducts, lavers, cellars with natural abilities in coldness, warmness and support are examples of underground space uses (providing cooling, heating and storing food and goods) in Iranian cities. The Main questions of this research are: what the role of undergrounds or cellars was in native Iranian architecture and how impressionable it was in reducing energy consumption. The theoretical framework of this study indicates that several factors had positive impacts on reducing energy consumption in cellars. To do this research, descriptive-analytical methods were uses and were analyzed according to case studies in Qazvin houses. The results of this study reveal that cellars had a main role in human thermal comfort and they caused reducing energy consumption in residential and even public spaces. Also, several factors such as the cellar's depth, height and dimensions had impacts on the reduction amount of energy consumption and the level of their impact was different.

Keywords: Energy, Climate, Underground Spaces, Housing, Cellar.

1. Introduction

One of the main issues in architecture is sustainability and design according to the environment. Environmental sustainability cannot be achieved without the guidance of human activity to conserve natural resources for the future. Environmental stability emphasizes on the reduction of energy consumption in the environment, reducing the production of harmful factors for human health and using recyclable resources. Yet, stability in architecture should advance in the direction of developing criteria that accentuate minimum energy consumption, use of reusable material, preserve and renew energy without producing pollution.

Sustainable development approach in the field of architecture and urban design, especially energy efficiency with the reform of the planning, design and construction of public and private spaces, is very important. In the contemporary period, big cities and their centers with undesirable skeletal and population density suffer from different issues such as increased temperature, climate change and in result, high consumption of energy (Molaei, 2011, p.18).

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One of the symbols of sustainable architecture is traditional Iranian architecture that responds to ecological and energy proficiency issues in terms of both low initial cost and current cost and function of the building.

Now, it is necessary to begin architecture with a new approach associated with paying attention to our own native architecture in order to be able to prevent the decline of fossil energy resources.

Paying attention to main purposes of continental design in every of country continental groups and forecast of cases in order to realize to these aims will cause consistency and incorporation of building and generally residential environment with continental terms, economy energy usage in different dimensions and also can cause identification of architecture in every continent, as traditional architecture of different country regions has special identification (Kasmaei, 1992, p. 305).

Many researchers have been accomplished in the field of constant architecture and native architecture of Iran. First, this essay worked on features and capability of ground, underground spaces and cellars in residential architecture. Then, the role of cellar was investigated in case studies of Qazvin houses and their influence was observed in reducing temperature.

This article tries to answer the two following essential questions:

1. What are the capabilities and features of underground spaces and cellars in residential architecture in reducing energy?

What are the roles of cellars in reduction of energy?

2. Research method

For access to desirable results in this essay, research method is descriptive-analytic and they were based on written and library information such as books, essays and sites and collection of available maps which are outcome of cultural inheritance and the writer objective observation and finally the writer analyzed them with survey of cause case studies and results were reported. Case samples are from Qazvin, so that 12 samples were surveyed from housing that had cellar and 6 samples were chosen according to space variety. The instruments which were implemented in this research were digital meter and thermal thermometer through which measure of dimensions and temperature accomplished in yard surface and cellar. And also measurement was done from morning till moon in each case sample. Numbers of measuring temperature were 3 consecutive days and numbers and information are given in average.

3. Theoretical basis

The practice of architecture can trace its origins back to the human civilization. Originally buildings are merely human – made structures used or intended for sheltering and occupying, so they have negligible negative effect on the natural environment. (Shanghai, 2012)
The main purpose of residential building construction is to provide comfort and preserved space against undesirable condition in outer environment for their citizens. Generally, thermal comfort can be defined as feeling convenience with putting in an artificial and biological space. The concept of thermal comfort is different for various people (Koch-Nielsen, 2011, p. 45).
One of the continental tactics for having thermal comfort is to sink the heart of solid and construction spaces in underground in order to use from soil's thermal capacity in different seasons of year (Zandieh & Parvardynezhad, 2010, p. 9).
Thermal benefits can be mentioned as the profits of ground physical. Temperature inside the soil or stone in depth below than 500 meters presents medium thermal environment in comparison with high thermal of ground surface in most of the world. Usage of the ground provides huge accessibility of energy source support and advantages of energy storage (Carmody & Sterling, 1993, p. 27).
Briefly, there are 4 essential tenets for energy storage via the earth. These tenets are:

1. Reducing direction (transition)
2. Descending maximum of air ventilation
3. Controlling air influence
4. Cooling through evaporation

These tenets of energy economy were put in most of the buildings which had underground spaces.
Constructing houses inside the earth accomplishes in some ways:

- In order to reduce thermal building waste
- In order to reduce wind influence in thermal building waste
- To Preserve of building against warm air
- To control daily fluctuations in temperature

Atmospheric factors and fluctuations of thermal degree have little affection on underground buildings and ground shell prevents building against these changes like a buffer. Storm and wind cannot permeate inside the ground and also ground shell prevents thermal transfer to inside the ground, like a thick thermal impediment. The more is the depth of the building from the ground, the less are the changes of thermal degree because the thickness of the soil is more and below the depth of 6.1 meters the earth temperature is fix and equals the average of annual temperature in the outside of that location. Fixed thermal degree of ground depth in every place can almost be calculated by measuring wells water thermal (non-thermal wells) in that place (Ghobadian, 1998, p.27).

4. Usage of ground energy in heating and cooling

Usage of ground is one of the methods through which cooling in can be made in the building. In this method, it can cool the external surface of building indirectly with capturing heat from soil on which the building is resided. Also, it can cool building and absorb the heat of building parts by circling water with in building parts (Zandieh & Parvardynezhad, 2010, p. 9).
According to accomplished studies, the soil temperature under the building is almost equal with medium temperature in region during a year. So, underground temperature in warm months is less than temperature of ground on floor spaces.
Building shell loses a part of its heat through complete or trivial contact with its underneath soil, and indirectly causes coolness in the inner spaces. Cooling and heating through the ground is not useful for the big buildings. Because, placing necessary instruments need a lot of money for launching them. Mechanism of air transmission from underground spaces before its entrance to the building, is one of the methods that causes cooling and it has been common for decades, though (Koch-Nielsen, 2011, p. 180).
When the weather is cold, the ground is the source of the heat. So, when the weather is so hot, the ground provides a cooler source (Barker, 1989, p. 59). Because of few fluctuations of heat degree in underground and of little contact with outside air, the heat degree is almost fixed.

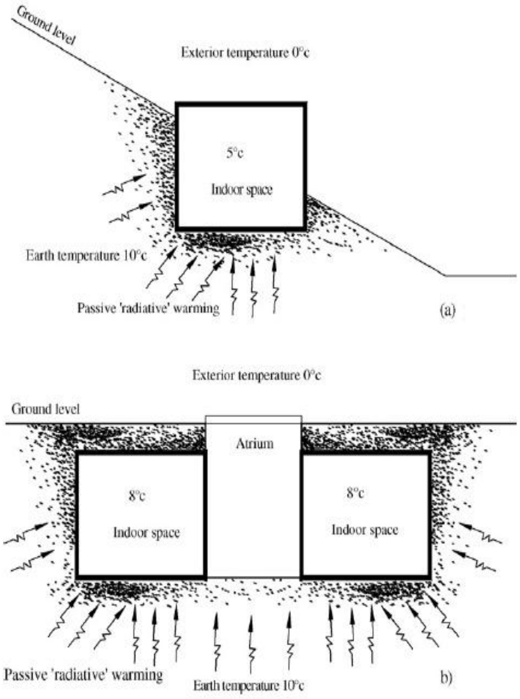


Fig. 1. Effects of PAHS and passive cooling on earth shelter indoor space in summer: (a) elevation or slope design and (b) atrium or courtyard design.

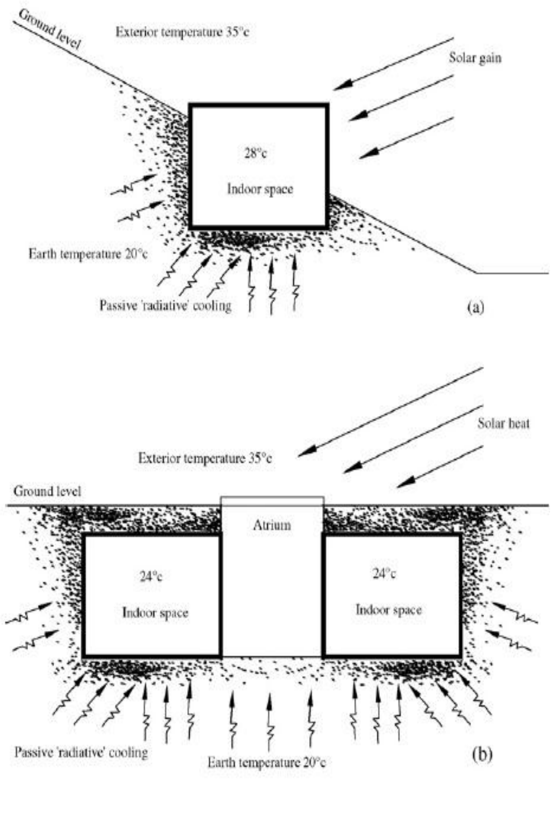


Fig. 2. Effects of PAHS and passive cooling on earth shelter indoor space in winter: (a) elevation or slope design and (b) atrium or courtyard design.

In Fig. 1, in summer that the outside temperature has been 35°, the temperature of the inside ground space has reduced because of coldness passive radiance and in case (a) (a part of the building is outside the ground) is reached to 28°. And in case (b) (the whole building space is in the ground) is reduced to 24° and in winter the reverse of this takes place.

Fig. 3. Mirianzadeh's cellar in Qazvin

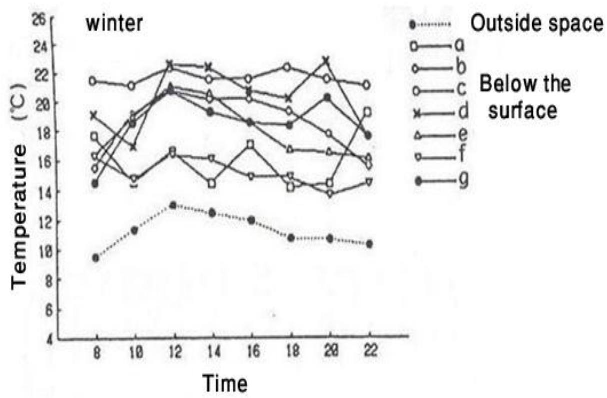


Fig. 4. The comparison of underground space temperature and surface in the underground malls in summer and winter (Source: Golany & Ojima, 1996, p. 188)

In this field, some researches can be mentioned in public spaces. According to one accomplished research in Tokyo (Japan) underground malls, their temperature is colder than outside in summer and warmer than outside in winter (Golany & Ojima, 1996, p. 188).

5. Usage of the soil's thermal capacity in winter and summer in the underground spaces

Usage of the soil's thermal capacity in the winter and summer in spaces such as, undergrounds, cellars and *shovadans* is because the ground is almost unlimited thermal source. Its capacity of thermal storage provides using it for storage of seasonal heat .The temperature of soil in lower depth of 20 feet (6 meters) is almost constant and equal to the average of year surface temperature.
Hence, the existence of summer and winter spaces and usage of ground depth and living in the heart of soil have had positive results (Zandieh & Parvardynezhad, 2010, p. 19). For example, underground has been a space for serving launch and having rest at the afternoon in Iran and most lands.
Also, usage of spaces like cellars and *shovadans* with the use of high capacity in the temperature of soil and sometimes the existence of water in them effectuate a pleasant space in continents with severe heat in the ground floor spaces.

6. Qazvin's Cellars

From case studies in Qazvin, 6 houses selected which had cellars as following:
Behrouzi, Aminiha, Asadi, Jalil, Arazi, Mirianzadeh (Yazdi), Mahmood Beheshti.
In these cases, the temperature of yard and cellars as well as the height of cellar from yard were checked and analyses and reducing energy amounts were done according to these information and statistics.

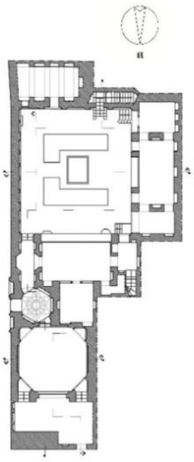
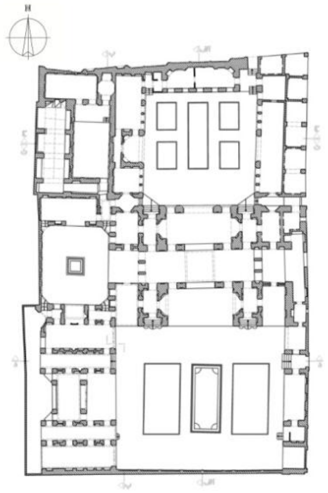
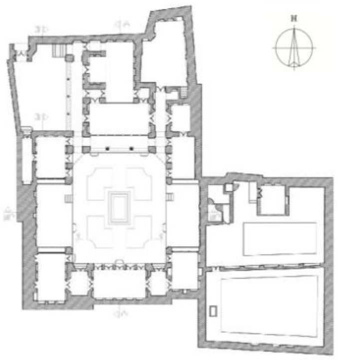
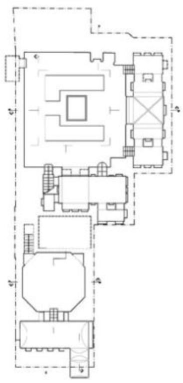
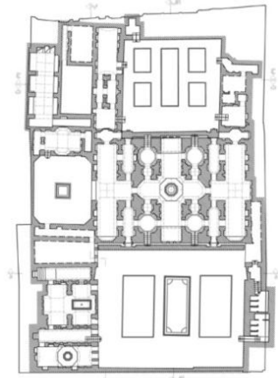
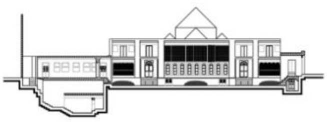
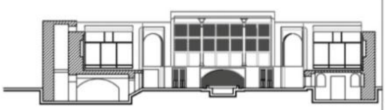
The investigation has been done in October. The differences of the depth of cellars in different houses can be seen in accordance to maps and segments and accomplished researches. In table 3, the depth of cellar from yard and also the difference among existed thermal degree are presented. Using this information, it can be said that: the reduction of thermal degree became more with increasing the depth of cellar. It is worth noting that the average of thermal degree in Qazvin Weather Station is 18° at the time of the investigation in which the minimum and maximum is 34 and 3/2 degree, respectively. The maximum of temperature in the year was 42/4 degree in July and the minimum of year temperature was 17/2 in January.

According to table 1, the temperature difference between yard and cellar in Beheshti's house was 2 degrees with reducing the depth of cellar from the floor of yard.

Table1
Statistical information from Qazvin houses

House	Yard's length	Yard's width	Yard's temperature	Cellar's temperature	Difference of thermal degree in yard and cellar	Depth of cellar from yard	Cellar's height
Behrouzi	14	12	28°	24°	4°	1.75	2.76
Aminiha	26.7	22.8	33°	23°	10°	2.74	3.37
Asadi	11.78	10.74	31°	28°	3°	1.5	2.36
Jalil Arazi	11.48	9.95	24°	20°	4°	1.74	2.7
Mirianzadeh	14.7	10.9	32°	27°	5°	1.55	2.4
Beheshti	11.6	11.2	31°	29°	2°	0.96	2.06

Table 2
Maps of mentioned houses in Qazvin

	Asadi's house	Aminiha's house	Behrouzi' house
Plan			
Under ground plan			
Section			
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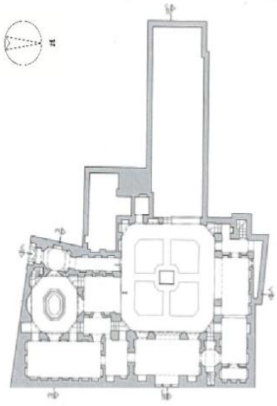
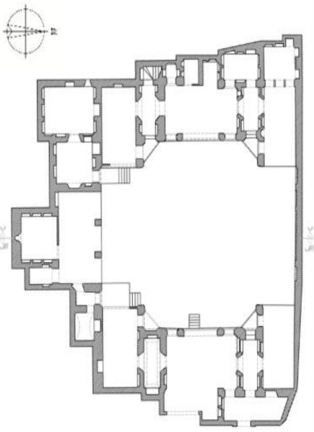
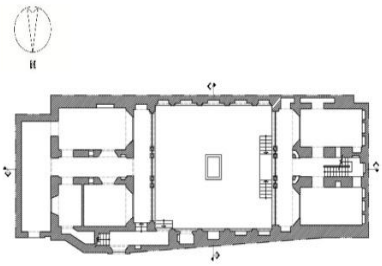
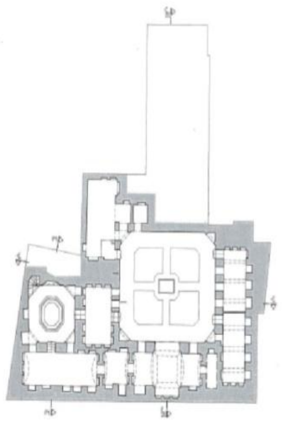
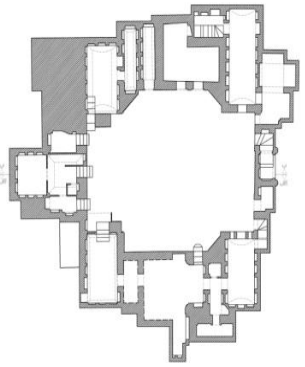
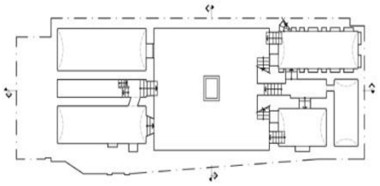
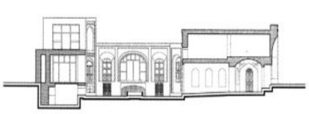
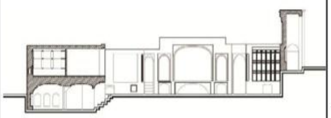
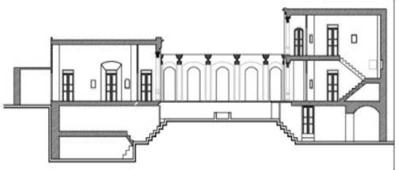
(Source: Maps: cultural heritage record of Qazvin, Pictures: The authors.)

Table 3
Maps of mentioned houses in Qazvin

	Beheshti' house	Mirianzadeh' house	Jalil Arazi' house
Plan			
Under ground plan			
Section			
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(Source: Maps: cultural heritage record of Qazvin, Pictures: The authors.)

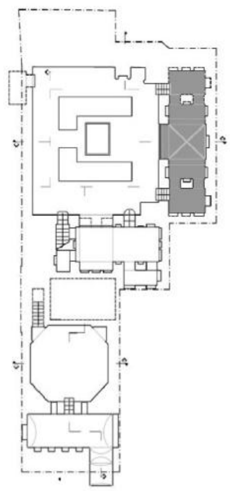
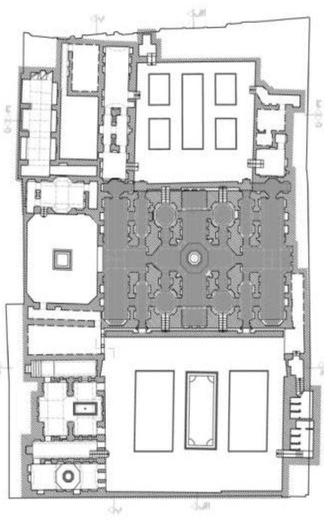
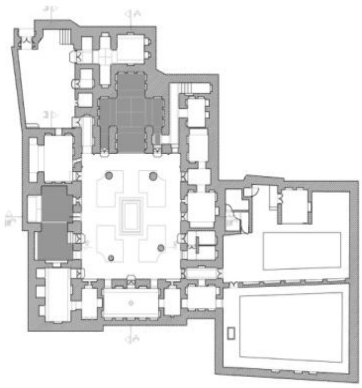
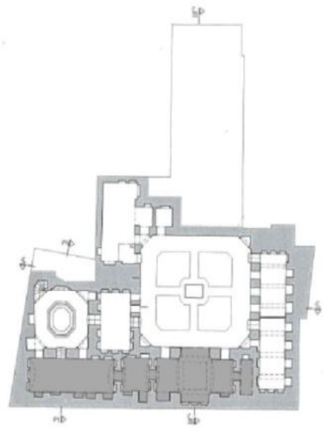
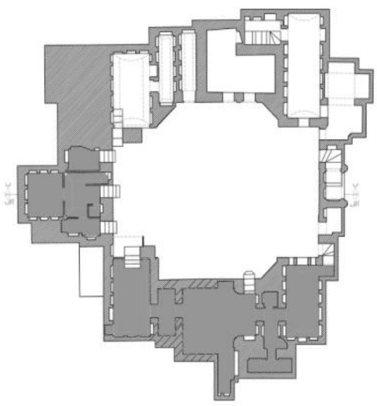
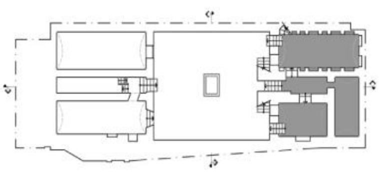
While the investigation of the whole cellars was not possible according to restrictions at the time of the visiting, the location of investigated cellars are presented with gray in table 4.
Measured temperatures and reported statistical analyses in determined cellars have been done.

7. The role of cellar in reducing energy

The effect of cellars and underground spaces in reducing energy depends on several factors. These factors are:

1. The depth of cellar
The below graph is drawn according to table 3 and investigated information that accordingly it can be said that the different temperature and reducing temperature in summer has a direct relation with the height of cellars from yard (sinking in depth of ground). Although, the inclination of lines was different, they worked in ascendant way. It means that the difference of thermal degree became more with increasing height.

Table 4
The cellar has been reviewed

Asadi's house	Aminiha's house	Behrouzi' house
		
Behesht' house	Mirianzadeh' house	Jalil Arazi' house
		

(Source: The authors)

2. The height of cellar
Based on the observations, 2 drawn graphs are operationally similar to each other (Fig. 6 and 7). Accordingly, it can be said that height of the cellar like the depth of the cellar has a main role in the difference of thermal degree. The more height of cellar caused increases in the hatches of the cellar and provides entry of air to these spaces in the summer besides creating development in visual sight to the yard. These hatches are covered in order to prevent waste of energy in the winter.

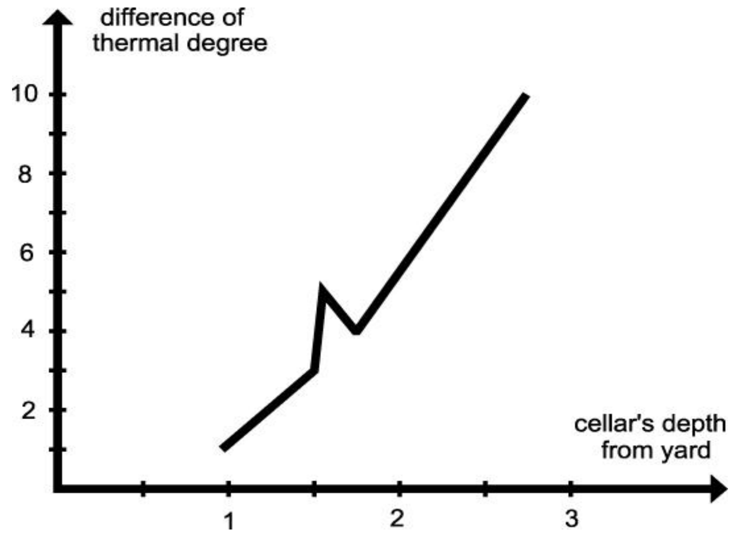


Fig. 5. Relation of the depth of the cellars from yard and difference of thermal degrees.

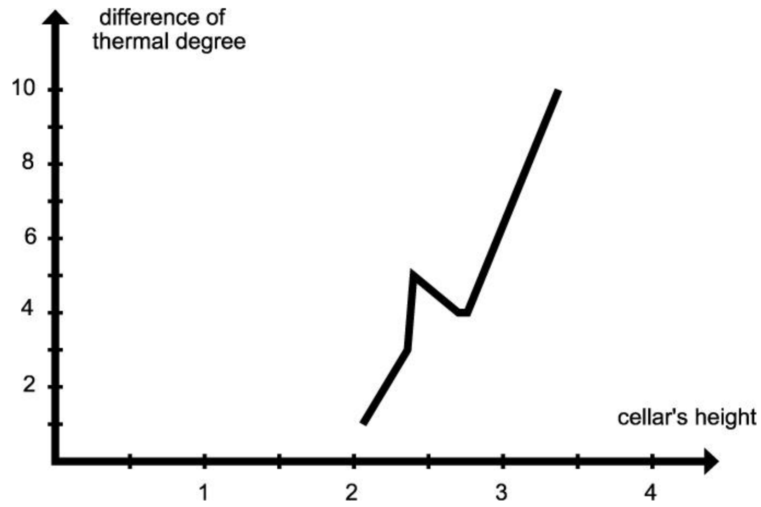


Fig. 6. Relation of the height of the cellar and difference of thermal degrees.

Based on Table 1, the reason of leap in above 2 figures is the existence of thermal degree differences in Aminiha's house and the depth of cellar from surface and also the height of cellar in this sample were more and the thermal degree temperature became more in this case because of the pool, more hatches, air entrance channels in this cellar (which have not been observed in other cases) as well as more area of cellar surface.

3. The dimensions of Yard
According to the drawn graph in Fig. 7, the difference of thermal degree has almost been increased with length and width increases of yard, but it did not have directly influenced more energy reduction. More width and length of the yard caused more hatches (like Aminiha's house), thus caused more passage of the air and wind within the cellar. So, it help the cellar become cool in the summer, especially if there is a shadowy trees in the yard that they

cause freshness in the air of environment, they direct more cool air by hatches within the cellar. Finally, it can be said that the length and width of yard did not have main roles in increasing the thermal temperature difference and consequently, they did not have direct influence in reduction of energy use but, as mentioned before, they had a role in reduction of energy use indirectly.

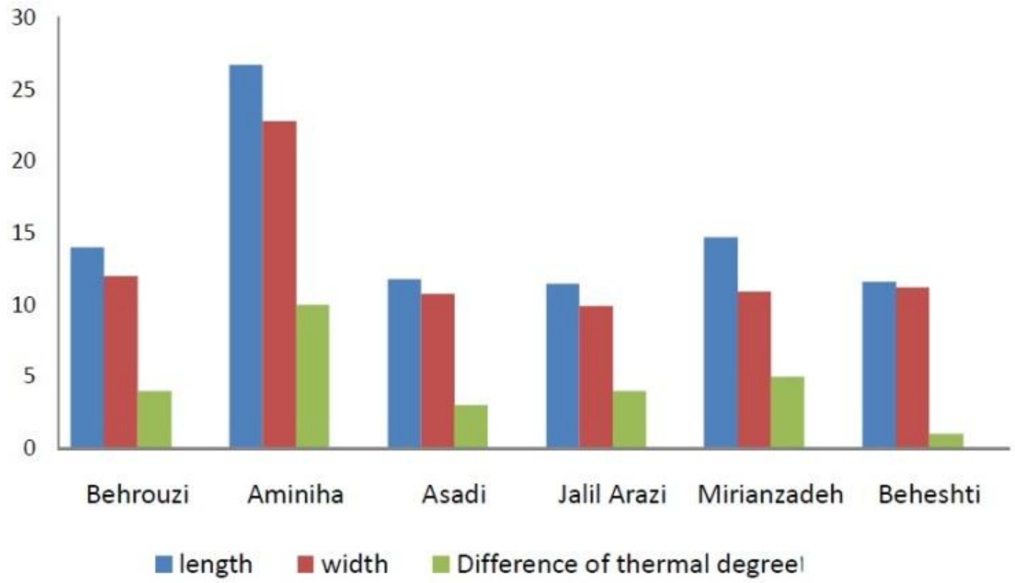


Fig. 7. Relationship among congruence, yard dimensions (width and length) and difference of thermal degree

4. Cooler factors
Pools and air inlet channels in cellars help to cool and fresh the space in the summer. Inlet channels lead the air to the space like windward. Pools and channels of air inlet in Qazvin cellars were only observed in Aminiha's house that the factors that mentioned above and the influence of air channels and pools have been the causes of high difference in thermal degree in relation to other of cases. According to the fact that height and depth of cellar in the Aminiha's house are more than other cases, remarkable point of the difference of cellar thermal degree belongs to air channels.

8. Conclusion

Generally, it can be said that underground spaces and cellars have been continental elements in the past which had important roles in thermal comfort of people. Thermal comfort was provided by these elements in winter with increasing temperature and in summer with reducing temperature. These reducing and increasing temperature caused energy economy.
As it is mentioned, there were many factors affecting the reduction of energy consumption by cellars and undergrounds spaces that their intensity of influence was different.
These factors are:
- Cellar depth: the difference of thermal degree and reduce of temperature has a direct relationship with cellar height from yard in summer.
- Cellar height: also, the cellar height has a main role in the difference of thermal degree like cellar depth.
- Dimensions of yard: as it is mentioned above, the temperature difference in thermal degree became somewhat more with length and width increases of yard, but they did not have direct influence on reducing energy.
- Cooler elements: this factor did not have a direct role in reducing thermal degree but it was effective in reducing energy consumption beside other factors.
These factors have had determinant roles in measuring energy reduces, directly and indirectly. Other factors influence reduction of cellar thermal degree. These factors include cooler elements (pool), geography direction of cellar, the skylight of cellar from the yard, ventilation, cellar material, and herbal cover of yard each of which were effective indirectly and their intervention were less than considered factors. So, their interventions have been removed from measurement. According to presented contents, these geography-continental counsels are using in design in order to help energy economy as far as it can based on reducing energy sources, today.

Note

All sources of whole table maps: cultural heritage organization, Mohammadzadeh, 2006.

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