THE EFFECT OF ARCHITECTURAL DETAILS ON DAYLIGHT DISTRIBUTION INSIDE A ROOM

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ABSTRACT

In Iranian historical architecture one of the most important design criteria is daylight accessibility and quality. To evaluate daylighting conditions in a historical house in Kashan city in Iran, one of its main rooms was examined according to field and simulation studies in the year 2012 and 2014. To evaluate the effects of architectural design details on daylighting conditions of the room, some elements such as balcony, ceiling shape and height, window size and frame, glass size and colour, where changed or eliminated by simulation. The amount and distribution of daylight inside the room was simulated in the morning, noon and afternoon of two sunny days in summer and winter on a horizontal mesh at 80 cm height. The important UDI (useful daylight illumination) levels on different parts of the room were calculated on this height in all months of the year. On a column diagram, the results of this calculation show the percentage of daylight accessibility in a year.

The illumination amount and its distribution inside the room show great differences in different architectural detail conditions. The results show that the original condition of the room has a delightful daylighting in comparison to changed configurations. Also it has the best UDI daylight distribution in all seasons and hours. The other result is that with the same sky view and room dimension, changing detail design such as ceiling shape, window height and size, glass details, and so on, has great effect on illumination distribution and light level in different seasons inside the room. Therefore, in some cases, it is possible to modify the daylight condition of a room just by deliberate detail changes in architectural design.

Keywords: daylight distribution, ceiling shape, window mesh, colour glass, Orosi window

INTRODUCTION

In Iranian historical architecture one of the most important design criteria is daylight accessibility and quality [1]. To find out daylight conditions in a historical house, Kashan city was chosen as one of the most historical cities in Iran, with a hot arid climate and sunny skies most time of the year. In this city, Ameriha House of Zandieh and Qajar period is a great house with five yards and 85 rooms [2] with different daylighting strategies. To examine architectural and detail design effects on daylighting condition, one of the main rooms of this house was chosen for field and simulation studies in the year2012 [3] and 2014 [4].

METHOD

Data Collection

To gather the illumination data of the room, a field study was done in the morning, noon and afternoon of two sunny days in summer and winter, on a horizontal mesh at 80 cm height [5], by a digital illuminance meter TES 13339R. A reference illuminance data logger was located on the roof to gather sky illumination data. These data were used in the radiance software to simulate the illumination in the room for a sample year. The reflectance of the room surfaces were measured by a Lutron RGB1002 colour analyzer. The exact size and details of the room, ceiling and windows were measured by a 3D digital meter (Fig. 1). To find out the effects of detail architectural design on the daylight conditions of the room, some elements such as balcony, ceiling shape and height, window size and frame, glass size and colour, where changed or eliminated by simulation.

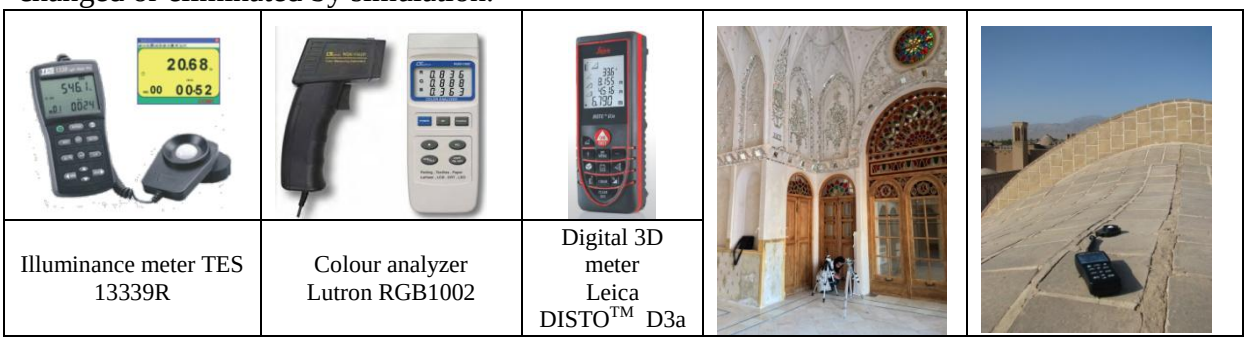


Figure 1: Field data collection instruments and location of the illuminance meters

The Case Study Room

The case room is a summer place located toward north/east (12 degrees from north) overlooking a large central yard with a wide sky view. The area of the room is 57.5 m^2 with a dome ceiling of 8.4 m height and a few decorative mirror works on its surface. The room has a three sash Orosi window [1] toward yard, with a crescent colour glass above it surrounded by three small colour glass circles. The room has extra indirect side lights from door/windows of the adjacent rooms. A balcony of 4.9 m deep and 9.3 m height is located in front of the room [3] (Fig. 2). The illumination information was gathered in 11-12 July 2011 & 10-12 Jan 2012.

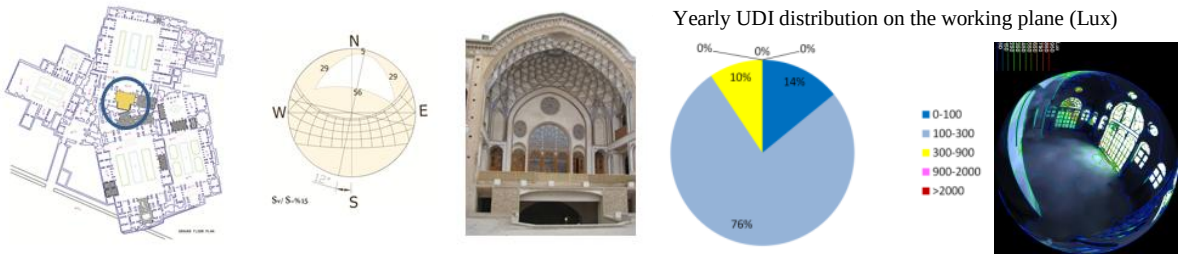


Figure 2: Architectural design condition of the study room on the yearly UDI distribution

RESULTS

To find out the effect of architectural and detail design changes on the daylighting condition, some changes were made in the room design and then the illumination results were simulated by the radiance software [4]. The changes were made in four groups: 1) eliminating the balcony, crescent of the main and side windows, 2) changing the roof shape and height, 3) changing the details of window mesh and glass colour, 4) changing the room to a modern ordinary room with flat low ceiling and transverse windows. The results are shown in Table 1.

The first and second column shows the made changes in the room. The middle columns show the illumination distribution on the plan of the room in a sample day in summer and winter in the morning (9am), noon (12 pm) and afternoon (15pm) on a horizontal mesh of 80 cm height. The field data gathering method is obtained through lighting standards [5, 6, 7, 8 and 9]. The last columns show diagram of UDI (useful daylight illumination) levels distribution in a whole year for illumination less than 100 Lux (fell short), 100-300 Lux (supplementary), 300-900-2000 Lux (autonomous) and more than 2000 Lux (exceeded) [10, 11].

DISCUSSION

The simulated results of Table 1 show:

1- In the original condition of the room, the horizontal observed surface has 14% illumination less than 100 lux, 76% between 100-300 lux and 10% more than 300 lux. It shows a balanced distribution of daylight in all times of the year.

2- Eliminating the balcony can increase the illumination inside the room in all seasons and hours. (36% 100-300 lux, 59% 300-900 lux and 5% more than 900 Lux). Although the illumination is increased, the low amount of uniformity may cause discomfort glare. The colour glass of the crescent window will adjust the light level.

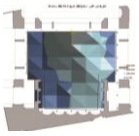
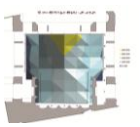
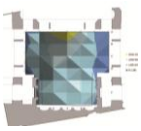
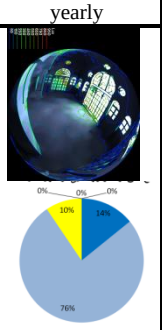
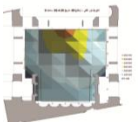
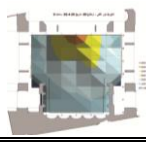
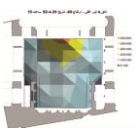
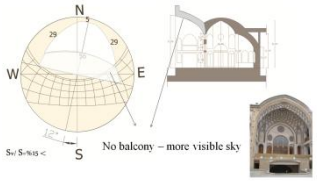
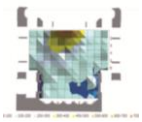
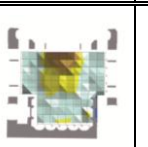
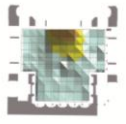
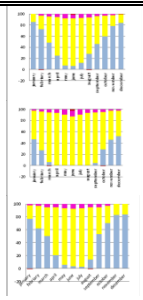
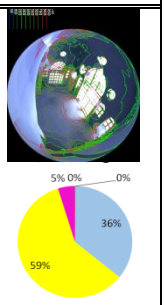
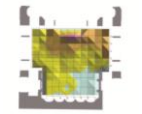
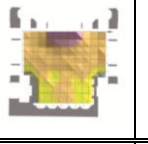
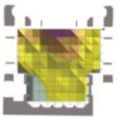
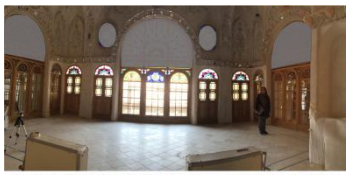
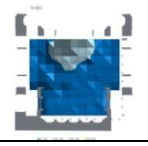
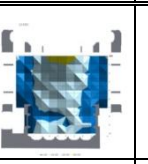
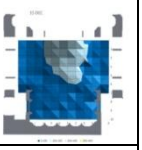
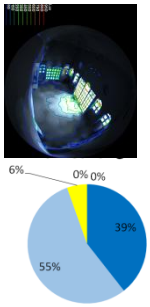
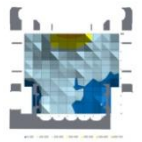
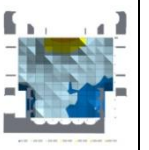
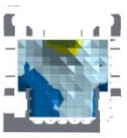
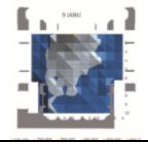
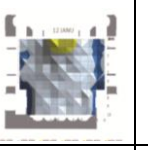
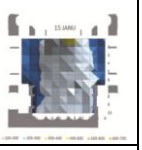
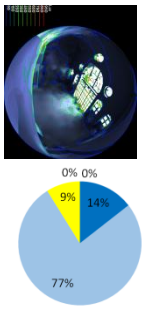
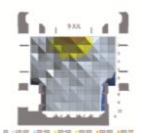
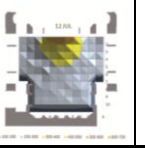
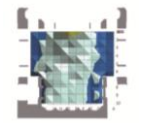
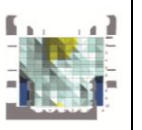
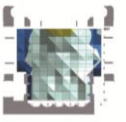
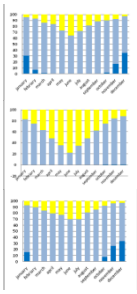
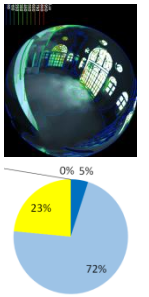
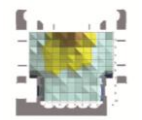
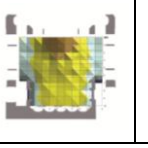
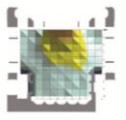
3- Eliminating the crescent colour glass and the colour glass circles above the sash Orosi window, causes the lack of illumination especially in morning and afternoon. (39% less than 100 lux, 55% 100-300 lux and 6% more than 300 Lux). The illumination at the depth of the room is very low. It shows that the height of the crescent colour window in the middle of the wall window is designed according to the depth of the room in Shahneshin (VIP sitting place at the end of the room). The crescent parts at the top of the side windows help to illuminate the sides of the room.

4- Eliminating the side windows has no important effect on the amount of illumination inside the room. They only help to illuminate the side light and uniform better daylight distribution.

5- Using no colour glass in all windows will increase the illumination inside the room without a good uniformity. Eliminating all the mesh frames of the Orosi window and the crescent above it and using simple no-colour glass, the increasing of illumination in all seasons and hours is conspicuous. (9% 100-300 lux, 85% 300-900 lux, 6% more than 900 lux). The illumination near the window is greater than in other parts of the room and the uniformity is not appropriate. The room will become much more illuminated in summer than in winter.

6- Decreasing the ceiling height to 4 meters and replacing it with a flat ceiling, has a considerable effect on reducing the illumination. (26% less than 100 Lux, 66% 100-300-900 Lux and 8% more than 900 Lux). In this case the differences of illumination from window to the depth of the room may cause discomfort glare.

7- Changing the room to an ordinary modern room with a low flat ceiling and transverse windows, causes non uniform distribution of daylight with 71% 100-300 Lux and 25% 300-900 Lux illumination in a year. Eliminating the balcony in this case may help for more illumination inside the room (26% 100-300 Lux and 72% 300-900 Lux) but in summer morning the sun patch may cause glare and the uniformity of daylight is not appropriate.

Room changes			Illumination distribution on the working plane of the room			Yearly UDI levels on the working plane area of the room	
			morning	noon	afternoon	9am-12pm-15pm	yearly
1- Original condition		21 Jan					
		21 June					
2- Balcony eliminating		21 Jan					
		21 June					
3- Crescent windows eliminating	 No crescent colour glass and no colour glass circles above the sash Orosi and side windows	21 Jan					
		21 June					
4- Side windows eliminating	 No side window	21 Jan					
		21 June					
5- No colure glass	 No colour glass	21 Jan					
		21 June					

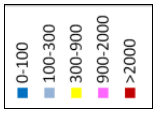
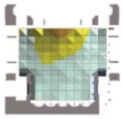
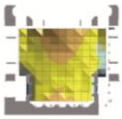
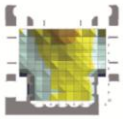
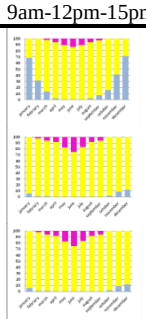
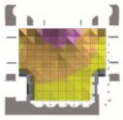
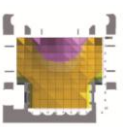
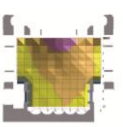
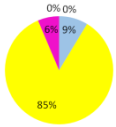
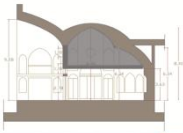
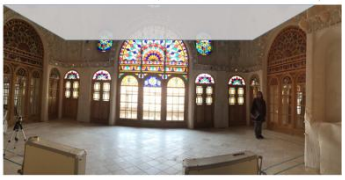
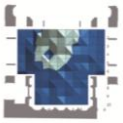
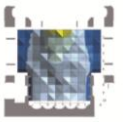
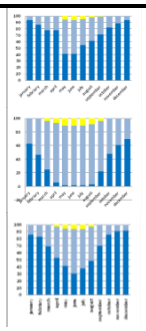
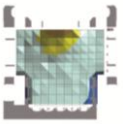
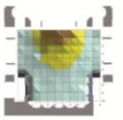
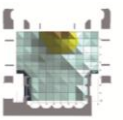
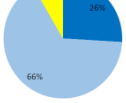
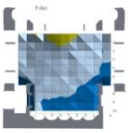
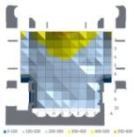
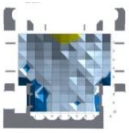
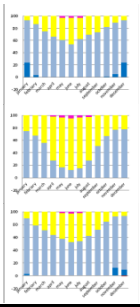
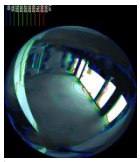
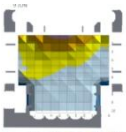
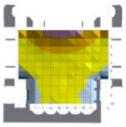
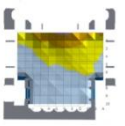
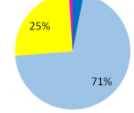
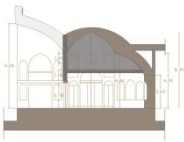
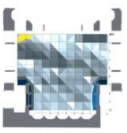
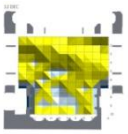
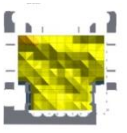
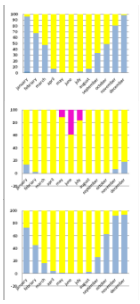
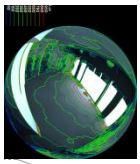
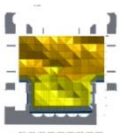
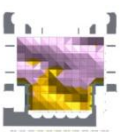
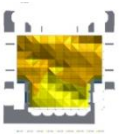
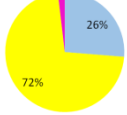


Table 1: Study results of the room changes (Lux)

Room changes			Illumination distribution on the working plane of the room			Yearly UDI levels on the working plane area of the room	
			morning	noon	afternoon	9am-12pm-15pm	yearly
6- No mesh no colour glass	 No mesh - No colour glass	21 Jan					
		21 June					
7- Flat ceiling 4 meters height	Flat ceiling 4 meters height  	21 Jan					
		21 June					
8- Flat ceiling no mesh no color	 Flat ceiling, no side window, no crescent window, transverse window with single glass	21 Jan					
		21 June					
9- Flat ceiling - no balcony	No balcony, flat ceiling, no side window, no crescent window, transverse window with single glass  	21 Jan					
		21 June					

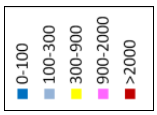


Table 1: (continued)

CONCLUSION

The results of this research show that in the historical house of Ameriha in Kashan, the original details of the studied room are designed for the best daylight distribution in all seasons and hours. It will create a delightful daylighting quality with coloured beautiful sun patches (Fig. 3). The mirror parts on the wall and ceiling with high curved ceiling help for better uniformity and adjust illumination in most parts of the room. The high crescent colour glass above the Orosi window is for enough illumination in the depth of the room, Shahneshin (VIP sitting place). This study also shows that with the same sky view and room dimension,

changing the detail design has great effect on illumination level and distribution inside the room. Therefore, in some cases, it is possible to modify the daylight condition of a room just by deliberate detail changes in architectural design.

Figure 3: sunlit position of the room in summer morning

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