



## Comparison of heat loss and air infiltration through the openings of Qajar and Pahlavi era houses in Tabriz

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### Abstract

The rapidly growing world energy use has already raised concerns over energy resources and greenhouse gas (GHG) emissions. Since the global contribution from residential buildings towards energy consumption, has steadily increased between 20% and 40% and as large openings have considerable energy and heat loss in dwellings, this paper establishes a coefficient of heat loss and air infiltration through large openings in 10 historic dwellings (Qajar and Pahlavi era) in Tabriz, Iran. The results show that although Qajar era houses have larger windows than Pahlavi era equivalents, the rate of heat loss of openings per square meter of facades ( $\dot{H}$ ) and the air infiltration per square meter of facades (FA) of openings for Pahlavi era houses is more than the Qajar era equivalents. Therefore Openings of Qajar era houses have been designed more efficient than those of the Pahlavi era. Although the generally accepted way of building energy saving houses in cold climate has been to use small windows, the results indicates that instead of exploiting small openings in facades, it is possible to enlarge the windows to get better lighting conditions and simultaneously decrease the area of openings per square meter of facades for lower heat loss through these openings.

**Keywords:** Heat loss, Air infiltration, Qajar, Pahlavi, House, Openings.

### 1. Introduction

Increasing population and the rising energy demand has led to a vast increase in the consumption of fossil fuels, resulting to the arising of greenhouse gas (GHG) emissions which increase the risk of climate change [1]. The scarcity of fossil fuels and the likely rises in energy prices over the next two decades is a challenging factor for the global energy sector [2]. The impact of energy consumption and growing number of people predicates a rapid growth in demand in the coming years [3]. According to one survey on energy consumption in Iran, about 38% of total energy consumed in year 2001 has been used for space heating [4] and residential with commercial buildings are responsible for 41% of the energy consumptions in Iran [5]. Thus residential buildings can have an important role in reducing the environmental effects of indoor space heating. Since 9.2% of energy transfer in buildings happens via the windows, they are interpreted as interested as one of the major means by

which building occupants control the indoor environment [6, 7].

The cultural value of traditional buildings as part of the built environment raises the question of their energy use. The long held principles of conservation are being challenged to use less energy and by proxy emit less CO<sub>2</sub> in buildings designed at a time when fuel consumption or emission reduction was not a priority [8]. Traditional buildings in Iran are classified according to their era: Safavi (1501-1736 AD), Afsharie (1736-1760 AD), Zand (1760-1796 AD), Qajar (1796-1925 AD) and First Pahlavi (1925-1941 AD) [9]. Shagagi and Mofidi [10] studied the texture and body of the buildings in the cold climate of Tabriz and analysed the strategies of designing buildings for this climate. Kaynejad and Shirazi [11] highlighted the process of transformation of spaces and the way spaces were reorganised over four different time periods: from the early, middle and late Qajar dynasty to the era of the First Pahlavi monarch (1796-1941 AD). Vahid ghubadian when writing about building forms indicates that one of the characteristics of buildings in cold climate is small openings [12]. The results of an article written by Arne Roos, and Maria Wall show that the size of the energy efficient windows does not have a major influence on the heating demand in the winter, but is relevant for the cooling need in the summer [13]. The coefficient of heat loss of openings ( $\dot{H}$ ) is the heat loss transmission through openings due to one degree difference between inside and

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outside temperature [11]. Air infiltration through large openings (FA) is the result of wind blowing through a large opening [14].

This paper analyses the air infiltration rate and the heat

transfer coefficient of 10 Qajar and First Pahlavi era houses in Tabriz, and obtained useful results about the energy transmittance through the openings. Details and facades of the case studies are at Fig. 1 and Fig. 2, [15, 16].

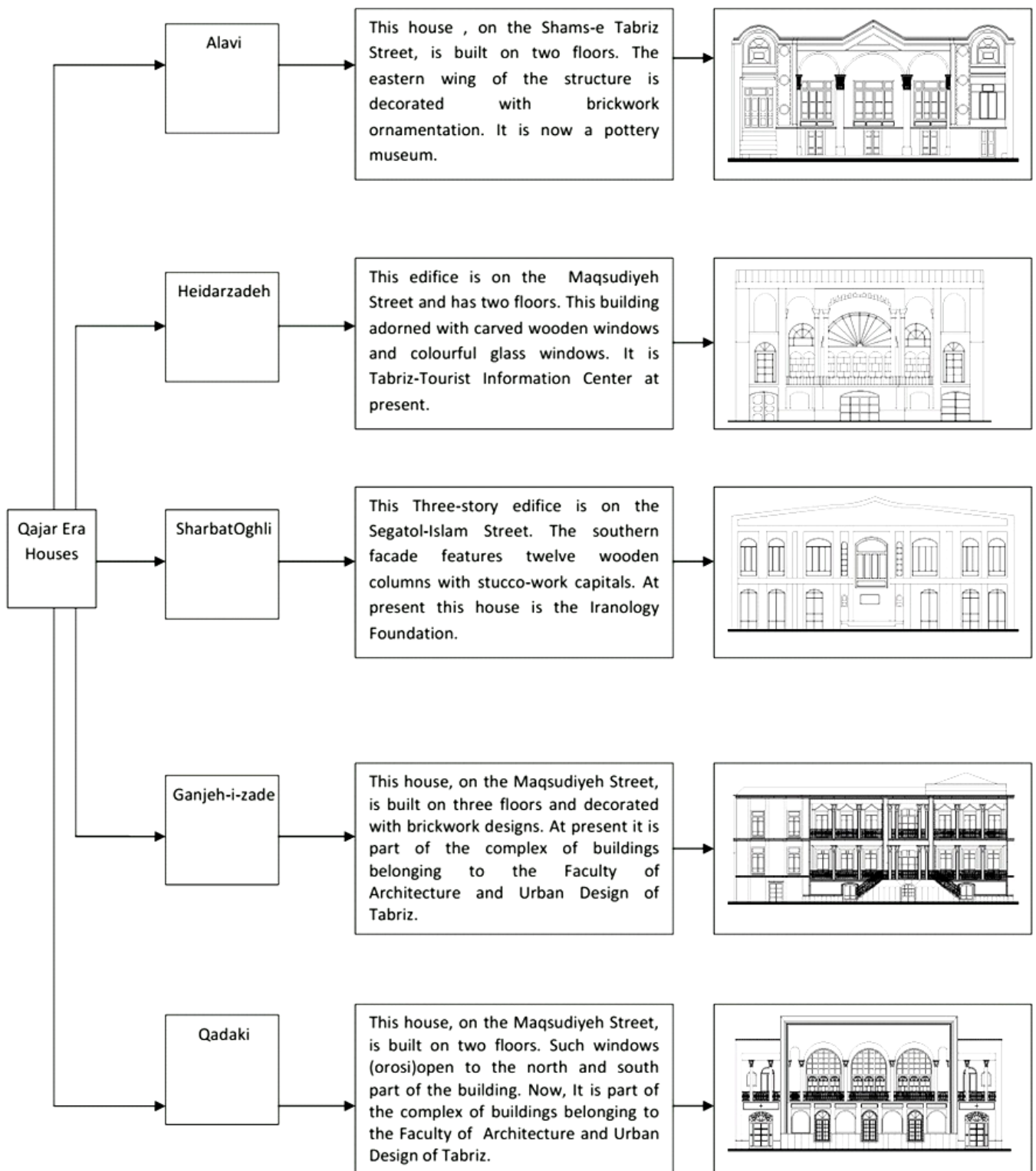


Fig. 1 Information and facades of Qajar era houses of Tabriz

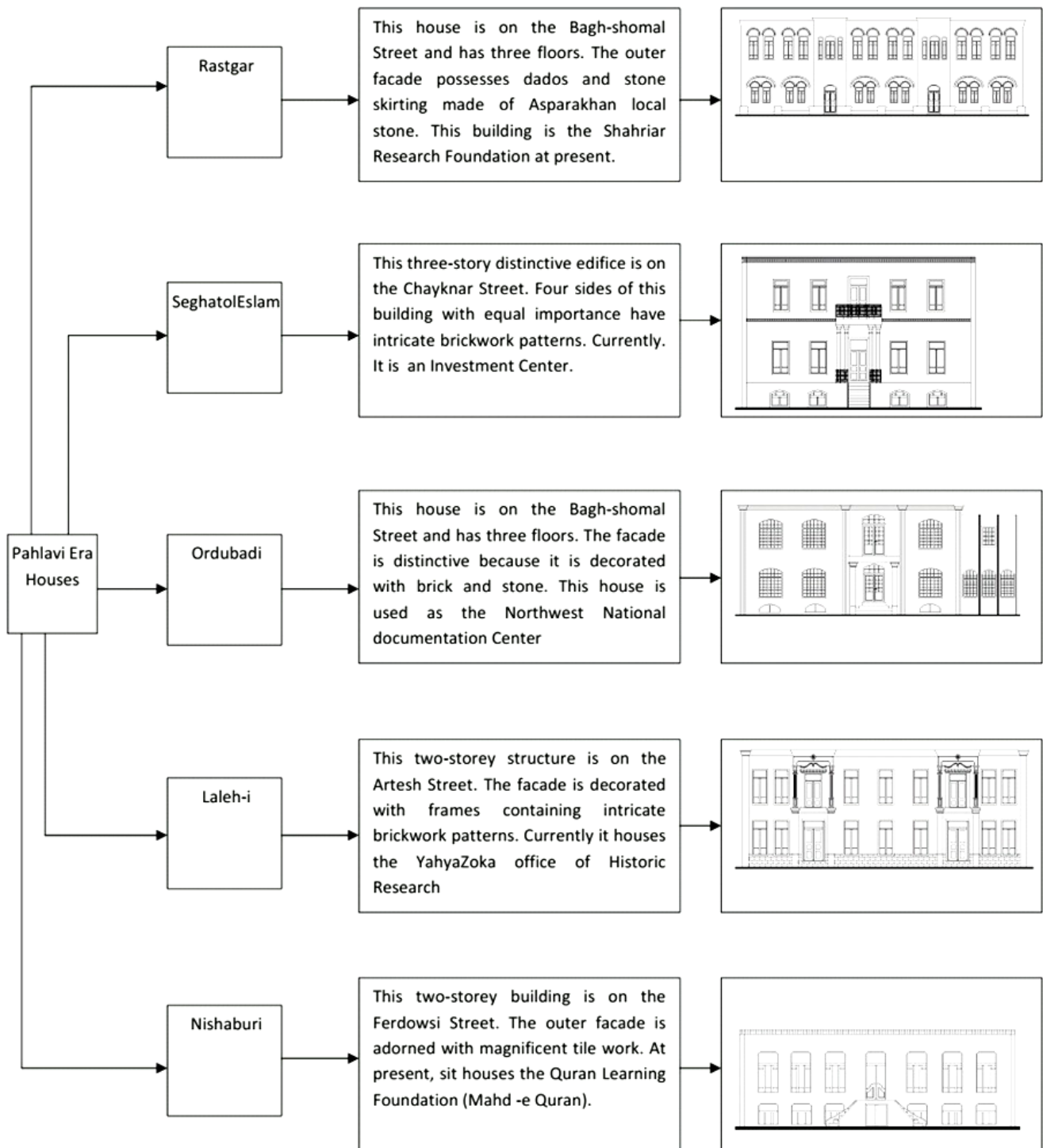


Fig. 2 Information and facades of Pahlavi era houses of Tabriz

## 2. Methodology

The project was carried out in four stages: identification and selection of houses, data collection for case studies, calculation and analysis. At the identification phase, 10 historic houses(Qajar era: Alavi, Heidarzadeh, SharbatOghli, Ganjeh-i-zade, Qadaki.Pahlavi era: Rastgar, SeghatolEslam, Ordubadi, Laleh-i, Nishaburi) were selected based on era and accessibility. Weather data for

the last 60 years was obtained from the Meteorology Bureau. Documented dimensional data on the buildings was found to be inaccurate or incomplete, and therefore measurements of openings was carried out. Table1 shows key parameters recorded, (A) indicates the area of facade, (ALW) the area of largest windows. Formulas for calculation phase are as below:

$$\hat{H} = A_G * U_G * R_G + A_D * U_D \quad (1)[11]$$

$\widehat{H}$  = Required coefficient of heat loss of openings (w/k)  
 $A_G$  = Area of translucent layers including frame (m<sup>2</sup>)  
 $U_G$  = Whole window coefficient of heat loss of translucent (w/m<sup>2</sup>.k)  
 $R_G$  = The average ratio of area of translucent layers with frames to area of translucent layers without frames  
 $A_D$  = Area of external doors (m<sup>2</sup>)  
 $U_D$  = Required coefficient of heat loss of external doors (w/m<sup>2</sup>.k)

$$F_A = E_0 \times A_o \times V/2 \times 1000 \quad (2)[14]$$

where:  
 $F_A$  = Air infiltration rate (L/s)  
 $E_0$  = Effectiveness of opening expressed as a unit less factor.. (Assume an average value of 0.40 for worked examples)  
 $A_o$  = Area of openings (windows and doors) (m<sup>2</sup>)  
 $V$  = Average seasonal wind velocity (m/s). The velocity is divided by two to account for the actual effect of the wind on infiltration [17].

It should be considered that Qajar and Pahlavi era houses have different area of facades and openings. In order to compare the results for the case studies, the required coefficient of heat loss of openings per square meter of facades and air infiltration rate of openings per square meter of facades were determined. Then using  $A_G/A$  (Area of translucent layers per square meter of facades) instead of  $AG$  and  $A_D/A$  (Area of external doors per square meter of facades) instead of  $AD$ , and  $A_o/A$  (Area of openings per square meter of facades) instead of  $Ao$ .

In other words, the formulas will be:

$$\widehat{H} = A_G/A * U_G * R_G + A_D/A * U_D$$

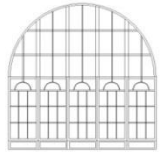
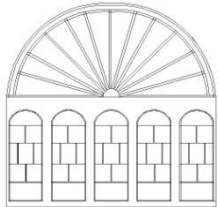
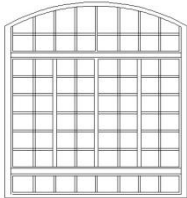
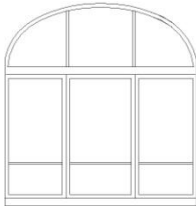
$\widehat{H}$  = Required coefficient of heat loss of openings per square meter of facades (w/k)


$$F_A = E_0 * A_o/A * V/2 * 1000$$

$F_A$  = Air infiltration rate of openings per square meter of facades (L/s)

In the analysis phase, we compared the obtained numerical results of formulas for Qajar and Pahlavi houses.

**Table 1** The Area of facades and their openings for Qajar and Pahlavi Era houses of Tabriz

Houses	A (m <sup>2</sup> )	A <sub>G</sub> (m <sup>2</sup> )	A <sub>D</sub> (m <sup>2</sup> )	A <sub>O</sub> (m <sup>2</sup> )	A <sub>O</sub> /A (m <sup>2</sup> )	A <sub>LW</sub> (m <sup>2</sup> )	Figure of ALW
Qajar Houses							
Alavi	720.0	54.72	18.44	74.21	13.65	0.1030	
Heidarzadeh	1065.0	93.081	20.24	113.38	5.00	0.1064	
Sharbatoghli	1091.2	109.40	28.82	138.22	14.62	0.1266	
Ganjeh-i-zade	1628.0	166.38	50.28	216.66	4.99	0.1330	

Qadaki	1030.0	178.13	35.37	213.21	13.11	0.2070	
Pahlavi Houses							
Rastgar	920.0	167.26	27.42	194.68	2.06	0.2116	
SeghatolEslam	562.0	104.22	28.13	132.35	3.40	0.2354	
Ordubadi	610.0	109.78	27.35	137.13	3.64	0.2248	
Laleh-i	163.7	56.73	18.25	74.98	4.6	0.4580	
Nishaburi	259.0	46.02	18.85	64.88	3.25	0.2505	

### 3. Location and Climate of Tabriz

Tabriz is located in northwest of Iran in East Azerbaijan province between Eynali and Sahand mountains in a fertile area in shore of Aji River and Ghuri River. (Fig. 3)

Tabriz has a semi-arid climate with regular seasons. The annual precipitation (any kind of water that falls from the sky as part of the weather) is around 380 millimetres



Fig. 3 Location of Tabriz

(15 in), a good deal of which falls as snow during the winter months and rain in spring and autumn. The city enjoys mild and fine climate in spring, dry and semi-hot in summer, humid and rainy in autumn and snowy cold in winter. The average annual temperature is 12 °C. Cool winds blow from east to west mostly in summer. Fig. 4 and Fig. 5 shows the precipitation and monthly average number of hours of sunshine per day for Tabriz.

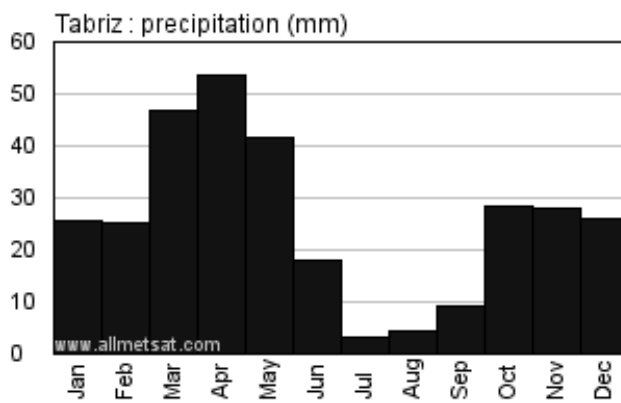


Fig. 4 Precipitation for Tabriz. (mm/inch)

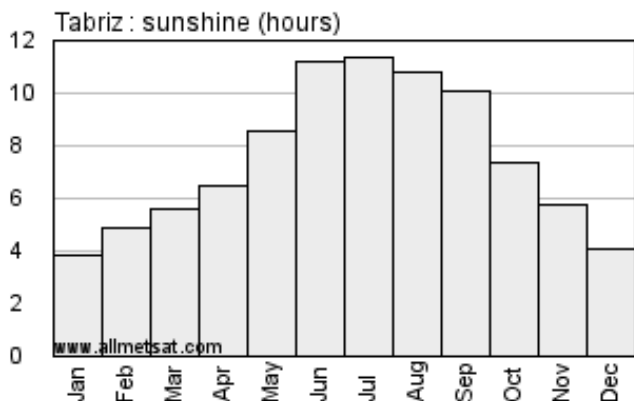


Fig. 5 Monthly average number of hours of sunshine per day for Tabriz

### 4. Analysis of Qajar and Pahlavi Era Houses

#### 4.1. Courtyards

Qajar era houses usually have two courtyards. Public courtyard is usually situated on the southern part of the house which lies at a level lower than the entrance. A pool is located in the middle, around which flower beds are arranged. Private courtyard is mostly located on the northern side. Access is gained either by means of a special front door or through the public courtyard and other indoor spaces (Fig. 6 and Fig. 7). In Pahlavi era houses only public courtyards were built (Fig. 8 and Fig. 9). [15].



Fig. 6 Public courtyard (1) and private courtyard (2) of Ganjeh-zade (Qajar era) house



Fig. 7 Public courtyard (1) and private courtyard (2) of Qadaki (Qajar era) house



**Fig. 8** Public courtyard of Laleh-i (Pahlavi era) house

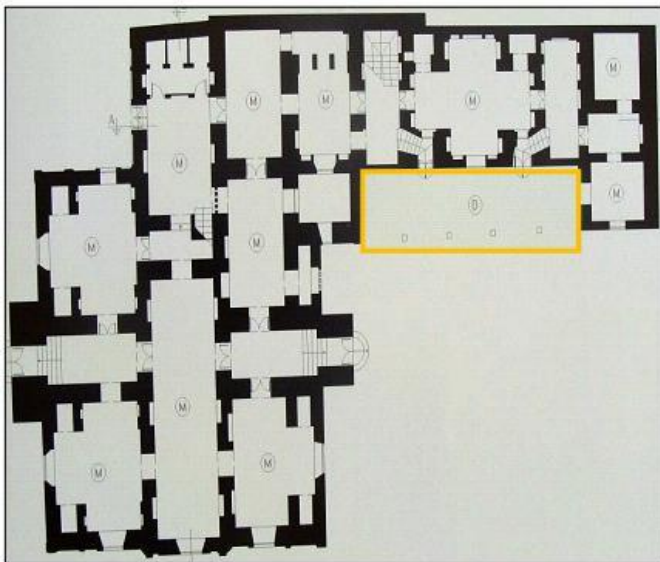


**Fig. 9** Public courtyard of rastgar (Pahlavi era) house

#### 2.4. Ivan

Ivan is one of the principal elements within a structure. In older houses, it is located in the range of the main axis of the construction. Ivans are often situated in the building in order to provide shade in the summer but they are not deep enough to prevent sunlight from reaching the full depth of reception hall in the winter. They are also designed to protect the windows against climatic phenomena such as rain and snow and also wind.

In Qajar era houses, the ivan is rectangular in shape and extends vertically to the main axis on the ground floor, running along the south reception hall. Over-all ivans are often franked by side rooms projected on either reception hall and are usually supported by a number of plastered columns with stucco-work capitals. These ivans are restricted on three sides and open on one side, and accessed through the courtyard (Figs. 10 to 15).



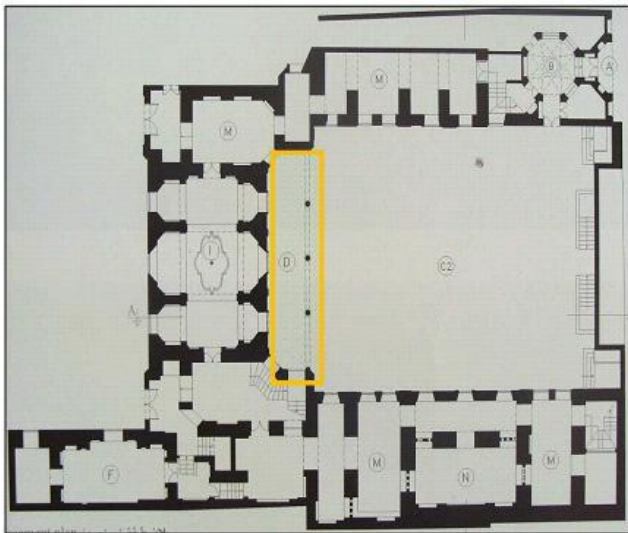
**Fig. 10** Over-all ivan in plan of Ganjeh-i-zade (Qajar era) house



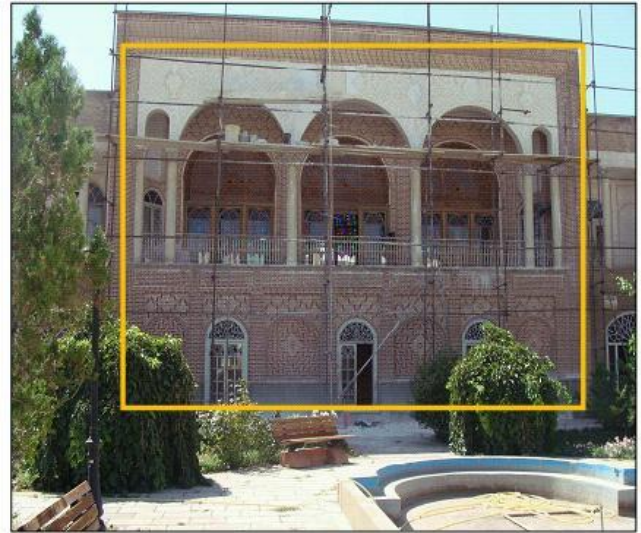
**Fig. 11** Over-all ivan in facade of Ganjeh-i-zade (Qajar era) house



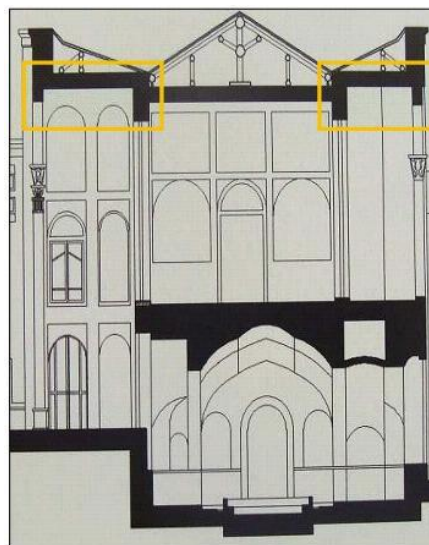
**Fig. 12** Over-all ivan(shelter for windows) in section of Ganjeh-i-zade (Qajar era) house



**Fig. 13** Over-all ivan in plan of Qadaki (Qajar era) house



**Fig. 14** Over-all ivan in facade of Qadaki (Qajar era) house

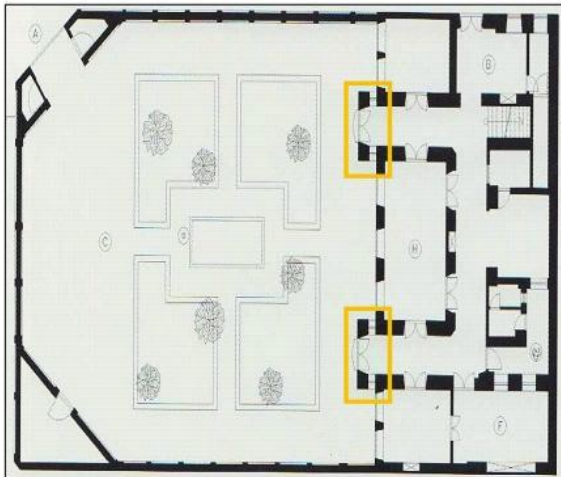


**Fig. 15** Over-all ivan(shelter for windows) in section of Qadaki (Qajar era) house



Pahlavi era houses have single ivans. This form indicates the extroverted character of architectural features during this era when ivans are projected outwards in order to draw the viewer's attention to the facade. Single ivans are allocated to a specific space through which one can gain access to them. They have the height of a one-storey building and since they are located on the upper floor of

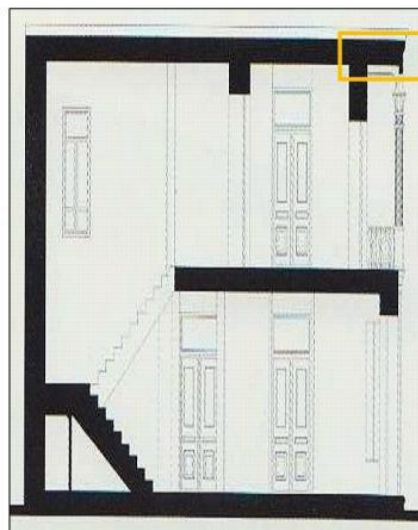
structures, they often feature a protective railing to prevent falls. Single ivans are supported by plastered columns with stucco-work capitals situated on the projected part of the ivan. Fig. 6 -16 indicate the differences of ivans in Qajar and Pahlavi era houses on plans, facade, elevation. (Figs. 16 to 21).[15].



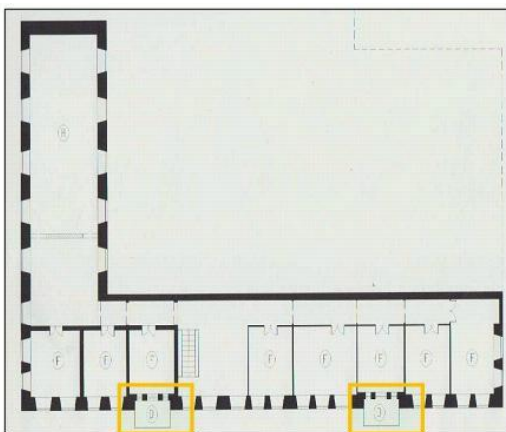
**Fig. 16** Single ivans in plan of Laleh-i (Pahlavi era) house



**Fig. 17** Single ivans in facade of Laleh-i (Pahlavi era) house



**Fig. 18** Single ivans (shelters for windows) in section of Laleh-i (Pahlavi era) house



**Fig. 19** Single ivans in plan of Rastgar (Pahlavi era) house



**Fig. 20** Single ivans in facade of Rastgar (Pahlavi era) house

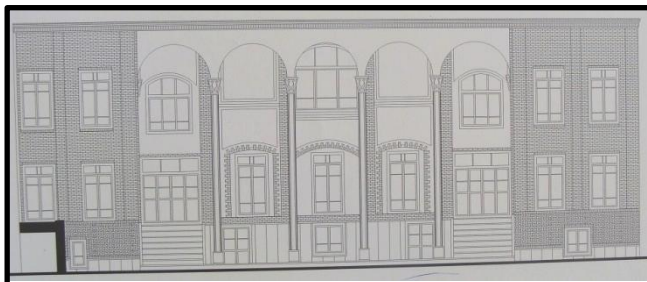


**Fig. 21** Single ivans (shelters for windows) in section of Rastgar (Pahlavi era)

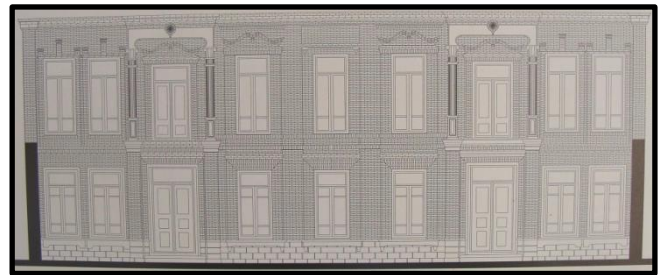
## 5. Results

Qajar era houses have larger windows. Pahlavi era

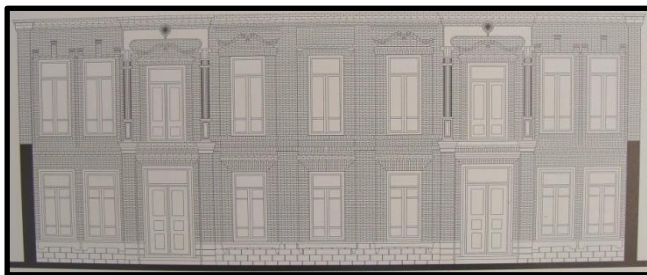
houses have more windows than Qajar era equivalents and also apply smaller windows. Figs. 22 to 25 shows the arrangement of windows for four houses.



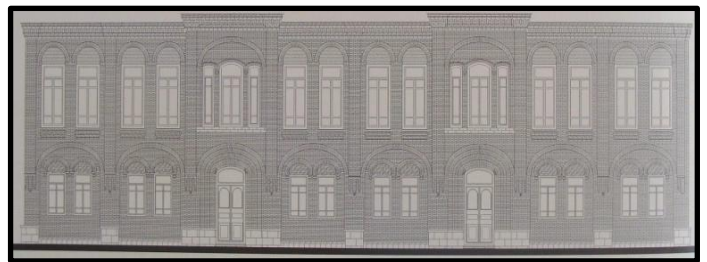
**Fig. 22** Arrangement of windows for Ganjeh-i-zade (Qajar era) house



**Fig. 23** Arrangement of windows for Qadaki (Qajar era) house



**Fig. 24** Arrangement of windows for Laleh-i (Pahlavi era) house



**Fig. 25** Arrangement of windows for Rastgar (Pahlavi era) house

The Area of facades and their openings for Qajar and Pahlavi Era houses of Tabriz are shown in Table 1.

Fig. 26 indicate that the area of largest windows (ALW) of Qajar era houses are larger than Pahlavi era houses. Accordingly, Qajar era houses have larger windows than Pahlavi era equivalents. In versus Area of openings per square meter of facades (Ao/A) for Pahlavi era houses is more than those in the Qajar era. (see Fig. 27).

The results of required coefficient of heat loss of openings per square meter of facades ( $\lambda$ ) and air infiltration per square meter of facades (FA) for case studies are at Table 2.

Values of ( $\lambda$ ) for Pahlavi era houses is more than Qajar era houses. Also, the heat loss of openings per square meter of facades for Pahlavi era houses is more than heat loss of openings per square meter of facades for Qajar era houses, see Fig. 28.

Also analysing the results at Table 2 shows that level of (FA) in Pahlavi era houses is higher than Qajar era houses. Therefore air infiltration per square meter of facades for Pahlavi era houses is more than air infiltration per square meter of facades for Qajar era houses, see Fig. 29.

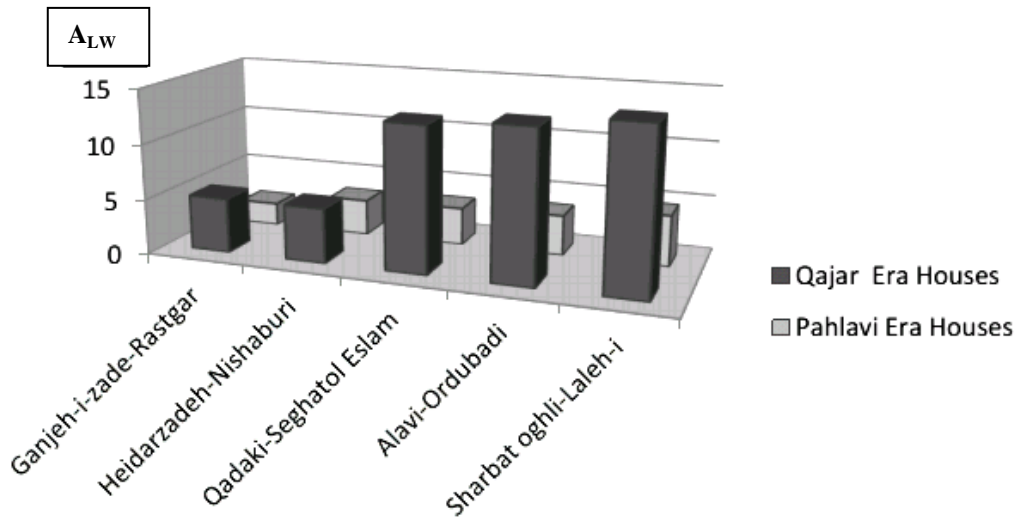


Fig. 26 Comparison of the ( $A_{LW}$ ) for Qajar and Pahlavi era houses of Tabriz

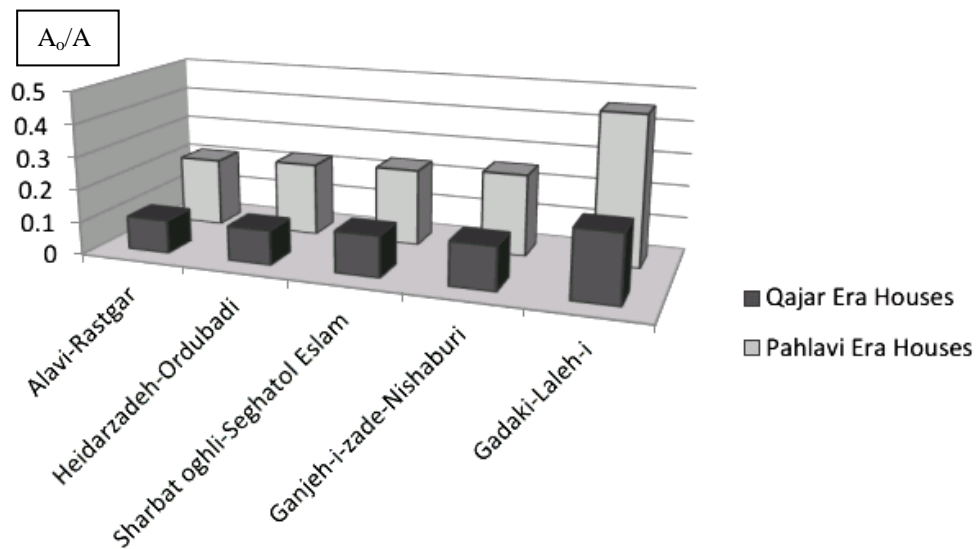


Fig. 27 Comparison of ( $A_o/A$ ) for Qajar and Pahlavi era houses of Tabriz

Table 2 The results of ( $F_A$ ) and ( $\rho$ ) for Qajar and Pahlavi era houses of Tabriz

Houses	$U_G$ ( $w/m^2.k$ )	$R_G$	$U_D$ ( $w/m^2.k$ )	$\hat{H}$ ( $w/k$ )	$V$ ( $m/s$ )	$F_A$ ( $L/s$ )
Alavi	2.7	0.5907	3.5	0.2108	5.1	0.1050
Heidarzadeh	2.7	0.7616	3.5	0.2462	5.1	0.1085
Sharbatoghli	2.7	0.4031	3.5	0.2014	5.1	0.1291
Ganjeh-i-zade	2.7	0.4191	3.5	0.2205	5.1	0.1356
Qadaki	2.7	0.5131	3.5	0.3595	5.1	0.2111
Rastgar	2.7	0.5713	3.5	0.3847	5.1	0.2158
SeghatolEslam	2.7	0.4953	3.5	0.4229	5.1	0.2401
Ordubadi	2.7	0.5144	3.5	0.4066	5.1	0.2292
Laleh-i	2.7	0.4393	3.5	0.8008	5.1	0.4671
Nishaburi	2.7	0.4332	3.5	0.4621	5.1	0.2555

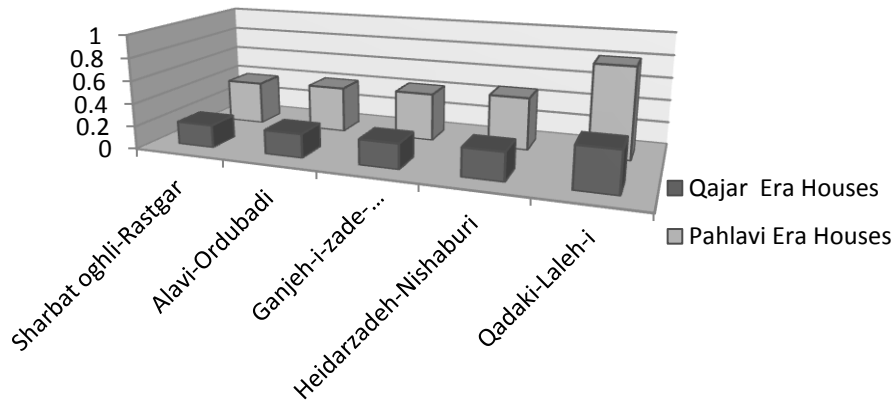


Fig. 28 Comparison of ( $\dot{H}$ ) for Qajar and Pahlavi era houses of Tabriz

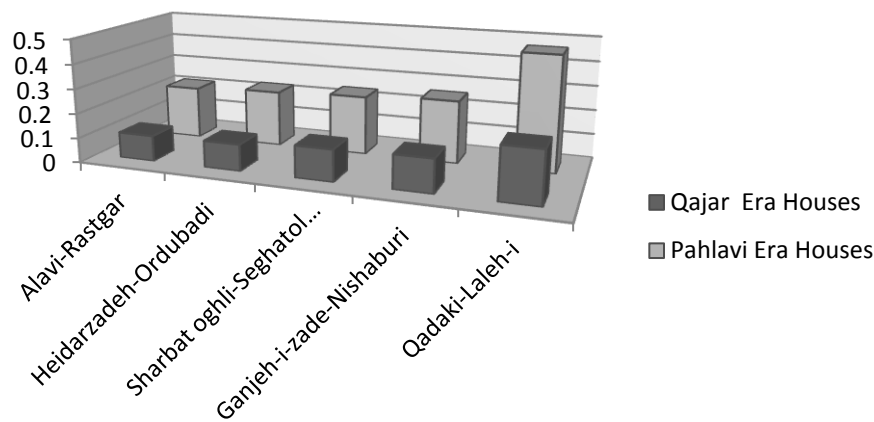


Fig. 29 Comparison of ( $F_A$ ) for Qajar and Pahlavi era houses of Tabriz

## 5. Discussion and Conclusions

By analysing of Qajar and Pahlavi era houses, it has been obtained that Qajar era houses usually have both public and private courtyards and in Pahlavi era houses only public courtyards were built. Pahlavi era houses have single and over-all Ivan and The arrangement of windows shows that Qajar era houses have larger windows. Pahlavi era houses have more windows than those in the Qajar era ones and use smaller windows.

The results obtained from analysing the tables and figures show that Qajar era houses have larger windows and less  $A_o/A$ . Also the rate of heat loss of openings per square meter of facades ( $\dot{H}$ ) and the air infiltration per square meter of facades ( $F_A$ ) of openings for Qajar era houses are less than Pahlavi era equivalents. Although the generally accepted way of building energy saving houses in cold climate has been to use small windows, the results indicate that instead of applying small openings in facades, it is possible to enlarge the windows to get better lighting conditions and simultaneously decrease the area of openings per square meter of facades for lower heat loss of openings. Therefore Openings of Qajar era houses have been designed more efficient than Pahlavi era equivalents.

Therefore we can use principals of openings of Qajar era houses to design future dwellings.

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