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Analysis of the photo–damaging performance of persian “orosi” in carpeted and non–carpeted spaces

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Abstract

Traditional building technologies have much to teach us about how to design regionally appropriate structures. The Orosi is one of these useful technologies, which has been used for many centuries in order to control the harsh sunlight in Iran. This architectural element was rather important because the intensive solar radiation could easily damage valuable carpets used in most spaces in Persian buildings. The main question of this research was how much could the traditional Orosi windows reduce the harmful spectrums of sunlight? In order to investigate this effect, a combination of field study, laboratory measurements, and case study research method was applied. Nine Persian traditional Orosi windows were chosen as case studies and the windows' geometric lattice (Gereh–Chini) and glazing color combinations were drawn and plotted. The experiment was carried out for carpeted and non–carpeted spaces. In order to measure the light transmission of the sample tinted glazing from the Orosi windows, a T80+ spectrophotometer was used. After calculating CIE and skin damage factors and visible transmittance for each piece of glass, an area weighting was used to calculate these factors for the entire Orosi. The results show a significant difference between CIE damage factors of the Orosis in carpeted and non–carpeted spaces; where the carpeted spaces had the least amount of CIE damage factor.

Keywords: *Orosi windows, Persian architecture, Tinted glass, Photo–damage, Solar transmittance, Carpet.*

1. Literature Review

Solar radiation is both the provider of daylight and energy, and a threat, which can cause overheating, glare, skin cancer, cataract, and other negative effects on the human health. Skin cancer is by far the most common kind of cancer diagnosed in many countries [1]. Ultraviolet (UV) exposure undoubtedly causes DNA damage of skin cells and is a major environmental risk for all types of skin cancers [2]. Recent studies show that wavelengths near the visible part of the spectrum, between UVA and UVB (around 315 nm) and specially UVA1 (340–400 nm), may be more carcinogenic than has previously been thought [3, 4]. The simple float glass, which is widely used in building facades, transmits a considerable part of the UVA spectrum, so that on average, an indoor occupant is exposed to 1,500 J cm^{-2} UVA exposure per year [5].

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Moreover, solar radiation can cause or accelerate the deterioration of many indoor building materials, especially recyclable/biodegradable ones, such as carpets, wood paneling, fabrics, furniture, books, and paintings. This damage ranges from discoloration (or yellowing) to a loss of mechanical integrity, depending on exposure levels and time. One the one hand, sustainable architecture, recommends using recyclable materials in buildings in order to reduce environmental impact; while it encourages the use of solar radiation in buildings in order to reduce the need for electrical lighting, despite the fact that most of the recyclable materials are greatly susceptible to degradation by solar radiation. This can cause a duality in the theories of sustainable architecture.

In order to reduce the photo–damaging effects of natural lighting, several strategies can be employed. Organic building materials can be protected by the use of light stabilizers and/or surface treatment, while human skin might be protected through sun–tan lotions and/or various clothing. But one of the best ways of protecting inside building materials is reducing photo–damage from the façade [6]. Therefore, the selection of appropriate glazing is very important especially in an environmentally–friendly building.

Human beings have been constructing environmentally–friendly buildings for millennia and have evolved house types that are well suited to particular climates, environments, and societies. This was done by learning from experience; and with the benefit of repetitive processes that help designers and builders through the complex range of tasks necessary to put a building together. Therefore, traditional building technologies have much to teach us about how to design regionally appropriate buildings.

Orosi, the Persian traditional window, is one of these useful technologies, which has been used for many years in order to control inward solar energy and daylight in different types of buildings in the hot regions of Iran [7]. The overall climate of Iran is semi–arid with clear skies, providing long hours of sunshine. The total annual solar radiation in Persia is estimated between 4000–7000 MJ/m^2 [8] which is above the universal normal value. Reported statistics represent around 280 days of clear sky in Iran, which shows a great potential and also a great danger. Orosi is a type of latticed window developed in Iran and surrounding countries (formerly known as Persia) in order to protect indoor from harmful radiation.

Orosi is composed of carefully–chosen, geometrically–shaped pieces of tinted glazing (typically in four different colors of blue, green, yellow and red) along with wooden geometric lattice (Gereh–Chini) that are assembled using the mortise and tenon technique, without any metal junction. Orosi was designed for practicality as well as beauty. Ahani has categorized four major roles for elements created to interact with natural light in traditional architecture of Iran (including Orosi): climatic, psychological, aesthetic, and symbolic/spiritual [9].

The Orosi's climatic function is based on the selective absorption of the visible part of the light spectrum. Even the modern smart windows relies on the adjusting of absorption in order to regulate their transmission [10]. Naee and collogues propose using tinted glazing mainly to increase visual privacy, reduce glare from the bright outdoors, and to reduce the amount of solar energy transmitted through the glass [11]. The use of Orosi creates a private space inside and increases interior quality by transmitting various colors of light. It also prevents glare by decreasing light intensity, and can even prevent overheating, by reducing energy transmittance of the inward light [12]. These features are well adapted with climatic conditions and social and cultural traditions of Iran (and other countries which used to be a part of former Persia).

The emergence of Orosi in Persian architecture is assumed to have taken place in the Safavid dynasty (1500–1736) [13] where it was commonly used in the main spaces of the buildings until the end of Qajar Dynasty in 1925 when it was replaced by modern float glazing. The Safavid dynasty is also called the "Golden Age of carpet weaving in Iran", as it was during this period that whole industries were established around carpet manufacture and the ruler of the time, Shah–Abbas, encouraged various arts and crafts [14, 15]. During this time and afterwards, valuable carpets began to be used in mosques, shrines and residential buildings.

The authors believe that there is a strong relationship between spreading the use of carpets and the emergence of the Orosi windows in Persian architecture. This is because reducing indoor light intensity was very important, since the intense solar radiation could easily damage valuable carpets used in most spaces. Thus, Orosi's performance in blocking the harmful spectrums of the sun is the subject of analysis in this paper. In order to investigate this effect, nine Persian traditional "Orosi windows" from carpeted and non–carpeted spaces were chosen as case studies and their geometry and glazing color combination were drawn and plotted, and the percentage of each glass sample in the whole Orosi window was quantified. Afterwards, spectral transmission from five glazing samples from the case studies were measured by the use of T80+ UV–VIS–NIR spectrophotometer. Then, CIE and skin damage factor for each glass sample was calculated based on ISO: 9050 standard [16]. Finally, area weighting was used to calculate these factors for the entire Orosi.

2. Study Area

2.1. Research method

The research method is a combination of case study, field survey, and laboratory measurements: case studies include nine Persian traditional Orosi windows, field surveys include surveying the geometric lattice of these glazing color combinations, and laboratory measurements include measuring the light transmission of the sample tinted glazing by spectrophotometer. Finally, a descriptive–analytical method was used to put the results of these parts together.

2.2. Choosing case studies

The first problem was to find unscathed windows, because most of the Orosi were victims of vicissitude during the years, either their geometry was damaged or their color combination was changed without leaving any documentation. Thus, after much research, nine different Orosi windows from six buildings, which had the least damages during the years, were chosen and studied.

2.2.1. Orosi windows of carpeted spaces

Most of the carpeted spaces in Persian architecture were multifunctional: the people sit on the carpets, have their meal on them, and also say their prayer on them. Muslims pray five times a day and they take great care to keep their place of prayer clean. So, most religious buildings, which were used continuously during the year (e.g. mosques) and most residential buildings, were covered with carpets and people took their shoes off in order to keep them clean. They also took their shoes off in holy shrines in order to show respect, and therefore these buildings were also covered with carpets. In the present study, two residential dwellings ("Dowlat–Abad" pavilion, "Reza Zadeh" house) and two continuously–used religious buildings ("Nasir Al–Molk" mosque and "Imamzadeh Zanjiri" shrine) were chosen and studied as samples of carpeted spaces:

- "Dowlat–Abad" pavilion was built for the governor of Yazd between 1752–4;
- "Reza Zadeh" building, was a house built between 1897–8 in Bushehr;
- "Imamzadeh Zanjiri", was a patron saint's shrine, built between 1844–8 in Shiraz.
- "Nasir Al–Molk" mosque, was built between 1878–90 in Shiraz.

2.2. Orosi windows of non–carpeted spaces

There were also buildings that were not covered with carpets for most of the year, or maybe they were carpeted, but their preservation was not that important. Some religious buildings such as "Tekyeh" (a place for mourning ceremonies of Imam Hossain in Moharam) were carpeted only in the limited times of usage. "Tekyeh Moaven Al–Molk" is a good example. Also there were governmental buildings that needed to show the authority of the monarch, such as "Karim Khan Zand" citadel, which was used for formal reception of other countries' ambassadors. Although this building was covered with carpets, the preservation of these carpets was not important. Therefore, it can be categorized as a non–carpeted space. So, the buildings chosen and studied as non–carpeted spaces were:

- "Karim Khan Zand" citadel built between 1766–7 in Shiraz. It was used by the king as living quarters.
- "Tekyeh Moaven Al–Molk" built between 1916–7 in Kermanshah. It was a mourning place for sacred "Imam Hussein", being used by Shiite Muslims for two months a year.

2.3. Field study

The window geometry and glazing color combination of the case studies were carefully drawn and plotted in the field surveys, and the percentage of each type of green, blue, red, yellow, and simple glass was specified. Fig.1 depicts an example of these case studies accompanied by its drawn model.

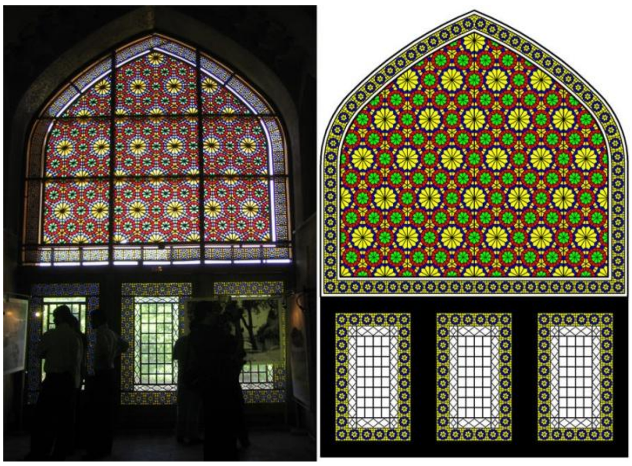

Fig. 1 Orosi's geometry of "Karim Khan Zand" citadel (left) and its drawn model (right)

2.4. Laboratory experiments

In order to investigate solar transmittance from the whole Orosi window, spectral transmittance from each of their glasses was to be measured. However, because of the conservation laws of historical buildings, it was not possible to detach the glazing from the Orosi windows. Therefore, only one sample from each kind of blue, green, red, yellow and simple glass was provided by the Fars Cultural Heritage Organization. Their transmittance from 200 to 1100nm was measured by the use of a T80+, UV–VIS–NIR spectrometer.

2.5. Calculation method

2.5.1. Solar factors of glass samples

CIE and skin damage factors and the visible transmittance for the glass samples, were calculated based on the ISO: 9050 standard [16]. According to this standard, wavelengths from 300 to 600nm were included in the calculation of CIE damage factor, wavelengths between 300 to 400nm were included in the calculation of skin damage factor and wavelengths from 380 to 780nm were considered in the calculation of visible transmittance.

2.5.2. Solar factors of the entire orosi window

Because the studied Orosi windows are not multi–layered, a simple multiplying of the data of glass samples cannot be used for calculating solar factors for the entire window. So, an area weighting technique was used to get the values normalized between 0 and 100%. These "modified" solar factors for the Orosi windows were calculated by equations 1-3:

$$T_{df\,(Orosi)} = T_{df(G)}.P_G + T_{df(B)}.P_B + T_{df(R)}.P_R + T_{df(Y)}.P_Y + T_{df\,(S)}.P_S \quad (1)$$

$$T_{sd\,(Orosi)} = T_{sd(G)}.P_G + T_{sd(B)}.P_B + T_{sd(R)}.P_R + T_{sd(Y)}.P_Y + T_{sd\,(S)}.P_S \quad (2)$$

$$T_{vis\,(Orosi)} = T_{vis\,(G)}.P_G + T_{vis\,(B)}.P_B + T_{vis\,(R)}.P_R + T_{vis\,(Y)}.P_Y + T_{vis\,(S)}.P_S \quad (3)$$

Where, $T_{df(i)}$ is CIE damage factor of the glass sample (i); $T_{sd(i)}$ is skin damage factor of the glass sample (i); $T_{vis(i)}$ is visible transmittance of the glass sample (i) and P_i refers to the percentage of glass sample (i) in the whole Orosi.

3. Results and Discussion

3.1. Glazing color combination of the cases

After quantifying color combination of the Orosi samples, it was found that the usage of each type of glass in carpeted and non–carpeted case studies were different. Simple glass was not used in the Orosi of the carpeted spaces. The usage of all other four colors were the same in carpeted spaces, while in non–carpeted case studies, the usage of yellow glass was the most and blue and green glasses were the least. The percentages of usage of each glass in carpeted and non–carpeted case studies are given in Table 1.

Table 1 Percentage of the use of each type of glass in the entire Orosi

Type		Model's name	Location	Yellow glass	Green glass	Blue glass	Red glass	Clear glass
Carpeted	A	Reza Zadeh Imaret	Bushehr	21.67%	25.34%	26.67%	26.32%	0.00%
	B	Nasir Al Molk Mosque, Type 1	Shiraz	25.35%	22.63%	24.68%	27.34%	0.00%
	C	Nasir Al Molk Mosque, Type 2	Shiraz	27.64%	21.72%	23.93%	26.71%	0.00%
	D	Nasir Al Molk Mosque, Type 3	Shiraz	21.88%	30.40%	23.65%	24.07%	0.00%
	E	Imamzadeh Zanjiri's Tomb	Shiraz	25.90%	25.82%	21.78%	26.50%	0.00%
	F	Dowlat–Abad grange	Yazd	31.29%	30.68%	14.74%	23.29%	0.00%
	Average of carpet–covered			25.62%	26.10%	22.57%	25.71%	0.00%
Non–carpeted	G	Karim Khan Zand Citadel, Type 1	Shiraz	33.93%	12.50%	15.44%	19.36%	18.76%
	H	Karim Khan Zand Citadel, Type 2	Shiraz	40.53%	11.36%	19.62%	17.01%	11.45%
	I	Tekyeh Moaven Al–Molk	Kermanshah	20.25%	12.54%	8.22%	15.21%	43.80%
	Average of non–carpet–covered			31.57%	12.14%	14.43%	17.19%	24.67%

In order to make green, yellow, and blue glasses, ferric and ferrous, sulfurous, and cobalt chlorides were used respectively. But gold chlorides were used to make red glass [17], which means that red glass cost much more than other colors. So, at first, it was assumed that red glass might be used less in Orosi color combinations. However, the results of the study showed a significant percentage of red glass in "Orosi window" of both carpeted and non–carpeted spaces. Possibly, this occurred because the owners wanted to demonstrate their wealth and power, and perhaps climatic conditions were also effective in the equation.

3.2. Glass measurements and spectroscopic data

The spectrophotometric measurements for the green, yellow, red, blue and simple glass, provided from the Fars Cultural Heritage Organization, are depicted in Fig. 2.

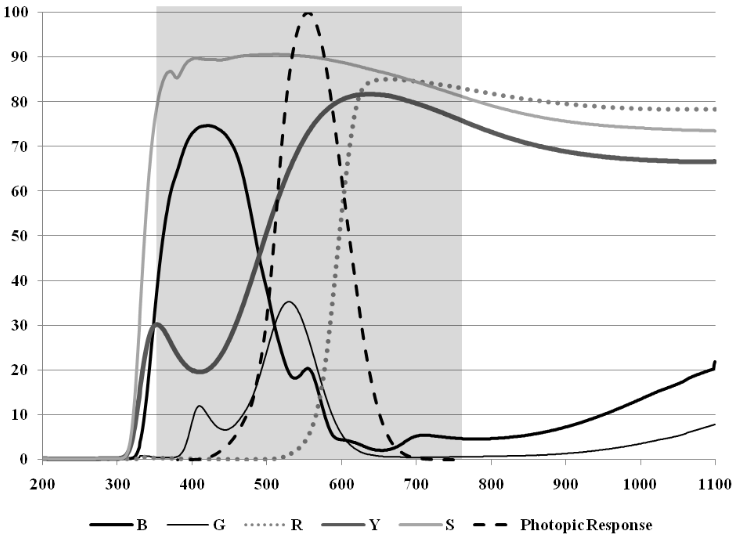

Fig. 2 Transmission in UV and VIS regions measured for the glass samples

Fig. 2 demonstrates that the transmission from none of the glass samples accommodates the human photopic response, therefore, expectedly indoor spaces would be darkish.

Damage–factors and Visible Transmittance for the Glass Samples

In Fig. 3, calculations of the CIE and skin damage factors have been plotted for the glass samples. Also, visible transmittance values for each glass sample is calculated in order to compare visibility with the various damaging factor levels. In Fig.3, photo–damage factor is the ordinate and visible transmittance is the abscissa.

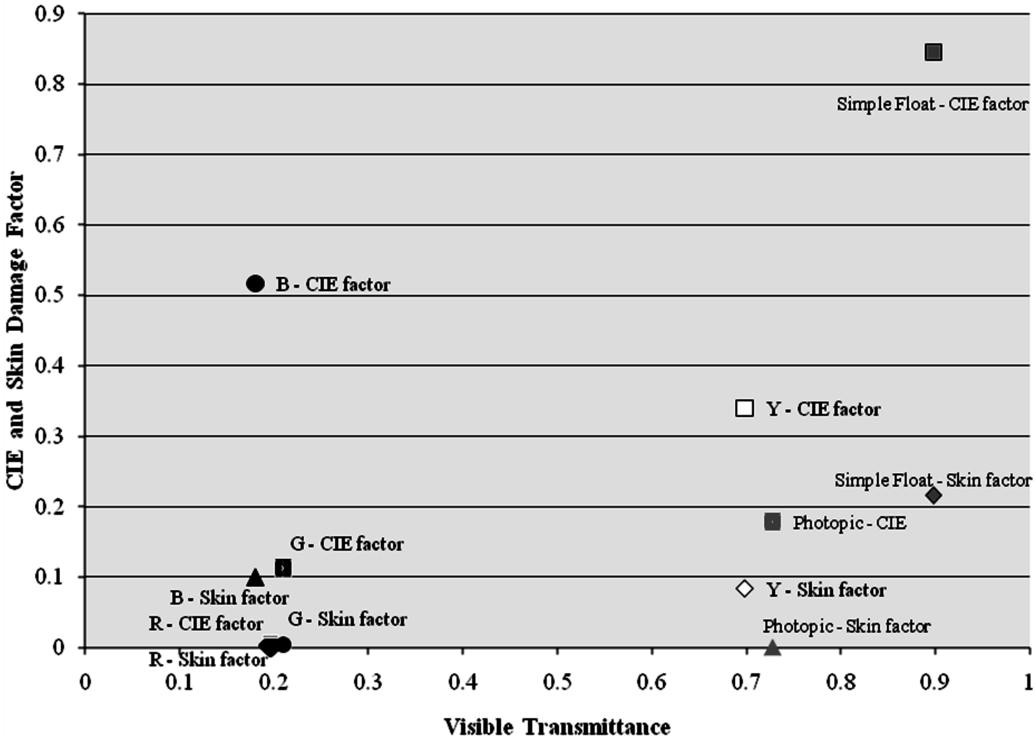

Fig. 3 Calculations of the CIE and skin damage factors vs. visible transmittance (T_{vis}) for the glass samples (B: blue, Y: yellow, G: green, R: red)

The results show that yellow and green glasses have the best performance in protecting the skin and building materials from photo–damaging effects, due to their visible transmittance. Also, it can be seen that both CIE and skin damage factor for the red glass are almost zero. So, the significant usage of red glass in Orosi windows can improve the protective effects both in carpeted and non–carpeted spaces.

3.3. Damage–factors and visible transmittance for the entire orosi windows

CIE and skin damage factor for different types of Orosi windows of carpeted and non–carpeted spaces are depicted in Fig. 4.

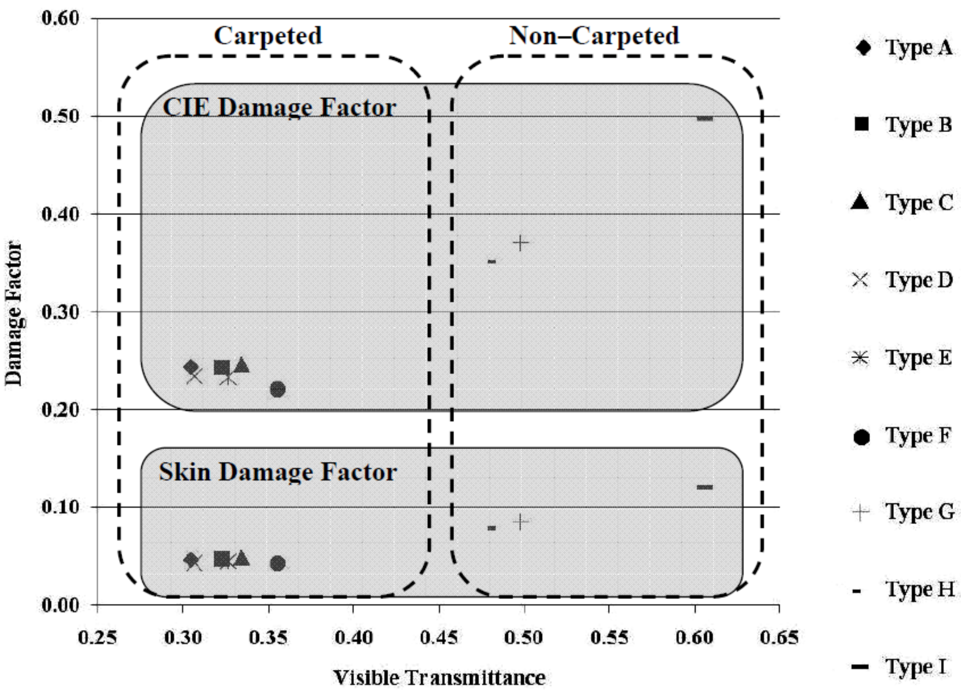

Fig. 4 CIE and skin damage factors for the entire Orosi windows of carpeted and non–carpeted spaces

4. Conclusions

The results show a meaningful relationship between the function of the space and the color combination and CIE damage factor of its Orosi windows. Dwelling spaces, which were covered with carpets, had the least CIE damage factor (Types A–F in Fig. 4). This is probably because of the vulnerability of the valuable carpets used to cover these spaces. The Orosi windows of "Karim Khan Zand" Citadel had the higher values of CIE damage factor, possibly because the governor wanted to impress people and foreign ambassadors with a bright space, and this was more important than preserving the carpets. CIE damage factor of "Tekyeh Moaven Al–Molk", which was used only for limited times during a year, was the highest, since it was not carpeted when it was not in use, and visible transmittance was the most important factor for that space. It should be mentioned that the skin damage factor of all studied models were approximately in the same range.

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